Analysis of investment models for megawatt scale photovoltaic power plant in Thailand

Phongsakorn Damnoen and Nipon Ketjoy*

School of Renewable Energy and Smart Grid Technology, Naresuan University,
Phitsanulok 65000, Thailand
***Corresponding author's email**: niponk@nu.ac.th
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Abstract

This paper is an analysis of the three common investment models for financing PV power plants in Thailand; (1) 100% investor financing of investment (capital), (2) 70% investor financing of investment with 30% finance by a bank loan and (3) 100% investor financing of investment (capital) and EPC (Engineering, Procurement & Construction) or installation cost. These three investment financing models were analyzed for three PV power plant project sizes; 5, 50, and 100 MW PV power plant capacities. The economic indicators used in the analysis include Cash flow, LCOE, PP, BCR, NPV, and IRR. The results of the analysis show that the greater the project size, the better is the economic performance because of economies of scale. The results demonstrated that 100% investor financing of investment (capital) is suitable for a 5 MW project while 100% investor financing of investment plus EPC cost is more appropriate for 50 and 100 MW projects. However, this investment model is suitable only for investors who have EPC experience. These are investors who have experiences as, utility-scale PV power station developers and operators, and have good business connection with other players of the PV industry in Thailand

Keywords:

financing, investment models, megawatt-scale PV power plant, grid parity, economic analysis, Thailand

1. Introduction

1.1 PV market development

Since the launched of the PV adder tariff in 2007, the "MW-scale PV power plant" sector has played an important role for driving Thai PV market, with the new installed PV power plant capacity increasing from 1.99 MW in 2007 to 1.03 GW in 2016. Almost all of 32.51 MW cumulative installed PV capacity in 2007 were off-grid systems while almost all of 2.45 GW cumulative installed PV capacity in 2016 were utility-scale PV power plants. In this period, the annual PV power generation had increased from a 23 GWh to 3.38 TWh. During this period, the investment cost of MW-scale PV power stations had decreased from 160 million THB/MW to 40 million THB/MW, on the other hand, during the same period, investment had increased from 0.2 billion THB in 2007 to 86.16 billion THB in 2016, with total cumulative investment of about 239 billion THB[1-4]. Figure 1 presents the PV power capacity installations and the corresponding investment values during 2007 to 2016. In only nine years of Thai PV market development, the installed PV power capacity e expanded by about 61 times, annual power generation by about 147 times, while the investment cost dropped by about 75%, but still annually, the investment value e increased by about 431 times., This PV market development had been dominated by "MW-scale PV power plant" sector. However, the PV market growth in Thailand has fluctuated because of changes made in government policies during this period.

1.2 Government policy and subsidy scheme

"Power Purchase Agreement (PPA)" quota and a subsidy scheme through the "Adder" and "Feed-in Tariff (FIT)" forms have been the main mechanisms to support the PV market in Thailand achieve the government policies and targets. The various government policies and the corresponding PPA target, adder or FIT price, subsidy period, and deadline are displayed in Table 1. Until 2017, the total PPA for large-scale PV power plant are 2.96 GW that include 1.57 GW for adder tariff, 0.97 GW for FIT (Phase 1 and 2), 0.41 GW for Government and Agricultural Cooperatives (Phase 1 and 2), and 0.01 GW for self-consumption [5-8].

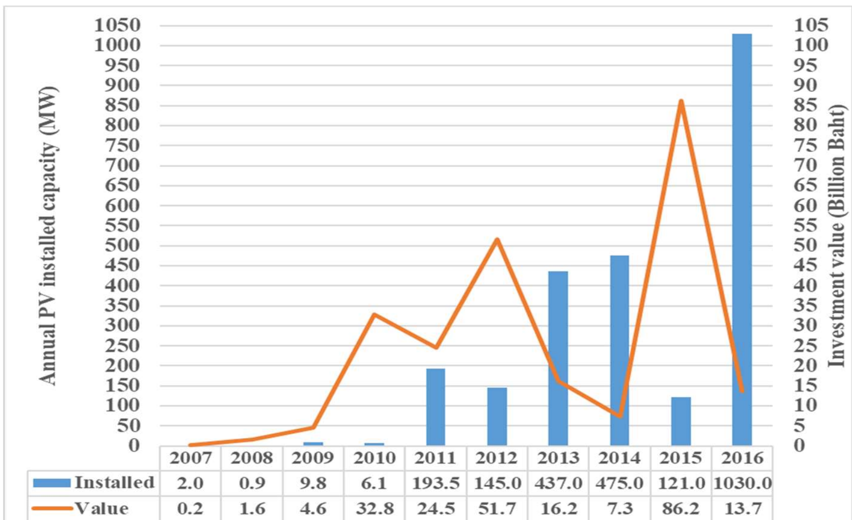

Fig. 1 Annual installed PV capacity and investment value during 2007 to 2016.

Table 1 Government policy, PPA target, adder or FIT price, subsidy period, and deadline.

Year	Government policy	PPA target	Adder/FIT price	Subsidy period	Deadline
2007	Renewable Energy Development Plan (REDP) 2007-2022	500 MW	Adder 8 THB/kWh	Start at 7 years extend to10 years	Apply in 2008 Accept in 2009
2010	Revised adder tariff. Temporarily halt the application acceptance in April.		Adder 6.5 THB/kWh	10 years	Accept after June 2010
2012	Alternative Energy Development Plan (AEDP) 2012-2021	2,000 MW	Adder 6.5 THB/kWh	10 years	Accept after June 2010
2013	Revised AEDP 2012-2021 Change from adder to FIT for the halted and new application	3,000 MW	FIT 5.66 THB/kWh	25 years	COD before end of June 2016
2015	AEDP 2015-2036 Government and Agricultural Cooperatives (Agro-Solar) Phase 1	6,000 MW	FIT 5.66 THB/kWh	25 years	COD in 2016
2017	Agro-Solar Phase 2		FIT 4.12 THB/kWh	25 years	COD in 2018

1.3 Investors' perspective and investment models

Thailand has been the most interesting country in Asia-Pacific for investing in large-scale PV power plants since the launching of the PV adder tariff in 2007. The PPA application for PV power plant installation has been always higher than the PPA quota in each round. However, the investment values for MW-scale solar power plant projects have fluctuated widely depending on the PPA quotas. These r clearly reflect the high interests and competition I among investors for developing utility-scale PV power plant projects in Thailand.

With the pressure from feed in tariff decreasing and the PPA limited only to governmental agencies and agricultural cooperatives, the type of investment models can be a major factor for a "MW-scale PV power plant" developer and investor to analyze and determine project feasibility, investment return, and cost of power generation. They will have to consider and choose the investment models that can provide the maximum profit.

There are many papers and published articles describing the various large-scale solar farm investment models. However, none of these papers and publications have discussed about utility-scale PV power plant investment models in Thailand.

In this regard, this paper now aims to present and empirical analysis of the three common MW-scale PV power plant investment models in Thailand and hope to provide important information to interested developers and investors. In this paper, we first provide a brief review of the three investment models and the important technical and economic parameters that were included in the investment model analysis. In the second part, the economic analysis procedure is presented. Then, the results in using the economic analysis for the three normal utility-scale solar farm investment models in Thailand, plus a hypothetical large-scale solar farm (5, 50, and 100 MW) in Thailand are described.

2. Investment model review and the important technical and economic parameters

Based on the literature review, MW-scale PV power station investment models can be e classified in three main groups based on the sales of electricity, voltage support, and/or conservation voltage reduction (CVR). However, in almost all developed utility-scale PV power station business models, electricity sale is used because of the limited economic chance of voltage support and CVR [9]. The two main groups of the large-scale solar farm investment models are "direct ownership" and "third-party ownership" models [10, 11] Direct ownership structures has been the more favorite in EU than in USA, but some PV industry analysts are forecasting growth in third party ownership model in EU as FIT policies decay and as financial products become more available [12].

Availability of academic studies on economic analysis of third-party ownership models such as "Crowd-funding" [13], and other third-party investment structures are limitede. On the other hand, direct-ownership investment models, which is the most popular investment structure that uses economic analysis parameters, is of interest to many academics researches around the world. Subsidy schemes and regulatory policies are an important parameter in economic analysis, and there many available academic publications from various countries such as China [14-16], Spain [17-19], Iran [20, 21], USA [22], and Ireland [23]. Solar radiation, climate, and geography of MW-scale PV power stations that dominate power generation and revenue are the significant parameters used in the economic analysis done t in academic papers from Germany [24], Italy [25], USA [26], Mongolia [27], Malaysia [28], Saudi Arabia [29], and Egypt [30]. Utility-scale PV power plant and its grid configuration is another main parameter studied in considerable number of academic journals [31-33]. Other parameters such as analysis process [34], maintenance strategy [35], self-consumption [36], carbon market [37], component failures [38], and other parameters are also studied in the economic analysis in some published academic papers.

In this study, many important technical and economic parameters were considered in the empirical analysis of large-scale PV power plant investment models. The technical parameters that directly affect business return of MW-scale PV systems include solar radiation, climate, and geographical location. The solar radiation potential of Thailand is between 4.1 to 5.6 kWh/m^2 day with the average solar radiation at 5.1 kWh/m^2 day. Around 14.3% of country area has solar radiation about 5.3-5.6 kWh/m^2 day, located g in the southern part of the Northeastern region and the Central part of the central region. About r 50.2% o has solar radiation of about 5.0-5.3 kWh/m^2 day that are scattered in every region of Thailand. Another 35% of country area has solar radiation around 4.4-5.0 kWh/m^2. Only 0.5% of country area has solar radiation lower than 4.4 kWh/m^2. The appropriate area for PV system in Thailand is about 380,000 km^2 or about 75% of total country area. The remaining 25% a is unsuitable areas, comprising of water bodies, protected areas, and high- slope or elevation lands. Most of inappropriate areas are located in the northern and western regions of Thailand [39-41].

Thailand is located in latitude of 5°-21° N and longitudes 97°-106° E. During May to October, the climate dominated by the southwest monsoon, which is characterized by warm and moist air movements from the Indian Ocean. From October to February, the climate is affected by the northeast monsoon, and is characterized by cold and dry air movement from China. The Southwest monsoon is causing abundant rain over most of the country. The Northeast monsoon, aside from bringing in rain, is causing the temperature to drop. in most of country, except in the southern region where the weather is milder in spite of torrential rain on the eastern coast.

Most of Thailand has tropical savanna climate except the southern region that has tropical monsoon and equatorial climate. The country has defined three seasons; summer (hot) season during March to May, rainy season during June to October, and winter (period of single-digit temperatures) during November to February. The southern region has longer rainy during June to February and dose not have a “winter season” [42].

The key technical parameter that influence power generation and income in economic analysis are performance parameters such as Performance Ratio (PR), Availability (AO), and Capacity Factor (CF). The literature survey and reviews, show that large-scale PV power stations in Thailand have PR of between 70 and 87%, depending on the power plant condition such as; lifespan, plant configuration, solar radiation, and climate. The earlier MW-scale solar farms installed before 2010 usually has PR of up to about 75% for c-Si PV power plants and up to about 80% for thin film PV power plants. The later MW-scale solar farms t installed since 2010 usually has PR over 80% for c-Si PV power plants and about 85% for thin film PV power plants., The difference in PR between c-Si and thin film solar farms is not significant in the modern utility-scale PV power plants but thin film solar farms usually have higher PR degradation rate. Large-scale PV power plant availability is in the 97%-100% range and most PV power plants have average availability over 99%. The CF factor of utility -scale PV power plants in Thailand is between 12% and 20%, t depending on the solar farm conditions. Thin film power station normally has higher CF than c-Si power station. Topology is an important parameter that influence PR, availability, and CF. Decentralized inverter power plants has commonly better PR, availability and CF performance characteristics compared with centralized inverter power plants [43-49].

The key parameters for economic analysis to determine successful economic business operation include, installation or EPC (Engineering, Procurement & Construction) cost, land cost, project development cost, and other pre-operational of a MW-scale PV power plant. The literature survey and reviews show that the trend of EPC and project developing costs are continuously decreasing while land costs is slightly increasing over time. Table 2 shows installation or EPC cost, land cost, and project developing cost in 2015 and in 2017 [50, 51].

Operation and maintenance (O&M) cost is the main parameter that influence both technical and economic performance of large-scale PV power plants. Most power plant operators endeavor to achieve PV power plant availability higher than 99%. To achieve, suitable O&M strategy with sufficient O&M budget is required.

Interest rate is the main parameter that effect economic analysis. In this study, the interest rate is based on the minimum loan rate (MLR) of commercial banks in Thailand.

Table 2 Installing or EPC cost, land cost, and project developing cost in 2015 and 2017.

No.	Cost category	2015 Price			2017 Price		
		Low (THB/W)	Average (THB/W)	High (THB/W)	Low (THB/W)	Average (THB/W)	High (THB/W)
1	EPC cost						
	PV module	20.0	22.0	25.0	8.9	10.2	13.5
	Inverter	4.0	5.0	6.0	1.5	1.7	2.0
	Racking, wiring, etc.	4.0	5.0	6.0	4.0	5.0	6.0
	Installation labor	8.0	9.0	10.0	8.2	9.3	10.3
	Civil	3.0	4.0	5.0	3.1	4.2	5.3
	Profit	3.3	4.4	5.5	3.0	4.0	5.0
2	Land costs	3.0	4.0	5.0	3.1	4.1	5.1
3	Project developing	2.0	2.0	2.0	1.8	1.8	1.8
	Total	47.3	55.4	64.5	33.6	40.3	49.0

From literature survey and reviews, the O&M cost per MW and interest rate in 2017 can be classified into three levels; high – 561 thousand THB O&M cost per MW and 6.025% (MLR) interest rate; average - 449 thousand THB and 5.775% (MLR-0.25%); and low - 363 thousand THB and 5.525% (MLR-0.50%); respectively [52, 53].

FIT (Feed-in Tariff) is the most important parameter that directly affects the economic analysis and revenue of MW-scale solar farms. In this paper, the FIT is based on the “Governmental Agency and Agricultural Cooperatives Program (Agro-solar Scheme) Phase 2”, which is at 4.12 THB/kWh [54]. In this Agro-solar Scheme, a part of the utility-scale solar farm income will be shared with the authorized governmental agency or agricultural cooperative that will hold the PPA (Power Purchase Agreement) for 25 years. From our survey, the sharing is about 8% of total revenue.

3. Investment models and economic analysis

In this research paper, three investment models for developing utility-scale PV power plant projects in Thailand were analyzed; 100% investor financing of the investment, 70% of investor financing of the investment with the remaining 30% loaned from the bank, and 100% investor financing of the investment plus the EPC. The analysis were done for three project sizes; 5 MW, 50 MW, and 100 MW. The contractor undertake the EPC in the first and second models while the investor/s take charge of EPC in the third model. To indicate the feasibility of these models in each project size, the following economic indicators such as cash flow (CF), levelized cost of electricity (LCOE), payback period (PP), benefit cost ratio (BCR), net present value (NPV), and internal rate of return (IRR) are included in the economic analysis.

3.1 Cash flow

Cash flow (CF) is n defined as the present cash inflow and outflow value of the project. It is the first parameter that should be analyzed. Equation (1) presents project cash flow equation in period n (CF_n) [55].

$$CF_n = CFO_n + CFI_n + CFF_n \tag{1}$$

CF_n = Amount of money that the solar farm owner receives and pays in each years (THB)
CFO_n = Cash flows from operating activities (THB)
CFI_n = Cash flows from investing activities (THB)
CFF_n = Cash flows from financing activity (THB)

In PV power generation business, CFO_n include various revenues and payments in period n that is possible to calculate from Equation (2) and (3) [56]. Equation (1) can be transformed to Equation (4) below [56]. In this study, CFI_n is available in only investment period (Year 0) and financing activity is not available.

$$R_e = 365 \times H_{I,d} \times PR \times A_O \times P_S \times P_{FIT} \tag{2}$$

$$CFO_n = (R_e - (C_{O\&M} + S_{PPA} + P_l))_n \tag{3}$$

$$CF_n = ((R_e - (C_{O\&M} + S_{PPA} + P_l))_n + CFI_n + CFF_n \tag{4}$$

R_e = Revenue from sold electricity (THB)
$H_{I,d}$ = Daily global or direct irradiation in the plane of the array (kWh/m^2 day)
PR = Performance ratio
A_O = Operation availability
P_S = Power plant size (kW)
P_{FIT} = Purchase price in PPA or FIT price (THB/kWh)
$C_{O\&M}$ = O&M cost (THB)
S_{PPA} = PPA holder share (THB)
Pl = Loan payment with interest (THB)

3.2 Levelized cost of energy (LCOE)

LCOE is one of the most dependable to economic indicators for practical comparison of power generation from alternative technologies that also have differences in in operation scales, investment costs, and operating periods. LCOE is defined as the ratio of discounted value of the project lifetime total cost (capital and operating costs) to the lifetime-generated power of the project as shown in Equations (5) [20] and (6) below [57].

$$\text{LCOE} = \text{Lifetime total cost/Lifetime generated power} \tag{5}$$

$$\text{LCOE} = \frac{\sum_{t=0}^{n} (I_t + C_{O\&M} + F_t + D_n)/(1+d)^t}{\sum_{t=0}^{n} (S_t (1-D)^t / (1+d)^t} \tag{6}$$

LCOE = Levelized cost of energy (THB/kWh)
I_t = Initial investment cost and loan repayments (THB)
F_t = Debt financed interest payments (THB)
D_n = De-commissioning costs (THB)
S_t = Annual generated power (kWh)
1-D = Degradation factor
d = Discount rate
n = PV power plant or project lifetime (year)

3.3 Payback period (PP)

PP is an economic indicator that shows the extent of investment recovery ed in the duration of the project. PP is defined as the period when the cumulative cash flows turn positive. A shorter PP is desirable for capital budgeting purposes. A longer PP can lead g to lack of capital for management, that is of course, economically unacceptable. In uneven cash flows case, PP can be calculated using Equation (7) [58].

$$PP = P_{LNCF} + (CCF_{LNCF} / CF_{LNCF+1}) \tag{7}$$

PP = Payback Period (Year)
P_{LNCF} = The last period with a negative cumulative cash flow (Year)

CCF_{LNCF}= The absolute value of cumulative cash flow at the end of P_{LNCF} (THB)
CF_{LNCF+1}= The total cash flow during the period after P_{LNCF} (THB)

3.4 Benefit cost ratio (BCR)

BCR is the relative profitability of the project that is calculated as a ratio of the present value of yearly income (benefit and savings) over yearly costs to the project equity. BCR can be calculated using equation (8) [21]. If the BCR is over one, the project should be economically acceptable.

$$\text{BCR} = \sum_{n=1}^{N} B_n / (1+d)^n \Big/ \sum_{n=1}^{N} C_n / (1+d)^n \tag{8}$$

BCR = Benefit cost ratio
B_n = The revenue in year n (THB)
C_n = The cost in year n (THB)

3.5 Net present value (NPV)

NPV is the value of all future prospective cash flows, discounted at the discount rate in present day currency. This is a general indicator of a project's economic feasibility. NPV is calculated by discounting all relevant cash flows as presented in equation (9) [20]. A positive NPV indicates s an economically feasible project, a bankable project that will generate anet profit whilea negative NPV indicates the opposite, an an economically infeasible project.

$$\text{NPV} = \sum_{n=0}^{N} CF_n / (1+d)^n \tag{9}$$

NPV = Net Present Value (THB)

3.6 Internal rate of return (IRR)

IRR is extensively used profitability indicator in terms of a project investment, t based on the return on invested capital. IRR is the interest rate at which the NPV of all the cash flows from a project or investment equals zero. It can be calculated from equation (10) [20]. The IRR methodology is usually used when there are objection on the using discount rate. Investments with IRR higher than the capital cost is considered financially feasible. IRR solves the issue of selecting the right discount rate for NPV, which is usually uncertain. Corporate finance use both NPV and IRR metrics, nd this is generally practice. The two indicators are complementary.

$$\text{NPV} = \sum_{n=0}^{N} CF_n / (1+IRR)^n = 0 \tag{10}$$

IRR = Internal Rate of Return

3.7 economic analysis and important parameter assumption

In this economic analysis, the technical and economic assumptions used were based on the Agro-solar Scheme Phase 2. The technical and economic information used were from 2017 as described in section II, and also from the survey data. These technical and economic assumptions are shown on Table 3.

In Case 3 (i.e.; 100% investor financing of investment and EPC), the total investment is lower than the other two cases, because the investor administers EPC and O&M by himself. This results in cost saving increasing profit for the contractor. The additional expense for EPC fluctuates based on the project size. The larger the project size, the lower the investment per unit because of economies of scale.

4. Results and discussion

The results of the analysis for the three cases of financing of project investments for the three project sizes are shown in this section.

It is difficult to compare the PV power plants of three different capacities using the cash flow analysis. Therefore, "cash flow per MW" is used in this analysis.

Table 3 The important technical and economic parameter assumption in the economic analysis.

No.	Technical and economic parameter	5 MW project	50 MW project	100 MW project
1	Total investment for 100% investor investment	245.0 million THB	2,015.0 million THB	3,360.0 million THB
2	Total investment for 70% and 30% investment by investor and bank loan	171.5 million THB	1,410.5 million THB	2,352.0 million THB
3	Bank loan for 70% and 30% investment by investor and bank loan	73.5 million THB	604.5 million THB	1,008.0 million THB
4	Bank loan payment period and interest rate	10 year 6.025%	10 year 5.775%	10 year 5.525%
5	Total investment for 100% investment and EPC by investor	220.0 million THB	1,815.0 million THB	3,060.0 million THB
6	EPC additional expense for 100% investment and EPC by investor	40.0 million THB	100.0 million THB	110.0 million THB
7	Annually O&M cost for 100% investor investment and 70% and 30% investment by investor and bank loan	2.81 million THB	22.45 million THB	36.30 million THB
8	Annually O&M cost for 100% investment and EPC by investor	6.00 million THB	20.00 million THB	30.30 million THB
9	PPA holder share		8%	
10	$H_{I,d}$		5.1 kWh/m^2 day	
11	PR		80%	
12	A_O		99%	
13	P_{FIT} / Subsidized period		4.12 THB/kWh / 25 Year	
14	PV module output degradation (D)		0.8%/Year	
15	d		4%	
16	n		25 Year	

For 5 MW solar PV farm, the first investment financing model has the best cash flow while the third model has the worst cash flow. For 50 and 100 MW PV power plant, the third investment financing model has the best cash flow while the second model has the worst cash flow. The cash flows of 5, 50, and 100 MW PV power plants in each investment model are displayed in Fig. 2, Fig. 3, and Fig. 4 respectively.

From the LCOE analysis of the 5 MW PV power station, the first investment financing model has the lowest LCOE while the third model has the highest LCOE. For 50 and 100 MW PV power station, the third investment financing model has the lowest LCOE while the second model has the highest LCOE.

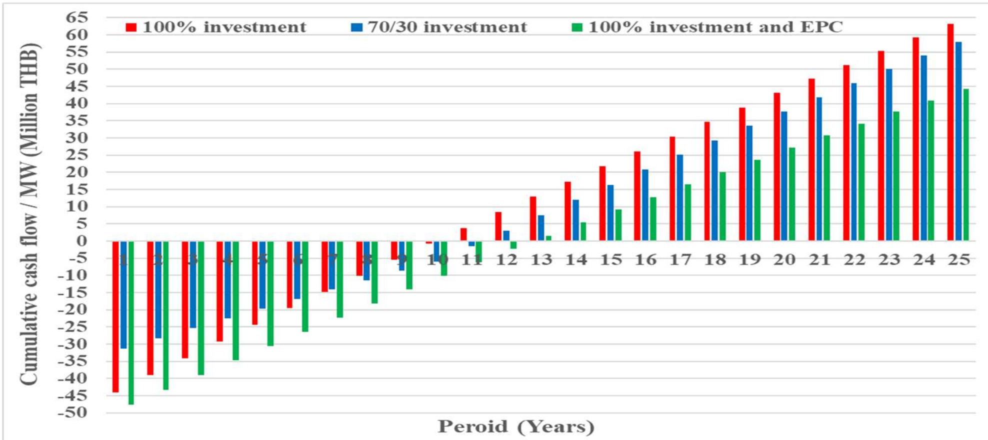

Fig. 2 The cash flows of 5 MW solar farm in each investment model.

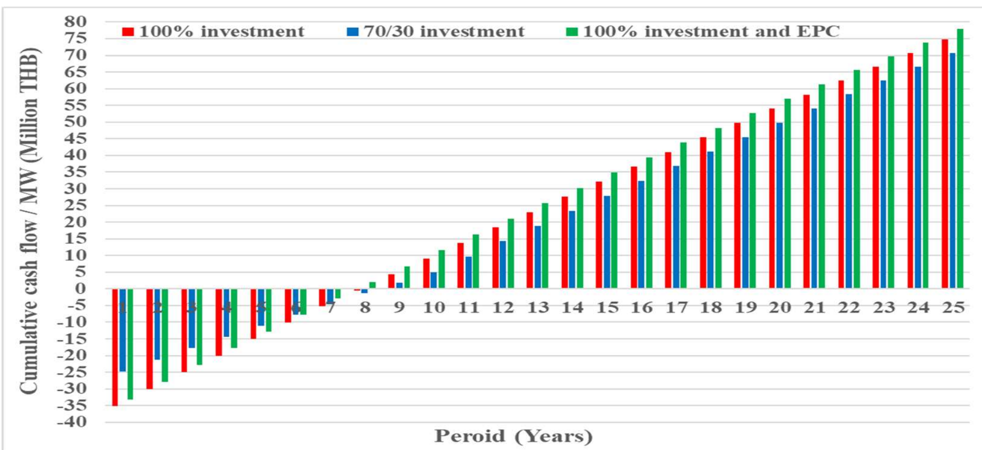

Fig. 3 The cash flows of 50 MW solar farm in each investment model.

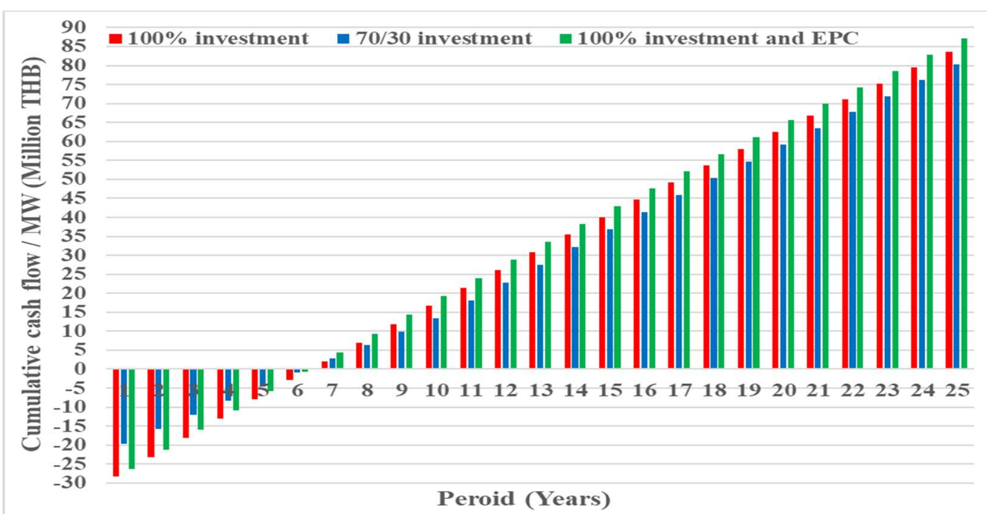

Fig. 4 The cash flows of 100 MW solar farm in each investment model.

In addition, LCOE in every case is lower than the electricity wholesale price from grid during peak period at 3.20 THB/kWh, except for the third investment financing model with the 5 MW solar farm. For 100

MW solar farm, LCOE in every investment financing model is lower than the electricity wholesale price from grid during off peak period at 2.36 THB/kWh [59]. This prove that power generation from MW-scale PV power plant in Thailand can attain grid parity. LCOE of all investment models for 5, 50, and 100 MW solar farm is showed in Fig. 5.

For 5 MW PV power plant, the first model has the shortest PP while the third model has the longest PP. In 50 MW PV power plant case, the third model has the shortest PP while the second model has the longest PP. For 100 MW solar farm, the third model has the shortest PP while the first model has the longest PP. From the results, PP of the first model is not significantly different for different plant sizes, while for the third investment financing model, PP is higher for the 5 MW solar farm and lower PP for the 50 and 100 MW solar farms. The PP of all investment financing models for 5, 50, and 100 MW solar farms is shown on Fig. 6.

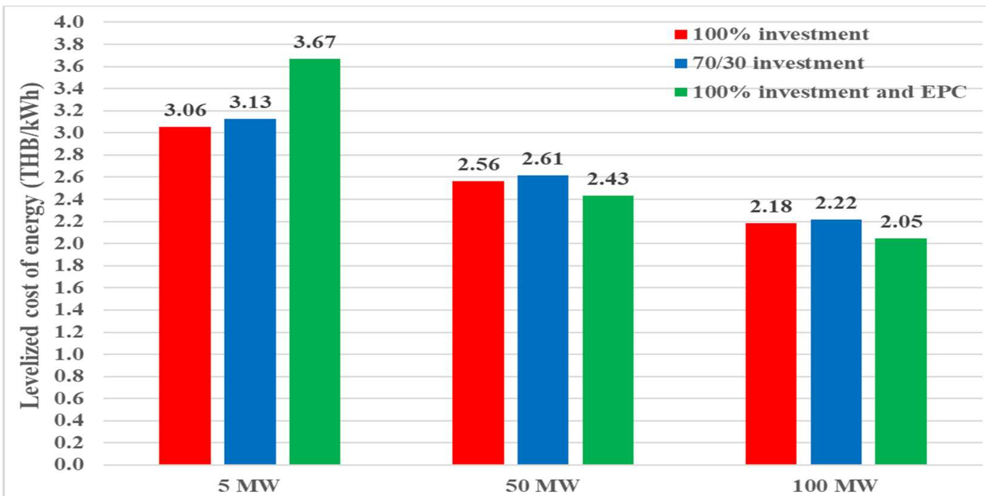

Fig. 5 The LCOE of all investment models for 5, 50, and 100 MW solar farms.

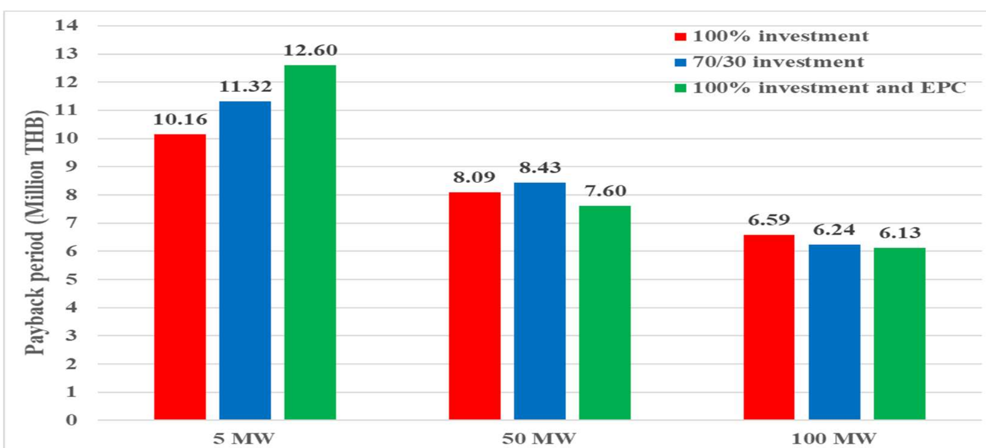

Fig. 6 The PP of all investment models for 5, 50, and 100 MW PV solar farms.

From BCR analysis of 5 MW solar farm, the first model has the highest BCR while the third model has the lowest BCR. For 50 and 100 MW solar farm, the third model has the highest BCR while the second model has the lowest BCR. Moreover, BCR of all case is higher than one that present the project possibility and BCR of the first model and the second model is not obviously different. Fig. 7 presents BCR of all investment model for 5, 50, and 100 MW solar farm.

From NPV analysis result, NPV of all case is higher than zero except the third model with 5 MW solar farm. The negative NPV signally indicates infeasible project. In addition, NPV of the first model and the second model is not clearly different. The first model has highest NPV for 5 MW solar farm while the third model has highest NPV for 50 and 100 MW solar farm. Fig. 8 displays BCR of all investment models for 5, 50, and 100 MW solar farms.

From IRR analysis, the first model has lowest IRR for 50 and 100 MW PV power plant, the second model has the highest IRR for 5 and 100 MW PV power station, and the third model has the highest IRR for 50 MW PV power station and lowest IRR for 5 MW PV power station. The lowest IRR definitely present infeasible project. IRR of the first and the second model is not evidently different for 5 MW solar farm while the second and third model is not evidently different for 50 MW solar farm. The IRR of all investment models for 5, 50, and 100 MW solar farms is showed in Fig. 9.

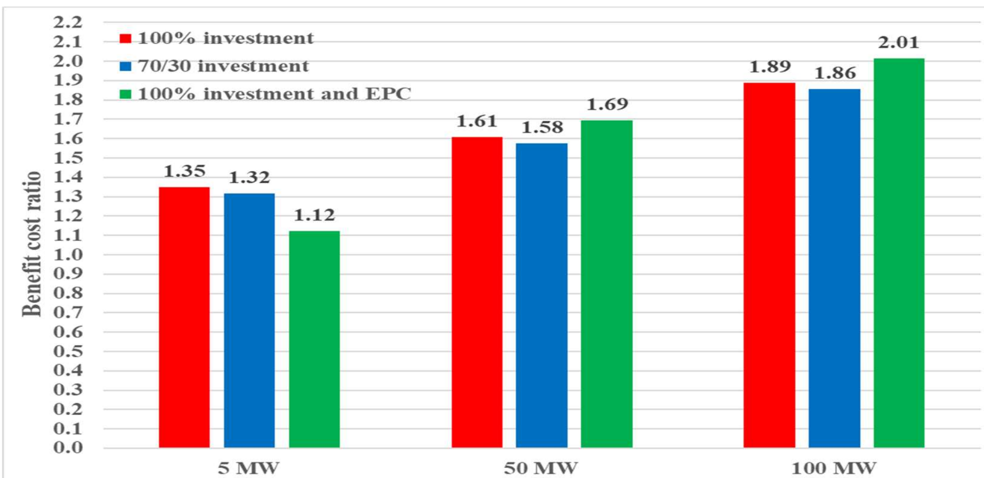

Fig. 7 The BCR of all investment models for 5, 50, and 100 MW solar farms.

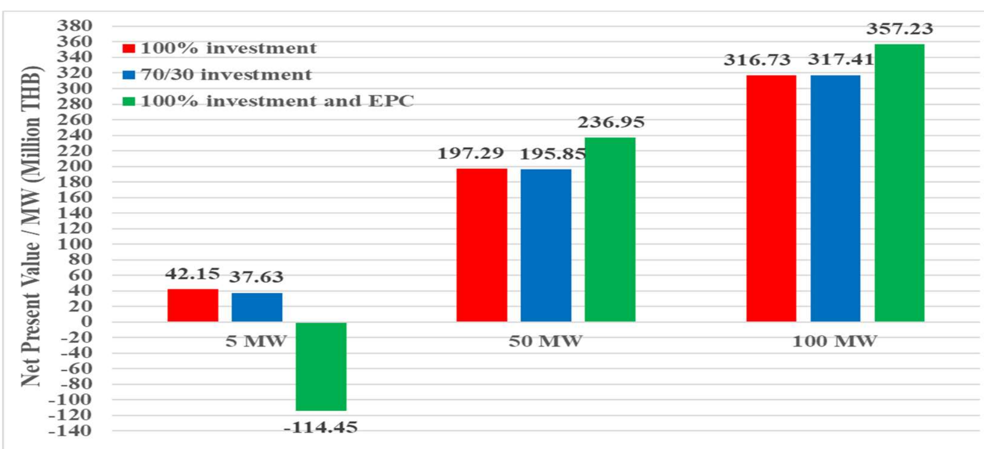

Fig. 8 The NPV of all investment models for 5, 50, and 100 MW solar farms.

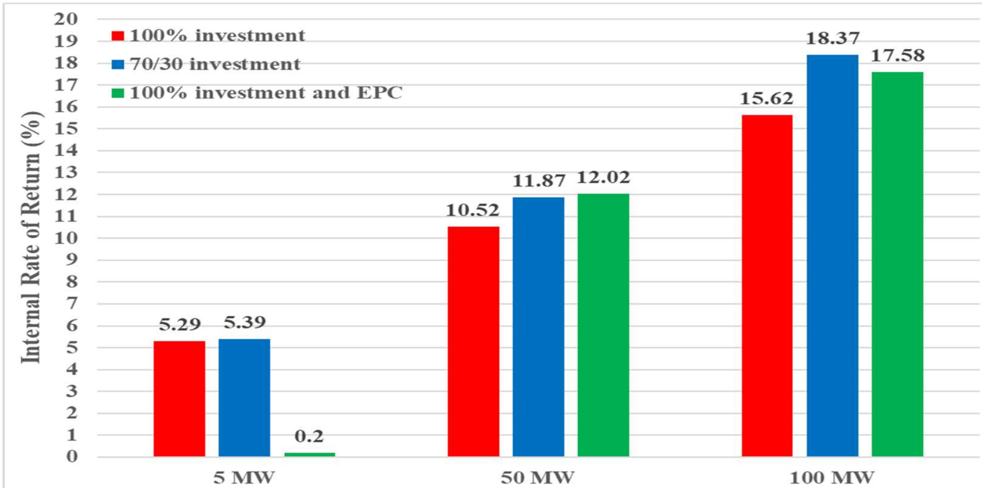

Fig. 9 The IRR of all investment models for 5, 50, and 100 MW solar farms.

The results of all economic indicator analysis show that the larger MW-scale PV power plants have better economic performance because of economies of scale. Each investment financing model demonstrate different economic performance depending on the size of the solar farm project.

For a 5 MW PV power plant, the first investment financing model showed the best economic performance while the third model the worst In addition, the economic performance of the second model is slightly lower than the first model.

For 50 and 100 MW PV power stations, the third investment financing model has the best economic performance. Moreover, the first and second models have nearly the same economic performance except for IRR, where the second model showed better results. Therefore, it can be concluded that the first and second models are the suitable investment financing model for a 5 MW project and the third model is the appropriate investment model for 50 and 100 MW projects.

However, the third model is appropriate only with investors who have EPC experience. These are investors, who are already solar farm developer and operators and/or who have good understanding of the PV industry of Thailand and good relations with other players in this industry.

5. Conclusions

This research paper is an demonstrate the t analysis of three current investment financing models in Thailand for MW-scale PV power plants. These three investment financing models are (1) 100% investor financing of investment (i.e. capital), (2) combine investor financing at 70% and bank loan financing at 30% of the investment and (3) 100% investor financing of investment (capital) and the EPC (Engineering, Procurement and Construction) or installation cost. These investment financing models are analyzed using three power plant project sizes - 5 MW, 50 MW, and 100 MW. Six economic indicators were evaluated, including cash flow, LCOE, PP, BCR, NPV, and IRR.

The results of the analysis show that bigger utility-scale PV power stations have better economic performance because of economies of scale. Each investment financing model analyzed is match with the different project sizes. The first and second investment financing models are more appropriate for a 5 MW project. The third model is shown to be inapplicable for a 5MW power plant. The third investment financing model is more suitable for 50 MW and 100 MW projects. In addition, the analysis indicate that the third investment financing model is suitable only with investors who have EPC experience. These are investors who have experiences as, utility-scale PV power station developers and operators, and have good business connection with other players of the PV industry in Thailand.

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