An Assessment of Photovoltaic System Installed at a Manufacturing Plant in Pampanga

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Abstract: PV technology is one of the solar power applications which uses cells made of solar PV materials to convert sunlight into direct current electricity. The benefits of implementing PV technologies include lowering overall electricity costs, defending against future increases in electrical power prices, helping to reduce environmental impacts, and achieving a good return on investment. The researchers conducted an assessment on the PV system installed in a pottery company located at Sto. Tomas, Pampanga to determine the type of solar panel and inverted used for the installation, its energy efficiency and the return of investment. The photovoltaic system used and installed in the company under investigation is a Canadian Solar CS3W-455MS (455W) Solar Panel and the inverter is Smart String Inverter wherein based on its technical specification, the maximum energy efficiency can reach 97.6%. The computed energy efficiency of the researchers based on the avarage peak sun hours of the Philippines is 90%. This means that the company can able to reduce their cost/expenses on electricity consumption because of PV system. Furthermore, the computed return of investment is 2.8661 years which is not a very long period for the company to return the money they have invested for the installation of their PV system.

Key Words: ***—Photovoltaic system, Solar panel, Pottery company.***

I. Introduction

In recent decades, the use of renewable energy sources has grown significantly because of the constant rise in the cost of fossil fuels and the growing concern about reducing environmental emissions from human activities (Waikar, 2010). The guidelines provided by the most powerful international institutions, such as the United Nations and the World Bank, emphasize the need to mark a turning point in the current trend of energy source distribution in order to increase the incidence of renewable sources to close to 16% of global produced energy (United Nations Development Program, 2015; World Bank, 2011).

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The world's reliance on renewable energy sources has increased dramatically from 13.2 percent in 2012 to 22 percent in 2013 in terms of electricity generation. It is expected to be at least 26% by 2020 (International Energy Agency, 2021). Explicitly, the World Energy and Climate Statistics has reported the total energy consumption of every continent of the world from 1990 to 2020 as shown in the figure below (Enerdata. 2021).

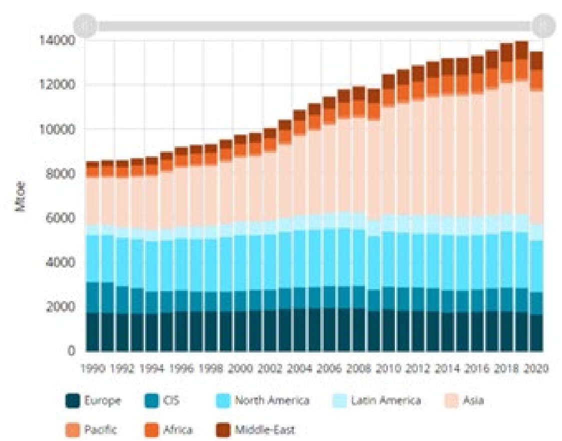


Fig.1. Total Energy Consumption (1990-2020)

The report also shows the breakdown of the energy resources used by different countries as shown on the figure below. The chart shows that 30% of energy resource comes from oil, 26%

from coal and 24% from gas (Enerdata, 2021).

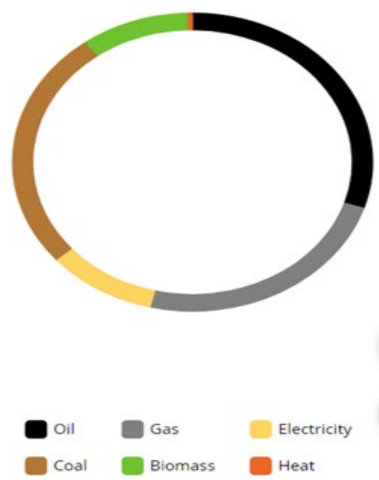


Fig.2. Breakdown of Energy Resources

In order to be more specific, the industrial sector is at the forefront of global energy consumption, accounting for approximately 54 percent of total delivered energy and projected to increase by 1.2 percent annually on average (Conti et al., 2016). In 2014, fossil fuel energy consumption accounted for 80.8 percent of total energy consumption worldwide (The World Bank Data, 2018).

In United States, the industrial sector accounted for 36% of total end-use energy consumption and 33% of total US energy consumption in 2020. The majority of industries obtain their electricity from electric utilities or independent power producers. Furthermore, some industrial facilities generate electricity for their own use by using purchased fuels and/or residues from their industrial processes. Manufacturing accounts for the majority of annual industrial energy consumption in the industrial sector, followed by mining, construction, and agriculture. Manufacturing is the transformation of materials or substances into new products through physical, mechanical, or chemical means (U.S. Energy Information Administration, 2021).

In the Philippines, In 2019, the Philippines' total primary energy consumption was approximately 1.9 quadrillion British thermal units (Btu). Petroleum and other liquids accounted for 45 percent of total primary energy consumption, followed by coal (36%), natural gas (7%), non-hydropower renewables (7%), and hydroelectricity (4%) (U.S. Energy Information Administration, 2020). The industry sector, the third largest energy consumer after transportation and households, reported an energy demand level of 7.5 MTOE in 2018, a 5.1 percent decrease from the previous year's level of 7.9 MTOE. The manufacturing sub-sector accounted for 92.7% of total energy demand, with energy-intensive industries accounting for 79.6% (Department of Enegy, 2021).

At present, strategic emerging industries such as the clean energy industry have grown rapidly as a result of policy dividends, but the front ends of these industrial chains are characterized by high energy consumption. One common example is the PV industry. Renewable energy is expected to dominate 30 percent of the global energy structure by 2030, with PV power generation accounting for more than 10% of total global electricity supply (De Castro, 2013). Thus, increasing the share of renewable energy in the industrial sector is perceived to provide environmental benefits, with a projected reduction in global carbon dioxide emissions of approximately 75% of their 1985 levels by 2050 (Kalogirou, 2009).

In this context, photovoltaic (PV) systems represent an excellent opportunity to meet the aforementioned targets, owing to the solar source's enormous theoretical potential of 3.9 trillion PJ per year (Quaschning, 2005). Thus, PV technology can be used to generate sustainable and green energy. PV technology is one of the solar power applications which uses cells made of solar PV materials to convert sunlight into direct current electricity (Mekhilef et al., 2012). The benefits of implementing PV technologies include lowering overall electricity costs, defending against future increases in electrical power prices, helping to reduce environmental impacts, and achieving a good return on investment (Younis, 2019).

Due to the fact that PV system, as one of the renewable energy sources, may possibly help the industry sector to reduce energy consumption coming from oil and coal and can able to use clean energy so as to reduce the negative effects on the environment as well as the the electricity costs they consume, this paper aims to assess the PV system installed in a pottery company in Pampanga. The researchers will determine the PV system, and efficiency of the installed PV panels in the said company. Furthermore, they will also determine the Return of Investment of this installed PV system.

The researchers adopted the Input-Process-Output model by McGrath (1964) that will provide a clear description of the action required throughout the study. Below figure shows the framework of the study:

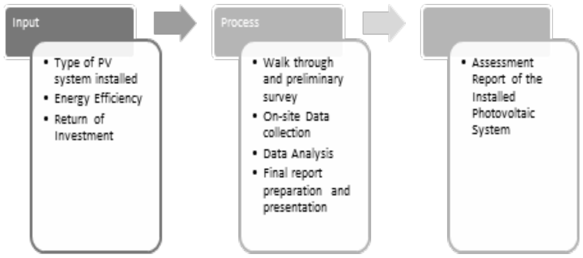


Fig.3. Conceptual Framework of the Study

The figure shown above illustrates the conceptual framework of the study. The researchers will identify the type of PV system installed and will determine its energy and efficiency. To achieve these, the researchers will conduct a walk through and preliminary survey on the plant. After the data collection, they will analyze the information and prepare the report. Subsequently, the researchers will present the final assessment report of the PV system installed in the pottery company being studied.

This study will help manufacturing companies understand the importance of using renewable energy sources like photovoltaic systems to reduce energy consumption and costs, as well as the environmental issues that have arisen as a result of their reliance on oil, gas, and coal as their primary sources of energy. Furthermore, this study could be a reference or guide that provides valuable references as a foundation for those who will conduct research similar to this study.

II. Methodology

The researchers used quantitative research design. Quantative research design is the dominant research framework. It refers to a set of strategies, techniques, and assumptions used to investigate psychological, social, and economic processes by examining numerical patterns (UTA Libraries, 2022). Specifically, the researchers will use descriptive research design since the process of gathering their data is thru observation and interview. Descriptive research can be defined as a statement of current events in which the researcher has no control over the variables (Business Research Methodlogy, 2022).

The study will take place in a pottery company in Pampanga. The researchers take a four-stage approach to conduct the assessment.

1. Walk through and preliminary survey
2. On-site Data collection
3. Data Analysis
4. Final report preparation and presentation

During the walk-through/preliminary survey, the following activities will be carried out:

1. Meeting/interview with relevant individuals
2. Identify the photovoltaic system installed inside the plant
3. Determination of critical points in assessing the energy consumption and economic cost of the PV system

To organize and summarize data gathered from the study, the researchers will descriptive statistics. Descriptive statistics are used to provide and describe the summary of the data collected (Trochim, 2021).

III. Results And Discussion

An energy assessment on the photovoltaic system of the pottery company that is being studied was carried comprehensively. The researchers were able to determine the type and specifications of the PV panel installed in the company, its energy efficiency, and the return of investment. The following are the summary of the technical findings for the company's PV system installation.

3.1 Type of Photovoltaic System Installed

The type of photovoltaic system utilized and installed in the company that is being studied is a Canadian Solar CS3W-455MS (455W) Solar Panel. Table 1 below shows its mechanical characteristics.

Table.1. Mechanical Charateristics of the Solar Panel

Mechanical Characteristics	
Type	Monocrystalline Silicon
Output Terminal Type	Canadian Solar T4
Output Cable Wire Gauge	12 AWG
Output Cable Wire Type	PV Wire
Output Cable Wire Length	13.8in (350mm)
Frame Color	Clear
Backsheet Color	White
Length 83in (2,108mm)	83in (2,108mm)
Width	41.3in (1,048mm)
Depth	1.6in (40mm)
Weight	54.9lb (24.9kg)
Installation Method	Rack-Mounted
Warranty and Certifications	
80% Power Output Warranty Period	25yrs
90% Power Output Warranty Period	10yrs
Workmanship Warranty Period	10yrs
UL Fire Classification	Type 1
Compliances	UL 1703, IEC 61215, IEC 61730, TUV
CSI Listed	No

1. PTC rating calculated using 42°C as the NOCT (Nominal Cell Operating Temperature)

Figure 4 below shows the inverter used to optimize the energy efficiency of the solar panels. The inverter used in installation is Smart String Inverter. Inverters are used to convert the output of a battery or solar panel to alternating current, which can then be connected to the grid or used by electric devices.

Fig.4. Inverter of the Solar Panel

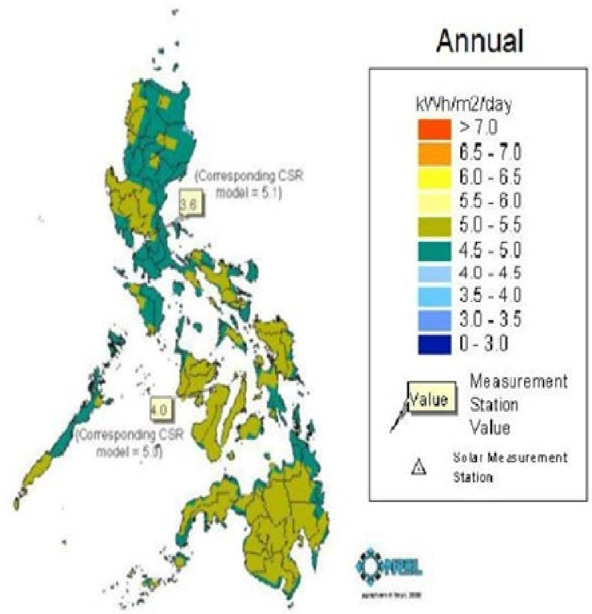
Table 2 below shows the technical specification of the inverter of the solar panel. The maximum energy efficiency of this inverter is 97.6%. This means that the pottery company can able to save up energy and reduce the energy costs of its operation.

Table.2. Technical Specifications of the Inverter of the Solar Panel

Technical Specification	SUN2000-20KTL-M3
Efficiency	
Max. Efficiency	97.6%
European Efficiency	97.2%
Input	
Recommended Max. PV Power	30,000 Wp
Max. Input Voltage [1]	750 V
Max. Current per MPPT	28 A
Max. Short Circuit Current per MPPT	40 A
Start Voltage	200 V
MPPT Operating Voltage Range [1]	200 V ~ 750V
Rated Input Voltage	360 V
Number of Inputs	8
Number of MPP Trackers	4
Output	
Rated AC Active Power	20,000 W
Max. AC Apparent Power	22,000 VA
Max. AC Active Power (cosφ=1)	22,000 W
Rated Output Voltage	120 Vac / 208 Vac, 3W/N+PE 127 Vac / 220 Vac, 3W/N+PE
Rated AC Grid Frequency	50 Hz / 60Hz
Rated Output Current	57.2 A / 208 Vac 52.5 A / 220 Vac
Max. Output Current	63.2 A / 208 Vac 58.0 A / 220 Vac
Adjustable Power Factor Range	0.8 LG 0.8 LD
Max. Total Harmonic Distortion	<3%
Protection	
Input-side Disconnection Device	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Monitoring Unit	Yes
Arc Fault Protection	Yes
Ripple Receiver Control	Yes
Integrated PID Recovery [2]	Yes
Communication	
Display	LED Indicators, Integrated WLAN + FusionSolar APP
RS485	Yes
Smart Dongle	WLAN/Ethernet via Smart Dongle-WLAN-FE (Optional) 4G / 3G / 2G via Smart Dongle-4G (Optional)
Monitoring BUS (MBUS)	Yes (Isolation Transformer required)
General Data	
Dimensions (W x H x D)	640 x 530 x 270 mm (25.2 x 20.9 x 10.6 inch)
Weight (with mounting plate)	43 kg (94.8 lb)
Noise Level	≤ 46 dB
Operating Temperature Range	-25 ~ + 60 °C (Derating above 45 °C @ Rated output power)
Cooling Method	Natural Convection
Max. Operating Altitude	0 - 4,000 m (Derating above 3000 m)
Relative Humidity	0% RH ~ 100% RH
Protection Degree	IP 66
Topology	Transformerless
Nighttime Power Consumption	≤ 5.5W
Optimizer Compatibility	
DC MBUS Compatible Optimizer	SUN2000-450W-P
Standard Compliance (more available upon request)	
Safety	EN 62109-1/-2, IEC 62109-1/-2, EN 50530, IEC 62116, IEC 60068, IEC 61683
Grid Connection Standards	

3.2 Energy Efficiency of the Solar Panel System

The researchers used the average peak sun hours to compute the energy efficiency of the solar panel system installed in the company they are being studied. Figure 4 below shows the average peak sun hours of the Philippines.



Source: https://images.app.goo.gl/E2Fcz1nHQRjtyden9

Fig.5. Average peak sun hours

Table 3 below shows the computation for the energy efficiency of the solar panel system installed using the average peak sun hours. The computation shows that the energy efficiency of the solar panel system is 90% and can also reach the maximum efficiency of 97.6% based on the technical specifications of the inverted used for the installation of the PV system.

Table.3. Computed energy efficiency

Inverter	Installed PV Panel	kW PV Panel	Peak Sun Hours	Efficiency	Average Day Harvest
20kW	37 pcs. 455 wPV	16.835kW PV	5	90%	75.758kW
20kW	37 pcs. 455 wPV	16.835kW PV	5	90%	75.758kW
20kW	37 pcs. 455 wPV	17.290kW PV	5	90%	77.805kW

3.3 Return of Investment

For the computation of the return of investment, the researchers requested for the sales invoice of the supplier of the pottery company where they have purchased the PV system to determine the initial investment which will be used for the computation of ROI. Based on the invoice, the initial investment of the pottery company for the purchase of PV system is 2,576,000php including inverter, solar panel, railings, PV and AC cable, mc4, electrical pipe, terminal lugs, epm, labor and engineering.

To compute for the ROI, the researchers determined the following:

PELCO III price per kWhr

1kWhr = 10.8872php

Inverter Installed 3 pcs, 20kW

3 x 20kW = 60kW

PV Panel Installed 112 pcs, 455W

112 x 455W = 50.960kW

Peak Sun Hours

4.5-5 hours on an average day

Energy Efficiency 90%

Formula for average harvest per day:

Average harvest = PV Panel x Peak Sun Hours x Efficiency

Harvest/day = 50.960kW x 5 hours x .90

= 229.320kWhr

PELCO III price per 1kWhr = 10.8872php

Compute the product harvest (per kWhr per day)

Harvest per day = 229.320kWhr

Change the value of kWhr to 10.8872 php

Therefore:

Harvest per day = 10.88726php (229.320)

= 2,496.65php

To get the savings per month, multiply the harvest per day by 30 days:

 2,496.65php x 30 days = 74,899.58php

To get the savings or harvest per year, multiply it by 12 months:

74,899.58php x 12 months = 898,794.96php

To get the ROI, the researcher used the formula below:

Return of Investment = Total Investment/Harvest Per Year

Where:

Total Investment = 2,576,000php

Total Harvest Per Year = 898,794.96php

ROI = 2,576,000/898,794.96

ROI = **2.8661 years**

IV. Discussion

The researchers conducted an assessment on the PV system installed in a pottery company located at Sto. Tomas, Pampanga to determine the type of solar panel and inverted used for the installation, its energy efficiency and the return of investment. The photovoltaic system used and installed in the company under investigation is a Canadian Solar CS3W-455MS (455W) Solar Panel and the inverter is Smart String Inverter wherein based on its technical specification, the maximum energy efficiency can reach 97.6%. The computed energy efficiency of the researchers based on the avarage peak sun hours of the Philippines is 90%. This means that the company can able to reduce their cost/expenses on electricity consumption because of PV system. Furthermore, the computed return of investment is 2,8661 years which is not a very long period for the company to return the money they have invested for the installation of their PV system.

V. Conclusion And Recommendation

The researchers have concluded that utilization of photovoltaic systems represent an excellent opportunity to many industries as it can be used to generate sustainable and green energy. The benefits of the PV system is that it reduces overall electricity costs, protects against future increases in electrical power prices, aids in environmental impact reduction, and provides a good return on investment.

The findings of the study have implications on the importance of the photovoltaic system to industries. Despite the fact that the investment on the solar panels is somehow expensive, the important is that the long term benefits that they can able to acquire to this system is greater than its cost. That is why the researchers recommend to conduct an impact analysis on the PV system installed in the pottery company to determine the energy consumption and cost before and after the intallation of the said system.

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