DIGITALES ARCHIV

ZBW – Leibniz-Informationszentrum Wirtschaft ZBW – Leibniz Information Centre for Economics

Chaiporn Suphahitanukool; Issaree Hunsacharoonroj; Parnuwat Usapein et al.

Article

An evaluation of economic potential solar photovoltaic farm in Thailand : case study of polycrystalline silicon and amorphous silicon thin film

Provided in Cooperation with: International Journal of Energy Economics and Policy (IJEEP)

Reference: Chaiporn Suphahitanukool/Issaree Hunsacharoonroj et. al. (2018). An evaluation of economic potential solar photovoltaic farm in Thailand : case study of polycrystalline silicon and amorphous silicon thin film. In: International Journal of Energy Economics and Policy 8 (4), S. 33 - 41.

This Version is available at: http://hdl.handle.net/11159/2135

Kontakt/Contact ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics Düsternbrooker Weg 120 24105 Kiel (Germany) E-Mail: *rights[at]zbw.eu* https://www.zbw.eu/econis-archiv/

Standard-Nutzungsbedingungen:

Dieses Dokument darf zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden. Sie dürfen dieses Dokument nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, aufführen, vertreiben oder anderweitig nutzen. Sofern für das Dokument eine Open-Content-Lizenz verwendet wurde, so gelten abweichend von diesen Nutzungsbedingungen die in der Lizenz gewährten Nutzungsrechte.

https://zbw.eu/econis-archiv/termsofuse

Terms of use:

This document may be saved and copied for your personal and scholarly purposes. You are not to copy it for public or commercial purposes, to exhibit the document in public, to perform, distribute or otherwise use the document in public. If the document is made available under a Creative Commons Licence you may exercise further usage rights as specified in the licence.





Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics



INTERNATIONAL JOURNAL O ENERGY ECONOMICS AND POLIC International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http://www.econjournals.com

International Journal of Energy Economics and Policy, 2018, 8(4), 33-41.



An Evaluation of Economic Potential Solar Photovoltaic Farm in Thailand: Case study of Polycrystalline Silicon and Amorphous Silicon Thin Film

Chaiporn Suphahitanukool¹, Issaree Hunsacharoonroj²*, Parnuwat Usapein³, Joseph Khedari⁴, Jompob Waewsak⁵, Jongjit Hirunalbh⁶

¹Rattanakosin College for Sustainable Energy and Environment (RCSEE), Rajamangala University of Technology Rattanakosin, Thailand, ²Rattanakosin College for Sustainable Energy and Environment (RCSEE), Rajamangala University of Technology Rattanakosin, Thailand, ³Rattanakosin College for Sustainable Energy and Environment (RCSEE), Rajamangala University of Technology Rattanakosin, Thailand, ⁴Faculty of Technology and Innovation, Bangkokthonburi University, Thailand, ⁵Research Center in Energy and Environment, Thaksin University, Thailand, ⁶Faculty of Technology and Innovation, Bangkokthonburi University, Thailand. *Email: issaree@rmutr.ac.th

ABSTRACT

Solar energy in Thailand plays an important role to achieve the target of the alternative energy development plan (AEDP). Enormous investments from investors are expected to occur for support AEDP. Therefore, the objective of this study was to evaluate and compare the economic potential of solar photovoltaic (PV) farm between polycrystalline silicon (PCSS) and amorphous silicon thin film (ASTF) type. Questionnaires submitted to private solar PV farm for collecting data. As a result, four main investment costs of PSS are identified: (1) photovoltaic module; (2) connection system; (3) inverter, and (4) engineering construction, distributed as 58.09%, 19.66%, 12.96%, and 4.47%, respectively. The financial analysis found that payback period, internal rate of return, and solar plant capital of ASTF were less than PCSS; however, it returns low income along 25 years than PCSS. It could be suggested that the investment on PCSS is worth than ASTF.

Keywords: Economic Potential, Solar Photovoltaic Farm, Investment, Financial Economic JEL Classifications: C8, G0, M2

1. INTRODUCTION

Nowadays, the importance of exploring renewable energy has dramatically increased. Increasing global population leads to more energy demand, while limited resources for energy supply. The International Energy Agency (IEA) has reported that developing countries will double their energy need in response to their growth by 2020 (IEA, 2008). Solar energy can convert to electric by using a photovoltaic (PV) device. With this device, the electricity produced from solar energy has less impact on the environment; furthermore, it has also secure, clean, and suitable (Shukla et al., 2018). Solar energy can provide many advantages on the environment, leading to worldwide attention on solar energy to support the critical need for energy usage. Therefore, the trend of installing solar system has highly continued growth around the world.

Likewise, Thailand has been very active in bringing solar energy to use, although the current situation of Thailand's electricity production is heavily dependent on fossil fuels, especially natural gas (69.22%) and coal (19.10%) (Usapein and Chavalparit, 2017). Energy resources in Thailand has been reduced, opposite with the energy demand in the country. In 2016, Thailand has imported energy with totaled value of 1.42 trillion baht, the highest value was come from crude oil (1.07 trillion baht), followed by natural gas, and liquefied natural gas, respectively (MoE, 2016). To reduce dependence on foreign energy imports, Thailand is urgently needed to encourage using more renewable energy. Therefore, the alternative energy development plan (AEDP) has established by Ministry of Energy to promote renewable energy consumption. In addition, the latest version of Thailand power development plan (PDP) has adjusted and increased the share of renewable energy to be at least 20% by 2025 (Ketjoy and Mansiri, 2013; MoE, 2011; Suthiwongwong, 2011). If this plan success, the electricity generation capacity from renewable energy will go up to 14,000 MW by 2021. With the expected electricity generation capacity from solar energy in AEDP (3,000 MW), solar energy will play an important role on the target of AEDP (EGAT, 2016).

According to the AEDP, it is expected that there will be huge investments in solar energy technology to support such plans. However, one of important problems is that most of the new Thai investment owners have lacked the knowledge about returns on their investment. Some projects have a risky investment due to the insufficient understanding of the nature of the renewable energy business. Some investors have a solar license from Thai government, but they are not knowledgeable or experienced on solar energy business (Rinphol, 2016; Suwanasang and Tongsopit, 2015; Tantisttayakul, 2015). In addition, the research paper related with the investment on solar PV farm in Thailand is very rare. Therefore, the objective of this study was to analyze and evaluate the economic potential of solar PV farm in Thailand along with primary and secondary data collection. The detail on cost of construction and operation will be evaluated and can be used as a guideline for researchers, policy maker, and consultants for proposing the new ideas of developing solar investments in the future.

1.1. Status of Solar PV Farm in Thailand

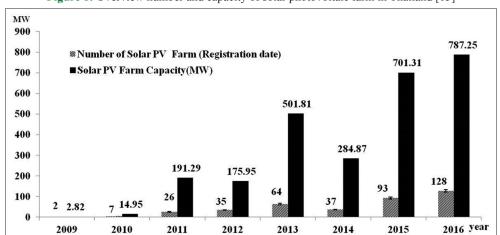
The solar PV farm in Thailand is becoming greater along with Electricity Regulator Commission (ERC) license system for the registration of solar PV farm. This is because Thai government has created the program by adding the prices of purchase electricity produced by solar cell for very small power producer (VSPP) (Hachigami, 2015; Jäger-Waldau, 2012; Sahay et al., 2013). Solar PV farm in Thailand have been increased exponentially both in number of stations and capacity for year 2009–2016, except in the year 2014, as shown in Figure 1.

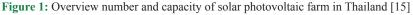
Although there had previously been a solar investment project supported by Thailand's government, the payback period (PB) took a long time. However, the increased financial knowledge on the types of solar PV farm, the amount of money needed to set up an investment fund, the length of time for the PB, the percentage of internal rate of return (IRR), the performance ratio and the plant capacity factor including turnover for a 25 years project have benefited to investors. Currently, the installed capacity of solar PV farm in Thailand have increased; however, the size of installed capacity has mostly as VSPP (about 92%) beyond independent power producer (IPP) and small power producer, as shown in Figure 2.

Updated total solar PV farm year 2016 in each province of each region in Thailand was gathered data from ERC. Regional arranging from highest to lowest in numbers of stations and capacity were as follows: Highest was the Central region at 274 plants with a total capacity of 1636 MW, Northeastern region at 75 plants with a total capacity of 392 MW and the lowest was the Northern region at 43 plants with a total capacity of 630 MW, as shown in Table 1. However, there was no registration of solar PV farm in the Southern region due to the crisis and terrorist situation. Lopburi and Kanchanaburi in the Central region, Nakorn Sawan in the Northern region, KhonKaen, Ubon Rachathani and Nakorn Rachasima in the Northeastern region have expanded the installation capacity for 3-4 years. Meanwhile, Phetchaburi, Saraburi and Suphanburi in the Central region, Tak, MaeHongSon, Kampangpetch in the Northern region, and Udonthani, SriSaKet, BuriRum, Chaiyaphum in the Northeastern have two consecutive years of capacity expansion. In present, the cumulative PV capacity at the end of year 2016 is 2660 MW.

The largest capacity of solar PV farm installed during year of 2009–2016 was 506 MW, while the smallest capacity was 11 MW. Most of solar PV farm in Thailand was located in the central region about 70%, followed by Northeast 19%, and North 20%, respectively. This is because the central area is suitable for both the intensity of the solar radiation and the wires that can be installed and sold the electricity to the government.

The frustrated of solar PV farm has main factor from government policy and depends on natural disaster in Thailand. Adder program has changed the rate of subsidy from 0.25 USD/kWh to 0.20 USD/ kWh in year of 2010. In 2013, the announcement of Feed-in-Tariff (FiT) for solar energy was delayed due to the government needs to





vare home 2000 2011 2012 2013 2014 2015 2016 Chachonesso 1 0 2 7 20 5 Chai Nat 7 7 7 1 1 Chan Nat 7 7 7 2 Chan Juan 3 64 7 7 2 Chan Juan 3 64 7 7 7 2 Kanchanzburi 11 12 6 2 90 13 13 Nakhon Nayok 8 17 60 87 14 160 13 Nakhon Palhori 2 12 156 45 203 39 Prachup Khiri Khan 2 12 156 45 203 39 Prachup Khiri Khan 2 12 127 17 7 Ayuthaya 3 8 13 24 7 280 28 11 20 12	Thailand (ERC, 2011)										
Ang Ihong1102720SChailon Statu77271Chain Nation77271Chanthaburi11112261617423I op Huri364182261617423Nakhon Nayok81760871418623Nakhon Nayok81760871418623Nakhon Nayok81760871418623Nakhon Nayok81760871418623Nakhon Nayok1225283710215Parahur Kin Kirkan2225283710215Prachur Kiri Kirkan238132477Rayong2381324712Samut Sakorn2381324712Samut Sakorn3641424227713Saraburi6141124227713Saraburi6141124227713Saraburi8139922306211Saraburi1819620204044Mayong18191341414<	Province				Capacit	y (MW)				Total capacity	No. of solar PV farm
Ang Ihong 1 IO 2 7 20 5 Chair Nati 7 7 1 Chanthaburi 7 7 2 Chanthaburi 11 11 22 61 6 174 23 Chon Buri 3 64 18 22 61 6 174 23 Lop Huri 3 64 18 22 61 6 174 23 Nakhon Nayok 8 17 60 87 14 186 23 Nakhon Nayok 8 17 60 87 14 186 23 Nakhon Nayok 12 25 28 37 102 15 Parahup Khirkhan 2 12 25 28 37 102 15 Prachup Khirkhan 2 12 25 28 37 12 17 Parahup Khirkhan 2 12 25 28 37 12 17 Parahup Khir Khan 2 2 78 13		2009	2010	2011	2012	2013	2014	2015	2016		
Chai NatIIIIIChai Nat772Chan Bari36772Chon Bari11126429013Chon Bari367772Kanchanbari11126429013Lop Buri367772Nakhon Pathon871418623Nakhon Pathon216182035Nakhon Pathon21516182035Prohubari221561820319Prohubari2125283112719Prohubari213813247Rayong2228882Prankorn Stor22288211Ayuthaya13153511Ayuthaya122288211Ayuthaya22288121212Ayuthaya1222881212Sanbur Songkhram222881212Sanbur Songkhram122771313Sanbur Songkhram122771314Lampang112	Ang Thong									20	5
Chai Nat ² 7 7 1 Chanthaburi 11 12 5 35 7 Chon Buri 3 64 18 22 61 6 174 23 Lop Buri 3 64 18 22 61 6 174 23 Nakhon Nayok 8 17 60 87 14 186 23 Nakhon Nayok 8 17 60 87 14 186 23 Nakhon Nayok 8 17 60 87 14 186 23 Pathonthani 2 1 28 28 20 5 Prachuburi 2 25 28 43 10 5 Prachuburi 2 2 26 45 127 17 Ayuthaya 3 2 6 8 2 13 Samut Skorn 2 2 6 8 2 14 Samut Skorn 3 8 13 8 2 15		1									
Chantabari		-			7						
					,				7		
Kanchanduri I 1 1 2 4 9 13 Lop Buri 3 64 18 22 61 6 174 23 Nakhon Nayok 8 17 60 87 14 186 23 Nakhon Nayok 8 10 8 8 2 10 10 1 Nathon Nayok 2 12 2 18 20 5 Pathonthain 2 2 18 20 5 Prachup Khir Khan 2 2 28 37 102 15 Prachup Khir Khan 2 3 8 13 24 7 Rayong 2 3 8 13 24 7 Samut Sakorn 3 8 13 24 22 77 13 Samut Sakorn 3 6 1 14 24 22 77 13 Samut Sakorn 3							30				
					11	11		12	5		
Nakhon Nayok			2	64			20		6		
Nakhon Pathom 8 17 60 87 14 180 23 Nonthaburi 10 10 10 1 Nonthaburi 2 10 8 8 2 Platchaburi 2 156 45 203 39 Prachuburi 12 25 34 51 87 19 Prankun Khiri Khan 2 34 51 87 19 Prankun Khiri Khan 2 3 5 18 13 24 7 Ayutfhaya 1 3 8 13 24 7 Rayong 2 2 2 280 48 2 Samut Skond 1 2 2 30 62 11 Samut Songkhram 1 8 30 9 8 5 5 1 Samut Skond 1 8 19 9 9 9 2 12 Chaic Rai<			3	04	10	22		01			
Nakhon Nayok 10 10 1 Pathomthani 2 2 18 20 5 Pathomthani 2 25 28 37 102 15 Prachup Khrin Khan 2 25 28 37 102 15 Prachup Khrin Khan 2 34 10 5 37 127 17 Prachup Khrin Khan 2 3 8 13 24 7 Ayuthaya 3 2 28 28 28 28 Yauthaya 2 3 8 13 24 7 Rayong 2 2 20 280 48 Samat Skorn 3 8 50 9 8 54 1641 Samat Skorn 8 10 100 48 64 1641 274 Samat Skorn 8 10 9 8 5 10 12 Samat Skorn 8 10 16 14 11 24 22 77 13 Starburi 8 50 9 8 5 10 14 14 Lampang 1 8 10 15				0	17	(0		07			
Nonthaburi Nonthaburi Nonthaburi No No <t< td=""><td></td><td></td><td></td><td>8</td><td>1 /</td><td></td><td></td><td>8/</td><td>14</td><td></td><td></td></t<>				8	1 /			8/	14		
Pathomhani 2 18 20 5 Phachinburi 12 25 28 37 102 15 Prachup Kirin Khan 2 37 102 15 41 34 10 5 37 127 17 Ayufhaya - - 3 8 13 24 7 Rayong - 2 6 8 2 3 34 7 Santus Sakom - 2 6 8 2 3 34 7 Samut Songkiram - 2 6 14 11 24 22 77 13 Samut Songkiram - 8 9 9 8 5 80 12 Saraburi 6 14 11 24 22 77 13 Saraburi Songkiram 8 9 1 13 16 16 16 16 16 16 16 16 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td>10</td> <td></td> <td></td> <td>0</td> <td></td> <td></td>						10			0		
Phetchaburi2564520339Prachuburi1225283710219Prankor Sri234518719Ayuthaya3381324719Ayuthaya38132477Ravong23813247Sakao38132477Sakao38132477Sakuo38132477Sakuo38132477Samut Sakorn6141124227713Samut Sakorn6141124227713Samut Sakorn6141124227713Samut Sakorn6131004896241641274Ching Rai1813069211004896241641274Ching Rai1111111111Ching Rai11111111111Ching Rai1111111111111111111111111111111 <th< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td></td><td></td><td>2</td></th<>								2			2
Prachinburi 12 25 28 37 102 15 Prankom Sri 41 34 10 5 37 127 17 Ayuthaya - - 3 8 13 24 7 Ratchaburi - 3 8 13 24 7 Rayong 2 - 6 8 2 Samut Skorn - 32 30 62 11 Samut Skorn - 32 30 62 11 Samut Skorn - - 32 30 62 12 Samut Skorn - - 32 30 62 12 Samut Songkhram - 8 50 9 8 5 80 12 Saraburi 6 14 11 24 624 1641 274 Chiang Rai - - 10 40 4 Chiang Rai - 10 135 137 4 Chiang Rai - 10 13 4 4 Kampono - 10 13 14 4 Machom Sowa 13 126 15			2								
Prachy Khiri Khan 2 34 51 87 19 Pranakom Sri 41 34 10 5 37 17 Ayutthay - 3 8 13 24 7 Rayong - 2 6 8 2 Sa kao - 280 280 48 Samut Sakorn - 32 30 62 11 Samut Sakorn - - 9 9 2 Samut Sakorn 6 14 11 24 22 77 13 Suphan Buri 6 14 11 24 5 80 12 Total Central region 1 8 139 69 211 100 489 624 1641 14 Lampang - 1 135 1 137 4 Lampang - 1 135 1 137 4 Lampang -<			2								
Prankom Sri 41 34 10 5 37 127 17 Ayuthaya - 3 8 13 24 7 Ratchaburi - 3 8 13 24 7 Rayong 2 6 8 2 Samut Skoron - 8 8 2 Samut Skoron - 32 30 62 11 Samut Skoron - 32 30 62 11 Samut Skoron - 32 30 62 11 Samut Songkhram - 8 50 9 8 5 80 12 Starburi 8 139 69 211 100 48 64 1 Chiang Rai - 4 - 4 1 1 Chiang Rai - 1 13 137 4 Lampon 1 13 126 1 13 137 4 Lampon 1 13 126 15 154 5 Phare Lampon 1 13 126 15 14 16 Phare Lampon - 1 3 <			•	12			25				
Ayuthaya Ratchaburi23813247Ratchaburi2682Sa Kaco28028048Samut Prakarn82306211Samut Sakorn992Saraburi6141124227713Suphan Buri8509858012Total Central region1813969211004896241641274Chiang Mai42020404114141414Lampong113135113741414Mar Hong Sorn11312615154514Phare101011414141414Nakon Sawan1312615154515Phare8811141414Phetchabun546518116Phetchabun51213371132Total North region0318518250121311Su Kho Thai212131321514 <td< td=""><td></td><td></td><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>			2								
Ratchaburi 3 8 13 24 7 Bayong 2 6 8 2 Sa Kaeo 2 280 280 48 Samut Sakorn 32 30 62 11 Samut Songktram 32 30 62 11 Samut Sakorn 6 14 11 24 22 77 13 Suphan Buri 6 14 11 24 9 9 2 2 Suphan Buri 8 50 9 8 5 80 12 12 Chiang Rai 1 8 19 624 1641 274 14 Lampong 1 13 13 13 13 14 14 Lampong 1 13 13 14 4 14 Lampong 13 126 15 154 5 Mact Mon Savan 13 126 15 154 5 Phate Mon 5 16 20 11 37				41		34	10	5	37	127	17
Rayong 2 6 8 2 Sa Kaco 280 280 48 Samut Sakorn 8 8 2 Samut Sakorn 9 9 2 Samut Songkhram 9 9 2 Sarbar Samut Songkhram 9 8 5 80 12 Suphan Buri 6 14 11 24 22 77 13 Suphan Buri 8 139 69 211 100 489 624 1641 274 Chiang Mai 1 8 139 69 211 100 489 624 1641 274 Chiang Mai 1 13 125 137 4 1 Lampang Pet 1 135 137 4 1 1 13 126 15 154 5 Phare 10 134 13 14 1 1 1 1 Phetchabon 3 5 18 5 12 63 1 1 1											
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$						3		8	13		
Samut Prakam	Rayong				2						
Samut Sakorn32306211Sambut Songkhram6141124227713Saraburi6141124227713Suphan Buri8509858012Chiang Mai81920404Chiang Rai12020404Lampong Pet113511374Lampon134551Mac Hong Sorn13126151545Phare13444Nakorn Sawan13126151545Phare10101111Phetchabun35101844Phetchabun35101844Su Kho Thai101135101Iak Kare620113755101Bengkard77116610121Su Kho Thai26211375121Su Kho Thai12631212111Bengkard711312221Su Kho Thai2131253121211Kakon Kace6157213<	Sa Kaeo								280	280	48
Samut Songkhram 0 0 2 Saraburi 6 14 11 24 22 77 13 Suphan Buri 8 50 9 8 5 80 12 Total Central region 1 8 139 69 211 100 489 624 1641 274 Chiang Mai 4 4 1 274 4 1 135 1 1 Chiang Mai 4 20 20 40 4 1 Lampang Pet 1 135 1 137 4 Lampang Pet 1 1 8 9 2 Mae Hong Sorn 13 126 15 154 5 Phare 13 126 15 154 5 Phare 10 10 1 1 1 Phetchabun 3 5 10 134 1 Phetchabun 3 5 10 134 1 Phetchabun 3 5 10 134 1 Su Kho Thai -12 134 134 1 Total North region 0 3 18 5 82 53 7 Burgkard -2 2 2 2 2 2 Chabyaphum -2 2 2 2 2 Nakhon Rachasima 5 11 45 6 5 7 1 Ron Gam 6 12 2 2 2 <td>Samut Prakarn</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>8</td> <td>8</td> <td>2</td>	Samut Prakarn								8	8	2
Saraburi6141124227713Suphan Buri8509858012Chaing Mai5511Chiang Mai274551Chiang Mai2020404Lampong Pet113511374Lampon1892Mac Hong Sorn1344Nakorn Sawan131251514Phetchabon1344Phetchabon10101Phetchabun3510184Phetchabun3510184Phetchabun35101341341Su Kho Thai620113755Total North region0318582537Chiang Kai2132537116612Chabun511171661612Chabun6152133121Na Khon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima51145651214 <td>Samut Sakorn</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>32</td> <td>30</td> <td>62</td> <td>11</td>	Samut Sakorn							32	30	62	11
Saraburi6141124227713Suphan Buri8509858012Chaing Mai5511Chiang Mai274551Chiang Mai2020404Lampong Pet113511374Lampon1892Mac Hong Sorn1344Nakorn Sawan131251514Phetchabon1344Phetchabon10101Phetchabun3510184Phetchabun3510184Phetchabun35101341341Su Kho Thai620113755Total North region0318582537Chiang Kai2132537116612Chabun511171661612Chabun6152133121Na Khon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima51145651214 <td>Samut Songkhram</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>9</td> <td>9</td> <td>2</td>	Samut Songkhram								9	9	2
Suphan Buri 8 50 9 8 5 80 12 Total Central region 1 8 139 69 211 100 489 624 1641 274 Chiang Mai 4 5 5 1 1 1 1 1 Chiang Rai 4 4 1 1 1 1 1 1 Kampang Pet 1 135 1 137 4 1 Lampoon 1 3 4 4 4 Nakorn Sawan 13 126 15 154 5 Phare 10 10 10 1 1 Phetchabon 3 5 10 18 4 Phetchabun 3 5 10 10 1 Su Kho Thai 5 46 51 8 1 Phitisanulok 5 182 50 212 159 629 43 Su Kho Thai 1 12 63 12 13 12 14 Su Kho Thai 2 77 7 1 14 13 12 Su Kho Thai 2 12 13				6	14	11		24		77	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$							9				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		1	8		69						
$\begin{array}{c c c c c c c c c c c c c c c c c c c $											
Kampang2020404Lampon113511374Lampon1892Mae Hong Sorn13126151545Phare881Phetchabon10101Phetchabun3510184Phetchabun546518Phetchabun546518Phitsanulok10101Su Kho Thai6201137Total North region0318518250Pata21325371Chayaphum51126312Khon Kaen35115213Nakhon Rachasima511456572Nakhon Rachasima511456121Nakhon Rachasima6152133Nakhon Rachasima51145611Nakhon Rachasima61117331Nakhon Rachasima6111733Nakhon Rachasima51145611Nakhon Rachasima51145611Nakhon Rachasima51145611Nakhon Rachasima51145611 <t< td=""><td></td><td></td><td></td><td></td><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td></t<>					4						
$\begin{array}{cccccccccccccccccccccccccccccccccccc$					•	20	20				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$							20	135	1		
Mac Hong Sorn1344Nakorn Sawan13126151545Phare881Phetchabon10101Phetchabun3510184Phetchabun3510184Phetchabun546518Phitchit546518Phitshild518250212159Su Kho Thai6011375Total North region0318518250212159Buri Ram21325371Chaiyaphum671322Kalsin22115213Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima615213314Nakhon Rachasima671111Nakhon Rachasima657215151515Nakhon Rachasima611733111Sakonakorn6572151514111111111111111111111111<									1		
Nakorn Sawan13126151545Phare010101Phetchabon3510184Phetchabun3510184Phetchabun546518Phichi546518Phitsanulok1341341Su Kho Thai10101Total North region031851825021215962943Bengkard771371101612Buri Ram213253771126312Kalasin251126312216Loei671323323Nakhon Rachasima51145657215Nakhon Rachasima511456111Nakhon Rachasima511456111Nakhon Rachasima5114561113Sakonakorn61572151511113Sakonakorn611710211113111311111111111111 <t< td=""><td></td><td></td><td></td><td></td><td>1</td><td></td><td></td><td>0</td><td></td><td></td><td></td></t<>					1			0			
Phare 8 8 1 Phetchabon 3 5 10 10 1 Phetchabun 3 5 10 18 4 Phetchabun 3 5 10 18 4 Phetchabun 5 46 51 8 Phitsanulok 5 46 51 8 Phitsanulok 10 1 134 134 1 Su Kho Thai 6 20 11 37 5 Total North region 0 3 18 5 182 50 212 159 629 43 Bengkard 7 7 1 1 10 1 1 1 Buri Ram 21 32 53 7 1 12 12 12 Kalasin 2 2 2 2 1 1 1 1 Loci 6 7 13 2 3 1 1 1 Nakhon Rachasima 5 11 45 6 5 72 15 Nakhon Rachasima 5 11 45 6 5 72 15 Nakhon Rachasima				13	1			15			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				15		120		15	8		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$						10			0		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$			2	5							
$\begin{array}{cccccccccccccccccccccccccccccccccccc$			5	5		10		0			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$						5					
Su Kho Thai10101Tak62011375Total North region031851825021215962943Bengkard7711871Buri Ram21325371Chaiyaphum51126312Kalasin2222Kon Kaen30181716616Loei671323Nakhon Phanom6152133Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima611111Roi Et8813311Sakonakorn611173311Ubon Ratchathani3710211Udon Thani25351031071311538975						3		40	124		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$							10		134		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$											
Bengkard771Buri Ram2132537Chaiyaphum51126312Kalasin222Kalasin222Kann30181716616Loei67132Nakhon Phanom615213Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima11111Roi Et88111Sakonakorn611173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975		0	2	10	-			010			
Buri Ram 21 32 53 7 Chaiyaphum 51 12 63 12 Kalasin 2 2 2 Kalasin 2 2 2 Khon Kaen 30 18 17 1 Loei 6 7 13 2 Nakhon Phanom 6 15 21 Nakhon Rachasima 5 11 45 6 5 Nakhon Rachasima 5 11 45 6 5 Nakhon Rachasima 5 11 45 6 12 Nong Kai 1 1 1 1 Roi Et 8 7 7 1 Sakonakorn 6 7 7 1 Sakonakorn 6 11 17 3 Surin 3 7 10 2 Ubon Ratchathani 5 3 13 21 Udon Thani 2 1 7 10 2 5 35 103 107 131 1 5 389 75		0	3	18	5	182		212	159		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$						0.1					
Kalasin2222Khon Kaen30181716616Loei67132Nakhon Phanom615213Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima11111Nong Kai11111Roi Et88111Sakonakorn61711Sakonakorn6173102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975											
Khon Kaen 30 18171 66 16Loei67132Nakhon Phanom615213Nakhon Rachasima51145657215Nakhon Rachasima51145657215Nakhon Rachasima1121211Nong Kai11111Roi Et87711Sakonakorn67102Sakonakorn61173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975						51					
Loei67132Nakhon Phanom615213Nakhon Rachasima51145657215Nakhon Rachasima1212111Nong Kai11111Roi Et87711Sakonakorn6771Sakonakorn61173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975					•	10					
Nakhon Phanom615213Nakhon Rachasima51145657215Nakhon Rachasima1212111Nong Kai11111Roi Et8771Sakonakorn6771Sakonakorn61173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975					30	18		1			
Nakhon Rachasima51145657215Nakhon Rachasima1212111Nong Kai11111Roi Et88111Sakonakorn6771Sakonakorn61173Surin37102Ubon Ratchathani531321Udon Thani217103Total Northeast25351031071311538975											
Nakhon Rachasima12121Nong Kai111Roi Et881Sakonakorn771Sakonakorn661Si Sa Ket611173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975							15				
Nong Kai111Roi Et881Sakonakorn771Sakonakorn661Si Sa Ket611173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975			5	11	45	6			5		
Roi Et881Sakonakorn771Sakonakorn661Si Sa Ket611173Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975							12				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$						1					1
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$					8						1
Si Sa Ket 6 11 17 3 Surin 3 7 10 2 Ubon Ratchathani 5 3 13 21 4 Udon Thani 2 1 7 10 3 Total Northeast 2 5 35 103 107 131 1 5 389 75							7				1
Surin37102Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975											
Ubon Ratchathani5313214Udon Thani217103Total Northeast25351031071311538975				6							
Udon Thani 2 1 7 10 3 Total Northeast 2 5 35 107 131 1 5 389 75											
Udon Thani 2 1 7 10 3 Total Northeast 2 5 35 107 131 1 5 389 75					5	3	13				
Total Northeast 2 5 35 103 107 131 1 5 389 75	Udon Thani	2									
	Total Northeast		5	35	103	107	131	1	5	389	75
	Total (Thailand)	3	16	192	177	500	281	702	788	2659	392

Table 1: Number of stations, capacity and location of solar farms during the year 2009–2016 in each regions	of
Thailand (ERC, 2011)	

more studies pros and cons of the program. Moreover, the rate of FiT was changed to be 6.16 THB/kWh (capacity >10–250 kWh) and 6.55 THB/kWh (capacity >250–1,000 kWh). This can affect to the investment attraction on solar PV farm decreased. In addition, Thailand has suffered from big flooding in 2011, which may affect to solar PV farm reduced in year of 2012.

2. METHODOLOGY

2.1. Primary Data Collection

Completed questionnaires submitted to private solar PV farm for primary data collection which were separated according to the type of solar cell. The questionnaires were sent to 200 polycrystalline silicon (PCSS) solar PV farm and 25 amorphous silicon thin-film solar PV farm. After that, the researchers took random samples to analyze the objective research of 20 plants which were selected from 10 plants each of the PCSS solar PV farm and the amorphous thin-film solar PV farm.

2.2. Secondary Data Collection

The relevant secondary data were gathered from reliable sources. The capacity of solar cell in Thailand was obtained from the ERC. The related data about renewable energy policy, PDP, and etc., were collected from the Department of Alternative Energy the Development and Efficiency (DEDE), the Metropolitan Electricity Authority, the Provincial Electricity Authority, academic research, dissertation, and Journal and/or other related articles/reports from the internet.

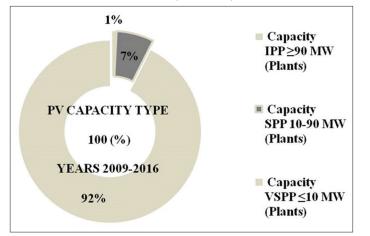
2.3. Calculation of Plant Capacity Factor and Performance Raito

According to the ERC's announcement for Environmental and Safety Assessment in the renewable solar energy sector (Jäger-Waldau, 2012), the private solar PV farm must design with a plant capacity factor of at least 15 % and a performance ratio >75% (Tanpipat, 2011). The plant capacity factor (%) and the performance ratio (%) can be calculated as shown in Equations (1) and (2):

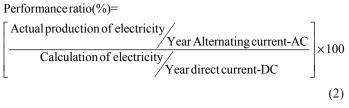
Plant capacity factor(%)=

$$\begin{bmatrix} (MWh_{AC}) / (MWh_{DC} \times Production Hours) \end{bmatrix} \times 100$$
(1)

Figure 2: Size of installed capacity of solar photovoltaic farm in Thailand (ERC, 2011)



Where MWh_{AC} /year represents the actual annual electricity production, and MWh_{DC} is the capacity of solar cell plant.



As shown in Table 2, the ten of PCSS solar PV farm have a performance ratio between 82-84% and a plant capacity factor between 17–18%, respectively.

Table 3 displays the ten of amorphous silicon thin film (ASTF) solar PV farm, which have a performance ratio between 80-83% and a plant capacity factor between 15-16%, respectively.

2.4. Investment Analysis

A private company usually considers the cash outcome to recover their initial investment along with the decision of where to invest their fund. The indicated parameter of the investment research in this paper inclusive as hereunder.

2.4.1 IRR (MoE, 2011)

This parameter is the project ratio return under the loan interest's rate and a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. If the result of IRR is higher than the return profit, the project has to

Table 2: Performance ratio and plant capacity factor of the PCSS solar PV farm

Plant	PCSS solar PV farm						
	Performance ratio (%)	Plant capacity factor (%)					
1	83	17					
2	82	18					
3	84	18					
4	83	18					
5	84	18					
6	84	17					
7	84	18					
8	84	18					
9	84	18					
10	83	18					

PCSS: Polycrystalline silicon, PV: Photovoltaic

Table 3: Performance ratio	and plant capacity factor of
the ASTF solar PV farm	

Plant	ASTF solar PV farm					
	Performance ratio (%)	Plant capacity factor (%)				
1	80	15				
2	82	16				
3	84	16				
4	84	16				
5	83	16				
6	82	16				
7	82	16				
8	83	15				
9	83	15				
10	83	15				

ASTF: Amorphous silicon thin film, PV: Photovoltaic

be reconsidered before beginning the project. On the other hand, when the IRR' calculation has a high return profit in consequence under the satiation of a low-interest rate, the project will have a higher return. IRR calculations rely on the same formula as NPV as hereunder.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$
(3)

 C_t = net cash inflow during the period t, C_0 =total initial investment costs, r = discount rate, and t= number of time periods.

2.4.2. PB

The PB determines the time to recover the cash inflows generated by the initial overall investment less the overhead and expenses during the project operation. The calculation of PB was shown in Equation (3). The unit of PB is by year. The short-recovery period means the project has a good profit in a relatively short time period.

Payback period =
$$\frac{\text{TIC}}{\text{NCF}}$$
 (4)

Where TIC represents to initial investment, and NCF represents to Cash inflow (USD/Year). The theory of PB must be shorter than the project age. In practice, the mega solar project accepts 7–8 years for the PB.

2.4.3. Cash flow

Cash flow evaluates the cost and expenses compared with the turnover. A cash flow calculation for the project is important because the project owner can resolve and plan to avoid a shortage of money for the project and do not cause project disruptions due to a lack of funds. The relevant elements affecting the proper capital investment are the cost and the expenses during the project period. While the investment cost of a solar project consisted of land preparation, photovoltaic module, inverter, transformer, connection system, cable, structure and installation, engineering, supplier, construction, fence, ditch and utilities, the operating cost consisted of gasoline expense for lawn remover, public supply cost for PV's cleaning and electrical system, telephone system and network cost, and etc. However, the cost and expenses vary depending on the selective technology, size of the project and government support scheme (Hachigami, 2015; Suthiwongwong, 2011).

Table 4: Analysis output in 25 years of PC
--

3. RESULTS AND DISCUSSION

The surveyed data was supported by private solar PV farm in each 10 of PCSS solar PV farm and ASTF solar PV farm. The location and commercial operation date (COD) of each survey data also show in Table 4. PB, IRR, and Turnover of ASTF and PCSS were analyzed. The currency applied in this paper refers to the average of exchange rate during year 2012. Therefore, the exchange rate was 32.4 USD/THB. Output analysis was based on hours/year at 8640 h. Output analysis resulted of PCSS is more than ASTF at 16% in average output along 25 years, as shown in Table 4. Energy output from solar cell depends on PV efficiency. Because the efficiency of PCSS is higher than ASTF around 50%, the output of PCSS shows higher result than ASTF.

After analyzed data, the result found that the average data of investment, PB, IRR, and turnover from ten samples of PCSS were 3.61 million USD, 8.40 years, 9.40%, and 5.97 million USD, respectively (Table 5). Meanwhile, the average data from ten samples of ASTF were 3.03 million USD, 8.76 years, 9.58%, and 4.66 million USD, consecutively (Table 6). The investment cost of PCSS was in a range of 3.45–3.7 USD per MW, which has PB about 8.35–8.74 years, and 8.97–10.01% of IRR. The income along 25 years was around 5.57–6.13 million USD. In case of ASTF, the investment cost was in a range of 2.79–3.20 US\$ per MW, with PB of 8.56–9.00 years, and 9.31–10.02% of IRR. The income along 25 years project was around 4.20–5.01 Million USD.

The average PB and IRR data of ASTF and PCSS were nearly the same result, while the turnover of PCSS was greater than ASTF by adding 8% of investment cost from ASTF and increasing 19% turnover compared with ASTF. In comparison of PB between ASTF and PCSS, the result indicated that PB of PCSS was slightly longer than ASTF. In case of IRR, PCSS has IRR less than ASTF about 2%. However, the average data of PB and IRR showed that the result was nearly the same outcome between PCSS and ASTF. Therefore, PB and IRR are not significant difference on the investment of PCSS and ASTF. Both of PCSS and ASTF, they have PB and IRR around 8 years, and 9%, respectively.

In comparison of investment cost and cash flow, this study selected each one of solar PV farm from PCSS and ASTF that have the same COD date during year 2012. As shown in Table 7,

Table 4. A	Table 4. Analysis output in 25 years of 1 C55 and A511									
No.		1	PCSS	ASTF						
	COD	Location	Average output MWh/year	COD	Location	Average output MWh/year				
1	2012	Roi Et	1,135	2012	Prachin Buri	912				
2	2012	NakornPathom	1,222	2011	Ayutthaya	997				
3	2012	NakornPathom	1,149	2013	Buri Ram	1,021				
4	2012	NakornPathom	1,145	2013	Buri Ram	1,021				
5	2012	NakornPathom	1,149	2012	Suphanburi	1,009				
6	2012	Korat	1,085	2012	Nakornpathom	997				
7	2013	Loei	1,149	2012	Suphanburi	997				
8	2014	Khon Kaen	1,149	2013	Lobburi	946				
9	2014	Khon Kaen	1,149	2013	Ayutthaya	946				
10	2014	Surin	1,135	2013	Ayutthaya	946				
Average			1,137	Average		979				

PCSS: Polycrystalline silicon, ASTF: Amorphous silicon thin film, COD: Commercial operation date

Table 5: Conclusion	n of analysis of PB, IRF	and turnover 25-y	years for PCSS sola	r PV farm
PCSS				

rcss						
Plant	Investment/MW	PB Year	IRR %	Turnover 25 year	Performance ratio (%)	Plant factor (%)
	Million (USD)			Million (USD)		
1	3.45	8.74	10.01	5.49	83	18
2	3.64	8.38	9.11	5.89	82	18
3	3.67	8.35	9.35	6.13	84	18
4	3.70	8.36	9.10	6.09	83	18
5	3.67	8.35	9.34	6.13	84	18
6	3.55	8.43	8.97	5.57	84	17
7	3.58	8.35	9.70	6.13	84	18
8	3.61	8.35	9.59	6.13	84	18
9	3.64	8.35	9.47	6.13	84	18
10	3.61	8.36	9.41	6.01	83	18
Average	3.61	8.40	9.40	5.97	84	18

PCSS: Polycrystalline silicon, PV: Photovoltaic, PB: Payback period, IRR: Internal rate of return

Table 6: Conclusion of analysis of PB, IRR and turnover 25-years for ASTF solar PV farm

ASTF							
Plant	Investment/MW	PB Year	IRR (%)	Turnover 25 year	Performance ratio (%)	Plant factor (%)	
	Million (USD)			Million (USD)			
1	2.79	8.92	9.60	4.20	80	15	
2	3.15	8.65	9.31	4.80	82	16	
3	3.20	8.56	9.44	5.01	84	16	
4	3.20	8.56	9.44	5.01	84	16	
5	3.18	8.60	9.36	4.91	83	16	
6	3.15	8.65	9.31	4.80	82	17	
7	3.15	8.65	9.31	4.80	82	17	
8	2.82	9.00	10.02	4.36	84	16	
9	2.82	9.00	10.01	4.36	84	16	
10	2.82	9.00	10.01	4.36	84	16	
Average	3.03	8.76	9.58	4.66	83	16	

ASTF: Amorphous silicon thin film, PV: Photovoltaic, PB: Payback period, IRR: Internal rate of return

Table 7: Comparison investment cost of solar PV farm between PCSS and ASTF

No.	Description 1: Construction cost	ASTF Million (USD)/MW	PCSS Million (USD)/MW
1	Capacity (MW)		
2	Preparation of land	0.08	0.08
3	Photovoltaic module	1.34	2.01
4	Inverter	0.39	0.45
5	Transformer	0.03	0.03
6	Connection system, cable, structure and installation	0.74	0.68
7	Engineering, supplier, and construction	0.15	0.15
8	Fence, ditch and utilities	0.06	0.06
	Total investment	2.79	3.45
No.	Description 2: Operation cost per year	USD/year	USD/year
1	Salary for all employee	18,518.52	18,518.52
2	Gasoline expense for lawn mover	1,111.11	1,111.11
3	Public supply cost for PV's cleaning	1,851.85	1,851.85
4	Public supply cost for electrical system	7,407.41	7,407.41
5	Telephone system and network cost	3,703.70	3,703.70
6	All risk insurance	3,343.70	4,144.44
7	Ground rent per month	2,962.96	2,962.96
8	Other expenses	370.37	370.37
	Total operation cost per year	39,269.63	40,070.37
No.	Item description 3: Data solar PV farm (data by feed)		
1	Performance ratio (%)	80	83
2	Plant capacity factor (%)	15	18

ASTF: Amorphous silicon thin film, PCSS: Polycrystalline silicon, PV: Photovoltaic

the construction cost and operation cost of ASTF was lower than PCSS. It seems that ASTF solar PV farm has shown the benefit financial beyond PCSS. This is because the module of PCSS was expensive than ASTF, which was directly affect to the total investment cost due to be the largest portion (Figure 3). The estimate cost of ASTF was around 0.83–0.93 USD/W, while

Table 8: Cash flow	, cash collection and IRF	R of PCSS in 25	vears project

Year	Christian era	Cash flow (Million USD)	Cash collection (Million USD)	IRR (%)
0	2012	-3.4537	-3.4537	-
1	2013	0.4181	-3.0356	-88
2	2014	0.4131	-2.6225	-58.84
3	2015	0.4081	-2.2144	-37.94
4	2016	0.4031	-1.8113	-24.39
5	2017	0.3981	-1.4131	-15.42
6	2018	0.3931	-1.0200	-9.25
7	2019	0.3881	-0.6318	-4.87
8	2020	0.3831	-0.2487	-1.66
9	2021	0.3781	0.1294	0.75
10	2022	0.3731	0.5025	2.60
11	2023	0.3681	0.8706	4.04
12	2024	0.3631	1.2336	5.18
13	2025	0.3580	1.5917	6.09
14	2026	0.3530	1.9447	6.83
15	2027	0.3480	2.2926	7.43
16	2028	0.3429	2.6355	7.93
17	2029	0.3379	2.9734	8.35
18	2030	0.3328	3.3062	8.69
19	2031	0.3278	3.6340	8.98
20	2032	0.3227	3.9567	9.23
21	2033	0.3176	4.2743	9.44
22	2034	0.3126	4.5869	9.62
23	2035	0.3075	4.8944	9.77
24	2036	0.3024	5.1968	9.90
25	2037	0.2973	5.4941	10.01

The data occurred on the table was collected from PCSS solar PV farm site, Roi Et province. Total investment 27.26 million USD, COD: June 2012, original capacity 8 MW, PB=8.74 years, IRR=10.01%, Turnover 25 years=5.49 Million USD. IRR: Internal rate of return, PV: Photovoltaic, PB: Payback period, COD: Commercial operation date, PCSS: Polycrystalline silicon

Year	Christian Era	Cash flow (Million USD)	Cash collection (Million USD)	IRR (%)
0	2012	-2.7864	-2.7864	-
1	2013	0.3287	-2.4577	-88
2	2014	0.3247	-2.1330	-59.46
3	2015	0.3206	-1.8125	-38.65
4	2016	0.3165	-1.4960	-25.10
5	2017	0.3124	-1.1835	-16.10
6	2018	0.3083	-0.8752	-9.91
7	2019	0.3042	-0.5710	-5.49
8	2020	0.3001	-0.2708	-2.25
9	2021	0.2960	0.0252	0.18
10	2022	0.2919	0.3171	2.05
11	2023	0.2878	0.6050	3.51
12	2024	0.2837	0.8887	4.67
13	2025	0.2796	1.1683	5.59
14	2026	0.2755	1.4437	6.34
15	2027	0.2713	1.7151	6.96
16	2028	0.2672	1.9823	7.47
17	2029	0.2631	2.2453	7.89
18	2030	0.2589	2.5043	8.25
19	2031	0.2548	2.7591	8.54
20	2032	0.2506	3.0097	8.80
21	2033	0.2465	3.2562	9.01
22	2034	0.2423	3.4985	9.19
23	2035	0.2382	3.7367	9.35
24	2036	0.2340	3.9707	9.48
25	2037	0.2298	4.2005	9.60

The data occurred on the table was collected from ASTF solar PV farm site, Prachin Buri province. Total investment 22.28 million USD, COD: June 2012, original capacity 8 MW. PB=8.92 year, IRR=9.60%, and Turnover 25 year=4.20 million USD. IRR: Internal rate of return, PV: Photovoltaic, PB: Payback period, COD: Commercial operation date, ASTF: Amorphous silicon thin film

PCSS was around 1.02–1.24 USD/W, respectively. Meanwhile, the levelized cost of energy of PCSS was between 0.25 and 0.65

(USD/kWh) which was longer than ASTF (0.26–0.59 USD/kWh) (Sahay et al., 2013).

Figure 4 shows the percentage of operation cost in each of item. It can be noticed that the largest portion of operation cost was come from the expense of salary for employee (46.21%), followed by public supply cost for electrical system (18.49%), and all risk insurance (10.34%), respectively.

It is well known that there are two types of return on investment: Economic and financial returns. In case of government agencies, as non-profit organization, they will consider both the economic and financial implications for investment considerations in order to maximize the value of the project to the public according to the government mission, while the private investment will often consider only financial return. This study only considers the views of private investors.

The result of comparative solar PV farm investment was shown in Tables 8 and 9. This study assumed that the solar system has deteriorated which resulted in the decrease of electricity production yield, approximately 1% annually. It was noticed that the profit was occurred at 9th year of project operation. Revenues of the project was come from electricity sales at 0.35 USD per unit (0.25 USD adder prices and 0.11 USD for selling prices). Cash flow depends on the productivity of each type of solar power plant. In this paper, the output analysis of PCSS was more than ASTF since year 2012–2037. Hence, the result of analysis on IRR of PCSS was also higher than ASTF. As a result, the final income/turnover of PCSS is better than ASTF. However, it should be recognized that solar cell has life cycle around 25 years, but solar cell is deteriorating every year. Therefore, maintenance and insurance costs are required during the year, which will be part of the lifetime operating costs.

4. CONCLUSIONS

This research has investigated the economic potential of solar PV farm in Thailand. The primary data were collected from 20 solar PV farm plants, which included investment data, type of solar cell, and data analysis. After analysis, four main investment costs of PCSS solar PV farm are identified: (1) Photovoltaic module; (2)



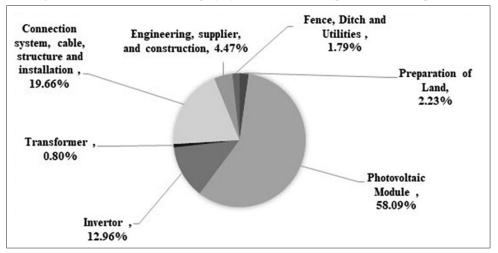
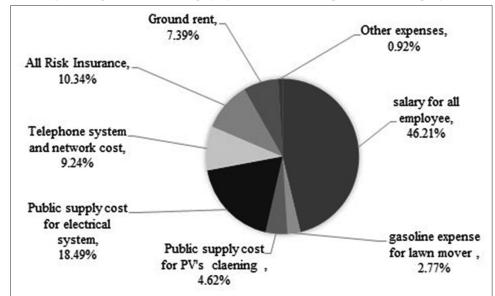


Figure 4: Operation cost of the polycrystalline silicon solar photovoltaic farm per year



connection system; (3) inverter, and (4) engineering construction, distributed as 58.09%, 19.66%, 12.96%, and 4.47%, respectively. In addition, four main operation costs of the PCSS solar PV farm are also recognized: (1) Salary for all employees; (2) public supply cost for electrical system; (3) all risk insurance, and (4) telephone and network system, distributed as 46.21%, 18.49%, 10.34%, and 9.24%, respectively. When compared the economic potential between PCSS and ASTF, PCSS provide more profit than ASTF because of having short PB and more turnovers.

5. ACKNOWLEDGMENTS

The study was supported by a grant from the National Research Council of Thailand (NRCT). The authors express deep gratitude to the Energy Regulatory Commission (ERC), Department of Alternative Energy Development and Efficiency (DEDE), and Solar Farms Private companies for their support on this study.

REFERENCES

- EGAT. (2016), Understanding Energy Development with Steadily Country. Available from: https://www.egat.co.th/(in Thai language).
- ERC. (2011), Energy Information Center. Available from: http://www.erc.or.th.
- Hachigami, M. (2015), Training Manual Renewable Energy Solar Energy (Theoretical Part). 1st ed. Thailand: Ministry of Energy.
- IEA. (2008). Renewable Energy Services for Developing Countries. In Support of the Millennium Development Goals: Recommended Practice and Key Lessons. Available from: http://www.iea-pvps.org/ fileadmin/dam/public/report/technical/rep9 09.pdf.

Jäger-Waldau, A. (2012). Thailand PV Status Report 2012. Available

from: http://www4.dede.go.th/dede/images/stories/jum_circular_55/ PV_Status_Report_eng_final.pdf.

- Ketjoy, N., Mansiri, K. (2013), Tech-economic evaluation of fixing and tracking PV power plant in Thailand. Journal of Science and Technology MSU, 32(5), 598-605.
- MoE. (2011), Development and Investment Guideline for Alternative Energy Producer. Available from http://webkc.dede.go.th/testmax/ node/822.
- MoE. (2016), Importing energy in Thailand. Available from: http://www. info.energy.go.th/th (in Thai language).
- Rinphol, N. (2016), Basic Design Guide of Solar Power System. 9th ed. Thai Solar Book:Thailand.
- Sahay, A., Sethi, V.K., Tiwari, A.C. (2013), A comparative study of attributtes of thin film and crytalline photovoltaic cell. *VSRD* Internation Journal of Mechanical, Civil, Automobile and Production Engineering, 3(7), 267-270.
- Shukla, A.K., Sudhakar, K., Baredar, P., Mamat, R. (2018), Solar PV and BIPV system: Barrier, challenges and policy recommendation in India. Renewable and Sustainable Energy Reviews, 82, 3314-3322.
- Suthiwongwong, C. (2011), Solar Power Technology Development Program. Thailand: Ministry of Energy.
- Suwanasang, N., Tongsopit, S. (2015), An assessment of the technical and economic potential of rooftop solar systems on chulalongkorn university's buildings. Journal of Science and Technology, 12(2), 59-74.
- Tanpipat, N. (2011), Thailand PV Status Report 2011. Available from: http://www.eri.chula.ac.th/eri-main/?p=345&lang=TH. [Last accessed on 2017 Jan 16].
- Tantisttayakul, T. (2015), An assessment of financial promotion measures for residential solar photovoltaic rooftop system in Thailand. Journal of Science and Technology, 23(4), 606.
- Usapein, P., Chavalparit, O. (2017), Life Cycle Assessment of Producing Electricity in Thailand: A Case Study of Natural Gas Power Plant. MATEC Web of Conferences, 103, 5009.