Maximizing Energy Efficiency: An In-depth Analysis of the Feasibility of Integrating Solar Power Grid at Wesleyan University-Philippines

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Abstract- ***This study aims to assess and analyze the feasibility of fully implementing a solar power grid at Wesleyan University-Philippines. Utilizing a descriptive-comparative research approach, the study details the current partial implementation of the solar power grid at the university and its impact on power consumption, analyzing this data to evaluate the feasibility of full implementation. The existing implementation is a 202.4 KWp Grid-Tied Solar PV System, divided into three systems, generating energy ranging from 12,212.01 KWh to 30,804.08 KWh. This results in a 39.93% energy savings compared to the absence of a solar grid. With the current implementation, monthly savings of Php 131,719.90 indicate that it will take approximately 227 months to recover the investment. After the 120-month repayment period, a balance of Php 14,062,624.57 will remain on the loan. Conversely, full implementation would allow the investment to be recouped in about 87 months, and after the 120-month repayment period, the loan would be fully paid off, yielding a profit of Php 12,966,493.90. Based on these findings, the researchers concluded that the Solar PV System implemented at Wesleyan University-Philippines is a sound investment in terms of sustainable energy efficiency and economic viability.***

Indexed Terms- ***Solar PV System, Energy Savings, Renewable Energy, Solar Energy, Sustainable Development***

I. INTRODUCTION

Solar energy is an environmentally friendly resource that is becoming more and more popular because of its abundance and cleanliness. Solar energy has advanced significantly in recent years, despite the fact that it may not be as efficient as some other renewable energy sources. For example, according to Ness (2020), solar electricity generation has increased dramatically in the USA and now stands for approximately two percent of the country's total electricity output. Technological developments that optimize energy production by addressing the temporal and spatial variations of solar radiation have contributed to this progress in part (Morales, 2019).

In line with the global trend towards sustainable energy solutions, nations like India are working hard to realize the potential of solar energy. Similar to wind energy, solar energy is believed to be one of the renewable energy sources that is growing the fastest. It is praised for being an endless, pure, and cost-free resource (Ness, 2020). Regardless of these advantages, there are disadvantages to solar energy. With efficiencies ranging from 18% to 30%, it is more costly and less effective than some other renewable energy sources (Morales, 2019).

In the USA, solar parks had 264,504 MW of installed capacity as of 2019. In 2018, these parks produced a record-breaking 743,177 GWh of electricity, a 69% increase over the 440,677 GWh produced in 2010. Wind and solar energy accounted for nearly 90% of the increase in the United States' electricity generation between 2008 and 2018 (Morales Pedraza, 2019). Furthermore, a study by Daus et al. (2019) found that the cost of electricity per kilowatt-hour dropped significantly during periods of peak solar activity, from 8.1 rubles/kWh to 3.6 rubles/kWh. This reduction has resulted in notable savings for businesses that utilize solar energy. Germany's Energiewende, or energy transition, offers an

insightful example of how solar energy can be effectively adopted on a large scale. Germany has made substantial investments in solar power, positioning itself as one of the top global producers of solar energy. This shift has not only helped Germany reduce its carbon emissions but also decreased its reliance on fossil fuels (Energy Transition, 2020).

Similarly, the California Solar Initiative (CSI) has played a pivotal role in promoting solar energy within the state. By offering rebates for solar system installations, the initiative has spurred a significant increase in solar energy usage. Over 3,000 MW of solar capacity have been installed under CSI, greatly contributing to California's renewable energy targets and helping to cut down greenhouse gas emissions (Go Solar California, 2020).

China's approach to solar energy is also noteworthy. As reported by Renewable Energy World (2020), China has seen a massive expansion in its solar energy capacity over the past decade. The country's investments in large-scale solar farms and efforts to reduce production costs for solar panels have made China the largest producer and consumer of solar energy worldwide. This rapid growth has been essential in meeting China's escalating energy needs and in efforts to mitigate air pollution.

Meanwhile, the Philippines is aiming to shift towards renewable energy, with a strong focus on solar power. The country has been progressively investing in expanding its solar energy capacity, benefiting from its high solar irradiation levels and numerous islands. Currently, about 77% of the Philippines' energy mix is derived from fossil fuels, with the remaining 23% coming from hydro, geothermal, wind, and solar sources. Despite its abundant sunlight, solar energy accounts for less than 1% of the nation's total energy consumption. This underutilization has prompted the Department of Energy to advocate for the integration of more solar projects into the Philippines' ambitious renewable energy plans. Experts anticipate a 15% compound annual growth rate (CAGR) in the Philippines' solar energy market from 2022 to 2027, driven by substantial investments and strong confidence in the country's long-term energy goals. (Koons, 2024)

In response to a worldwide demand for the utilization of renewable energy, Wesleyan University-Philippines began partly integrating solar power grid in 2021 which aids in providing its power needs. This study wants to assess and analyze the feasibility of full implementation of solar power grid at Wesleyan University-Philippines and specifically answer the following research questions:

1. What are the implementation schemes of a solar power grid at Wesleyan University-Philippines?
2. How may the electrical energy consumption profile of Wesleyan University-Philippines be described in terms of:

a. non-integration of solar power grid and
b. with integration of solar power grid.

3. How may the energy consumption savings of Wesleyan University-Philippines be described at:

a. current solar power grid implementation and
b. full solar power grid implementation.

4. What are the expected long-term savings and return of investment?

The data for this study is limited to the period from the initial partial implementation of the solar power grid at Wesleyan University-Philippines in 2021 through 2023. The study's parameters, including power generation consumption costs, materials and equipment costs, inflation, and other time-bound factors, are based on the cumulative data from these two years.

II. MATERIALS AND METHODS

In this study, a descriptive-comparative type of research was used which focuses on describing the current situation of partial implementation of solar power grid at Wesleyan University-Philippines and its impact on university’s power consumption and analyzing these data for a feasibility of a full implementation. The researchers began by acquiring the necessary data before and during the installation of the PV system and analyzing them for a forecast of long-term savings and return on investment.

The researchers used a time series data gathering technique analyzing the monthly power generation and consumption for two years specifically from November 2021 through October 2023.

Weighted mean and frequency distribution techniques were used in describing the energy consumption profile of the university. Tables and graphs were also used to clearly present the data gathered. Feasibility computations were also utilized to forecast long-term savings and return of investment. The data gathered were analyzed through the aid of the latest version of the SPSS software.

III. RESULTS AND DISCUSSION

a. Implementation Scheme of Solar PV System

The 202.4 KWp Grid-Tied Solar PV System installed at Wesleyan University-Philippines is divided into three systems, one 119.6KWp and two 41.4 KWp Solar PV System. The whole system consists of Four Hundred Forty (440) pieces of 460 Wp Jinko Solar modules and three (3) units of Huawei Three-phase Grid-Tied Inverters, one 100 KW and two 36 KW with the total price of Php 29,869,012.56 (interest and VAT included). The monthly installment is Php 248,908.43 for 120 months.

For the 119.6 KWp Solar PV System which is in Wesleyan gymnasium, the solar modules are arranged in thirteen (13) strings, with twenty (20) modules per every string. All the strings then go to the PV input side of 100 KW inverter.

While for the two 41.4KWP Solar PV System which are in Computer Science building and Senior High School Building, the solar PV modules are arranged in five (5) strings, with eighteen (18) modules per every string. All the strings then go to the PV input side of 36 KW inverter. The two systems also applied with net metering, it allows them to export the excess power, or the unused power given by the solar PV system to the grid and reduce their future electric bills.

Being a grid-tied PV system, the electrical energy generated by the solar modules will supplement the Main Grid in supplying electrical energy to the building. The block diagram below illustrates the electrical design of the system:

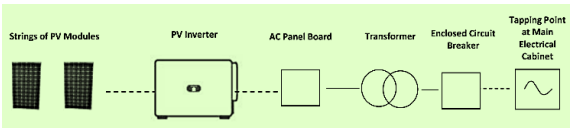

Fig. 1. The Block Diagram of the Implemented Solar PV System

b. Energy Consumption Profile

Wesleyan University-Philippines energy consumption in terms of KWh during November 2021 to October 2023 without the Solar PV System integration ranges from 28,521.25 KWh to 96,863.91 KWh with the lowest energy consumption during October 2023 while the highest was during May 2023. Meanwhile, with the integration of the Solar PV System, the energy consumption ranges from 6,792.93 KWh to 74,030.53 KWh with the lowest energy consumption during October 2023 and the highest was during November 2023. The average energy consumption during the integration of Solar PV System is 40,161.65 KWh while the average power consumption without the Solar PV System is 63,647.84 KWh. The full monthly consumption comparison was shown in Figure 2.

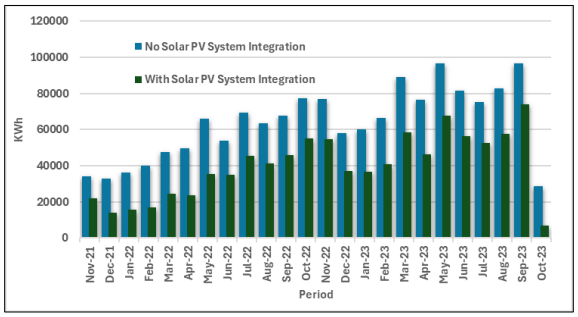

Fig. 2. Power Consumption Comparison between the Integration and Non-integration of the Solar PV System

As shown in Figure 2, energy consumption tends to increase during summer months of April, May, and June compared to other months. This is so because during these months there is an increased use of cooling systems within the university.

c. Energy Generation and Savings

In terms of energy generation, the system generated an average of 23,486.18 KWh of energy which accounts for an average of 39.93% of energy savings. The highest energy generated was during March 2023 with

30,804.08 KWh while the least energy generated was 12,212.01 KWh recorded during the first month of implementation, November 2021. Energy savings ranges from 23.31% to 76.18% with the months of September 2023 and October 2023 having the least to most energy savings respectively. These data were presented in Figure 3 and Figure 4.

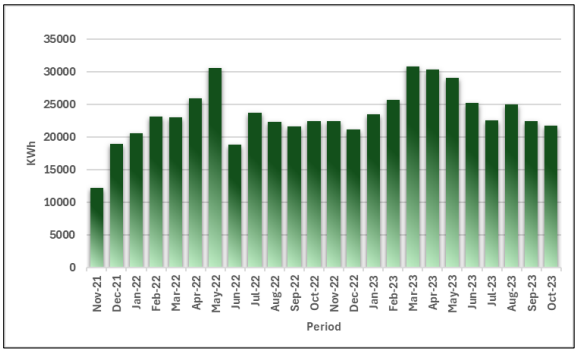

Fig. 3. Energy Generation of the Solar PV System

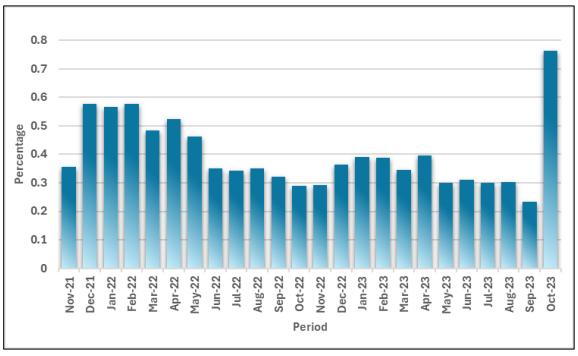

Fig. 4. Energy Savings during the Integration of the Solar PV System

TABLE I. APPROXIMATE MONTHLY SAVINGS DATA

Data	Mode of Implementation	
	Current Implementation	Full Implementation
Average Monthly Consumption (KWh)	63,647.84	63,647.84
Average Monthly Generation (KWh)	23,486.18	63,647.84
Generation Charge (Php)	5.6804	5.6804
Monthly Savings (Php)	131,719.89	356,962.55

As shown in Table I, the current implementation having an average of 23,486.18 KWh energy generated, the approximate savings will be Php 131,719.89 per month computed at the generation charge of Php 5.6804 (October 2023 rate, Cabanatuan Electric Cooperative). For full implementation of Solar PV System at the university, the total monthly savings will be Php 356,962.55 with an average monthly energy consumption of 63,647.84 KWh.

d. Feasibility Analysis and Return of Investment

For analysis on the return of investment, the cost of investment is Php 29,869,012.56 payable in 120 months. For current implementation, with monthly savings of Php 131,719.90, it will take approximately 227 months to compensate for the said amount and after the payable period of 120 months, there is Php 14,062,624.57 left payable for the loan. Meanwhile for full implementation, it will only take approximately 87 months to compensate for the full amount of investment and after the payable period of 120 months, the amount is duly paid plus a profit of Php 12,966,493.90. The return of investment and long-term savings analysis were summarized in Table II.

TABLE II. LONG-TERM SAVINGS AND RETURN OF INVESTMENT

Data	Current Implementation	Full Implementation
Total Amount of Investment (Php)	29,869,012.56	29,869,012.56
Payable Period (Months)	120	120
Monthly Savings (Php)	131,719.89	356,962.55
Approximate Duration of Payment (Months)	227	84

Approximate Profit after the Payable Period (Php)	-14,062,624.57	12,966,493.90

IV. CONCLUSION AND RECOMMENDATIONS

This study wants to analyze the feasibility of integrating a solar power grid at Wesleyan University-Philippines. The current implementation scheme is a 202.4 KWp Grid-Tied Solar PV System divided into three systems. These Solar PV System generates energy ranging from 12,212.01 KWh to 30,804.08 KWh which accounts to 39.93% energy saving s compared to non-integration of the solar grid.

Moreover, for analysis of savings and return of investment, with the current implementation, monthly savings of Php 131,719.90 mean it will take roughly 227 months to recoup the investment. After the 120-month repayment period, there will still be Php 14,062,624.57 remaining on the loan. In contrast, full implementation will allow the investment to be recouped in about 87 months, and after the 120-month repayment period, the investment will be fully paid off, plus a profit of Php 12,966,493.90.

With these data, the researchers concluded that the Solar PV System implemented at Wesleyan University-Philippines is a great investment in terms of sustainable energy efficiency and economic viability.

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