© AUG 2022 | IRE Journals | Volume 6 Issue 2 | ISSN: 2456-8880

A Propose Design of Off-Grid Type PV Panel at An Electric Rice Mill in Sto. Niño, Tabuan Arayat, Pampanga

JEROME P. CANTOR[1], PETER PAUL B. CARLOS[2], JEREMO V. CRUZ[3], JOHN MARK C. CUNANAN[4], CHRISTIAN JHOR D. REMIENDO[5], JAYMILYN L. SAFICO[6], REYNALDO GOMEZ[7], EDGARDO M. SANTOS[8]

[1, 2, 3, 4, 5, 6, 7, 8] *Department of Electrical Engineering, Don Honorio Ventura State University, Philippines*

Abstract*—This research project unfolds the practicability of utilizing an Off-Grid connection Type PV Panel at an Electric Rice Mill in Sto Niño, Tabuan Arayat, Pampanga. Rice mills are the most energy intensive industry in Arayat. To satisfy the aims of this research, a Solar PV System design was used to make use of the solar energy converting it to electrical energy to supply the whole machine. This study was guided by doing a load schedule of the machine to acquire the total power and total energy consumption, using it as a basis for the selection of the required electrical components and computation of the roof area to select a suitable solar panel in order to ensure the functionality of the whole Solar PV System. The raw data gathered was analyzed using formulas to acquire the needed electrical values For the canvassing of the price of significant components, bill of materials for consumables, grounding (bill of materials specific), manpower cost for installation, operation & maintenance cost, delivery of materials, and net-metering application cost, the researchers consulted a registered electrical engineer working at Transnational Uyeno Solar Corporation (TUSC). The Payback Period was calculated by dividing the total cost by the total savings. After completing all the information needed, the proponents came up with the result. The total estimated expenses amounted is ₱1,657,632.29. The payback period is expected to last at least 6 years, and 1 month. The findings resulted in the development and completion of the Solar PV System Design. The last part of the research is the results, discussions, conclusions, and recommendations. These provided the finalization and endorsement of the whole study.

***Indexed Terms*— Electric Rice Mill, Off-Grid, PV Panel—**

I. INTRODUCTION

Rice is the globe second largest extensively produced food crop, and it feeds more than half of the worldwide people. Over 3 billion individuals consume over 100 kilograms of rice each year. Because of the scarcity of global water resources for agriculture, the expansion of urban and industrial sectors in Asia, where land is already limited, and the high costs of developing new lands suitable for rice production in different parts of the world, the possibility of expanding areas under rice-based systems will remain very limited in the near future.

The Philippines is the globe eighth largest rice producer, with 2.8 percent of worldwide rice output. In 2010, the Philippines was the world's largest rice importer. Palay was produced in roughly 15.7 million metric tons in 2010. Palay contributed 2.37 percent of GNP and 21.86 percent of total value added in agriculture in 2010. In 2015, rice self-sufficiency reached 88.93 percent.

In 2018, the Philippines ranked seventh in the world for rice output (FAOSTAT, 2020). In Luzon, Western Visayas, Southern Mindanao, and Central Mindanao, rice is abundantly farmed. Rice output has grown over the last two decades, from 12 Megatons in 1999 to 19 Mt in 2008. (FAOSTAT, 2020). The total rice harvested area on a yearly basis is approximately In the Philippines, there are 4.7 Mega hectares with an average yield of 3.95 tons per harvested hectare.

The usage of new and alternative energy sources, particularly solar energy, has increased and will continue to increase as we try to reduce our reliance on older, non-renewable energy sources. One of the most difficult aspects of using solar energy, or renewable energy in general, is how to make this energy available to the general people. The efficiency with which solar electricity may be captured and turned into usable energy, as well as the expense of the technology to do so, are some of the limiting variables.

II. BACKGROUND OF THE STUDY

Rice is beneficial in our world, due to the rapidly increasing demand of rice not only in the Philippines but also around the world, advancement of rice milling, particularly, electric, can play a vital role in production. Electric rice milling consumes a large amount of electricity.

According to Goyal, S.K., Jogdand, S.V et al (2014), rice milling industry is one of the most energy consuming industries. Like capital, labor and material, energy is one of the production factors which is used to produce the final product. In economic terms, energy is demand-derived goods and can be regarded as intermediate goods whose demand depends on the demand of the final product. This paper deals with various types of energy patterns used in rice milling industries viz., thermal energy, mechanical energy, electrical energy and human energy.

Furthermore, Loofal Protech Solution (2021) states that, due to the frequent power outage of electricity supply, solar energy has become a better option today. Solar power plants are very good solution for rice mills. Most rice mills are located in areas where there is a power problem. In such a situation, diesel generators have become a costly deal today. As the price of oil is increasing, it will be very difficult to use diesel generators after some time. In view of such circumstances, A solar power plant for a rice mill is becoming a better option for the mill owners.

III. STATEMENT OF THE PROBLEM

According to the owner of a 23 kW electric rice mill in Sto. Nino, Tabuan Arayat, the milling is supplied by PELCO 1 through a 3-phase transformer with 10 kilo-Volt Ampere (kVA) each transformer. The monthly billing averages Php 9,000 a month. More so, in 6 months, the cost of electricity bills is averaging 54,000 pesos. With this, the proponents propose the installation of a 25 kilo-Watt-Peak Photovoltaic panel which will solve the problems like reducing dependence on oil and fossil fuels and use only renewable clean energy, reducing the cost of maintenance and electricity bills.

IV. OBJECTIVE OF THE STUDY

The study aims to know whether the proposed design of an off-grid type photovoltaic panel at an electric rice mill in Sto Niño, Tabuan Arayat, Pampanga can be powered by solar energy or not. Furthermore, the specific objectives of this project are:

- To know how much solar panels are involved to operate the electric rice mill.
- To determine where the owner can save money
- To assess how the solar energy will contribute to the overall effectiveness of the rice mill.

V. METHODS

Research Design

This study used a quantitative form of research. The purpose of this study is to assess the off-grid type photovoltaic panel in an electric rice mill that can be powered by solar energy in the Sto. Nino, Tabuan Arayat, Pampanga and determine how much can be saved by using this when the solar energy will contribute to the overall effectiveness at the rice mill.

Research Approach

The respondents were the owner of the electric rice mill and the people associated in the Pelco 1 in their billings. To collect data, the researchers conducted an interview by using a descriptive survey.

Data Collection Method

The primary data will be collected from the owner of the electric rice mill and with people associated in Pelco 1 as mentioned. Moreover, these data will be gathered directly from the respondents through an interview.

Data Analysis Method

The data analysis of this study will be mostly represented in a qualitative manner. It has been mentioned earlier that the data will be gathered by an interview using a descriptive survey. As a result, the analysis will be qualitative. However, there will be a few quantitative solutions.

Cost – Benefit Analysis

The researchers will assess all the costs associated with making the proposed design system operational, as well as the number of years required to recoup all of the expenditures made. The researchers will also be able to assess the investment's effectiveness.

System Design

The series-connected PV panels will be installed on the roof of the rice mill plant, which faces south east where the sun is at its highest peak. The energy generated by the system will be used to operate the rice mill at the site. The solar panels will also charge the generators, ensuring that the facility will have electricity even if the sun is not shining. The researcher will seek for the ideal area to store and attach the generators, inverters, and breakers during the site visit. The researcher will employ an inverter generator, which may be linked to the grid.

Formulation of Design

To get the exact value of each material used in this study. We compute the number of items and rated specifications for each and by using the given formulas listed upon in order we easily define the value. That the off-grid type PV panel really needed of materials that was evaluated well. We used also figures and charts to simply analyze the data we have gathered.

Power = Quantity x Motor Rating (kW)
No. of Panels = Total Power/Solar Panel Rating (Watts)
Peak Power = 500 x 5.41 x 0.75
Peak Energy Consumption per Solar Panel = Solar Panel Rating (Watts) x Average Hours of Sunlight x Coefficient Installation of Solar Panels
Solar Panel Tilt Angle= Latitude x 0.87

The researchers have found that the 2.06m x 1.03m dimension is appropriate and best fits the present 2.187m x 1.102m roof of the facility as this will only require fifty (50) solar panels upon installation and gives the maximum surface area exposed to sunlight leaving only 1m in each side of the roof space.

Estimated Payback Period= Total Expense/Annual Saving

In addition, the researchers also followed the school's ethical rule.

VI. RESULTS AND DISCUSSION

Table I. Total Energy Consumption (kWh) and Power (kW) of the Combine Rice Mill

Name of Machine	Quantity of Motor	Motor Rating (kW)	Total power (kW)	Working hours (h)	Energy Consumption (kWh)
Combine Rice Mill	9	2.56	23.04	11	253
Total Power			23.04	*Total Energy Consumption*	253

Table I shows the Combine Rice Mill daily energy usage in kilowatt-hours. The first column displays the name of the machine, which is the primary focus of the study. The second column lists the number of motors in the rice mill. The third column displays the kW rating of each motor. The fourth column displays the rice mill's daily working hours. The last column calculates the rice mill's energy usage by multiplying Quantity, Power, and operating hours per day.
The researchers were able to calculate the overall power consumption of the rice mill using this calculation:

Power = Quantity x Motor Rating (kW)

The researchers totaled the total power for the rice mill after computing the entire power to determine the total power of the Solar PV System Design. The number of solar panels required was derived using the following formula:

No. of Panels = Total Power/Solar Panel Rating (Watts)
No. of Panels = 25 kW/500Watts
No. of Panels = 50 Panels

Table II. Solar Panel Rating, Average Hours of Sunlight, and Coefficient Installation

Solar Panel Rating (W)	Average hours of Sunlight	Coefficient Installation
500	5.41	0.75

The researchers utilized the formula below to calculate the amount of peak energy.

Peak Energy Consumption per Solar Panel = Solar Panel Rating (Watts) x Average Hours of Sunlight x Coefficient Installation of Solar Panels

Peak Power = 500 x 5.41 x 0.75
Peak Power = 2028.75 Wh
Peak Energy Consumption = 2028.75 kWh per solar panel

Peak power is the greatest power that a power source can withstand for a brief period of time and is also known as peak surge power. Peak power is distinct from continuous power, which refers to the amount of electricity that the supplier can continually deliver. Table 3 shows that a normal average hour of sunshine is 5. The power supply is chosen based on the maximum total system power, which is estimated in Volts Amps Watts(TDK-Lambd, 2009).

Fig. 1. Latitude and Longitude of Arce Rice Mill

The latitude and longitude value for the Arce Rice Mill facility is 15.184352, N 120.801856E as shown in Figure 1.

Solar panel tilt angle is calculated by the latitude value. This angle is multiplied by 0.87 if the latitude value is less than 25. If the latitude value is between 25 and 50, it is multiplied by 0.87 and added 3.1 degrees to the result (Yilmaz, 2018).

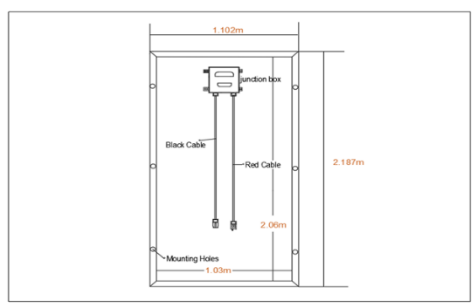
Solar Panel Tilt Angle= Latitude x 0.87
Solar Panel Tilt Angle= 15.2 x 0.87 = 13.224

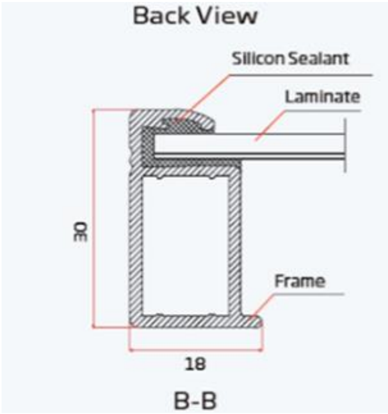
As a result of this calculation, the solar panel should be directed to the South at 13.224 degrees angle for use throughout the year in the Arce Rice Mill facility position. To get the most from solar panels, you need to point them in the direction that captures the most sun. But because the sun is higher in the summer and lower in the cold season, you can capture more energy during the whole year by adjusting the tilt of the panels according to the season (Landau, 2017).

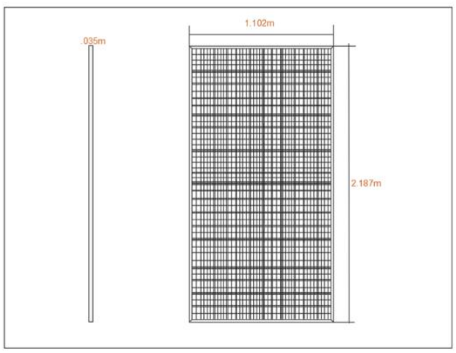
The proposed design is based on the idea of using a PV panel as an auxiliary power source to reduce the consumption of grid-connected power.

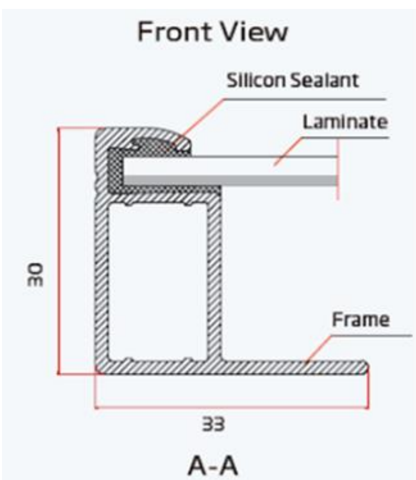
The data analysis shows that this system has good performance, which means it can be used with other systems and can produce more energy than what would be used from the grid. However, there are some limitations such as:

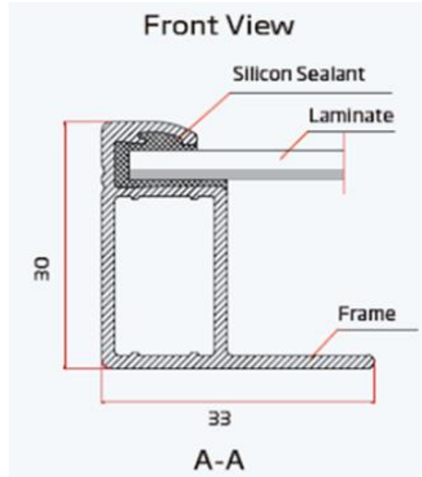
- The solar panels must be installed at a right angle because of their orientation towards sunrays; otherwise, they will not work properly due to shading by surrounding objects like trees or buildings.
- It is necessary for all components inside each module (such as tube frame) to be made from same material or else when one component breaks down then others also get affected by corrosion.
- The inverter should have ability of monitoring its own output so that any changes in output voltage can be noticed immediately instead waiting until later when it might get damaged causing unnecessary losses in production capacity











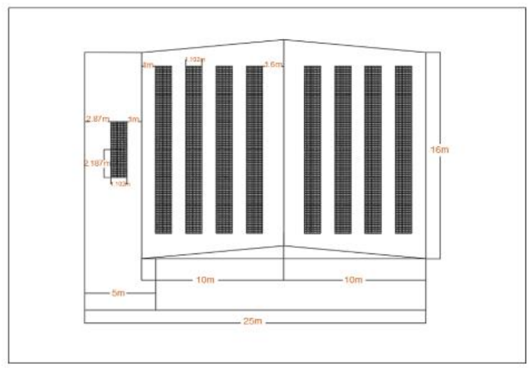


Figure 2. Dimensions of Solar PV MODULES (unit: mm)

Figure 2 shows the Front and Back view along with the measurements of the solar panel that is most suitable for the roof of Arce Rice Mill facility while Appendix A shows the 500W Trina Solar Vertex solar panel model conforming with the computed size of the solar panel to be used. The researchers have found that the 2.06m x 1.03m dimension is appropriate and best fits the present 2.187m x 1.102m roof of the facility as this will only require fifty (50) solar panels upon installation and gives the maximum surface area exposed to sunlight leaving only 1m in each side of the roof space.

Table III. Technical Specifications of SUN2000-30KTL-US

Technical Specifications	SUN2000-30KTL-US
	Efficiency
Max. Efficiency	98.6%
	Input
Max. DC power	30,800W
Max. Input Voltage	1,000 V
Max Current per MPPT	25A
Min. operating voltage	200 V
MPP Voltage Range @ Full Load	560 V~850 V
Rated Input Voltage	720 V
	Output
Rated AC Output Power	30,000 W
Max.AC Output Power	33,000VA
Max. ActivePower (cosφ=1)	30,000W
AC power frequency	60 Hz
Max Output Current	40 A
	General
Dimensions (W×H×D)	550×770×270 mm (21.7×30.3×10.6 inch)

Table 3, displays the technical specifications of the String Inverter SUN2000-30KTL-US that the researchers will use to convert the total power produced by the fifty (50) solar panels from DC to AC. The researchers chose the SUN2000-30KTL-US because it can convert the 23.04kW produced by the fifty (50) solar panels installed due to its maximum DC power of 30,000W, rated AC output power of 30,000W, and maximum AC output power of 33,000VA. With dimensions of 550x770x270 mm, the inverter takes up the least amount of room in the electrical room. Since some power can be wasted as heat during the conversion, the researchers also commend the SUN2000-30KTL-US for having a high efficiency. So, with a peak efficiency of 98.6%, there will be less power lost during the conversion of DC to AC.

Figure 3. View of the facility roof of the project place

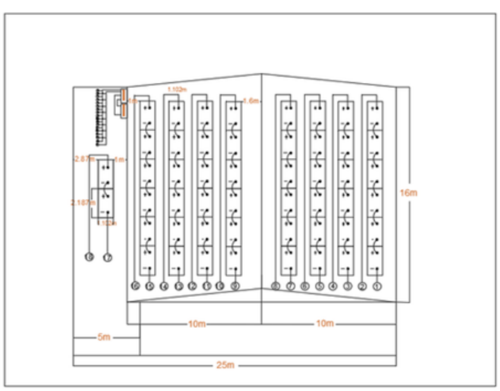


Figure 4. Photovoltaic Panels Layout

There is enough space in the Arce Rice Mill building to install a PV system that will produce enough energy to power the rice mill. The installation of PV modules on the rooftop will reduce heat waves from the rooftop that penetrate the entire building. The solar PV installation is meticulously planned to avoid any potential shadow cast by nearby structures or trees. Figures 3 and 4 depict the rooftop view of the Arce Rice Mill Building. The strings are arranged so that there is no shadow from one string to the next. This specific design for solar PV installation has a total roof area of approximately 320m².

In this illustration, it can be seen how a PV panel is connected to create a string. The researcher used a number symbol to designate the connectors to easily show how the wiring layout must be connected to the inverter.

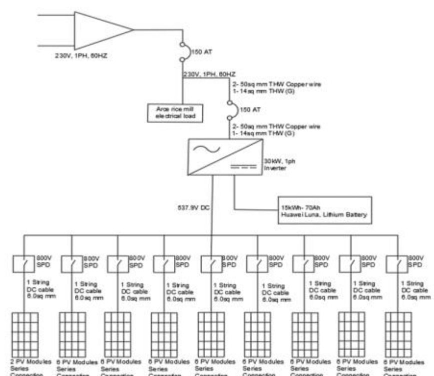


Figure 5. Single Line Diagram

The researchers proposed 50 photovoltaic modules divided into 9 strings with each group connected in series. The researchers also designated each group a surge protection device 800V-two pole for protection and isolation of equipment. The researchers added a 15kW-hr battery to sustain a lighting load in the evening.

Table IV. Total Expense of Solar PV System Design

This table shows the items needed to install an off-grid connection solar panel in the facility as well as its quantity and calculated price. Each item secures the best quality available in the market.

Total Expense of Solar PV System Design= Php 1,657,632.29
System Design Capacity= 25 kW
Generation Per Day= 25x5.38 (average peak sunshine hours)
=134.5 kWh/day (units per day)
Monthly Generation = 134.5 x 30 = 4035 kWh/month
Average Monthly Rate: 5.61

Table V. Billing Rates Schedule for PELCO I Consumers (PELCO I, 2022)
So, the amount of the Average Monthly Bill.

(Monthly Generation) (Average Monthly Rate) = Php 22,636.35

*Annual Saving = Php 22,636.35 x 12 = Php *271,636.2*

Estimated Payback Period= Total Expense/Annual Saving
= Php 1,657,632.29/271,636.2
Estimated Payback Period = 6.10 years

The researchers were able to compute the payback period of 6.101 years by utilizing the formula adapted in the study by Shujauddin et al., (2020). The term payback period refers to the amount of time it takes to recover the cost of an investment. Simply put, it is the length of time an investment reaches a break-even point (Kagan, 2022). Upon the completion of the project, the researchers have found that it will take 5 years before the total expense of Solar PV System design will be earned back.

Amount of Years= Lifetime of Solar PV- Payback
= 25 – 6.10
=18.9 years
Net Profit = Annual Saving x Amount of Year – (P Battery + P Inverter)
= Php. 271,636.2 x 18.9 – (450,651.20 + 101,306.89)
= Php. 4,581,966.09
O and M Solar PV System Design= Php. 100/kW per year (First Philippine Solar Rooftops Inc.)
Total Investment= Initial Investment + O and M
= 1,657,632.29 + (25 x 1000 x 25)
= Php 2,282,632.29
Estimated ROI= (Net Profit – Total Investment)/Total Investment
= (4,581,966.09–2,282,632.29)/2,282,632.29 x 100%

Description Items	Quantity	Unit Price	Total
500 W Trina Solar Vertex Monocrystalline Solar Panels	50 pcs	Php 11, 700.00	Php 585, 000
30 kW Huawei Solar Inverter	1 pc	Php 101,306.89	Php 101,306.89
15 kWh Huawei Battery	1pc	Php 450,651.201	Php 450,651.20
Surge Protection Device	9 pcs	Php 192.67	Php 1,734
Panel Railing	95 pcs	Php 1,097.36	Php 104,249.2
Cables and Wires (DC)	100 meters	Php 193.00	Php 19,300
Cables and Wires (AC)	20 meters	Php 270.00	Php 5,400
150 AT Circuit Breaker	1 pc	Php 1,200	Php 1,200
Solar Connector MC4	18 pcs	Php 24.33	Php 438
Tex Screw	95 pcs	Php 115.20	Php 10,944
L foot	95 pcs	Php 70.00	Php 6,650
End Clamp	36 pcs	Php 69.44	Php 2,500
Inner Clamp	82 pcs	Php 100.72	Php 8,259
Miscellaneous	Php 12,000/kW (30kW)	Php 360,000	Php 360, 000
			Total= Php 1,657,632.29

Month (Yr 2021-2022)	Rate (php/kWp)
May-21	4.79
Jun-21	4.69
Jul-21	4.71
Aug-21	5.53
Sep-21	5.13
Oct-21	5.16
Nov-21	5.19
Dec-21	6.58
Jan-22	6.29
Feb-22	5.42
Mar-22	5.43
Apr-22	7.03
May-22	7.01
Average Monthly Rate	5.61

Estimated ROI = 100.73%

CONCLUSION

The proposed off-grid type PV panel has been developed by using the best materials and technologies available to us. The design of this system is simple, easy to implement and operate with minimum maintenance requirements. The proposed system can be used for power generation in rural areas where there is no grid connection or load shedding facility available. This paper has discussed various issues related to implementation of such systems including their comparison with conventional grid-based systems, cost analysis etc., which will help the reader understand benefits offered by these types of technologies when compared with conventional solutions like diesel generators or batteries. Solar panels are the best way to use for the generation of electrical power. It is one of the most popular methods for generating electricity. This type of system uses sunlight as its energy source, which means that it doesn't require any fuel or other external input.

RECOMMENDATION

- The researchers suggest encouraging the rice mill owners as well as the government to support and introduce the usage of solar power in generating rice mills to help conserve electricity, energy, as well as cost of rice mill production.
- Future researchers are recommended to dig in further research about solar powered rice mill to enhance the reliability and sustainability of using solar power in rice mills.
- Future researchers are recommended to conduct further research about the utilization or implementation of solar power-generated rice mill that will not compromise or affect the natural environment.

REFERENCES

[1] China Wintone Machinery, (ND) Desciption of rice milling. Retrieved from http://www.wintonemachinery.com/plants/rice_milling_machine.html?g=g&keyword=rice%20milling%20unit&matchtype=p&creative=592786509771&device=m&16871224269=16871224269&target=&placement=&gclid=EAIaIQobChMIoY_Lpe7W9wIVylBgCh1QAAw8EAAYAiAAEgLO5vD_BwE

[2] Goyal, S.K., Jogdand, S.V. & Agrawal, A.K. (2014). Energy use pattern in rice milling industries—a critical appraisal. J Food Sci Technol 51, 2907–2916. Retrieved from https://doi.org/10.1007/s13197-012-0747-3

[3] (NA). (ND). Agriculture in the Philippines. Retrieved from https://en.m.wikipedia.org/wiki/Agriculture_in_the_Philippines

[4] FAOSTAT (2020). Rice Rank Production. Retrieved from https://www.yieldgap.org/philippines#:~:text=Average%20annual%20production%20of%20rice%20is%2026%20Mt,Luzon%2C%20Western%20Visayas%2C%20Southern%20Mindanao%2C%20and%20Central%20Mindanao

[5] Johnston, M. (2022) Disadvantage of Solar energy. Retrieved from https://www.investopedia.com/articles/investing/053015/pros-and-cons-solar-energy.asp#:~:text=One%20of%20the%20biggest%20problems,days%20can%20interrupt%20the%20supply

[6] Matungwa, B. (2014). Thesis submitted in partial fulfillment of the requirments for the Degree of Master of Philosophy in Culture, Environment and Sustainability. Retrieved from https://core.ac.uk/download/pdf/30903741.pdf

[7] TDK-Lambda, (ND). Inverter. Retrieved from https://www.emea.lambda.tdk.com/uk/distributors/

[8] Landau, C. (2017). Optimum Tilt of Solar Panels. Retrieved from https://www.solarpaneltilt.com/

[9] Clarine, S., Drury, A., and Kagan, J. (2022) Payback Period. Retrieved from https://www.investopedia.com/terms/p/paybackperiod.asp