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Research Article

การวิเคราะห์ผลกระทบของเอลนีโญและลานีญาต่อการผลิตไฟฟ้าด้วยพลังงานแสงอาทิตย์ ณ จังหวัดสมุทรปราการ ประเทศไทย

An analysis of the impact of el niño and la niña on solar energy production in Samut Prakan Province, Thailand

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บทคัดย่อ

งานวิจัยนี้เกี่ยวข้องกับข้อมูลพลังงานแสงอาทิตย์และระบบผลิตกระแสไฟฟ้าด้วยพลังงานแสงอาทิตย์ โดยงานวิจัยนี้ทำการวิเคราะห์สมมติฐานด้านการเปลี่ยนแปลงสภาพภูมิอากาศของเอลนีโญและลานีญา รวมทั้งประเมินความคุ้มค่าของการลงทุน โดยการวิจัยนี้ได้เลือกระบบผลิตกระแสไฟฟ้าด้วยพลังงานแสงอาทิตย์ ณ จังหวัดสมุทรปราการ เป็นกรณีศึกษา จากการเปรียบเทียบค่าเฉลี่ยของการผลิตพลังงานไฟฟ้าในช่วงปรากฏการณ์เอลนีโญและลานีญา พบว่ากำลังไฟฟ้าเฉลี่ยที่ได้จากการผลิตกระแสไฟฟ้าในช่วงปรากฏการณ์เอลนีโญอยู่ที่ 88 กิโลวัตต์ชั่วโมงต่อวัน และกำลังไฟฟ้าเฉลี่ยที่ได้จากการผลิตกระแสไฟฟ้าในช่วงปรากฏการณ์ลานีญาที่ 73.65 กิโลวัตต์ชั่วโมงต่อวัน ซึ่งกำลังไฟฟ้าเฉลี่ยที่ผลิตได้ในช่วงปรากฏการณ์เอลนีโญนั้นสูงกว่ากำลังไฟฟ้าเฉลี่ยที่ได้จากการผลิตกระแสไฟฟ้าในช่วงปรากฏการณ์ลานีญาอยู่ 14.35 กิโลวัตต์ชั่วโมงต่อวัน คิดเป็น 16% อย่างไรก็ตามข้อมูลประวัติผลิตกระแสไฟฟ้า (solar profile) ณ จังหวัดสมุทรปราการ แสดงให้เห็นว่าในช่วงปรากฏการณ์เอลนีโญและลานีญา มีสัดส่วนการผลิตกระแสไฟฟ้าอยู่ในระดับเดียวกันในฤดูร้อน แต่มีความผันผวนในฤดูหนาวและฤดูฝน ในด้านการลงทุนทางการเงินเมื่อคำนวณต้นทุนเฉลี่ยตลอดอายุโครงการ (LCOE) เป็น 5 บาทต่อกิโลวัตต์ชั่วโมง จะได้ระยะเวลาคืนทุน (PBP) เป็น 11 ปี ซึ่งมีความคุ้มค่าในระบบที่มีอายุการใช้งาน 25 ปี

คำสำคัญ: การผลิตไฟฟ้าด้วยพลังงานแสงอาทิตย์; เอลนีโญ; ลานีญา; ต้นทุนเฉลี่ยตลอดอายุโครงการ; ระยะเวลาคืนทุน

Abstract

This research investigates the impact of El Niño and La Niña climate phenomena on solar energy generation and system performance. A solar photovoltaic (PV) system in Samut Prakan province was selected as a case study to analyse this hypothesis. By comparing average energy production during El Niño and La Niña events, it was found that the mean power output during El Niño was 16% higher than the mean power output during La Niña. Although the solar profiles at Samut Prakan indicated similar energy production levels during both phenomena in the summer, greater variability was observed during winter and rainy seasons. Regarding financial investment, a Levelized Cost of Electricity (LCOE) of 5 Baht/kWh was calculated, resulting in a Payback Period (PBP) of 11 years for a 25-year project lifespan. This suggests a favourable economic return on investment.

Keywords: Solar Production; El Niño; La Niña; Levellised Cost of Electricity; Payback Period

Introduction

The production rate of solar energy is influenced by fluctuating weather conditions, particularly in Southeast Asia. Two significant phenomena contributing to these fluctuations are El Niño and La Niña. The El Niño-Southern Oscillation (ENSO) can indirectly affect the availability of sunlight, which is crucial for solar production rates. During El Niño events, Southeast Asia often experiences altered weather patterns due to warmer-than-average sea surface temperatures in the central and eastern Pacific Oceans. These changes can lead to drier conditions in certain regions, resulting in clearer skies and increased sunlight, ultimately benefiting solar energy production [1-2].

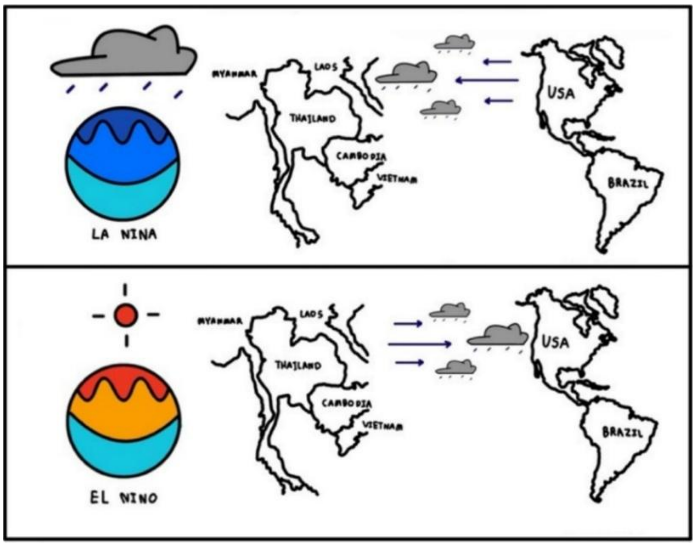


Figure 1 The Phenomena of El Niño and La Niña. [1]

Conversely, the La Niña phenomenon, which is caused by cooler-than-average sea surface temperatures in the central and eastern Pacific Ocean, may also differ in weather patterns in Southeast Asia. This shift includes an increase in cloud coverage and precipitation in some areas. This event could potentially reduce the amount of sunlight available for solar production. Although El Niño and La Niña have an impact on full-time sunlight of the solar production rates, their effect can vary depending on the region and other atmospheric factors. [1-2]

Samut Prakan, Thailand, is an ideal site for studying the effects of El Niño and La Niña on solar production due to its geographic proximity to the Gulf of Thailand, which exposes it to significant climatic influences from the El Niño-Southern Oscillation (ENSO). The region's tropical climate features distinct wet and dry seasons that allow for examination of how these variations impact solar energy generation. Additionally, ongoing investments in solar infrastructure enhance the relevance of this research, while the availability of historical meteorological data supports comprehensive analyses. As a populous province, findings from this study could inform energy policies and strategies aimed at improving sustainability and resilience in urban energy systems.

Objectives

1. To demonstrate the effect of La Niña and El Niño on average solar generation; this study is hypothesized that the average solar generation during El Niño is higher than during La Niña.

2. To create a solar profile in a specific area, Samut Prakan, Thailand, wherein experiences fluctuating weather conditions.

3. To assess the financial investment of this renewable energy system by computing the PBP according to the LCOE.

4. To analyse the cost efficiency of the on-grid 24-kWp solar system, the system of solar energy production.

Methods

To gather comprehensive insights into solar energy production in Samut Prakan, Thailand, data will be collected from both the solar system and local weather conditions using supporting applications such as Energy Viewer and the Physical Sciences Laboratory of the National Oceanic and Atmospheric Administration (NOAA). The analysis will cover a one-year period from June 1, 2023, to May 31, 2024, allowing for a detailed examination of the interactions between solar generation and fluctuating weather patterns. Following the data analysis, the investment's worthwhileness will be assessed, culminating in a summary of the findings and computations derived from the analysis.

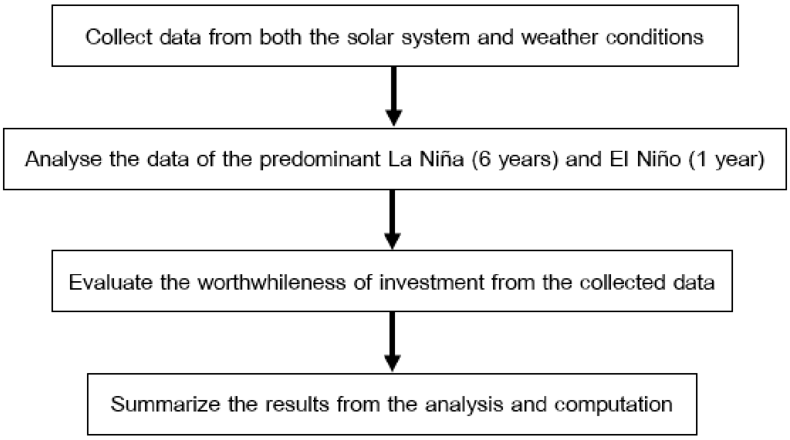


Figure 2 The Flow Chart of the Methods.

1. Collecting data

The energy generated by solar power systems is monitored using the Energy Viewer application, which enables users to track energy production over specific timeframes, including daily, weekly, monthly, annual, and cumulative totals since installation. It is noteworthy, however, that the application has a limitation: aside from the cumulative energy since installation, it only retains data for a maximum of 365 days. Consequently, this study will analyse solar energy production by comparing average output during a full year characterized by El Niño conditions against the average output over a predominant six-year period of La Niña conditions.

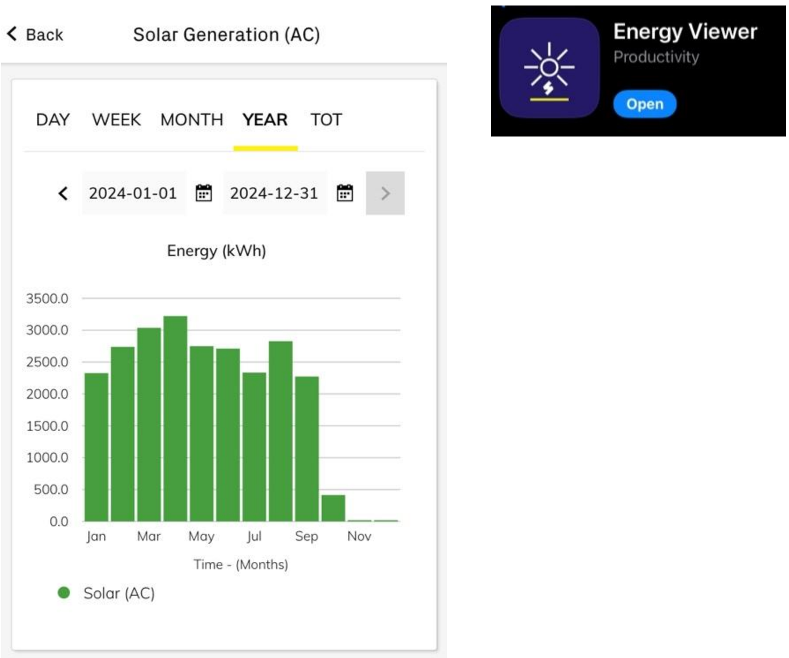


Figure 3 The Data from Energy Viewer.

Moreover, the NOAA supported the data of the Phenomena of El Niño and La Niña from 1980 to 2024. In addition, El Niño has an effect over the central and eastern Pacific Ocean during the middle of 2023 and 2024. Thus, the solar production rate in such period is hypothesised to be increased from the normal average full-time of sunlight without clouds.

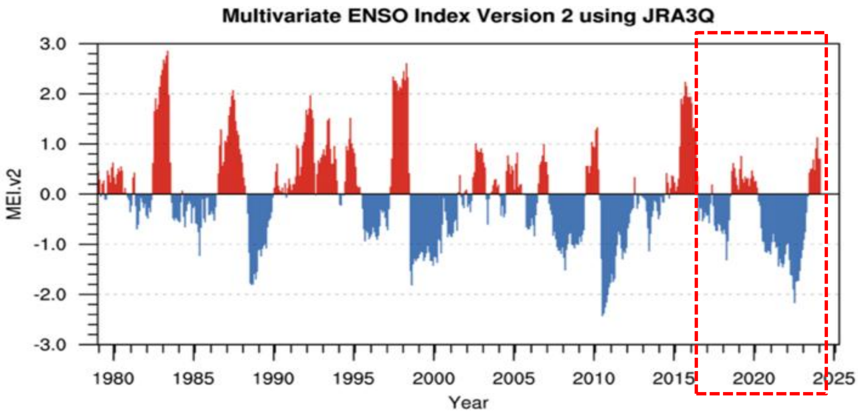


Figure 4 The Phenomena of El Niño and La Niña from 1980 to 2024. [3]

2. An analysis of the accumulative data

During the data collective period, La Niña predominantly occurred from 2017 to 2023, while El Niño occurred between the middle of 2023 to the middle of 2024, as illustrated in Figure 4. The occurrence of these two phenomena strongly influences the amount of sunlight available for solar production, which is correlated to the empirical statistics. Particularly, the average production of solar energy on El Niño was higher compared to the average solar production on the predomination of La Niña which is approximately 88 kWh/day and 73.65 kWh/day, respectively.

The system is located in Samut Prakan, Thailand, at latitude 13°36’32.53” N and longitude 100°35’34.41” E. The solar energy production in the mentioned area thrives due to its consistent tropical climate which facilitates the system with extensive sunlight throughout the year. Furthermore, there are three seasons in Thailand, summer, winter and rainy. Specifically, March, April and May are in summer, while winter covers November, December, January and February. The five months left, June, July, August, September and October, are in the rainy season. Accordingly, it could be noticed in Figure 5 that the highest output is in summer, April 2024, at 3,003 kWh. Conversely, the lowest is in the rainy season, October 2023, at 2,307 kWh. Figure 6 shows the data of energy (kWh/day) in those months.

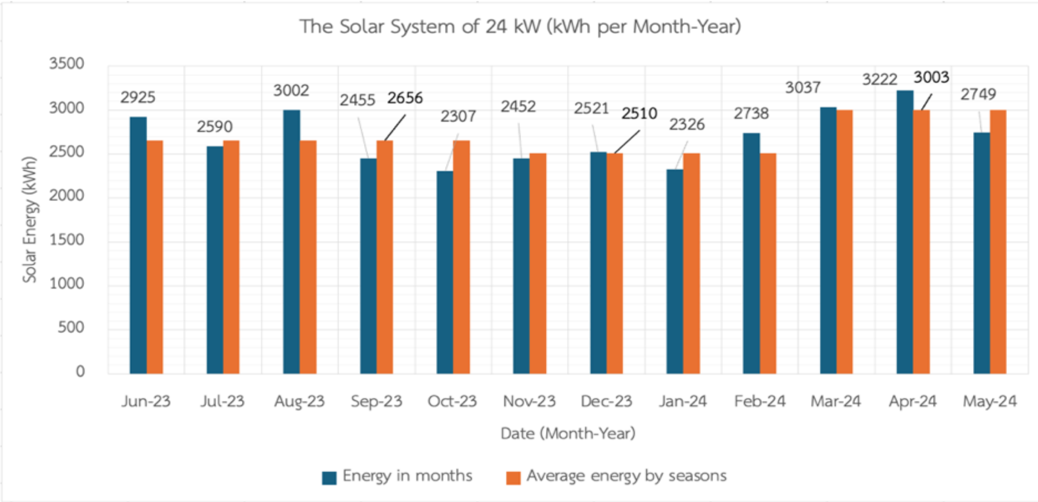
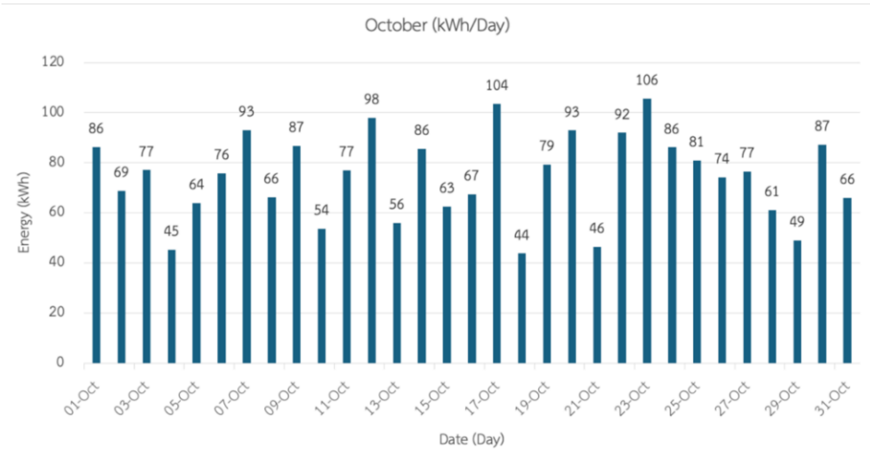
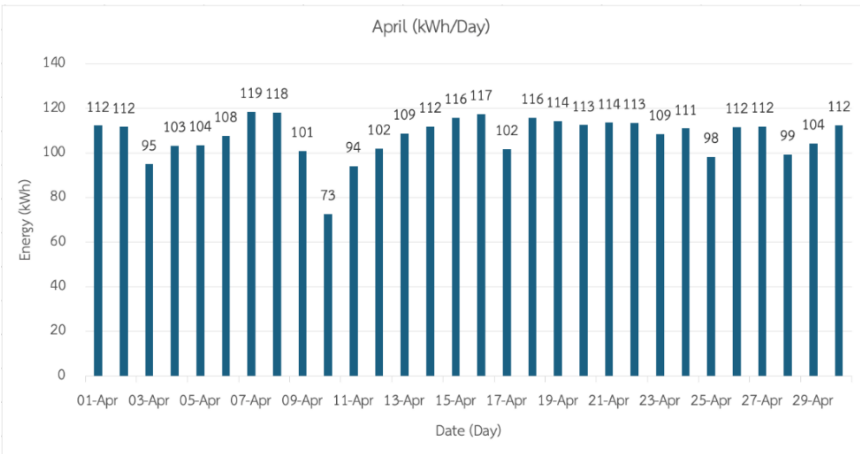


Figure 5 The Record of Solar Energy from June 2023 to May 2024.



(1)



(2)

Figure 6 The Record of Solar Energy (1) in October 2023, (2) in April 2024.

Table 1 shows that the peak energy is at 3,003 kWh/month in summer while the average in rainy and winter seasons are 2,656 kWh and 2,510 kWh/month, respectively.

Table 1 The Record of Solar Energy Categorised by Seasons (During the El Niño event).

Season	Rainy					Winter				Summer		
Month	Jun 2023	Jul 2023	Aug 2023	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024	Apr 2024	May 2024
Energy in months (kWh)	2925	2590	3002	2455	2307	2452	2521	2326	2738	3037	3222	2749
Average energy by seasons (kWh)	2655.64					2509.51				3002.74		

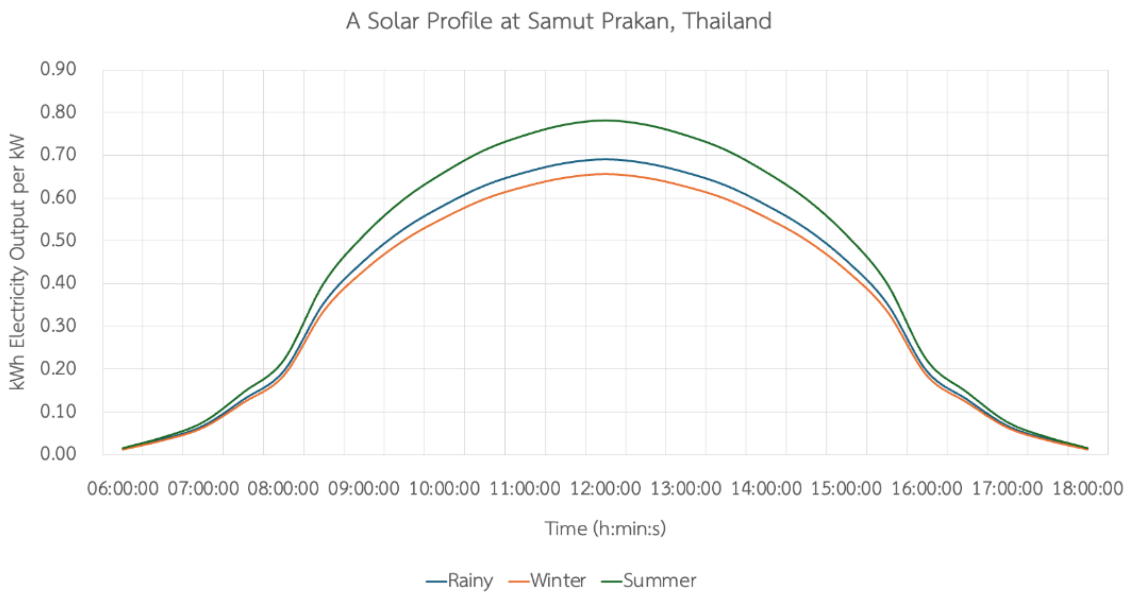


Figure 7 The Solar Profile of Samut Prakan During 2023-2024.

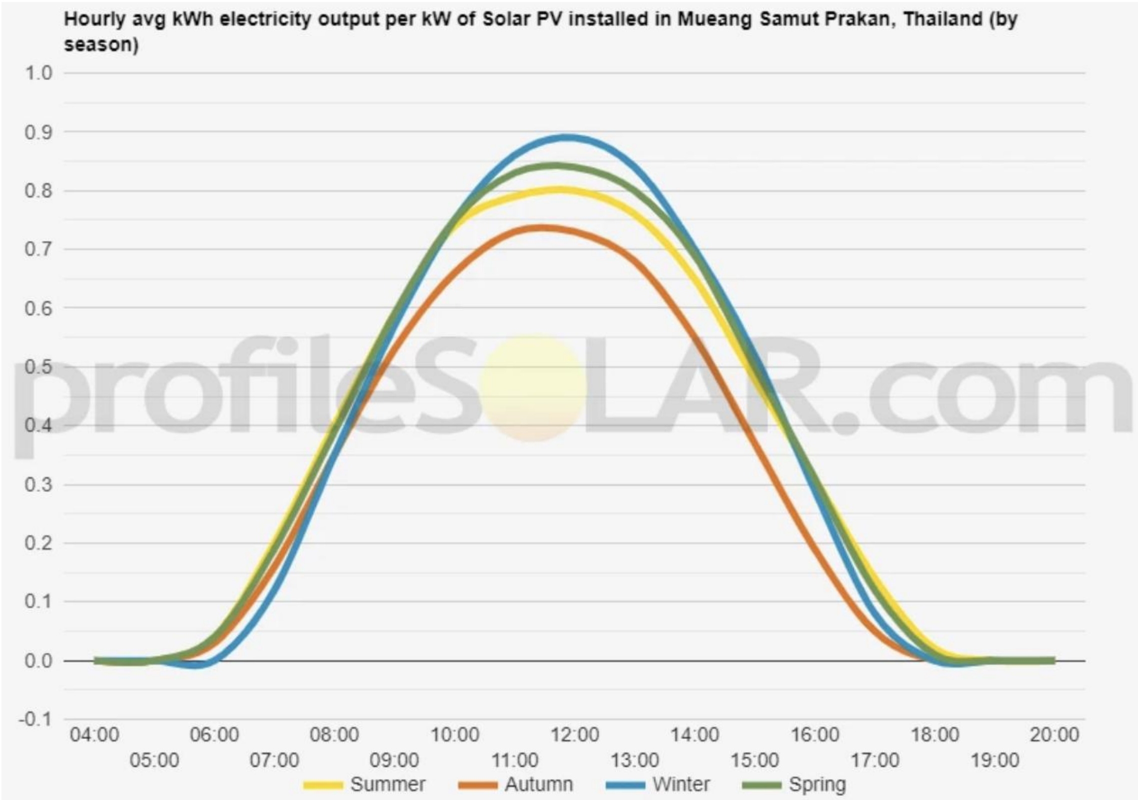


Figure 8 The Average of Solar Profile of Samut Prakan. [4]

Figure 7 presents the solar profile during El Niño in Samut Prakan during 2023 to 2024. The result also shows that the highest ratio is in summer at about 0.8, while the lowest ratio is in winter at around 0.65. Conversely, Figure 8 show the solar profile of Samut Prakan on the predominant of La Nina during 2019 to 2024 from the Power API of the National Aeronautics and Space Administration (NASA) [4]. Two seasons, summer and winter, can be compared. Notably, in summer, the solar profiles are noticed to be the same level at about 0.8. the solar profile in winter during El Niño is lower than La Nina period at 0.65 and 0.9 respectively. In other words, the available of sunlight in winter during El Niño is lower than La Nina in winter season.

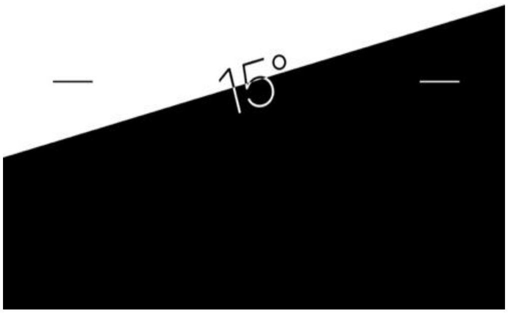
3. Installation and Financial Assessment

The 24-kWp system is a solar rooftop grid tie system which is installed on the deck area including 20 rows of 4x300W panels, and the tilt angle towards the South is 15 degrees, as represented in Figure 9.

(1)

(2)

(3)



(4)

Figure 9 The Solar Installation and Tilt Angle (1) Back Side of The Solar Panel, (2) Frontside of The Solar Panel, (3) Inverter of The System, (4) The Tilt Degree of The Panel.

However, despite favourable tropical conditions, challenges may arise during the wet season due to the increased cloud coverage and rainfall which potentially reduce solar irradiance levels. In addition, the panels could be damaged and soiled by the strong winds which will decrease the output efficiency. Weather-resistant materials and structures are implied in the installation design enabling the panels to withstand heavy rain and high winds without performance degradation. Additionally, regular cleaning schedules or yearly maintenance are necessary to prevent dust or debris accumulation that could obstruct sunlight. As a result, the total installation cost is 1,200,000 Baht with the annuitized capital cost of maintenance at 5,000 baht per year. Overall, the solar system can be observed in Figure 10 by a single-line diagram.

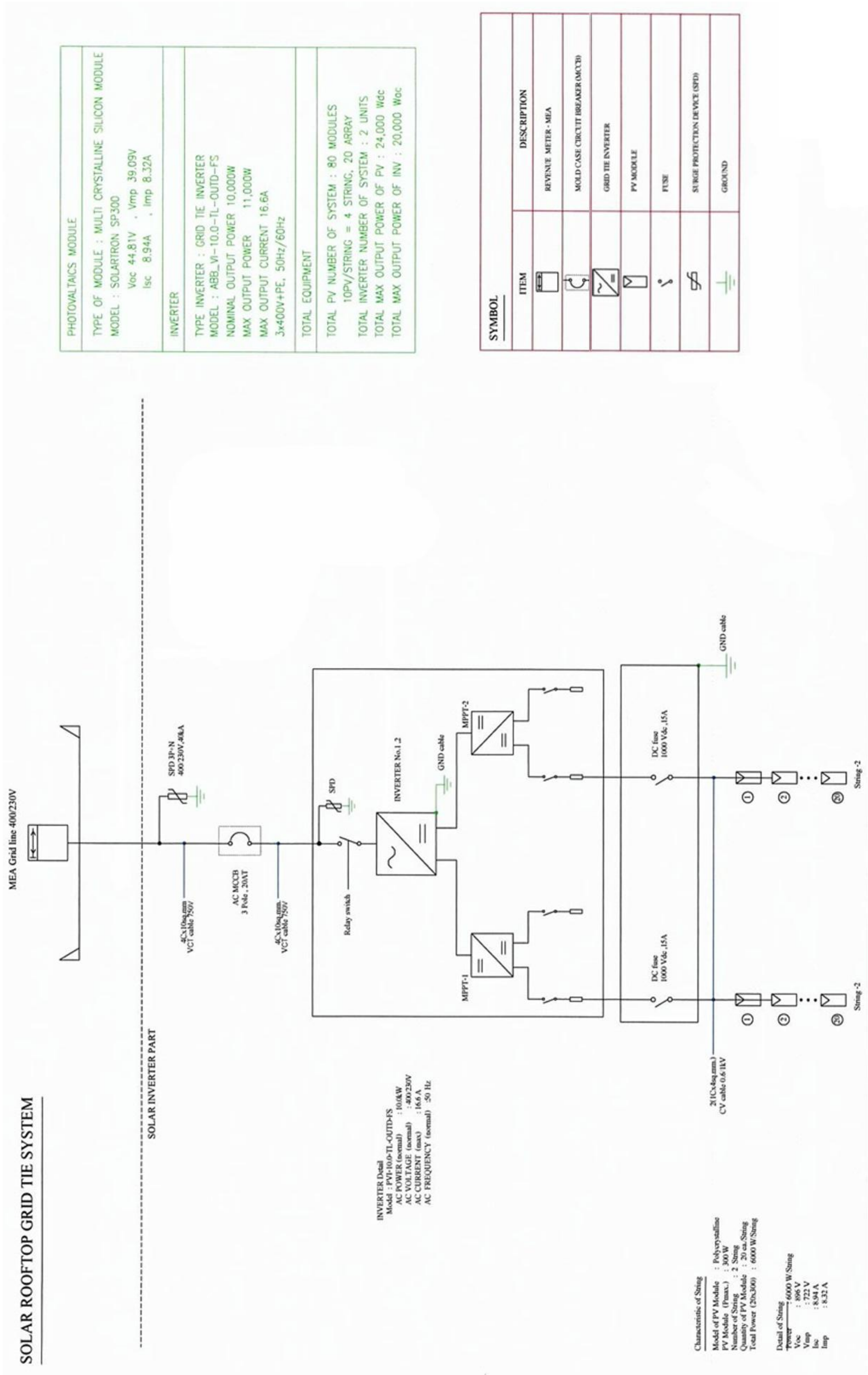


Figure 10 The Single-Line Diagram of 24-kWp System.

The Payback Period (PBP) and Net Present Value (NPV) are essential metrics for evaluating the financial viability of solar energy systems. The PBP indicates the time required to recover the initial investment through cash flows, providing insights into liquidity and risk. In addition, NPV calculates the present value of future cash flows minus the initial investment, accounting for the time value of money; a positive NPV signifies that the investment is expected to yield more value than its cost. Together, these metrics offer a comprehensive view of a project's profitability and help investors make informed decisions when comparing various renewable energy options. However, the expenses typically fall into two main categories which are capital costs and annual costs. Capital costs normally comprise installation expenses, site improvements, and components [5], while annual costs refer to maintenance expenses incurred each year. Additionally, factors such as the discount rate, and project lifespan are to be considered. In this framework, a proposed discount rate (r) as well as an inflation rate of 3% is applied based on the average inflation rate over 20 years in Thailand [6], as shown in Figure 11.

Figure 11 The Rate of Inflation in Thailand from 2000 to 2020.

Given the grid infrastructure, the Feed-in Tariff (FIT) policy is advocated to incentivize the adoption of renewable energy sources such as solar power generation [7]. Additionally, the PBP is impacted by the Levelized Cost of Electricity (LCOE) generated from renewable sources. Both the LCOE and PBP, along with the system's capacity [8-9], can be determined using equations (1) and (2).

$$\text{LCOE} = \frac{\text{A}+\gamma}{\text{Actual Energy to Grid System}} \quad (1)$$

$$\text{Payback Period} = \frac{\text{All Cost Investment}}{\text{Annual Net Cash Flow}} \times 100\% \quad (2)$$

where A is the annualised capital cost (Baht/year) and γ is the annual running cost (Baht/year). In this system, the LCOE is approximate to 5 baht/kWh following the rate of electric fee from the grid system, which is about 4.2 baht/kWh without taxation [10]. Nevertheless, to scrutinise and analyse whether this system is worthwhile to invest, the present value, net present value and the present value of annuity are to be analysed as shown in Equations (3) - (6) [8].

$$V_p = \frac{V_n}{(1+r)^n} \tag{3}$$

$$NPV = \frac{V_1}{(1+r)^1} + \frac{V_2}{(1+r)^2} + \frac{V_3}{(1+r)^3} + .. + \frac{V_n}{(1+r)^n} \tag{4}$$

$$A = V_p \frac{r}{1-(1+r)^{-n}} \tag{5}$$

$$NPV = NPV\ (benefits) – NPV\ (costs) \tag{6}$$

Where V_p is the present value, V_n is the value in n year, r is the discount rate, A is an annuity, and n is the number of payback period. In terms of investment, if the NPV of the whole system is higher than 0, profit is made, and the project is worth doing. Regarding to the lifespan of solar panel, 25 years are expected to be a lifespan because in the first 25 years of solar panel age, the approximate efficiency of solar panel degradation is over 80% [11].

Results

The occurrence of El Niño and La Niña can affect the amount of sunlight available for solar production. The results show that solar energy produced during El Niño is higher than La Niña by 16%, calculating from to the average solar energy production on the El Niño last year and the predomination of La Niña in 6 years at 88 kWh/day and 73.65 kWh/day, respectively. Moreover, it could be noticed that when comparing summer and winter, solar profiles are similar in summer. However, during winter, there is more sunlight available during La Nina than during El Niño.

Regarding to the investment, the NPV of the whole system is higher than 0, meaning the profit is made, while PBP is about 11 years which is shorter than its lifespan. Consequently, this system is worthwhile, as illustrated in Figure 12.

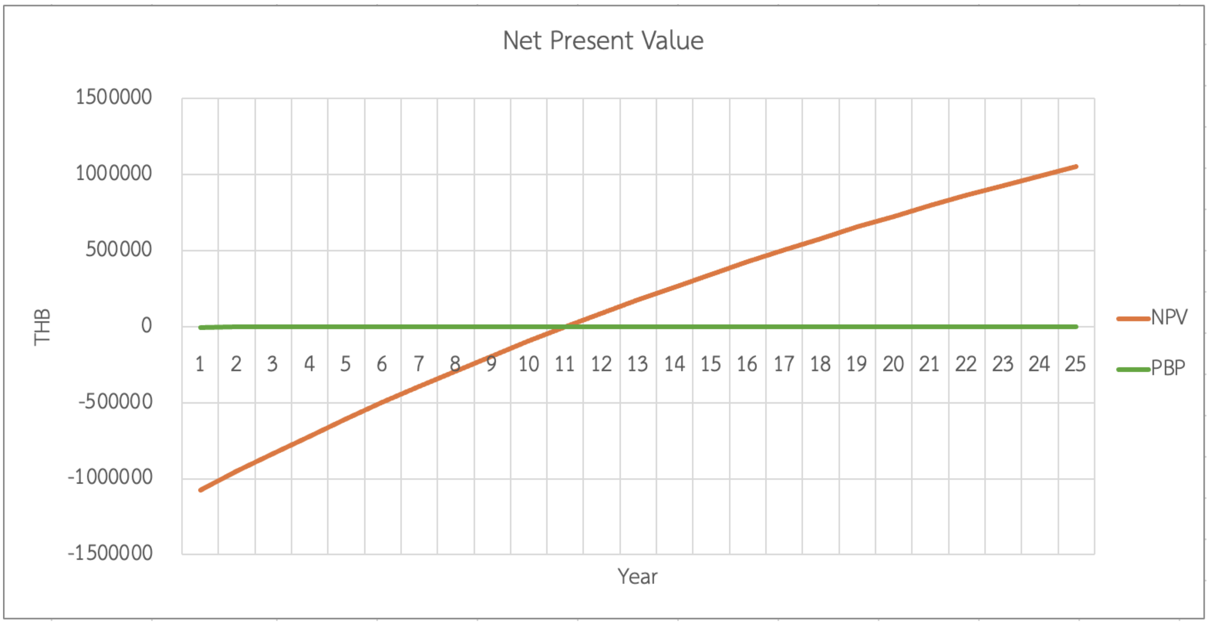


Figure 12 The Net Present Value (NPV) and Payback Period (PBP) of the Solar System.

Conclusions and Discussions

The average solar production rate depends on the weather conditions. Specifically, the effect of El Niño in the middle of 2023 and 2024 causes drier-than-average or clearer skies in Southeast Asia resulting in higher-than-average solar production at 88 kWh/day for the 24-kWp solar system. In contrast, the predominant effect of La Niña over 6 years shows the average solar production at 73.65 kWh/day which is lower than the last 12 months by 16%. Thus, it could be argued that the effect of El Niño can contribute to the higher rate of solar energy, and the energy production gap between La Niña and El Niño is around 16%. When comparing summer and winter, solar profiles are similar in summer. However, solar profiles are similar across summer, but winter solar conditions are more favourable during La Nina than El Niño. Hence, although the annual available sunlight is higher during El Niño than La Nina, there could be a seasonal deficiency in sunlight availability during El Niño winters

Regarding financial investment, the Levelized Cost of Electricity (LCOE) is computed along with the Payback Period (PBP) over a 25-year period. In capsulation, an LCOE of 5 Baht/kWh which results in a PBP as 11 years; the investment appears to be profitable. Moreover, Net Present Value (NPV) of the system's lifespan is positive, affirming Mueang Samut Prakan as a promising location for year-round solar power generation.

References

[1] Papapapong. (2024). *Climate change El Nino and La Nina effects Central and South America, Southeast Asia*. Vecteezy. https://www.vecteezy.com/vector-art/25740479-climate-change-el-nino-and-la-nina-effects-central-and-south-america-southeast-asia

[2] Mohammadi, K., and Goudarzi, N. (2018). Study of inter-correlations of solar radiation, wind speed and precipitation under the influence of El Niño Southern Oscillation (ENSO) in California. *Renewable Energy*, *120,* 190-200.

[3] Physical Sciences Laboratory. (2024). *Multivariate ENSO index version 2 (MEI. v2).* PSL NOAA. https://psl.noaa.gov/enso/mei/#datacomp

[4] Profilesolar. (2024). *Solar photovoltaic systems for Thailand*. ProfileSOLAR. https://profilesolar.com/locations/Thailand/Mueang-Samut-Prakan/

[5] Fernandes, M. R., and Schaefer, L. A. (2021). Levelized cost of energy of hybrid concentrating photovoltaic-thermal systems based on nanofluid spectral filtering. *Solar Energy*, *227,* 126-136.

[6] Bureau of Trade and Economic Indices. (2024). *Thailand inflation rate.* Trading Economics. https://tradingeconomics.com/thailand/inflation-cpi

[7] Energy Regulatory Commission. (2024). *Procurement of electricity from renewable energy under the Feed-in Tariff (FiT) scheme from 2022 to 2030 for the no-fuel-cost group*. https://www.erc.or.th/th/power-purchasing3/2697 (in Thai)

[8] Lai, C. S., Locatelli, G., Pimm, A., Tao, Y., Li, X., and Lai, L. L. (2019). A financial model for lithium-ion storage in a photovoltaic and biogas energy system. *Applied Energy*, *251,* 113-179.

[9] Chiang Mai University. (2024). *Chapter 3: Research methodology.* https://archive.lib.cmu.ac.th/full/T/2541/econ0841ps_ch3.pdf (in Thai)

[10] Electricity Generating Authority of Thailand. (2023). *Tariff calculation*. MEA. https://www.mea.or.th/our-services/tariff-calculation/other/D5xEaEwgU (in Thai)

[11] Kilgore, G. (2024). *Solar panel efficiency over time: When to replace (& why degradation matters).* 8Billiontrees. https://8billiontrees.com/solar-panels/solar-panel-efficiency-over-time/