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Performance Analysis of Solar PV System installed in Chitwan Medical College

by

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ABSTRACT

In various places of the world grid-connected and off-grid rooftop solar PV systems have been installed, either to export energy to the grid or to reduce electricity bills in an industry, hospitals, etc. A 201.96 kWp solar PV plant with 7, identical 25 KW off-grid inverters was installed in the Chitwan Medical College, Chitwan. The plan of the study was to carry out the performance analysis of installed multi-crystalline solar panels for a period of one year and to evaluate the results with the results simulated in the PVsyst. The generation data has been extracted using the Wattmon Cloud Portal. The main aim of this work was to evaluate and determine various performance characteristics of an already-existent solar system that has been installed at Chitwan Medical College, Chitwan. It was found that annual energy generation of 236.99 MWh, Performance ratio was 79.80 %, Capacity Utilization Factor 13.58%, and specific Yield was 1173.24 kWh per kWp per Year. The difference between the actual and simulated generation (54.30 MWh) suggests there may be factors impacting the system's performance. These could include equipment inefficiencies, shading, maintenance issues, or inaccuracies in the simulation model used.

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LIST OF ABBREVIATION

AC	Alternating Current
AEPC	Alternative Energy Promotion Centre
a-si	amorphous silicon
˚C	Centigrade
CMCTH	Chitwan Medical College Teaching Hospital
CUF	Capacity Utilization Factor
DC	Direct Current
DOD	Depth of Discharge
DOED	Department of Electricity Development
E_{gen}	Energy Generation
GW	Giga Watt
IAM	Incidence Angle Modifier (IAM)
IEA	International Energy Agency
I_{MPP}	Current at Maximum Power
I_{sc}	Short Circuiting
kWh	Kilowatt Hour
kWp	Kilowatt Peak
masl	meter above sea level
mc-si	monocrystalline silicon
MPPT	Maximum Power Point Tracker
MWh	Megawatt Hour
mm	Millimeter
NREL	National Renewable Energy Ltd.
NEA	Nepal Electricity Authority

NOCT	Nominal Operating Cell Temperature
pc-si	polycrystalline silicon
PR	Performance Ratio
PV	Photovoltaic
P_{MPP}	Maximum Power Output
PVGC	Photovoltaic Grid Connected
STC	Standard Test Condition
STEEP	Social, Temperature, Economic, Environment, & Political
STP	Sunny Tri Power
SWOT	Strengths Weakness Opportunities Threat
TUTH	Tribhuwan University Teaching Hospital
UV	Ultraviolet
V_{MPP}	Voltage at Maximum Power
V_{OC}	Open Circuit Voltage
W	Watt
Wh	Watt-hour
Y_A	Array Yield
Y_f	Final Yield
Y_R	Reference Yield

CHAPTER ONE: INTRODUCTION

1.1 Background

Solar Energy, itself is a comparatively new and primitively developing field. Solar energy can be utilized in two different ways: Solar PV and Solar Thermal energy. The former converts solar radiation into electricity directly, whereas the latter is used to convert solar energy into heat energy. Renewable energy has been considered as high priority for fuel substitution to produce electrical energy and Solar PV technology is one of the best renewable energy sources. From the commercial sources, there was 65% of consumption from petroleum products and electricity; besides 15% and 20% reliance on other modern energies such as coal renewable modern energies, solar, and wind are still holding less than 3% (Lohani et al. 2022). The main challenge with solar PV systems, taking the example of Nepal, is that solar radiation, on average is available for only about 5 sun hours/day and that would equal roughly 4.5-5.0 KWh/m2 /day (though comparing world leader in solar power, Germany gets 2-3 KWh/m2 /day) (Aryal et al. 2010).

So, either the solar power has to have a provision of being connected to the national grid after production on a national scale or even for household purposes, which doesn't quite look possible, or, they should have large battery banks to store the daylight energy to be used later.

The solar photovoltaic (PV) industry has historically lacked sufficient data related to rooftop load for solar installations. Also, different parameters are assumed to affect solar PV efficiency. Some of them are solar irradiance, temperature, shading, soiling, snow, and solar efficiency. Usually, the solar panel output varies according to the temperature (Jiang, 2016). One of the primary parameters that affect the electricity output of the Solar Panels is the temperature. It's a common misconception that more sunlight and higher heat lead to increased electricity generation, but this isn't accurate. Different panels differ in their sensitivity to ambient temperature but all in all, power outputs reduce with increasing temperatures (Gauchan, 2017).

A characteristic of the solar panels' potential is how their efficiency reduces when exposed to temperature, which is known as the temperature coefficient. On the datasheet that the manufacturer of the solar panel provides, this is known as the temperature coefficient P_{MAX}. This usually as a negative percentage value shows how

the temperature rises or falls impact the efficiency or the panel. The primary method of power testing of the solar panel is done at 25°C and temperature coefficient % reveals the increase or decrease of efficiency with every degree above or below the said standard. For instance, if the temperature coefficient of a given type of panel is negative zero point zero eight then it means that the panel will suffer a negative change of 0. 8% for every degree Centigrade of temperature rise above the reference. 5%, so for each 10°C increase the maximum power of a PV panel will be reduced by 0. 5%.

Therefore, when the environmental temperature could rise to 45°C as shown here, a panel with the coefficient of -0.5% The no-offshore windpower scenario would have a maximum power output reduction of 10% compared to the business-as-usual scenario for an investment of 5%. On the other hand, if it was a clear winter's day as seen above the panels are actually more efficient. The distribution of photovoltaic power potential in Nepal is depicted in the Figure 1.1.

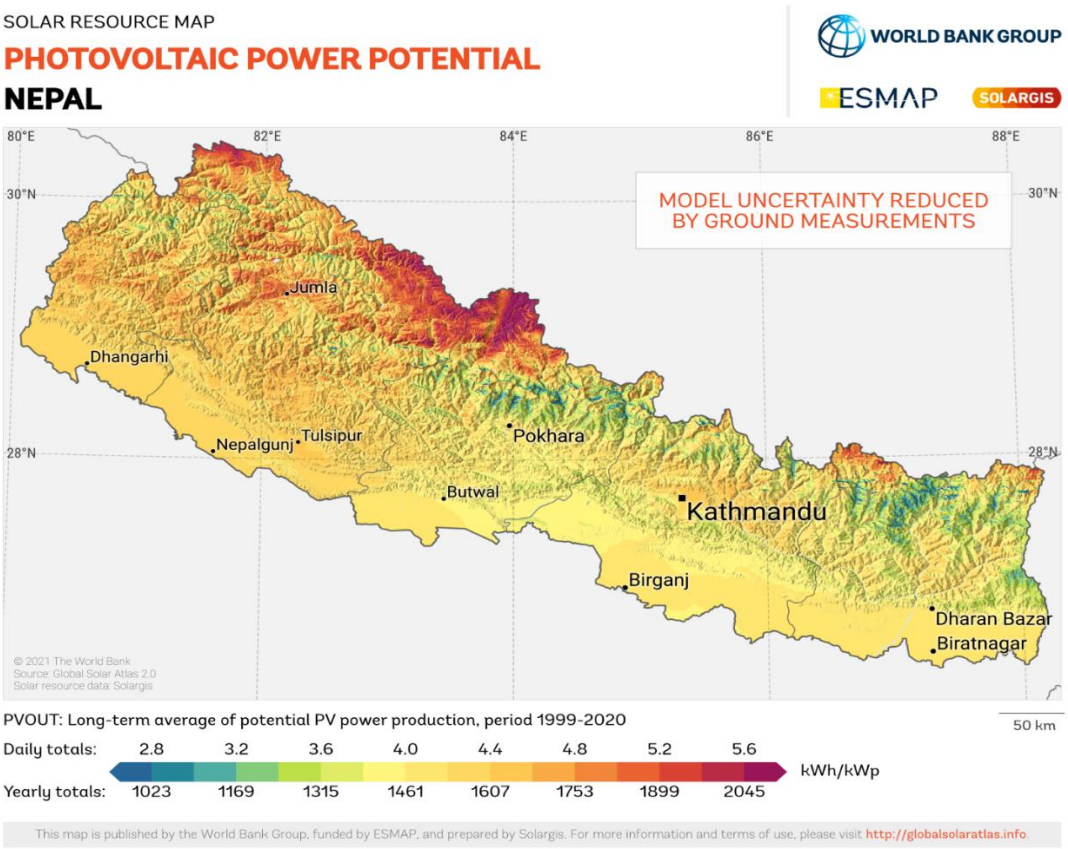


Figure 1.1 Photovoltaic Power Potential of Nepal (Source: Global Solar Atlas)

The use of a battery system for larger PV Grid-connected systems is usually avoided due to the maximum cost and short life cycle of the battery. The battery bank is used to store DC energy, which is transformed by the inverter into AC power. This paper is

basically intended to study the performance analysis of solar PV plants and find areas of improvement for the current system.

The IEC 61724 standard defines a set of performance parameters of solar PV related to the energy output, irradiation, and other losses that occur in the photovoltaic system which can be utilized to determine the overall photovoltaic system behavior. The four key aspects of reference that are of value in the context of this assessment are the performance ratio, the final yield, reference yield, and finally the capacity utilization factor (Marion et al., 2005).

1.2 Current Scenario in Nepal

Nepal has the highest possibility of energy generation from solar power since Nepal is receiving an annual average insolation of 4.9 kWh/m^2/Day. Solar energy is a clean source of energy. Nepal gets an average of 5 sun hours per day. Different departments of the government of Nepal are interested in Solar energy generation through solar PV cells. Department of Electricity Development is working under the Ministry of Energy, Water Resources and Irrigation. DOED is established to develop and endorse the electricity sector and to progress the financial efficiency of this sector at the national level by appealing to private sector investment. Under DOED 13 solar power plants are operating and which are producing 68.38 MW energy. A list of the solar plants operating under DOED is given in below Table 1.1.

Table 1.1 Solar Plant Operating Under DOED

S. N.	Project	Capacity (MW)	Issued Date	VDC/District	C O D
1	Solar Energy	0.68	12/10/2067	Bungamati (Lalitpur)	12/10/2067
2	Bishnu Priya Solar Farm Project	1.00	9/27/2073	Ramnagar (Nawalparasi)	8/13/2075
3	Grid-Connected Solar Power Project	8.50	2/14/2076	Butawal (Rupandehi)	7/15/2077
4	Bel Chautara Solar Farm Project	5.00	3/18/2076	Khairenitar (Tanahu)	7/1/2078

S. N.	Project	Capacity (MW)	Issued Date	VDC/District	C O D
5	Mithila Solar PV Power Project, Dhanusa	10.00	5/6/2076	Begadawar (Dhanusha)	11/22/2077
6	Som Radha Krishna Solar Farm Project	4.40	7/14/2076	Rupakot (Kaski)	7/14/2079
7	Solar PV Pratappur, Grid Connected	5.00	9/11/2076	Pratappur (Nawalparasi)	5/27/2079
8	Chandranigahpur Solar Project	4.00	10/1/2076	Chapur (Rautahat)	5/6/2078
9	Grid-Connected Solar PV Project	2.00	6/11/2077	Ramgram, Nawalparasi	1/2/2080
10	Utility Scale Solar PV, Grid Connected	6.80	7/6/2077	Banigama (Morang)	12/30/2079
11	Solar PV Project Banke, block-2	10.00	8/29/2077	Raniyapur (Banke)	1/18/2080
12	Solar PV Project, Raniyapur, Block 1	10.00	9/2/2077	Raniyapur (Banke)	9/25/2080
13	Solar Power Project, Dhalkebar	1.00	12/30/2077	Dhalkebar (Dhanusha)	10/2/2078
	Total	**68.38**			

Nepal Electricity Authority has started the generation from solar PV with the capacity of 25MW which was directly connected to the national grid. The project is spread over 25 hectares and has the potential to generate electricity for more than 5 hours. The electricity produced by the solar plant is spread to the Devighat Hydropower Station from where it is supplied to Kathmandu.

Figure 1.2 Solar Power Plant of 25 MW in Nuwakot by NEA(Source NEA)

1.3 Statement of the Problem

There have been exponential advancements in the field of renewable energy technology and solar photovoltaics exponentially. There are many on-grid and off-grid PV systems connected at various places throughout the world. The system may be grid-connected with synchronization of voltage and frequency or off-grid type with its own frequency and voltage.

Nepal, with its geographical diversity, has a significant potential for solar energy, receiving an average insolation of 4.9 kWh/m^2/day. Chitwan Medical College, located in Bharatpur, is situated in a region that benefits from this solar potential. Despite the favorable conditions, solar PV systems, particularly in the context of Chitwan Medical College, face challenges in performance. The existing solar PV system's actual energy generation and performance parameters have not been thoroughly analyzed since installation, leading to uncertainties in efficiency and effectiveness. Understanding the performance of the solar PV system is crucial for optimizing energy generation, reducing reliance on non-renewable energy sources, and supporting Nepal's energy needs sustainably. The findings could guide future installations in similar settings, ensuring better planning and implementation. The different research questions originated the idea of carrying out the study where the main objective is to conduct a detailed performance analysis of the solar PV system installed at Chitwan Medical College. This includes measuring the total connected load, contrasting actual performance data with evaluated results, and calculating key performance parameters. These research questions are listed below;

- What are the actual performance parameters of the solar PV system at Chitwan Medical College?
- How does the real performance data compare with the evaluated results from PVSYST?
- What modifications can be recommended to enhance the system's performance based on the analysis?

The initial study showed much less generation than expected, and hence the performance parameters are to be calculated as well as reason behind such system behavior is to be studied so that future installations won't suffer from similar difficulties.

A similar project by AEPC and the government intends to set up similar solar power plants at other large hospitals in urban as well as rural areas. Thus, this research may be a base for setting up similar large solar PV plants for other hospitals, where the cost of generators can be minimized and reliability can be maintained. The hospital with a 750-bed capacity serving over 1400-1500 patients daily has the largest team of specialist doctors, highly trained nurses, and technicians. CMCTH has contracted with Gham Power for the installation of a solar PV system. (Solar modules of 330Wp were installed at the top of the hospital building and at the parking space). This system has an off-grid inverter connected to a single system and performance analysis of such a system in terms of technical parameters has been done in limited numbers around the globe.

1.4 Objective of the Research

1.4.1 Main Objective

- To conduct a performance analysis of the solar photo voltaic system installed at Chitwan Medical College, Bharatpur, Chitwan.

1.4.1 Specific Objectives

- To measure the total connected load and study details of the existing system installed at Chitwan Medical College, Bharatpur, Chitwan.
- To contrast the real performance data with evaluated results of PVSYST.

- To calculate Performance Parameters (Total Generation, Annual Specific Yield, Capacity Utilization Factor, Array Yield) of the solar system at Chitwan Medical College, Bharatpur, Chitwan.

1.5 Limitations of the Research

- The metrological statistics are taken from PVsyst for Simulation.
- The performance analysis is carried out from the data from May 2022 to August 2023.

CHAPTER TWO: LITERATURE REVIEW

2.1 Status of PV and previous research on similar field

Fossil energies, as it is becoming tougher to produce and also due to the rise in demand for electrical energy over the past few decades have led to the rise and increased importance of renewable energy. As a result, the industry has grown rapidly with the photovoltaic (PV) business at the forefront. Solar PV electricity is vital in the context of renewable energy in its applicability, from large power plants to distributed roof-top power, as well as geographical coverage. It is predicted that by the year 2050, wind power will be able to contribute as much as 11% of electricity produced globally (IEA, 2014).

More photovoltaic accumulations were added in 2017 and new connections rose by 34% year on year, with increases in the photovoltaic capacity by 95 GW. The total installed photo voltaic capacity has been increasing at a global level from 2015 to reach almost 512 GW at the end of 2018, among which 180 GW (35%) is the utility-scale plants (IEA 2017). In the year 2019, it was established that the instance of solar energy was approximately 3% of the world's electricity usage (wiki-solar, 2019) (IEA, 2020). In the contemporary era, renewable energy generation technologies have significant societal impacts and must be evaluated from various perspectives, including social, technological, economic, environmental, and political (STEEP) (Sheikh and Kocaoglu, 2011). Assessing energy technologies is a complex task due to the involvement of multiple criteria and decision-makers, often necessitating analytical models. Solar PV electricity is a vital renewable energy source, offering a wide range of applications from utility-scale projects to residential rooftops and being widely distributed across major countries globally. It is projected to provide 11% of total global electricity generated by 2050 (IEA, 2014).

The research presented in the thesis "Performance Analysis of Solar PV System Installed in Chitwan Medical College" aims to contribute to the existing knowledge by providing a comprehensive performance analysis of an installed solar PV system in a real-world setting. It addresses the gap in data related to rooftop solar installations, particularly in the context of Nepal, where solar radiation and temperature variations significantly impact PV system efficiency. By evaluating the system's performance against simulated models and actual measured data, the research offers valuable

insights into the factors affecting solar PV efficiency, such as temperature coefficients and environmental conditions. This study not only aids in understanding the practical challenges and performance metrics of solar PV systems but also serves as a foundational work for future installations in similar settings, thereby enhancing the reliability and cost-effectiveness of solar energy solutions in Nepal and similar regions.

2.2 Research on PV Field and New Technologies

The market share is experiencing a fair amount of saturation by a number of new PV technologies, all performing at various levels and with various claims. For instance, a recent international market research firm, New Energy Strategies, has reported over 250 PV technologies (including variants), production methods, and leading R&D programs in the world. These reports cover different generations of PV technologies. The first generation and the most frequently used are the mono/poly crystalline silicon (c-Si) panels which have large glass and thick silicon since the 1960s. Since its inception, the U. S. National Renewable Energy Laboratory (NREL) has updated and ensured the accuracy of the chart of the generations of PV systems for over three decades. What this chart shows is that extensive research into PV has given birth to not just multiple technologies but multiple generations too and the latest is just the 5th generation R and D. The current society has shifted to the use of low-cost and environmentally friendly materials (NREL, 2013).

According to an article from The Economic Times, India's total installed rooftop solar capacity has crossed the 1 gigawatt (GW) mark this year with 513-megawatt (MW) generation capacity added over the past year.

According to Chumpolrat et al. (2014), an increase in temperature has both a direct and indirect effect on degrading PV Modules, and on the performance of the inverter. According to the experiment, it is noticed that the overall efficiency of the inverter was as high as 2. To achieve a 5% reduction in wound healing time when the ambient temperature is above 37°C, the following measures will be implemented.

2.3 Status of the Research On Off-grid/On-grid Solar Farming

Yemula et al. recently conducted a techno-economic analysis of off-grid rooftop solar PV systems, finding the cost to be approximately Rs. 2.19 Lakhs IC. Over 25 years, the system is projected to yield a profit of Rs. 3 Lakhs IC. The payback time was estimated

to be around 10.5 years. However, the study did not include a significant examination of solar panel efficiency.

Shiva Kumar et al. conducted a performance evaluation of a 10 MW grid-connected solar photovoltaic power plant in India. They found a performance ratio of 86.12% and a capacity utilization factor of 17.68%, with the plant receiving an average annual irradiation of 4.97 kWh/m²/day.

Paras et al. conducted a comparative study using PVSYST on grid-tied photovoltaic (PV) systems in Kathmandu and Berlin. They discovered that Kathmandu can feed 70% more energy into the grid compared to Berlin, attributed to its higher solar insolation of 4.5-5 kWh/m²/day.

Sunfarmer Nepal has entered into a long-term contract with Bayalpata Hospital in Achham to install a 100 kWp solar PV system. As part of this initiative, 42 kWp of solar capacity has already been installed to power essential, life-saving medical equipment.

Nyaya Hospital, Bayalpata, Achham was provided solar PV system by Gham Power for oxygen machines, refrigerators, laptops, routers, printers, Lights, and all types of machinery which are used in the hospital to have power back up (Giri, 2011)

According to an article from The Economic Times, India's total installed rooftop solar capacity has crossed the 1 gigawatt (GW) mark this year with 513 megawatt (MW) generation capacity added over the past 12 months.

2.4 Effect of the Dust, Sand, and Snow Deposition

Basant et al. conducted a case study and analysis on the impact of dust on the efficiency of solar panels in Kathmandu. Their findings revealed that the power output decreased by 3.16% within one day of dust deposition, reaching 10.41% after ten days, and 15.74% within a month. Additionally, they proposed a cleaning device equipped with brushes, a slider, and a DC motor to address this issue.

Paudyal et al. (2017) discovered that in the Kathmandu Valley, the efficiency of solar modules subjected to natural dust deposition decreased by 29.76% compared to modules cleaned daily. The dust deposition density on the PV module was measured at 9.6711 g/m².

There is a negative relationship between increments of humidity and decrement in efficiency as well as between wind speed and decrement in efficiency. On the other

hand, an increase in environmental temperature implies an increase in sunlight and hence implies more efficiency. (Sani et al., 2018)
Kazem et al. (2022) found that just 35 days of dust accumulation caused a decrease in power from mono-crystalline panels by 20% and 12% in poly crystalline panels.

2.5 Study on Financial Parameters

Bajra & Maharjan (2019) performed a techno-economic assessment of a 64.6 kWp grid-tied solar PV system at Nepal Telecom, Sundhara. Their findings indicated a performance ratio of 0.859 and a capacity utilization factor of 14.09%.

In the year 2014, Shrestha et al. for a one MWp Solar PV system installed in Trishuli presented a techno-economic analysis. These findings suggested that the plant consumes 855119. 26 KWH/ year and produces an energy output of 1768 MWH/year with a final yield of 4. 81 kWh/kWp-day. Further, they noted that the capacity utilization factor of 20.18% was achieved and a performance ratio of 77.30% of the total cost of the solar PV plant over twenty-five years of utilization, generating an internal rate of return of 12%. Their research findings assert that Nepal's challenges in accessing adequate energy can be effectively managed through the establishment of a large-scale PVGC plant mainly due to the project being economically and technically sustainable.

In the present scenario, the techno-economic viability of off-grid Rooftop Solar PV systems has been carried by Yemula et. al recently which states that the rooftop solar PV system cost is estimated to be around Rs. 2.19 lakhs IC and a lifetime profit of Rs 3 lakhs IC (in twenty-five years). In order to determine the payback period, the result was estimated and it was found to be about 10.5 Years However, no outstanding research on the enhancement efficiency of solar panels was conducted.

2.6 Performance Parameters

The IEC standard 61724 outlines the solar PV performance parameters related to energy generation, irradiation, and different system losses. These parameters serve to characterize the overall performance of a photovoltaic system. Key parameters considered in this analysis include the performance ratio, final yield, reference yield, and capacity utilization factor (Marion et al., 2005).
The annual Energy generation is calculated as the total energy (kWh) generated throughout the specific year.

The annual total of global irradiation, denoted as h, received by the module is unique to its location and can be acquired from databases, measurements, or initially, from an irradiance map. This value is expressed in [kWh/m^2]. For example, in Berlin, it typically ranges around h ~ 1,200 kWh/m^2.

The "specific yield" (kWh/kWp) is the total annual energy generated per kWp installed. It is frequently used to estimate the financial value of an array and compare operating results from various technologies and systems. It's also termed total yield. It refers to the amount of energy supplied annually at AC.

The effectiveness of a PV power plant is frequently assessed using a measure known as the capacity utilization factor. This metric represents the ratio of the actual output generated by a solar plant throughout the year to the maximum potential output it could achieve under ideal conditions for a year. Typically, the capacity utilization factor is presented as a percentage.

$$Capacity\ Utilization\ Factor = \frac{Actual\ Energy\ from\ the\ Plant\ (KWh)}{Plant\ Capacity(KWp) x\ 24\ x\ 360}$$

The actual plant energy production in kWh can be read at the end of the year if a net energy metering system or device for energy measurement is available. The calculated annual nominal plant output is composed as follows:

Nominal plant output = Annual incident solar irradiation at the generator surface of the solar PV plant x efficiency of the power plant.

The performance ratio is a dimensionless quantity, and it is determined under the effect of certain factors. Usually, its value should be under 100% as the operating conditions do not provide the best suitable temperature and irradiance for solar generation, as compared to the test conditions. There are various factors that affect the performance ratio of a solar PV plant. The following factors affect the performance ratio of a solar PV plant:

- Temperature of the PV Module
- Solar irradiation and power Dissipation
- Measure gauge (example- Sunny Sensor Box) in the shade or soiled.
- Shading or contamination of PV Modules.
- Measurement Period.
- Conduction Losses
- Efficiency Factor of the Inverter.

- Degradation of solar cells.

Figure 2.1 offers an in-depth look at energy losses in photovoltaic (PV) systems, dividing them into pre-photovoltaic losses, module losses, and system losses. At the top, the figure begins with the complete intensity of incoming sunlight at 100%, which represents the total solar energy available to the PV system. Pre-photovoltaic losses, which make up 8%, occur before the sunlight is converted into electricity. These include inefficiencies where low-energy photons are not absorbed and high-energy photons are not effectively utilized.

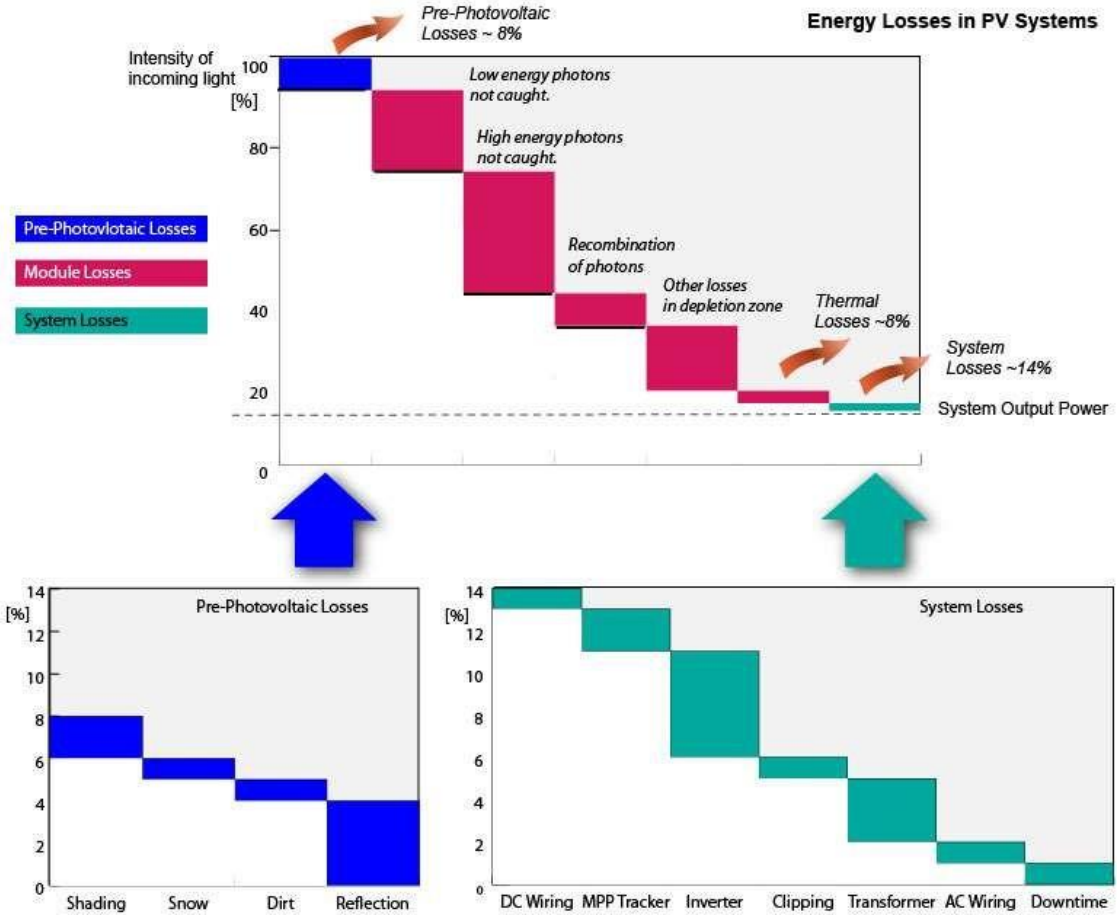


Figure 2.1 Energy Losses in PV System (Source:- IEA)

Module losses take place within the PV panels. These encompass losses due to photon recombination, additional losses in the depletion zone, and thermal losses, collectively contributing to another 8% of the total energy loss. These reduce the amount of energy that the PV system can convert into electricity.

System losses, totaling 14%, represent inefficiencies within the PV system. These include energy lost in direct current (DC) wiring due to resistance, inefficiencies in the

Maximum Power Point (MPP) tracker, and conversion losses in the inverter during the conversion of DC to alternating current (AC). Additional system losses arise from energy lost due to clipping, transformer inefficiencies, resistance in the AC wiring, and periods when the system is not operational.

The bottom left section of the figure details specific pre-photovoltaic losses, including the effects of shading, snow coverage, dirt on the panels, and reflection losses, all of which reduce the sunlight reaching the PV cells. On the bottom right, the figure further breaks down system losses, highlighting losses in DC wiring, inefficiencies in MPP tracking, inverter conversion losses, clipping losses, transformer inefficiencies, AC wiring losses, and downtime.

Overall, the diagram shows how each type of loss impacts the total energy output of a PV system and underscores the importance of optimizing each component to improve overall efficiency and energy yield. Addressing these losses can help maximize the solar energy converted into usable electrical power.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Conceptual Framework

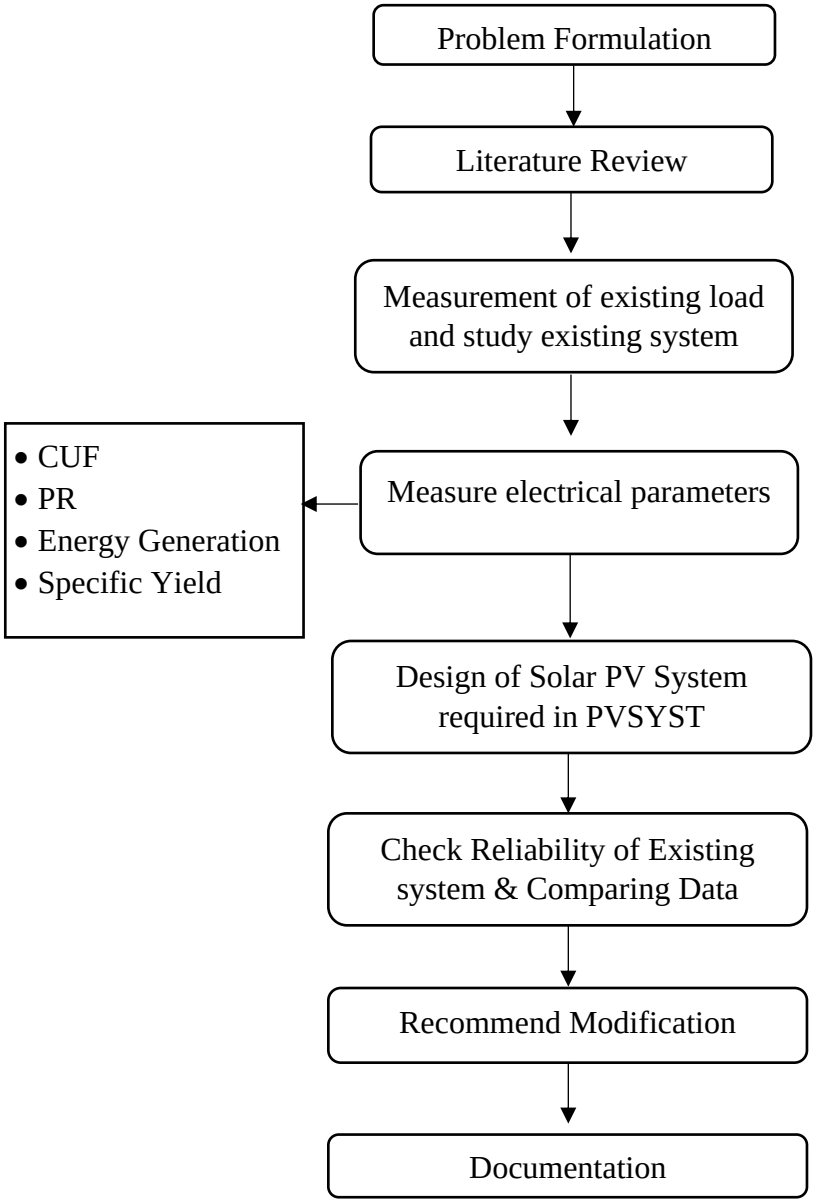


Figure 3.1 Flowchart of Methodology Adapted

The basic structure framework of the methodology adopted in this thesis work is as per Figure 3.1. Based on the formulation of the problem and after the literature review preliminary data and system configuration were established in the PVSYST in order to predict the technical result. After comparing the technical performance of PVSYST with measured data, conclusions and recommendations are drawn.

3.2 System Description

Chitwan Medical College is located in Bagmati Province, Bharatpur-10, Chaubiskoti, Chitwan, Nepal is receiving annual regular insolation of 4.9 kWh/m^2/Day. Bharatpur, situated in the Terai Plain Area, is among Nepal's significant emerging urban centers, with an elevation of 196 meters above sea level. The climate here tends to be extremely hot during summer and chilly with fog in winter. The salient Features of the project are shown in Table 3.1.

Table 3.1 Salient Feature of the Project

Project Location	
Province	Bagmati
District	Chitwan
Municipality/ward	Bharatpur, Chaubiskoti
Geographical Coordinate	
Latitude	27°6853
Longitude	83°4312
Altitude	196 meters above sea level
Meteorology	
Average annual Insolation	4.9 kWh/m^2 /day
Average annual Temperature	25°C
Average annual Relative Humidity	62%
Average annual Wind Speed	0.9 m/s
Clearness Index	0.486
General	
Installed Capacity	201.96 kW_p [DC]
Contract Annual Energy	435,872 KWh
Rated Power frequency	50 Hz
Construction period	2021/22

3.2.1 Existing System Block Diagram

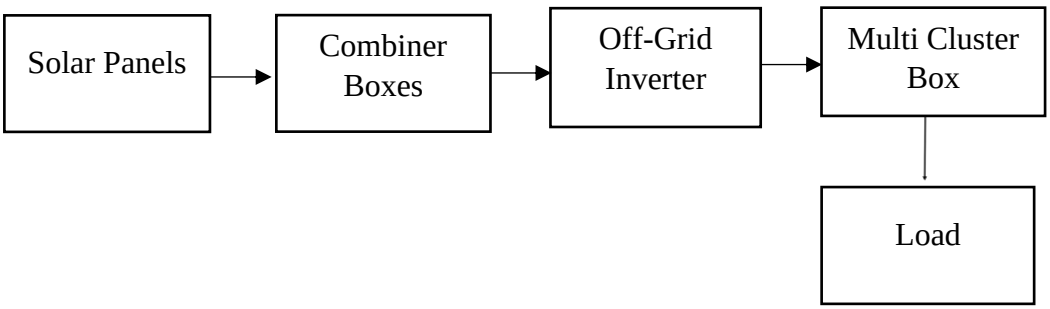


Figure 3.2 Existing System Block Diagram

The output from each array of solar panels is fed to a combiner box. The combiner box is a connection box, where the dc output of various panels in an array is connected as shown in Figure 3.2.

The dc output form the combiner box is now fed to the Off-Grid inverter. The major function of this inverter is to invert the dc signal into ac signal. Each inverter is supplied with input from combiner boxes. Thus, there are Seven inverters, altogether 163 kVA capacity. The output of the inverter is fed to a multi-cluster box, which is a common bus bar for interconnection between load and inverters.

The PV system obeys the system archetype outlined by Owolabi et al. (2022), illustrated in Figure 3.3, where the essential components are the solar panels and inverter. Various variables including air temperature, wind speed, and solar irradiation are monitored as they influence the solar panel's performance. The solar irradiation which is measured offers the baseline yield in comparison to which the yield of the panel gets determined. The DC out from the panel represents the array result and the AC output shows the energy produced to get performance parameters like the Performance Ratio, Capacity Utilization Factor, System Efficiency, and the Final Yield.

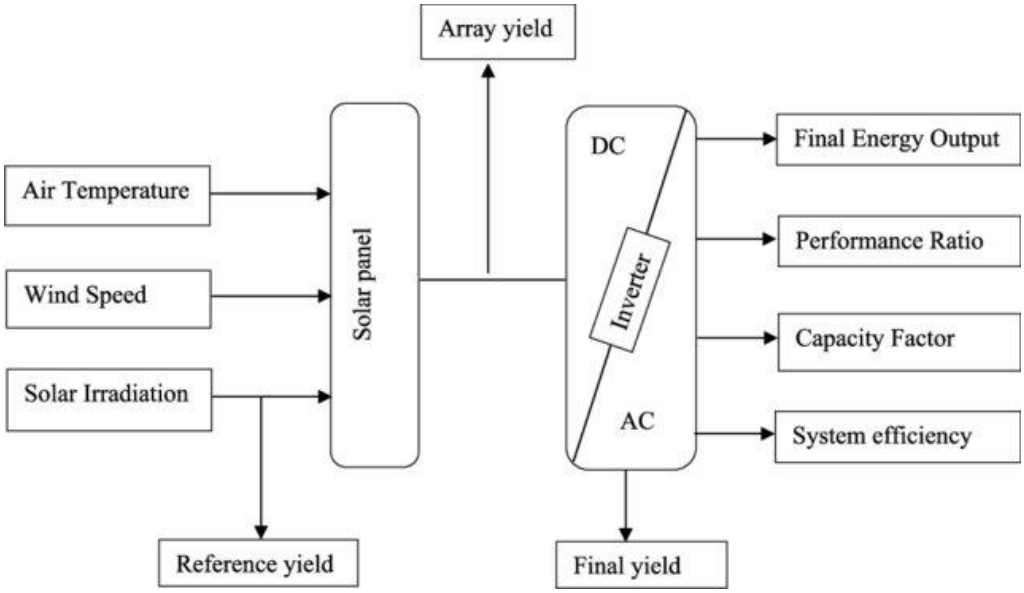


Figure 3.3 Archetype Solar Photovoltaic System

3.2.2 System Layout

The dc output form the combiner box is now fed to the Off-Grid inverter. The major function of this inverter is to invert the dc signal into ac signal. Each inverter is supplied with input from two combiner boxes. Thus, there are seven inverters, altogether 80 kVA capacity. The output of the inverter is fed to a multi-cluster box, whichis a common bus bar for interconnection between load, and inverters.

Trinasolar polycrystalline panels are installed at the rooftop of the Main Block and above parking for the two-wheelers and four-wheelers around the building surrounding.

3.2.3 Panels

The solar panels used are Polycrystalline Trinasolar Module, each with 330Wp at Standard Temperature and Pressure.

There are Trinasolar solar panels used, thus comprising a system with a total capacity of 201.96 kWp. The detail technical description is shown in Table 3.2.

Table 3.2 Solar Module's Specification (Trinasolar)

Particulars	**Value**
Manufacturer /Model /Technology	Trinasolar/ TSM-330PE14A/ Multi crystalline
Origin	China
Rated Capacity	330 W_p
Voltage at maximum power (V_{mpp})	37.4 V
Current at maximum power (I_{mpp})	8.83 A
Open circuit Voltage (V_{oc})	45.8 V
Short circuit current (I_{sc})	9.28 A
Module Size (mm)	1960×992×40
Efficiency	17.00%
NOCT	44°C (±2°C)
Temperature coefficient of P_{mpp}	-0.41 %/°C
Temperature coefficient of Voc	-0.32 %/°C
Temperature coefficient of Isc	0.05 %/°C

3.2.4 Inverter

The SMA inverters having multiple MPPT inputs have been used with MPPT working voltage ranging from 390V to 800V. The seven identical Off Grid inverters have a total capacity of 80 kVA.

The efficiency of the grid inverter is quite high, 98.3% at full load. The inverters run most efficiently when the PV Voltage is around 600V.

The detailed description of Sunny Tripower, which is an Off-Grid inverter, and thus takes DC input from panels and converts it into AC signal is illustrated in Table 3.3.

Table 3.3 Salient Feature of The Inverter Installed in the Plant (SMA Technology)

Manufacturer/Model	SMA Solar Technology/STP25000TL-30
Country of origin	Germany
Input DC	
Max. Generated Power	45,000 Wp

DC Rated Power	25,550 W
Max. Input Voltage	1000 V
MPP Voltage Range/ Rated Input Voltage	390V to 800 V / 600 V
Min. Input Voltage/Start Input Voltage	150 V/ 188 V
Output (AC)	
Rated Power (at 230 V, 50 Hz)	25,000W
Max AC Apparent Power	25,000 VA
AC Voltage Range	180 V to 280 V
Rated Power Frequency/ Rated Grid Voltage	50 Hz / 280 V
Max. Output Current/ Rated Output Current	36.2 A/ 36.2 A
Max. Efficiency	98.3 %
Self-Consumption (at night)	1 W

3.3 System Design

The design of the solar photovoltaic was started by finding the details of the site, and then the load for the was defined according to the requirement.

The sizing of the array was done using the formula;

$$\text{I array} = \frac{Total\ Average\ Daily\ Load\ in\ Ah\ at\ System\ Voltage}{Peak\ Sun\ x\ Derating\ Factor\ x\ Columbic\ Efficiency}$$

The level of output from a PV power plant is commonly measured by a measure known as the capacity factor. It is the total energy output achieved by the plant in the course of a year divided by the total energy that can be produced by the plant per year in an ideal world. It is also important to note that the capacity utilization factor is often given in the form of a percentage.

$$Capacity\ Utilization\ Factor = \frac{Actual\ Energy\ from\ the\ Plant\ (KWh)}{Plant\ Capacity(KWp) x\ 24\ x\ 360}$$

The actual plant energy production in kWh can be read at the end of the year if a net energy metering system or device for energy measurement is available. The calculated annual nominal plant output is composed as follows:

Nominal plant output = Annual incident solar irradiation at the generator surface of the solar PV plant x efficiency of the power plant.

Also, the Performance Ratio(PR) is calculated as the ratio of Y_F and Y_R (Shiva Kumar & Sudhakar,2015). It multiplies the average value with respect to irradiance and combines the total effect of losses from PV module temperature soiling or snow, incomplete utilization of irradiance by reflection of the frontal face of the PV module, inefficiencies of PV module and inverter, wiring losses, failed components, and system downtime.

$$PR = \frac{System\ Yield\ (\mathrm{YF})}{Reference\ Yield(YR)}$$

3.4 Simulation from PVSYST

A detailed study of the system was done particularly in PVSYST and therefore it has been modeled. However, the input panel provided a string array of the system layout where all data regarding panels and inverter used existed and was accurately available. The panels that were used in the system were of a similar kind as the inverters available in the PVSYST library and therefore the detailed modeling of the system was done with this tool. This software is useful in determining the performance capability of solar PV panels for various applications. This simulation is different from the existing system, as it consists off-grid inverter only and thus 100% of generation from panels can be sent to the grid during simulation estimations. This software is used to determine the capacity of panels in a system to feed energy to hospitals annually.

3.4.1 Site Selection and System Information

The site was selected Chaubiskoti, Chitwan from the google map with coordinates 27.6853° N, 84.4298° E at an attitude of 196m. The irradiance data was taken from Meteonorm 8.1 (1996-2015) and the PV system azimuth was 0^0 with a tilt angle of 30^0.

3.4.2 System Modifications

The modifications or recommendations, that can be implemented in the existing system are discussed after a detailed study of the system. The result of the low generation and cascading effect of on-grid and off-grid inverters in a single system is determined, and some recommendations are suggested after those obtained results. The analysis of extra cost or cost-recovery in the modified or added extra components has been discussed.

3.4.3 SWOT Analysis

Solar PV energy is one of the most abundant clean energy resources, which does not affect the environment. Thus, its use has been abundantly increasing day by day in many developing countries in the present scenario. SWOT analysis is a simple strategic planning technique that has four major components, namely Strengths, Weaknesses, Opportunities, and Threats. The general purpose of the SWOT analysis is to fine-tune the business strategy in order to ensure that you have thoroughly assessed your business's strengths and weaknesses along with the possible opportunities that it has available to it, as wells as the threats it faces in the market place. It is a tool used to moderate and define the crucial factors that can influence a project's profitability. The Strengths and Weaknesses are considered as the internal factors whereas the remaining two factors- Opportunities and Threats are considered to be the external factors that do not have user control. Installing a PV system enables electricity production from the solar energy.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Observed Primary Parameters

The real field factors were obtained from the help of Wattmon Cloud Portal, a monitoring system. The data is collected from the Wattmon Cloud Portal from the year May 2022 up to August 2023.

4.2 Monthly generation, Performance Ratio Specific Yield, and Capacity Utilization factor

The table demonstrates the actual primary measured data and performance parameters calculation on a monthly basis.

Table 4.1 Evaluated Performance Parameters

Month	**Egen** KWh	**PR (%)**	**Y_f** kWh/kWp	**CUF (%)**
Jan	15,521.67	65.20	76.84	10.67
Feb	18,225.72	80.79	90.23	12.53
Mar	26,143.94	89.94	129.43	17.98
Apr	22,582.95	85.10	111.80	15.53
May	24,737.72	93.01	122.46	17.01
Jun	19,308.55	84.85	95.59	13.28
Jul	18,382.81	90.57	91.00	12.64
Aug	16,277.53	71.94	80.58	11.19
Sep	17,063.05	75.18	84.47	11.73
Oct	19,945.84	73.55	98.74	13.72
Nov	20,442.25	79.12	101.20	14.06
Dec	18,362.06	68.37	90.90	12.63
Yearly	**236,994.10**	**79.80**	**1173.24**	**13.58**

From above Table 4.1, we came to know that In January, the electricity generation is 15,521.67 KWh, with a PR of 65.20%, a specific yield of 76.84 kWh/kWp, and a CUF of 10.67%. These metrics reflect the system's efficiency and utilization under the lowest average temperature of the year. February shows an increase in generation to 18,225.72

KWh, with improved PR (80.79%), specific yield (90.23 kWh/kWp), and CUF (12.53%), correlating with a rise in temperature.

March, with the highest monthly electricity generation of 26,143.94 KWh, also has high-performance metrics: PR at 89.94%, specific yield at 129.43 kWh/kWp, and CUF at 17.98%. These values indicate optimal system performance as the temperature rises further. April maintains high performance with 22,582.95 KWh, a PR of 85.10%, a specific yield of 111.80 kWh/kWp, and a CUF of 15.53%.

In May, electricity generation is substantial at 24,737.72 KWh, with the highest PR (93.01%) and specific yield (122.46 kWh/kW) of the year, alongside a CUF of 17.01%. June sees a slight dip in electricity generation to 19,308.55 KWh, with a PR of 84.85%, a specific yield of 95.59, and a CUF of 13.28%.

During July, the electricity generation is 18,382.81 KWh, with a PR of 90.57%, a specific yield of 91.00 kWh/kWp, and a CUF of 12.64%. August shows a further decrease in generation to 16,277.53 KWh, PR at 71.94%, specific yield at 80.58 kWh/kWp, and CUF at 11.19%.

In September, electricity generation is 17,063.05 KWh, with a PR of 75.18%, the specific yield of 84.47 kWh/kWp, and CUF of 11.73%. October sees an increase in generation to 19,945.84 KWh, PR at 73.55%, a specific yield of 98.74 kWh/kWp, and CUF of 13.72%.

November's data reflects a generation of 20,442.25 KWh, with a PR of 79.12%, specific yield of 101.20 kWh/kWp, and CUF of 14.06%. December closes the year with 18,362.06 KWh, PR at 68.37%, specific yield of 90.90 kWh/kWp, and CUF at 12.63%.

Annually, the total electricity generation is 236,994.10 KWh, with an average PR of 79.80%, total specific yield of 1173.24 kWh/kWp, and an average CUF of 13.58%. These annual metrics indicate the overall efficiency and utilization of the electricity generation system throughout the year. The data highlights the correlation between temperature and performance metrics, with higher generation and performance during warmer months due to high sunshine hours.

Figure 4.1 outlines the specific yield (kWh/kWp) of a solar power system over a year, broken down by month. This measure indicates the amount of electricity produced per kilowatt-peak (kWp) of installed solar capacity, offering insight into the system's performance across different seasons.

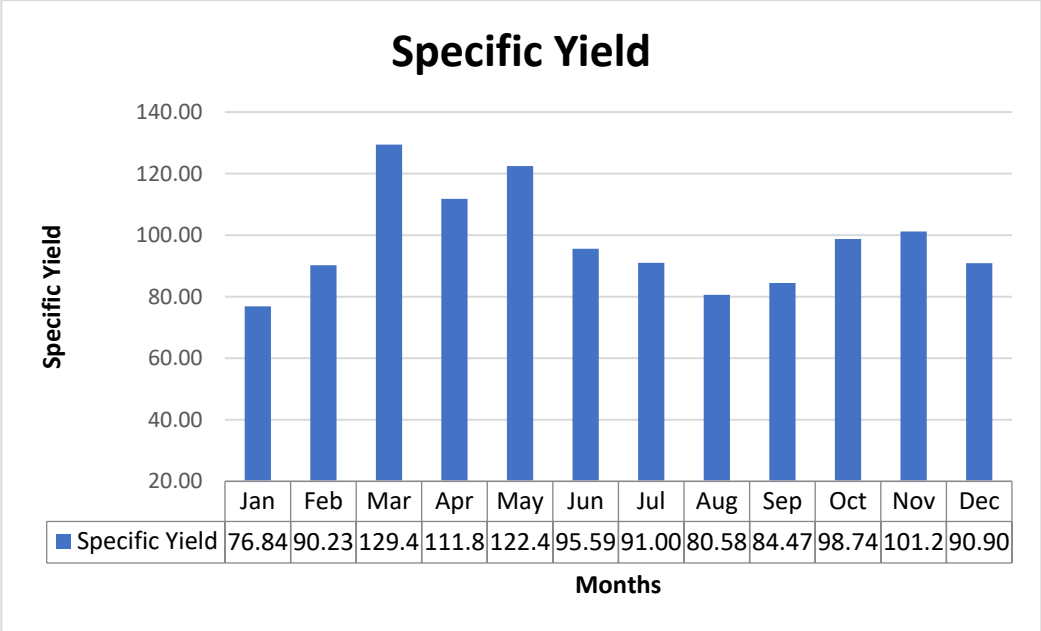


Figure 4.1 Specific Yield Variation over the year

In January, the system generated 76.84 kWh/kWp, the lowest monthly yield, likely due to shorter daylight hours in winter. The yield increased to 90.23 kWh/kWp in February. March recorded the highest yield of the year at 129.43 kWh/kWp, indicating optimal early spring conditions for solar energy production.

April's yield slightly decreased to 111.80 kWh/kWp, followed by May's high production of 122.46 kWh/kWp, the second highest of the year. These spring months show consistently high performance. The yield dipped to 95.59 kWh/kWp in June and further to 91.00 kWh/kWp in July. In August, the yield decreased to 80.58 kWh/kWp, reflecting summer variability likely due to factors like heat and cloud cover.

In the fall, yields were moderate and stable: September produced 84.47 kWh/kWp, October 98.74 kWh/kWp, and November slightly increased to 101.20 kWh/kWp. December ended the year with a yield of 90.90 kWh/kWp, slightly higher than January's low, reflecting typical winter conditions.

The annual specific yield totaled 1173.24 kWh/kWp, indicating significant seasonal variation. Peak performance occurred in spring, while winter saw lower yields. This seasonal pattern is crucial for optimizing energy use and storage in solar power systems, ensuring adequate energy supply throughout the year. Understanding these trends helps in planning and managing energy needs effectively.

The Figure 4.2 showcases the Performance Ratio (PR %) of a solar power system on a monthly basis. The Performance Ratio, which measures the system's efficiency in converting solar energy into electricity, varies throughout the year due to factors like sunlight availability, temperature, and system inefficiencies.

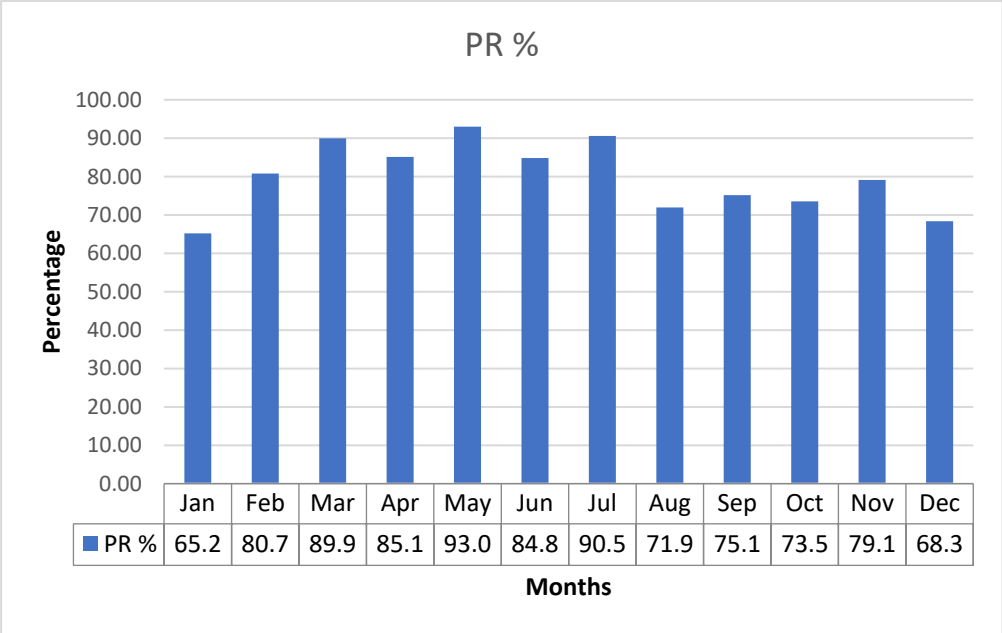


Figure 4.2 PR Variation over the year

In January, the system had its lowest PR of 65.20%, likely due to limited sunlight and colder weather. In February, the PR improved to 80.79% as the days grew longer. March saw a further increase to 89.94%, reflecting high efficiency in early spring. In April, the PR was slightly lower at 85.10% but still indicated good performance.

May recorded the highest PR of the year at 93.01%, showing optimal conditions for solar energy conversion. June maintained high efficiency with a PR of 84.85%. July saw a slight increase to 90.57%, indicating strong performance in mid-summer. However, the PR decreased to 71.94% in August, possibly due to higher temperatures affecting efficiency.

September's PR was 75.18%, showing moderate performance as summer ended and fall began. In October, the PR slightly decreased to 73.55%, consistent with the shorter days of fall. November's PR improved to 79.12%, better than the previous two months. December's PR dropped to 68.37%, reflecting typical winter inefficiencies.

Overall, the annual PR averaged 79.80%, indicating that the solar power system operated at nearly 80% efficiency throughout the year. This data highlights the seasonal

variations in solar energy conversion efficiency and underscores the importance of understanding these trends for optimal solar power system management.

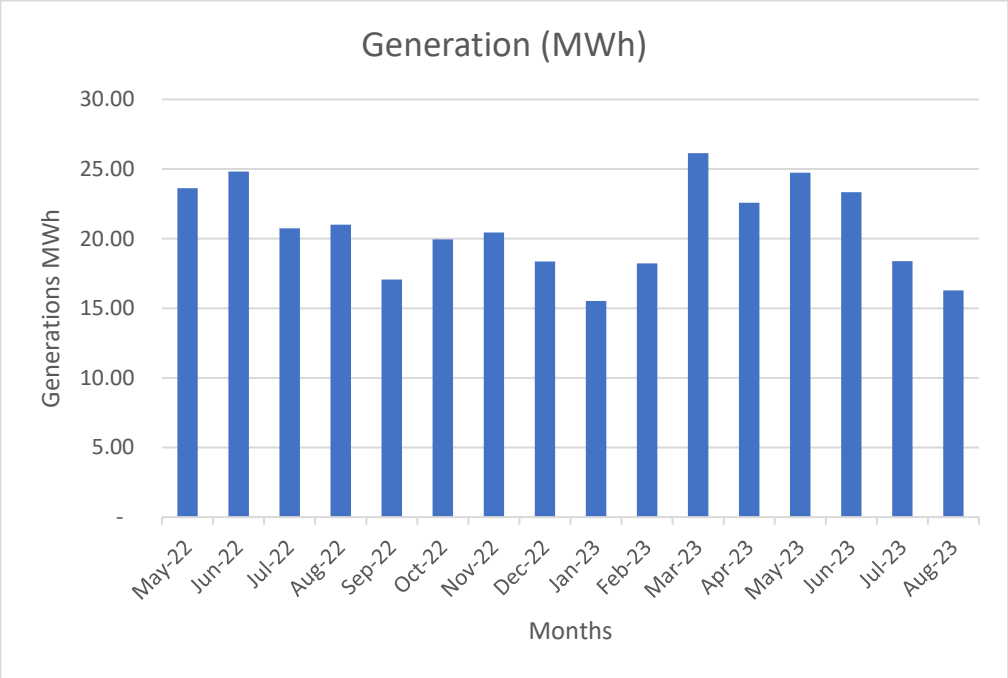


Figure 4.3 Monthly Energy Variation with Temperature Since the plant was operating

Figure 4.3 provides a comprehensive view of the electricity generation trends over the specified period, showing monthly variations and overall performance. The highest generation month was March 2023, with 26.14 MWh (26,143.94 kWh), indicating a peak in system output. The lowest generation occurred in January 2023, with 15.52 MWh (15,521.67 kWh), reflecting reduced output during the colder period. The total generation for the entire period sums up to 331.22 MWh (331,219.81 kWh), showcasing the system's capacity and performance across different months and seasons. Chitwan Medical College is situated alongside the East-West Highway and the maintenance of the road was ongoing so that dust was deposited in the solar panel which decreased the energy generation.

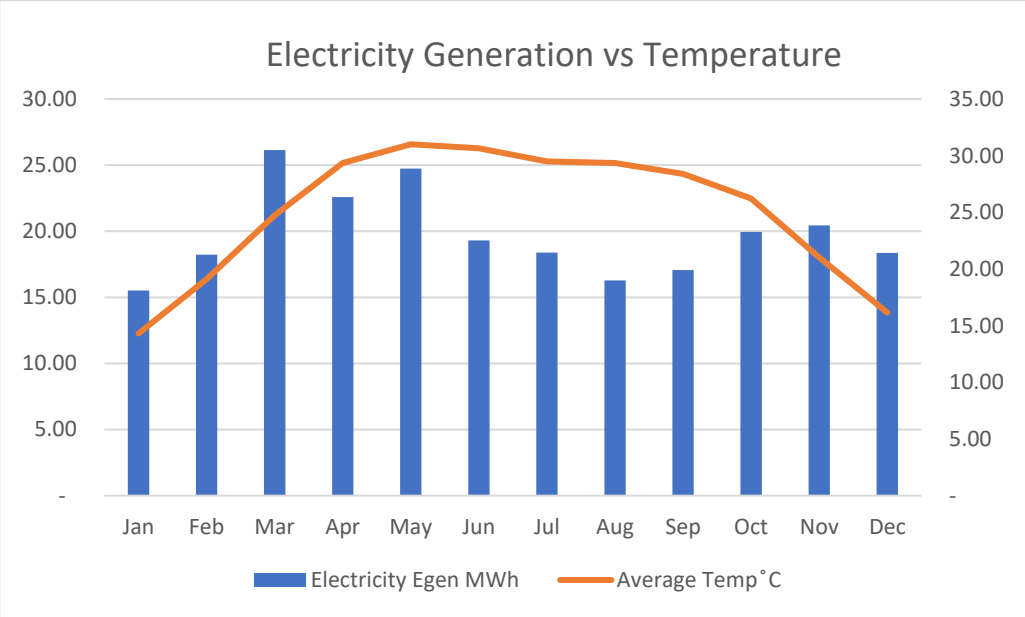


Figure 4.4 Monthly Energy Variation with Monthly Average Temperature

Figure 4.4 provides a comprehensive overview of the monthly and yearly electricity generation from a solar power system, expressed in megawatt-hours (MWh), alongside the average temperature (in degrees Celsius) for each month.

In January, the system generated 15,521.67 kWh (15.52 MWh) with an average temperature of 14.31°C. February saw a slight increase in generation to 18,225.72 kWh (18.23 MWh) as the average temperature rose to 19.10°C. March marked the highest generation of the year at 26,143.94 kWh (26.14 MWh), corresponding with an average temperature of 24.74°C. In April, electricity generation was 22,582.95 kWh (22.58 MWh), with temperatures climbing to 29.36°C.

May's output was 24,737.72 kWh (24.74 MWh) with the highest average temperature of 31.01°C. In June, the system generated 19,308.55 kWh (19.31 MWh) as temperatures slightly decreased to 30.66°C. July saw a further reduction in generation to 18,382.81 kWh (18.38 MWh), with an average temperature of 29.50°C. August had the lowest generation at 16,277.53 kWh (16.28 MWh) despite a consistent temperature of 29.36°C.

In September, the system produced 17,063.05 kWh (17.06 MWh) with temperatures cooling to 28.39°C. October's generation increased to 19,945.84 kWh (19.95 MWh) with an average temperature of 26.22°C. November saw a slight further increase to 20,442.25 kWh (20.44 MWh), while temperatures dropped to 21.01°C. Finally, in

December, the system generated 18,362.06 kWh (18.36 MWh) with an average temperature of 16.15°C.

Over the course of the year, the solar power system produced a total of 236,994.10 kWh (236.99 MWh). The average annual temperature was 24.98°C. The data reveals a correlation between temperature variations and electricity generation, where higher temperatures in the summer months do not necessarily result in higher electricity production. This could be due to factors such as reduced efficiency at higher temperatures and seasonal variations in solar irradiance. Monitoring both generation data and temperature trends is crucial for understanding and optimizing the performance of solar power systems.

4.3 Simulated Values using PVsyst

PVsyst is quite an all-inclusive software for simulation or prediction of specific performance of solar PV systems; they prized PVsyst for being user-friendly, immensely database, and easy to use. With the help of PVsyst's simulation tools, it provided the potential power production that can be fed to the grid-connected system with net metering if the system is fully integrated. The software includes detailed models of the panels and inverters commonly used in existing systems, all accessible through its extensive database.

The Result from the PVsyst software in order to install a solar plant with the 201.96 kWp power output. System Summary

Table 4.2 System Summary

S.N	Particulars	Result	Remarks
A.	**System Summary**		
i.	No. of Solar Module Required	612	
ii.	Number of String	34	
iii.	Number of Module in series	18	
iv.	Area Covered	1212 m^2	
v.	Number of Inverter Required	7	
vi.	Pnom Total	202 kWp	
vii.	P nom Ratio	1.154	

S.N	Particulars	Result	Remarks
B.	**Results Summary**		
i.	Produced Energy	291287 kWh/year	
ii.	Specific Production	1442 kWh/kWp/year	
iii.	Performance Ratio	82.89%	

From Pvsyst we came to know that in order to generate the energy of 202 kWp, we need 612 modules of the solar which will cover up to 1,121 m^2 land area. The total energy generated from the above-mentioned solar plant is annually 291,287 kWh with a performance ratio of 82.89%. Most of the solar panels were mounted on the roof of the hospital and above the parking space in Chitwan Medical College, Chitwan Bharatpur

4.3.1 Sun Paths at Chaubiskoti

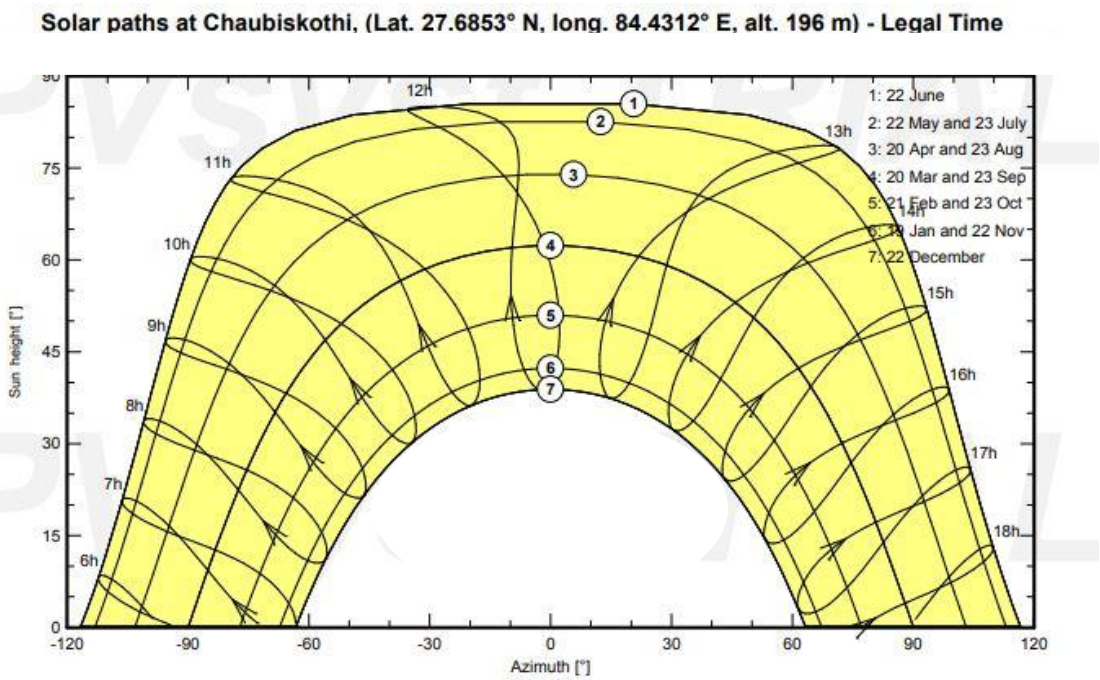


Figure 4.5 Sun Path at Chaubiskoti, Chitwan generated from PVsyst

Sunpath at Chaubiskoti, Chitwan is generated from PVsyst and is shown in above Figure 4.5. It has the longest sunshine hour at 22 June and the lowest sunshine hour at 22 December. Overall average sunshine hour in Nepal is 5 hours.

Figure 4.6 illustrates the normalized production of a photovoltaic (PV) system with a nominal power of 202 kWp, displaying the breakdown of energy production and losses per installed kWp on a daily basis throughout the year.

Across the year, the produced useful energy averages 3.95 kWh/kWp/day. Collection losses due to PV-array issues are consistently around 0.74 kWh/kWp/day, while system losses from the inverter are approximately 0.07 kWh/kWp/day. The figure demonstrates the seasonal variations in energy production, with higher production in spring and early summer, and lower production during winter and late summer months.

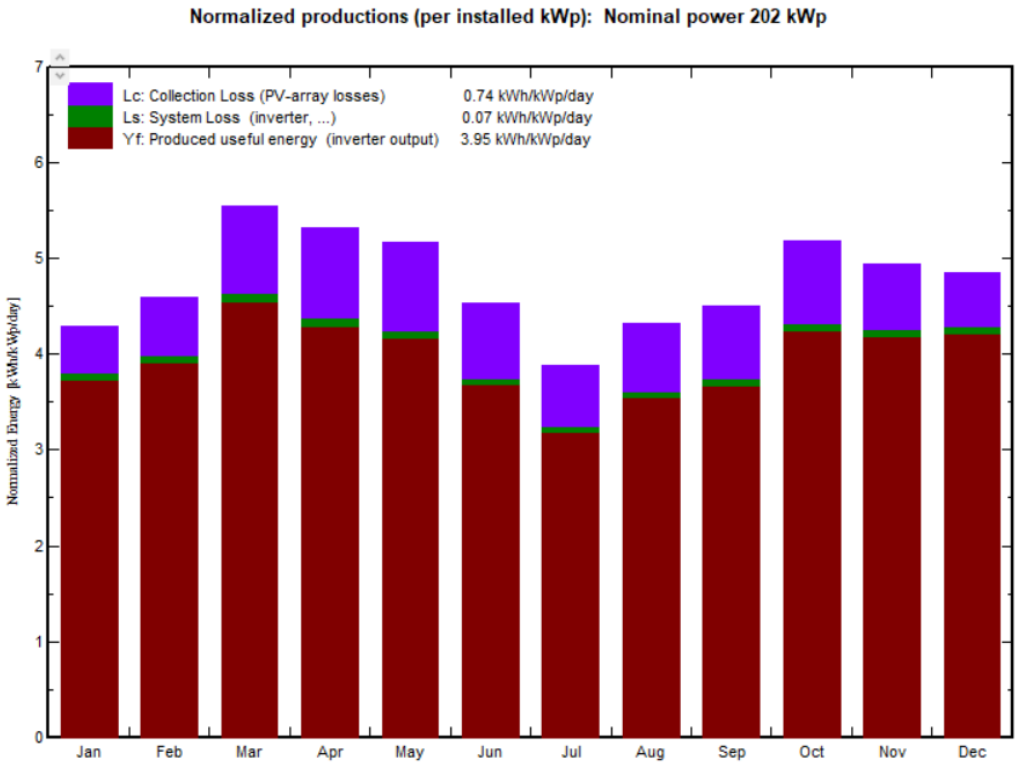


Figure 4.6 Specific Yield Variation over the year

Figure presents 4.7 a detailed summary of the simulated Performance Ratio (PR%) for a solar power system on a monthly and yearly basis. The Performance Ratio is expressed both as a percentage and a decimal value, providing a clear understanding of the system's efficiency.

In January, the simulated Performance Ratio was 86.90%. February's simulated Performance Ratio was slightly lower at 85.20%. March showed a Performance Ratio of 82.10% (0.821), indicating a slight decrease in efficiency compared to the previous months. In April, the Performance Ratio continued to decrease to 80.70%, or 0.807. May's simulated PR was 80.50%, equivalent to 0.805, showing a marginal decrease from April.

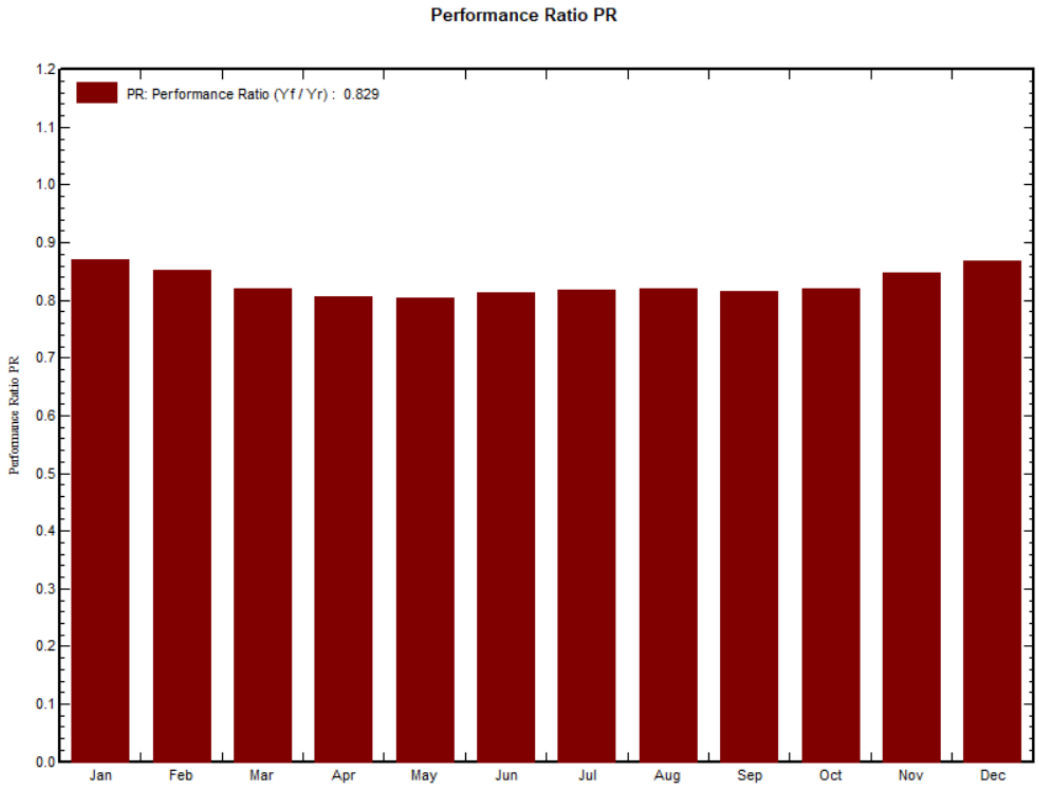


Figure 4.7 PR Variation over the year

June saw a minor increase in the simulated Performance Ratio to 81.30% (0.813). July maintained a steady Performance Ratio of 82.00% (0.820), consistent with August, which also had a PR of 82.00% (0.820). In September, the Performance Ratio was 81.50%, or 0.815, showing a slight decrease from the summer months. October's Performance Ratio returned to 82.00% (0.820).

In November, the simulated Performance Ratio rose to 84.80%, or 0.848, showing an improvement as the year approached its end. December saw a further increase to 86.70% (0.867), reflecting higher system efficiency during this month.

On a yearly basis, the average simulated Performance Ratio was 82.98%, which translates to 0.830 in decimal form. This annual Performance Ratio value highlights the overall efficiency of the solar power system throughout the year, taking into account the variations in monthly performance. The data demonstrates fluctuations in system efficiency due to seasonal changes, with higher Performance Ratio values in the cooler months and slightly lower values during the warmer months, possibly due to temperature-related efficiency losses. Understanding these simulated Performance Ratio values is crucial for optimizing the performance and predicting the output of the solar power system.

Table 4.3 Balance and Main Results

New Simulation Variant								
Balances and Main Results								
	Glob Hor kWh/m²	**Diff Hor kWh/m²**	**T_Amb ℃**	**GlobInc kWh/m²**	**Glob Eff kWh/m²**	**E Array kWh**	**E Grid kWh**	**PR Ratio**
Jan	98.10	43.70	14.31	133.10	131.30	23,807.00	23,372.00	0.869
Feb	105.90	56.90	19.10	128.80	126.50	22,558.00	22,150.00	0.852
Mar	153.90	76.90	24.74	172.10	168.90	29,067.00	28,516.00	0.821
Apr	160.40	90.70	29.36	159.90	156.30	26,536.00	26,040.00	0.807
May	172.80	100.60	31.01	160.50	156.70	26,597.00	26,094.00	0.805
Jun	151.70	93.70	30.66	136.00	132.30	22,757.00	22,335.00	0.813
Jul	133.80	82.10	29.50	120.50	117.00	20,297.00	19,926.00	0.819
Aug	139.90	87.20	29.36	134.20	130.70	22,628.00	22,221.00	0.820
Sep	128.90	69.00	28.39	135.40	132.10	22,696.00	22,269.00	0.815
Oct	135.20	64.90	26.22	160.60	158.10	27,118.00	26,599.00	0.820
Nov	110.00	50.90	21.01	148.20	146.00	25,838.00	25,380.00	0.848
Dec	104.00	43.70	16.15	150.70	148.50	26,855.00	26,386.00	0.867
Year	**1594.6**	**860.30**	**25.01**	**1,740.00**	**1,704.40**	**296,754.00**	**291,288.00**	**0.830**

Similarly, the mean global horizontal irradiation and global diffuse irradiation are 1,594.7 kWh/m^2 and 860.2 kWh/m^2. The annual mean temperature is 25.01℃ with an annual generation of 291,288 kWh. The performance ratio is lowest at 0.805 and highest at 0.869. Monthly Energy generation is lowest in July with 20,297.00 kWh and the highest energy generation is in March with 29,067.00 kWh.

The energy loss diagram in Figure 4.8 shows that annually a total of 344,351 kWh of energy is generated from the solar PV system of 201.96 kWp with 1,595 kWh/m^2 Global Horizontal Irradiation but only 291,287 kWh injected to the grid with 53,064 kWh losses. The losses are due to irradiance losses, cable losses, inverter losses, etc.

Figure 4.8 details the conversion of solar energy to electrical energy through a photovoltaic (PV) system, highlighting various stages of energy losses and inefficiencies. Initially, the system receives a global horizontal irradiation of 1595 kWh/m², which is positively adjusted by 9.1%, resulting in an incident irradiation of 1704 kWh/m² on the collector plane. This value accounts for the 1212 m² collector area and includes a 2.0% reduction due to the Incidence Angle Modifier (IAM) effect.

The effective irradiation on the collectors, with a system efficiency of 16.67% at Standard Test Conditions (STC), translates to 344,351 kWh of energy. This energy undergoes several reductions: 0.6% due to the irradiance level, 11.1% due to temperature effects, 0.7% due to module quality issues, 2.1% from mismatch losses within the modules and strings, and 1.0% from ohmic wiring losses. After these reductions, the array's nominal energy output is 296,752 kWh.

At the Maximum Power Point (MPP), the system experiences an inverter efficiency loss of 1.8%, without additional losses from nominal power, input current, voltage, or threshold constraints. Consequently, the available energy at the inverter output is 291,287 kWh. The final energy injected into the grid, accounting for all system losses and inefficiencies, is also 291,287 kWh, representing the net output from the PV system.

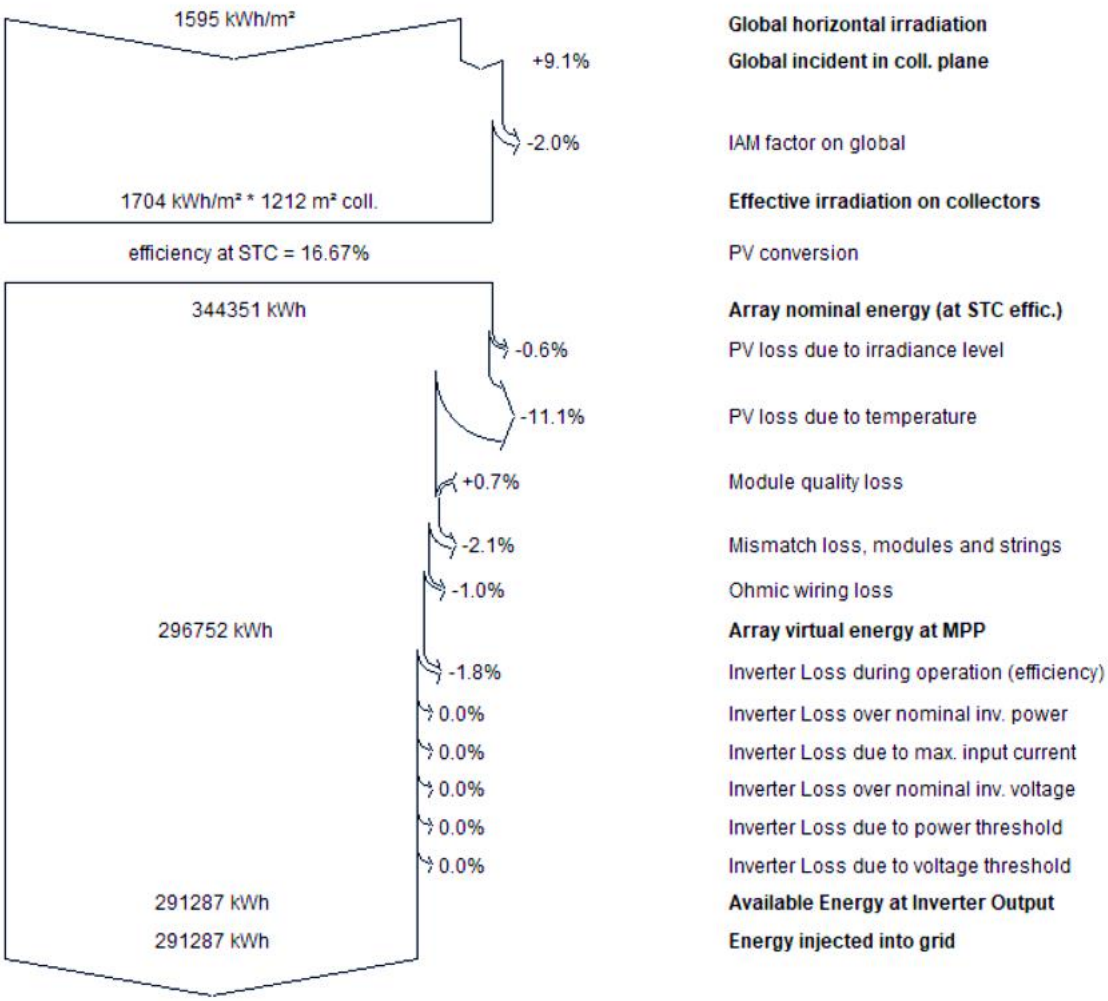


Figure 4.8 Energy Loss Diagrams from PVsyst

4.4 Comparison between Actual and simulated parameters

4.4.1 Monthly Generation

The 201.96 kWp in Chitwan Medical College came into operation in 2022 April. We took data from a 1-year period. Actual generation from the site and generation from the PVsyst is shown below given Figure 4.9.

Figure 4.9 presents a detailed monthly and yearly summary of electricity generation and simulation data for a solar power system. The data is displayed in both megawatt-hours (MWh) and kilowatt-hours (kWh) for easier interpretation.

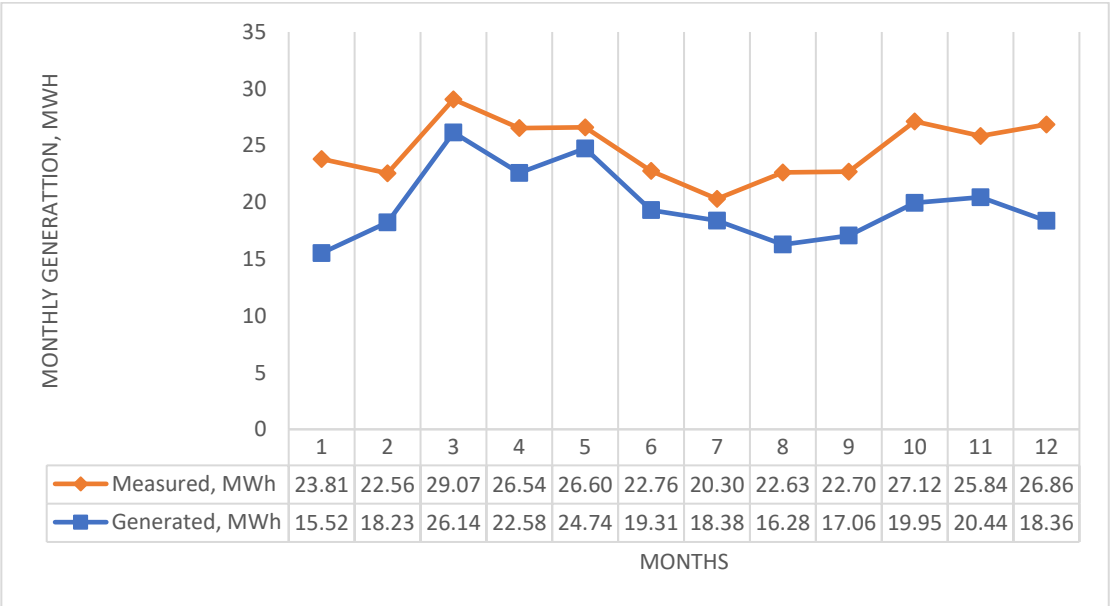


Figure 4.9 Simulated and Measured Monthly Generation

In January, the system generated 15,521.67 kWh (15.52 MWh) of electricity, while simulations estimated a higher value of 23,807.00 kWh (23.81 MWh). February saw an actual generation of 18,225.72 kWh (18.23 MWh), compared to the simulated 22,558.00 kWh (22.56 MWh). March marked the highest production with 26,143.94 kWh (26.14 MWh) generated, whereas simulations predicted 29,067.00 kWh (29.07 MWh). In April, the system produced 22,582.95 kWh (22.58 MWh) against a simulated 26,536.00 kWh (26.54 MWh). May's output was 24,737.72 kWh (24.74 MWh), while simulations suggested a slightly higher 26,597.00 kWh (26.60 MWh).

In June, the system generated 19,308.55 kWh (19.31 MWh) versus a simulated 22,757.00 kWh (22.76 MWh). July's production was 18,382.81 kWh (18.38 MWh), while simulations estimated 20,297.00 kWh (20.30 MWh). August saw a generation of 16,277.53 kWh (16.28 MWh), compared to the simulated 22,628.00 kWh (22.63

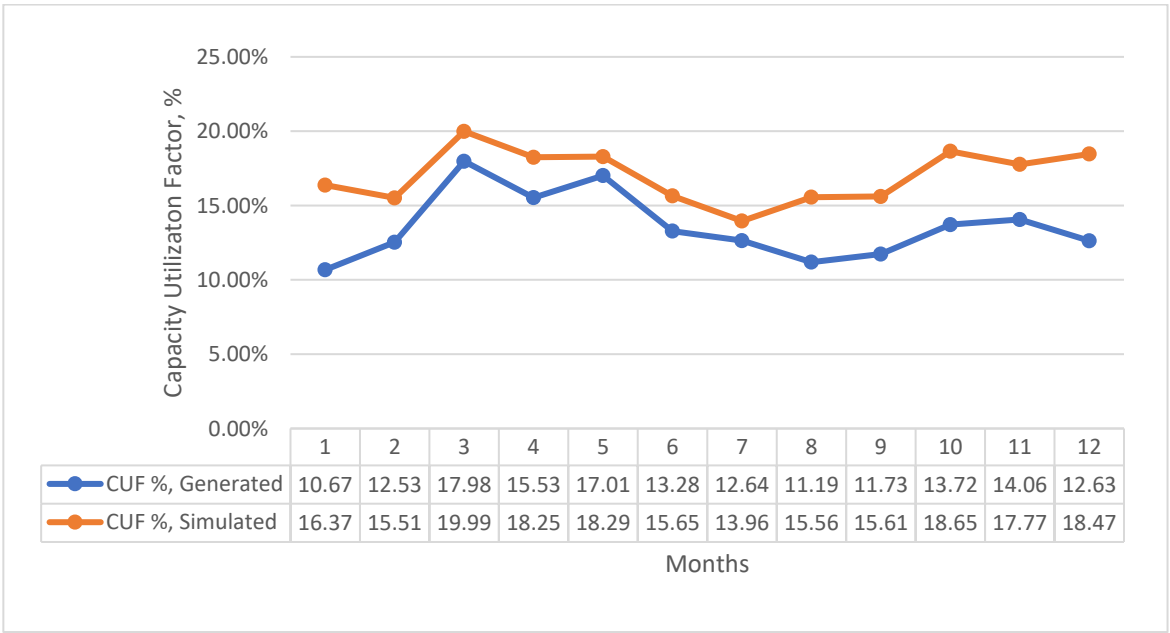
MWh). In September, the system produced 17,063.05 kWh (17.06 MWh) against a simulated 22,696.00 kWh (22.70 MWh). October's generation was 19,945.84 kWh (19.95 MWh), with simulations predicting 27,118.00 kWh (27.12 MWh).

November saw the system generate 20,442.25 kWh (20.44 MWh), while simulations estimated 25,838.00 kWh (25.84 MWh). Finally, in December, the system produced 18,362.06 kWh (18.36 MWh), compared to the simulated 26,855.00 kWh (26.86 MWh).

Over the course of the year, the solar power system generated a total of 236,994.10 kWh (236.99 MWh). In contrast, the simulations projected a higher annual generation of 296,754.00 kWh (296.75 MWh). This discrepancy between actual and simulated values highlights the variability in system performance due to factors such as weather conditions, system efficiency, and potential losses. The data underscores the importance of monitoring and analyzing both actual and simulated outputs to better understand and optimize solar power generation.

4.4.2 Capacity Utilization Factor

Figure 4.10 outlines the performance of a solar power system on a monthly and yearly basis, focusing on electricity generation (in kWh), and the Capacity Utilization Factor (CUF) for both actual and simulated data.



	1	2	3	4	5	6	7	8	9	10	11	12
CUF %, Generated	10.67	12.53	17.98	15.53	17.01	13.28	12.64	11.19	11.73	13.72	14.06	12.63
CUF %, Simulated	16.37	15.51	19.99	18.25	18.29	15.65	13.96	15.56	15.61	18.65	17.77	18.47

Figure 4.10 Simulated and Measured CUF Comparison

In January, the system generated 15,521.67 kWh with a CUF of 10.67%, whereas simulations estimated 23,807.00 kWh with a CUF of 16.37%. February's output was 18,225.72 kWh with a CUF of 12.53%, compared to the simulated 22,558.00 kWh and CUF of 15.51%. March had the highest generation at 26,143.94 kWh and a CUF of 17.98%, while simulations showed 29,067.00 kWh and a CUF of 19.99%. In April, the actual generation was 22,582.95 kWh with a CUF of 15.53%, versus a simulated 26,536.00 kWh and CUF of 18.25%. May's figures were 24,737.72 kWh with a CUF of 17.01%, compared to the simulated 26,597.00 kWh and CUF of 18.29%. June saw 19,308.55 kWh generated with a CUF of 13.28%, while simulations indicated 22,757.00 kWh and a CUF of 15.65%. For July, the system produced 18,382.81 kWh with a CUF of 12.64%, against the simulated 20,297.00 kWh and CUF of 13.96%. August's generation was 16,277.53 kWh with a CUF of 11.19%, compared to 22,628.00 kWh and a CUF of 15.56% in simulations. September's output was 17,063.05 kWh with a CUF of 11.73%, versus the simulated 22,696.00 kWh and CUF of 15.61%. In October, the system produced 19,945.84 kWh with a CUF of 13.72%, while simulations showed 27,118.00 kWh and a CUF of 18.65%. November's generation was 20,442.25 kWh with a CUF of 14.06%, compared to 25,838.00 kWh and a CUF of 17.77% in simulations. December saw 18,362.06 kWh produced with a CUF of 12.63%, against the simulated 26,855.00 kWh and CUF of 18.47%. For the entire year, the system generated 236,994.10 kWh with an average CUF of 14%, while simulations estimated a total of 296,754.00 kWh with an average CUF of 17.01%. This highlights the differences between actual and simulated performance, influenced by factors such as weather and system inefficiencies. Bajracharya & Maharjan (2019) conducted a techno-economic analysis of a 64.6 kWp solar PV System at Nepal Telecom, Sundhara Kathmandu, and found out CUF of 14.09%. Tiwari at. Al (2017) found a 10.01 % average CUF of a 100 kW PV System at the NEA training Center, Kharipati.

4.4.3 Performance Ratio

Figure 4.11 provides a detailed comparison of the Performance Ratio (PR%) of a solar power system, contrasting actual generated values with simulated values on a monthly and yearly basis.

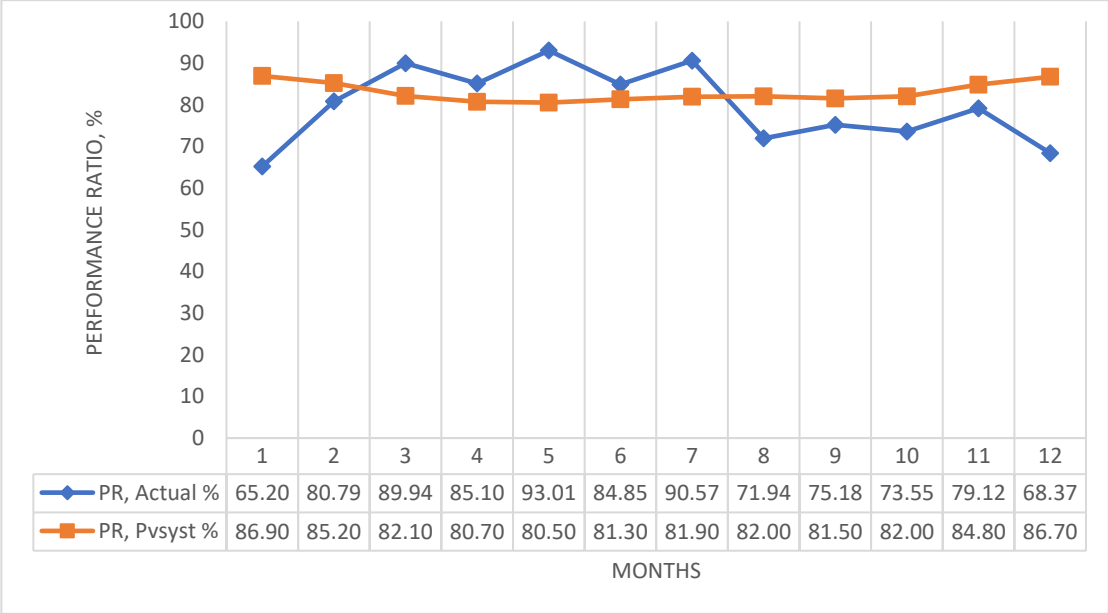


Figure 4.11 Simulated and Measured Performance Ratio Comparison

In January, the actual PR was 65.20%, significantly lower than the simulated PR of 86.90%. February saw an actual PR of 80.79%, close to the simulated 85.20%. March had a high actual PR of 89.94%, slightly exceeding the simulated 82.10%. In April, the actual PR was 85.10%, compared to the simulated 80.70%. May showed an actual PR of 93.01%, the highest for the year, while the simulated PR was 80.50%.

June's actual PR was 84.85%, near the simulated 81.30%. In July, the actual PR reached 90.57%, higher than the simulated 82.00%. August saw a drop in the actual PR to 71.94%, while the simulated PR remained steady at 82.00%. September's actual PR was 75.18%, compared to the simulated 81.50%. In October, the actual PR was 73.55%, with the simulated PR again at 82.00%.

November's actual PR was 79.12%, slightly below the simulated 84.80%. Finally, in December, the actual PR was 68.37%, significantly lower than the simulated 86.70%.

Over the entire year, the average actual PR was 79.80%, while the simulated average PR was higher at 82.98%. This overall comparison highlights discrepancies between the actual and simulated performance ratios. These differences could be due to various factors such as actual operating conditions, weather variations, and system inefficiencies that were not accounted for in the simulations. Monitoring both actual and simulated PR values is crucial for optimizing system performance and improving predictive accuracy. Bajracharya & Maharjan (2019) measured a performance ratio of

85.90% at Sundhara, Kathmandu. Tiwari et. al. (2017) measured a performance ratio of 54% at Kharipati, Lalitpur.

4.4.4 Comparison between Actual and simulated parameters

The actual generation and other parameters are less as compared to the PVsyst simulated parameters. The table presents the yearly analysis.

Table 4.4 Actual and Simulated Parameters Comparison

Annual Data	Actual	Pvsyst	Differences	Units
E_{GEN}	236.99	291.29	54.30	MWh
Y_F	1173.24	1496.08	322.84	kWh/kWp
CUF	13.58	17.01	3.43	%
PR	79.8	82.9	3.1	%

Legends,

E_{GEN} Energy Generation in MWh

Y_F Specific Yield in kWh/kWp

PR Performance Ratio in %

CUF Capacity Utilization Factor in %

4.4.5 Comparison with the simulated parameters of the solar GIS

We had set up the same PV system in the solar Gis. The result from the solar Gis are

Table 4.5 Generated Result from Solar Gis

Annual Data	At System Start-up	Average of 25 Years	Differences	Units
Egen	280.64	262.32	18.32	MWh
PR	77.30	72.20	5.10	%
CUF	14.80	14.80	-	%
Y_f	1,389.60	1,298.90	90.70	kWh/kWp

In Table 4.5 result from the solar GIs is shown. From the result, we came to know that the annual energy generation was 280.64 MWh in the initial system startup which will be an average of 262.32 MWh in 25 years. The capacity Utilization factor is 14.80%.

The performance Ratio is 77.30% in the initial start and it will become an average of 72.20% in the coming 25 years.

While comparing the generated/simulated data from the solar Gis with the measured data in the site result in the following Table 4.6 is obtained.

Table 4.6 Comparing the generated data from solar with measured data

Annual Data	Actual	Solar Gis (at Startup)	Differences	Units
Egen	236.99	280.64	43.65	MWh
Yf	1,173.24	1,389.60	216.36	kWh/kWp
CUF	13.58	14.80	1.22	%
PR	79.80	77.30	2.50	%

According to the solar Gis annual energy generation is 280.64 MWh whereas measured annual energy generation is 236.99. The specific Yield is 1389.60 kWh/kWp in Solar gis but 1,173.24 kWh/kWp is obtained from measured data. The capacity utilization factor is 14.80% in Solar Gis and 13.58% is obtained from measured data.

4.4.6 Comparison with Other Research

Previous research has provided the following results about the research done on different power plants around Nepal. We presented the following findings of the Performance Ratio, Capacity Utilization Factor, and Temperature of different solar modules with different technologies in different time spans in different locations around Nepal.

Table 4.7 Performance Ratio, CUF, and Temperature of Different Solar PV Plants

S.N.	Source	Year	Location	Power	Temp	PR	CUF
1	Shrestha et al.	2014	Trishuli, Nuwakot	1 MWp	20 ˚C	77.30 %	20.18%
2	Tiwari Bhoj et al.	2017	Kharipati, Bhaktapur	100 kWp	22.9˚ ˚C	54%	10.10%
3	Aryal & Bhattarai	2017	TUTH, Kathmandu	115 kWp	19˚C	17.41 %	3.52%
4	Bajracharya & Maharjan	2019	Sundhara, Kathmandu	64.6 kWp	19˚C	85.90 %	14.09%
5	Kishor et. al	2022	Butwal, Rupandehi	10.61 MWp	25˚C	64.00 %	13.00%
6	From this research	2023	Chitwan, Bharatpur	201.96 kWp	25.01 ˚C	79.80 %	13.58%

In Table 4.7, we presented details of the different solar PV plants around Nepal. We presented installed power, Temperature, Performance, and Capacity Utilization Factor.

4.5 Financial Analysis of the plant

The different components are listed along with their market values and the total investment on the plant is carried out which is listed below;

Table 4.8 Total cost of installment of the plant

Items	Unit	Quantity	Amount (NRs)	Per unit cost
Panel	kWp	201.96	8,159,184.00	40,400.00
Combiner Box	Set	1	60,000.00	60,000.00
Inverter	Set	201.96	1,413,720.00	
Mounting Structure	kWp	201.96	2,284,571.52	11,312.00
Wiring Cost	m	300	450,000.00	1,500.00
Monitoring System	Set	1	150,000.00	
Installation, Testing Cost			200,000.00	
Transportation Cost			25,000.00	
Contingencies			500,000.00	
		Total	**13,242,475.52**	

The initial investment on the plant is of NRs. 13,242,475.52. The discount rate is considered to be 10% and operation and maintenance cost on the plant is taken as 1.5% of the total investment which increases by 5% annually. The degradation rate is taken to be 1.5%. The inverter is changed each 11 years. Considering above factors the IRR and NPV is calculated for the plant. It is observed that the plant has the simple payback period of 5.74 years, discounted payback period of the plant is 9.32 years and IRR is 15.23% with NPV of 4,708,202.18.

4.6 SWOT Analysis for the existing system and Nepalese scenario

The strengths, weaknesses, opportunities, and threats of the existing system are summarized as:

4.6.1 Strengths

- Nepal is blessed with almost 300 sunny days a year and irradiation of around 4.5-5kWh/m2/day which is quite high.
- This helps to reduce the energy deficit and sell energy to the grid too.
- There are abundant rooftop places to install solar PV. There are very less chances of shading too.
- Electricity generation from solar PV is environmentally friendly.
- The government has subsidized the PV sector with no tax on Solar panels, Inverter and Charge Controllers.

- It needs less installation cost as well as less completion time than Hydropower Plants

4.6.2 Weaknesses

- The initial installation cost of solar PV is quite high. So, normal consumers do not prefer solar PV installation compared to NEA/utility mains.
- Energy generation from Solar PV fluctuates very little during monsoon/rainy days and winter days, as well as no reduction during night time.
- Most of the components needed for PV installation are imported.
- The dust accumulation decreases efficiency and is troublesome to clean panels at regular intervals.
- Comparatively very low PV efficiency (13% to 19%)

4.6.3 Opportunities

- Frequent fuel shortage problems while importing, but solar irradiation is a natural source.
- International trend of yearly decrease in cost per kWp for solar PV.
- The country is ready to invest larger capital and increase energy diversity to balance the risk associated with each source.

4.6.4 Threats

- Very little awareness among people at the local level to enhance the use of solar technologies
- Insufficient institutional contribution

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study was conducted to evaluate the performance analysis of solar PV system installed in Chitwan Medical College, Bharatpur, Chitwan. The conclusion of the study is as:

- The simulation from PVSYST shows that 291.29 MWh of energy can be annually injected into the grid for a similar 201.96 kWp solar PV system. The performance parameters from the PVSYST are a Performance Ratio of 82.9%, a Capacity Utilization Factor of 17.01%, and a Specific Yield of 1496.08 kWh/kWp over a year.
- Since its operation from May 2022, the solar plant in Chitwan Medical College, Bharatpur, Chitwan has generated electricity of 331.22 MWh till August 2023.
- The measured performance parameter on-site shows that 236.99 MWh of energy is being injected into the hospital line from the 201.96kWp solar PV system. The Performance parameters from measured data are a Performance Ratio of 79.8%, Capacity Utilization Factor of 13.58%, and Specific Yield of 1173.24 kWh/kWp over a year.
- The difference between simulated data obtained from PVsyst and measured data on the site is 54.30 MWh in Annual Energy Generation, 322.84 kWh/kWp, 3.43% CUF, and 3.1% in Performance Ratio.
- Energy generation over recent months has decreased. The prime cause of the low generation in recent months is due to dust composition on the solar panel from maintenance of the road.

5.2 Recommendations

This work has been done with the least information and resources available to the author. As much as necessary the data from the developers and the clients used in this research were not easily accessible. The following recommendations therefore highlight the best approach in analyzing the performance of the solar PV plant under various climatic conditions for the demonstration of its technical and economic viability.

- Since dust precipitation is a major problem for having low electricity generation, scheduling the cleaning of the solar panel is needed.

- The current solar PV system is not sufficient for overcoming the electricity demand of the hospital so, the addition of solar panels over all the parking spaces and the roof somehow helps to overcome the demand of the hospital.
- Undesirably high panel temperatures lead to lower conversion performance and reduced reliability over the long term. So, it is recommended to use effective cooling methods for solar panels like; (active cooling, cooling with phase change materials, or cooling with PCM additives that helps to improve overall efficiency, especially during hot weather or intense sunlight.

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APPENDIX

Appendix-A: Monthly Energy Variation Generation (MWh) with Months from installation

Months	Generation (MWh)	Generation (kWh)
May-22	23.63	23,626.19
Jun-22	19.31	19,308.55
Jul-22	20.74	20,743.90
Aug-22	21.01	21,009.09
Sep-22	17.06	17,063.05
Oct-22	19.95	19,945.84
Nov-22	20.44	20,442.25
Dec-22	18.36	18,362.06
Jan-23	15.52	15,521.67
Feb-23	18.23	18,225.72
Mar-23	26.14	26,143.94
Apr-23	22.58	22,582.95
May-23	24.74	24,737.72
Jun-23	23.33	23,333.75
Jul-23	18.38	18,382.81
Aug-23	16.28	16,277.53
Total	**325.71**	**325,707.03**

Appendix-B: Monthly Energy Variation with Monthly Average Temperate over a year

Month	Electricity Egen KWh	Electricity Egen MWh	Average Temp˚C
Jan	15,521.67	15.52	14.31
Feb	18,225.72	18.23	19.10
Mar	26,143.94	26.14	24.74
Apr	22,582.95	22.58	29.36
May	24,737.72	24.74	31.01
Jun	19,308.55	19.31	30.66

Jul	18,382.81	18.38	29.50
Aug	16,277.53	16.28	29.36
Sep	17,063.05	17.06	28.39
Oct	19,945.84	19.95	26.22
Nov	20,442.25	20.44	21.01
Dec	18,362.06	18.36	16.15
Yearly	**236,994.10**	**236.99**	**24.98**

Appendix –C: Simulated and Measured Capacity Utilization Factor over Months

Month	**Electricity Egen KWh**	**CUF %, Generated**	**Electricity, Pvsyst KWh**	**CUF %, Simulated**
Jan	15,521.67	10.67%	23,807.00	16.37%
Feb	18,225.72	12.53%	22,558.00	15.51%
Mar	26,143.94	17.98%	29,067.00	19.99%
Apr	22,582.95	15.53%	26,536.00	18.25%
May	24,737.72	17.01%	26,597.00	18.29%
Jun	19,308.55	13.28%	22,757.00	15.65%
Jul	18,382.81	12.64%	20,297.00	13.96%
Aug	16,277.53	11.19%	22,628.00	15.56%
Sep	17,063.05	11.73%	22,696.00	15.61%
Oct	19,945.84	13.72%	27,118.00	18.65%
Nov	20,442.25	14.06%	25,838.00	17.77%
Dec	18,362.06	12.63%	26,855.00	18.47%
Yearly	**236,994.10**	**13.58%**	**296,754.00**	**17.01%**

Appendix-D: Simulated and Measured Performance Ratio Comparison over Months

Month	Electricity Generated KWh	PR %, Generated	Electricity, Simulated	PR %, Simulated
Jan	15,521.67	65.20	23,807.00	86.90%
Feb	18,225.72	80.79	22,558.00	85.20%
Mar	26,143.94	89.94	29,067.00	82.10%
Apr	22,582.95	85.10	26,536.00	80.70%
May	24,737.72	93.01	26,597.00	80.50%
Jun	19,308.55	84.85	22,757.00	81.30%
Jul	18,382.81	90.57	20,297.00	82.00%
Aug	16,277.53	71.94	22,628.00	82.00%
Sep	17,063.05	75.18	22,696.00	81.50%
Oct	19,945.84	73.55	27,118.00	82.00%
Nov	20,442.25	79.12	25,838.00	84.80%
Dec	18,362.06	68.37	26,855.00	86.70%
Yearly	**236,994.10**	**79.80**	**296,754.00**	**82.98%**

Appendix-E: Simulated and Measured Monthly Generation over Months

Month	Electricity Generated MWh	Electricity Generated MWh	Electricity Simulated, KWh	Electricity Simulated, MWh
Jan	15,521.67	15.52	23,807.00	23.81
Feb	18,225.72	18.23	22,558.00	22.56
Mar	26,143.94	26.14	29,067.00	29.07
Apr	22,582.95	22.58	26,536.00	26.54
May	24,737.72	24.74	26,597.00	26.60
Jun	19,308.55	19.31	22,757.00	22.76
Jul	18,382.81	18.38	20,297.00	20.30
Aug	16,277.53	16.28	22,628.00	22.63
Sep	17,063.05	17.06	22,696.00	22.70
Oct	19,945.84	19.95	27,118.00	27.12
Nov	20,442.25	20.44	25,838.00	25.84

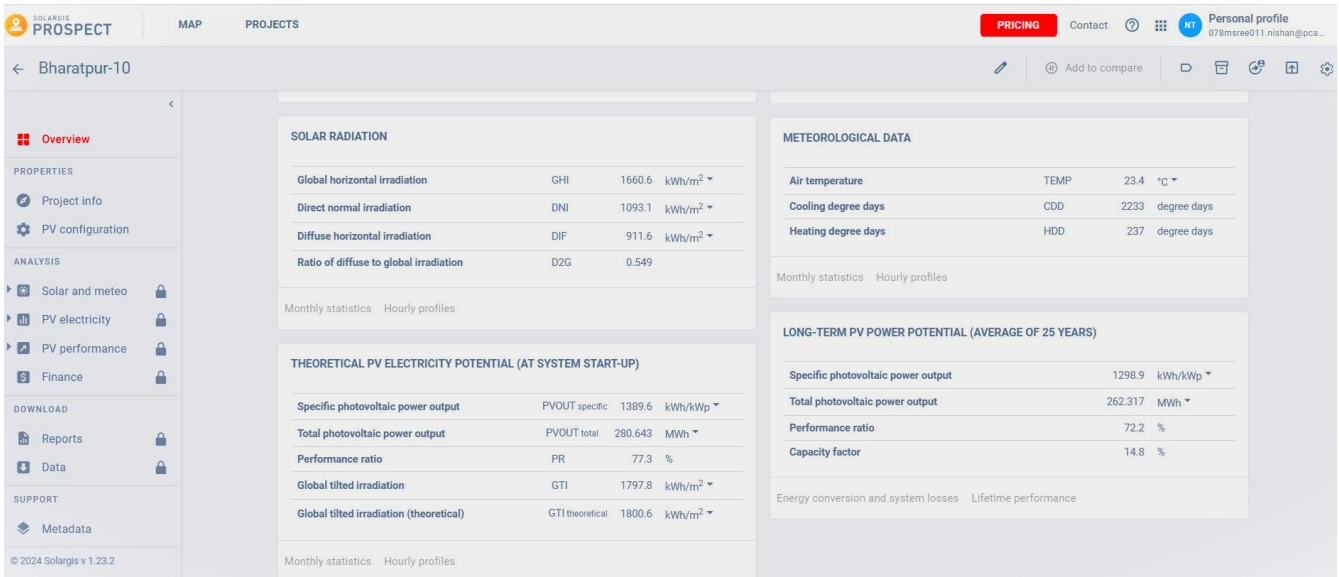
Dec	18,362.06	18.36	26,855.00	26.86
Yearly	**236,994.10**	**236.99**	**296,754.00**	**296.75**

Appendix-F:- Monthly generation data from Wattmon Cloud Portal of August 2023

Time	**Solar Meter AC Frequency**	**Solar Meter kWh Total Import**	**Solar Meter kWh Total Generation**
8/1/2023 0:00	50.18	315,696.59	754.31
8/2/2023 0:00	50.28	316,278.81	582.22
8/3/2023 0:00	50.11	316,782.50	503.69
8/4/2023 0:00	50.18	317,399.13	616.63
8/5/2023 0:00	50.20	-	-
8/6/2023 0:00	50.19	318,439.69	1,040.56
8/7/2023 0:00	50.15	318,785.69	346.00
8/8/2023 0:00	50.18	318,824.72	39.03
8/9/2023 0:00	50.18	319,273.88	449.16
8/10/2023 0:00	50.16	320,039.97	766.09
8/11/2023 0:00	50.23	320,761.94	721.97
8/12/2023 0:00	50.18	320,881.47	119.53
8/13/2023 0:00	50.15	320,978.41	96.94
8/14/2023 0:00	50.26	321,517.88	539.47
8/15/2023 0:00	50.14	322,347.16	829.28
8/16/2023 0:00	50.20	323,193.47	846.31
8/17/2023 0:00	50.17	323,950.72	757.25
8/18/2023 0:00	50.22	324,624.75	674.03
8/19/2023 0:00	50.23	325,132.75	508.00
8/20/2023 0:00	50.20	325,620.00	487.25
8/21/2023 0:00	50.15	325,869.97	249.97
8/22/2023 0:00	50.24	326,118.97	249.00
8/23/2023 0:00	50.28	326,372.88	253.91
8/24/2023 0:00	50.28	326,822.03	449.16
8/25/2023 0:00	50.16	327,094.78	272.75
8/26/2023 0:00	50.24	327,576.44	481.66

8/27/2023 0:00	50.17	328,146.34	569.91
8/28/2023 0:00	50.25	328,836.19	689.84
8/29/2023 0:00	50.15	329,525.38	689.19
8/30/2023 0:00	50.13	330,397.13	871.75
8/31/2023 0:00	50.12	331,219.81	822.69
Monthly	**50.19**	**331,219.81**	**16,277.53**

Appendix:- G:- Result from Solar Gis



Appendix H:- Cash flow of Solar PV project at CMC Medical College

Year	0	1	2	3	4	5	6
Investment	(13,242,475.52)						
Amount saved	(13,242,475.52)	2,621,154.75	2,581,837.42	2,543,109.86	2,504,963.22	2,467,388.77	2,430,377.94
Maintenance cost	(13,242,475.52)	198,637.13	208,568.99	218,997.44	229,947.31	241,444.68	253,516.91
Inverter change							
Net savings	(13,242,475.52)	2,422,517.61	2,373,268.44	2,324,112.42	2,275,015.90	2,225,944.09	2,176,861.03
PV		2,202,288.74	1,961,378.87	1,746,140.06	1,553,866.47	1,382,136.15	1,228,781.30
NPV	(13,242,475.52)	(11,040,186.78)	(9,078,807.91)	(7,332,667.85)	(5,778,801.37)	(4,396,665.22)	(3,167,883.92)
IRR	**15.23%**						
Simple payback	(13,242,475.52)	(10,819,957.91)	(8,446,689.47)	(6,122,577.05)	(3,847,561.14)	(1,621,617.05)	555,243.97
					Simple Payback Period		**5.74**

Year	7	8	9	10	11	12	13
Investment							
Amount saved	2,393,922.27	2,358,013.43	2,322,643.23	2,287,803.58	2,253,486.53	2,219,684.23	2,186,388.97
Maintenance cost	266,192.76	279,502.39	293,477.51	308,151.39	323,558.96	339,736.91	356,723.75
Inverter change					1,413,720.00		
Net savings	2,127,729.51	2,078,511.04	2,029,165.72	1,979,652.19	516,207.57	1,879,947.32	1,829,665.22
PV	1,091,861.67	969,640.74	860,564.35	763,241.62	180,927.60	599,009.15	529,988.84
NPV	(2,076,022.25)	(1,106,381.51)	(245,817.16)	517,424.46	698,352.06	1,297,361.21	1,827,350.05
		Discounted Payback Period		**9.32**			
Simple payback	2,682,973.49	4,761,484.52	6,790,650.24	8,770,302.44	9,286,510.01	11,166,457.33	12,996,122.55

Year	14	15	16	17	18	19	20
Investment							
Amount saved	2,153,593.13	2,121,289.24	2,089,469.90	2,058,127.85	2,027,255.93	1,996,847.09	1,966,894.39
Maintenance cost	374,559.94	393,287.94	412,952.33	433,599.95	455,279.95	478,043.94	501,946.14
Inverter change							
Net savings	1,779,033.19	1,728,001.30	1,676,517.56	1,624,527.90	1,571,975.98	1,518,803.15	1,464,948.24
PV	468,475.04	413,669.77	364,859.07	321,404.18	282,733.70	248,336.45	217,755.22
NPV	2,295,825.10	2,709,494.87	3,074,353.94	3,395,758.12	3,678,491.82	3,926,828.27	4,144,583.49
Simple payback	14,775,155.74	16,503,157.04	18,179,674.61	19,804,202.51	21,376,178.49	22,894,981.64	24,359,929.88

Year	21	22	23	24	25
Investment					
Amount saved	1,937,390.97	1,908,330.11	1,879,705.15	1,851,509.58	1,823,736.93
Maintenance cost	527,043.45	553,395.62	581,065.40	610,118.67	640,624.61
Inverter change		1,413,720.00			
Net savings	1,410,347.52	(58,785.52)	1,298,639.75	1,241,390.90	1,183,112.33
PV	190,581.07	(7,221.56)	145,029.70	126,032.95	109,196.53
NPV	4,335,164.56	4,327,943.00	4,472,972.69	4,599,005.64	4,708,202.18
Simple payback	25,770,277.40	25,711,491.89	27,010,131.64	28,251,522.55	29,434,634.87

Chitwan Medical College, Bharatpur, Chitwan

Sunny Tripower Inverter used in CMCTH

Solar Panel Mounted in the roof of the CMCTH

Solar Panel Mounted in the roof of the CMCTH

Solar Panel Mounted on Roof

Solar Panel on Roof

Details Specification of the Solar Panel installed at CMCTH

Appendix:- I: Approval page for Paper publish in 14th IOE GC

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Date: November 26, 2023

To Whom It May Concern:

This is to certify that the paper titled "***Performance Analysis of Solar PV System of Chitwan Medical College, Chitwan, Nepal***" (Submission# **831**) submitted by **Nishan Timilsina** as the first author has been accepted after the peer-review process for presentation in the 14th IOE Graduate Conference being held during Nov 29 to Dec 1, 2023. Kindly note that the publication of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon the author's presence for presentation during the conference and timely response to further edits during the publication process.

Bhim Kumar Dahal, PhD
Convener,
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Performance Analysis of Solar PV System installed in Chitwan Medical College

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