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Study of photovoltaic system performance across different geographical region of Nepal

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Abstract

The objective of this work is to study the photovoltaic system performance across different geographical region of Nepal and its economic benefits. Nepal's solar irradiation varies significantly by season, from 4.5 kWh/m² in December to 7.2 kWh/m² in May. Notably, May has the highest irradiance levels, whereas December has the lowest. The Himalayan region, including Mustang, Kehami, and Jomsom, has greater irradiance levels ranging from 6 to 6.5 kWh/m²/day. The eastern half of Nepal has lower irradiance values, below 4.4 kWh/m²/day. The palce of high irradiance, has current output ranges from 19 A to 27.5 A, with peak PV power of 375 W when simulated with secondary data. The simulation observation shows temperature fluctuations has influence power output, with higher power at lower temperatures. Also, the power generation by PV rises with decreasing temperature and shifts to optimization voltage. The relationship between global horizontal irradiance and photocurrent is linear and increase from 9 to 19 A. At considered temperatures range the optimum creased photocurrent observed at 45°C. The economic analsyis was done considering 365 W solar PV system in Nepal's Himalayan region and Eastern Half. The parameters use for economic analysis are Payback Period, Return on Investment (ROI), and Net Present Value (NPV). The analysis show that at higher solar irradiance in the Himalayan region leads to a shorter payback (15.7 years), higher ROI (59.4%), and a less negative NPV in comparative to the Eastern Half of Nepal. These findings highlight the importance of knowing solar irradiance and temperature dynamics for optimizing PV system performance throughout Nepal's different geographical regions.

Keywords
Global horizontal irradiance, Himalayan, Hilly and Terai region, photocurrent, temperature, PV system performance

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1 Introduction

Photovoltaic (PV) cells are tools for transforming radiant energy from the solar to electrical in a sustainable manner. PV systems, which are typically consist of interconnected solar cells are shown in Figure 1. These cells are designed to produce to maximum output energy. Recent advances have enabled in the production of high-efficiency photovoltaic cells. They include certain multijunction solar cells approaching 50% of efficiency. The commercially accessible PV panels typically have converted efficiencies from 17% to 20% [1]. Now a days, manufacturers give the electrical requirements of photovoltaic devices on the basis of standard test settings (STC). They include a controlled temperature of 25°C along with incident irradiance of 1000 W/m^2. To capture non-linear electrical behavior and environmental unpredictability, limited data exists on actual annual energy yield. Nepal enjoys around 300 sunny days per year, offering strong potential for solar power. This makes it an ideal environment for photovoltaic technology to meet growing energy demands. However, many sites in Nepal still lack essential research on solar energy. This study addresses that gap by highlighting the importance of renewable energy in Nepal's context.

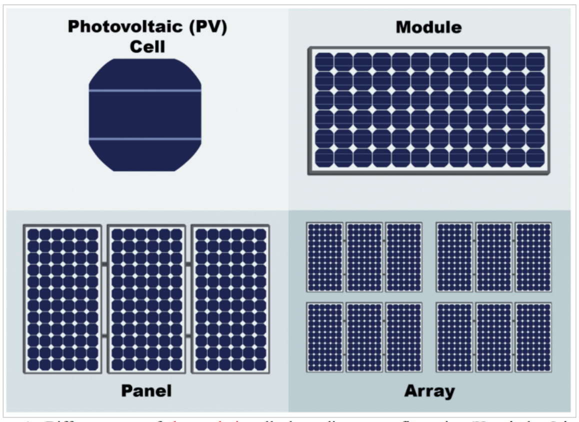

Figure 1: Different types of photovoltaic cells depending on configuration [2]

1.1 Research related to solar Irradiance in Nepal

Nepal's solar resource has inspired increased interest within photovoltaic systems. It is reported that roughly 1.1 million solar household systems. The Nepal Electricity Authority has recently introduced net billing to encourage the use of rooftop solar panels. Also the potential of technologies to assist governmental decisions on expanded power generation. A report by Kadle et al. shows Kathmandu, Pokhara, Butwal, Nepalgunj, and Biratnagar has tr rooftop solar panels potential, like 637 GWh per year in Kathmandu to 50 GWh per year in Butwal [3].

Nepal has favourable geography and abundant solar radiation, which averages between 3.6 and 6.2 kWh/m2/day and roughly 300 days of sunshine per year. The current statistics show that both the Thabang Solar Mini-Grid (TSMG) and Sugarkhal Solar Mini-Grid (SSMG) experience their peak energy generation in April. TSMG generated 83.206 MWh/year in 2021 with 112.140 MWh/year in 2022, having a peak sun hour (PSH) of 5.5 h. SSMG produced 64.14 MWh/year in 2021 as well as 68.79 MWh/year in 2022, with a PSH of 5.7 h [4]. A potential solution to the energy crisis in remote areas like Karnali Province where about 67% of the population lacks access to the national grid is the use of PV solar mini grids. Due to the region's rugged geographical region, extending the grid is challenging, making solar mini grids a more economical and efficient option with high generation potential [5].

1.2 Significant of research

Understanding solar energy in Nepal has impacts beyond research. Studying how solar radiation, temperature, and power generation interact can guide major improvements in the country's energy system. This knowledge can help create tailored plans to optimize solar power production, boosting energy independence and protecting against price changes. Identifying the best locations for solar PV can help use Nepal's vast solar resources for economic growth and rural development. Developing solar infrastructure can create jobs, attract investments, and support local industries, improving socioeconomic conditions. As Nepal faces climate change and environmental challenges, solar energy can reduce greenhouse gas emissions and reliance on fossil fuels. Closing research gaps and fully using renewable energy can lead Nepal toward a greener and more prosperous future.

1.3 Research Gap

Although there are studies on solar irradiance and power generation in Nepal, important gaps remain. One key gap is understanding how geography, solar irradiance, and temperature together affect photovoltaic system performance. Research on how these factors interact in Nepal's different regions, Himalayan, hilly, and eastern Terai is limited. These regions have diverse climates and geographical region, which likely influence solar power output differently. Additionally, economic feasibility studies comparing PV system performance across these regions are rare. Few studies combine technical data like irradiance, temperature effects, and power output with financial measures such as Payback Period, Return on Investment (ROI), and Net Present Value (NPV). This lack of integrated analysis makes it hard to determine the most suitable locations for solar energy projects. Overall, there is a strong need for comprehensive research that includes both technical performance and economic viability. Such studies would help identify optimal areas for solar power deployment throughout Nepal, considering its varied geography and climate conditions.

2 Methods and Materials

2.1 PV module used in this research

For the computation detial of studying the nature of power generated, voltage and current, Solarex MSX60 PV module, a conventional 60W module made up of 36 polycrystalline cells connected in series, was used in the investigation. The PV module more detial is shown in Table 1. These criteria served as the foundation for analysing the PV module's performance and attributes in the study.

Table 1: Specification of solar PV module used in this research: Solarex MSX60 [6] at 25°C

Parameter	**MSX60 Specification**
Maximum power (P_{max})	60 W
Voltage at P_{max} (V_{mp})	17.1 V
Current at P_{max} (I_{mp})	3.5 A
Short-circuit current (I_{sc})	3.8 A
Open-circuit voltage (V_{oc})	21.1 V

2.2 Theory

Solar cells serve an important role in transforming solar energy into electricity, providing an environmentally friendly and renewable source of energy. Solar cell technology has progressed throughout time, from single-crystal silicon to flexible film, organic, dye-sensitized, perovskite cells, etc. Material enhancement, construction, contact systems, characterization techniques are used to improve solar cell performance. The Shockley diode model is a popular model for solar cell analysis. It allows for extensive analysis and modelling to optimize the efficiency of solar cells and capacity, a single-diode model demonstrated in Figure 2.

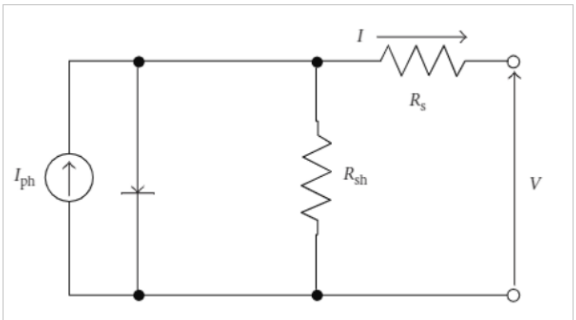

Figure 2: Circuit diagram of shockley diode model of solar cell [7]

The output current of an ideal solar cell is found as

$$I = I_{ph} - I_s \left[\exp\left(\frac{qV_{OC}}{N_s KAT_0} \right) - 1 \right] \tag{1}$$

where I_{ph} is photogenerated current, I_s is saturation current, q is elementary charge of an electron, V_{OC} is open-circuit voltage of the solar cell, N_s is Number of cells/modules in series, k is boltzmann constant, A is Ideality factor of the diode (typically between 1 and 2) and T_0 is reference or operating temperature. In the ideal scenario, beam produced power is directly proportional to irradiation brightness, and photovoltaics provide a reasonable estimate. The mathematical representation of a photovoltaic cell (real/practical cell type) containing infinite R_s (series resistance) along with R_p (parallel resistance), then the diode current becomes

$$I_d = I_s \left[\exp\left(\frac{q\,(V + IR_s)}{N_s KAT_0} \right) - 1 \right] \tag{2}$$

When R_s is taken into account, the resulting current of the module with N_s cells in series becomes:

$$I = I_{ph} - I_s \left[\exp\left(\frac{q\,(V + IR_s)}{N_s KAT_0} \right) - 1 \right] \tag{3}$$

When the solar energy system is coupled in series and parallel, the current using equation (3) is

$$I = N_p \times I_{ph} - N_p \times I_s \left[\exp\left(\frac{q\,(V + IR_s)}{N_s KAT_0} \right) - 1 \right] \tag{4}$$

The incident flux has a relationship to the photocurrent (I_{ph}), and thus not dependent on voltage (or R_s). The photocurrent generated by solar radiation along with the temperature influenced by it can be computed as

$$I_{ph} = [I_{SC} + K_i(T_0 - T_r)] \times \frac{G}{G_{ref}} \tag{5}$$

Where K_i is temperature coefficient of the short-circuit current (in A/°C), T_r is reference temperature (typically 25°C), G is actual solar irradiance (sunlight intensity) on the panel surface (in W/m^2) and G_{ref} is reference irradiance, usually 1000 W/m^2 (Standard Test Conditions). The single-diode model, which consists of a single diode component including five electrical parameters, constitutes one of the simplest representations of PV panels' intrinsic nonlinear features. Castaner and Silvestre (2002) created an implicit mathematical formula known as the usual I-V characteristic equation.

$$I = I_{ph} - I_s\left[e^{\frac{V+IR_s}{A_0 N V_t}} - 1\right] - \frac{V + IR_s}{R_{sh}} \tag{6}$$

The thermal voltage (V_t) can be mathematically stated as $V_t = kT/q$. Further circuit analysis can create a mathematical association between along with the incident ambient condition of the photovoltaic cell (radiation, G, and temperature, T) as reported [8].

2.3 parameters analysis of deploying PV systems in different regions

The methodology of this research involves a financial assessment of a solar photovoltaic system by calculating three key economic parameters: Payback Period, ROI, and NPV. First, the total initial investment cost is determined by summing the prices of solar panels, MPPT controllers, installation, and battery replacements over the system's 25-year lifespan. Next, the annual energy output is estimated based on the panel's rated power, local Peak Sun Hours (PSH), and system performance ratio. Using these values, the Payback Period is calculated by dividing the initial investment by the annual monetary savings, derived from multiplying annual energy output by the local electricity rate. ROI is then computed as the percentage difference between the total revenue generated over the system lifetime and the initial investment. Finally, NPV is calculated by discounting annual savings over 25 years at a chosen discount rate (6%) and subtracting the initial investment to assess the system's present economic value. This methodology allows comparison of the solar system's financial viability across different geographic locations with varying solar irradiance levels.

3 Results and Discussion

3.1 Solar Irradiance in Nepal

According to NASA's Surface Meteorology along with Solar Energy dataset, the average daily solar radiation on a horizontal plane in Nepal varies significantly by season. The annual irradiation rate ranges from 4.5 kWh/m^2 in December to 7.2 kWh/m^2 in May [9]. Notably, May has the highest average monthly sun irradiation, whereas December has the lowest amounts. This seasonal pattern represents the shifts in solar angle during daylight length caused by the tilt that occurs in the Earth's axis with its orbit around the solar system. Previous research, such as that undertaken by Neupane et al. [10], has found comparable seasonal variations in sun irradiance across Nepal's different geographical regions. Figure 3 from the 2023 Global Solar Atlas depicts the geographic distribution of solar radiation over Nepal, offering a spatial picture of the region's solar energy potential.

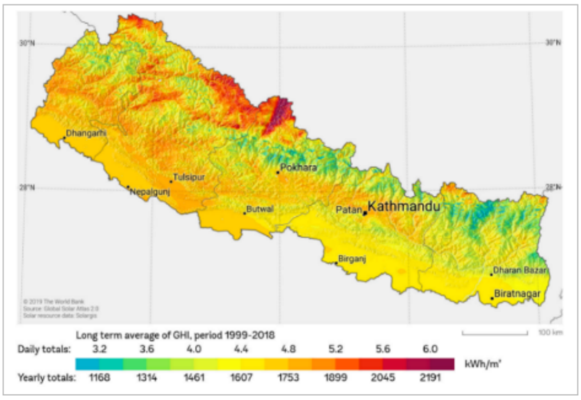

Figure 3: Solar Irradiance above Nepal ([9]

3.2 Current generated by PV modules at varying irradiation levels in Nepal.

Solar irradiation varies significantly in Nepal, affected primarily by topographical considerations. Solar irradiation levels in the Himalayan region, including Mustang, Kehami, as well as Jomsom, are significantly higher, ranging from 6 to 6.5 kWh/m^2/day. This increased irradiance causes higher current generation, with values ranging from 19 A to 27.5 A. Tinje, Saldang, Dolphu, as well as Mugu have high sun irradiation, which ranges from 5.6 kWh/m^2/day to 6 kWh/m^2/day, resulting in current outputs within this range. In contrast, the western area of Nepal experiences significantly lower sun irradiation, average around 4.8 kWh/m^2/day. In the eastern section of the country, solar irradiance values are below 4.4 kWh/m^2/day.

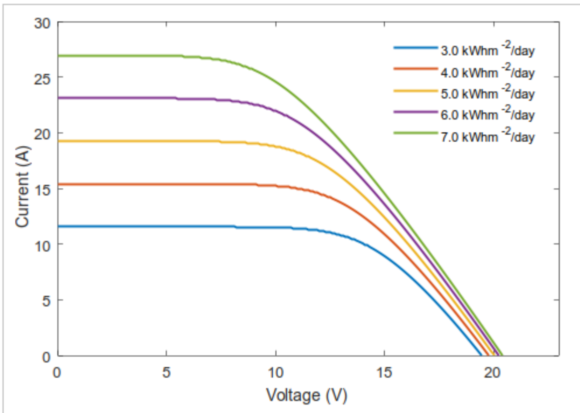

Figure 4: PV current generated at different geographical region at 45 °C, at different region of Nepal on the basis of irradiance level

Figures 4–6 demonstrate current-voltage characteristics at various temperatures and solar irradiation levels. It has been found that as the temperature drops, the voltage increases while the current flowing decreases. Also, the current-voltage graphs show that when temperature decreases, the current switches to higher voltages before rapidly falling beyond particular voltage thresholds. The convergence of current with rising voltage occurs at around 20V at 45°C (Figure 4), 22V at 25 °C (Figure 5), along with 24V at 0°C (Figure 6). These findings are comparable with prior research conducted on the Pulchowk campus [11], indicating the validity and dependability of the provided results. The observation drops in power and current with increasing temperature is similar with the results of [12].

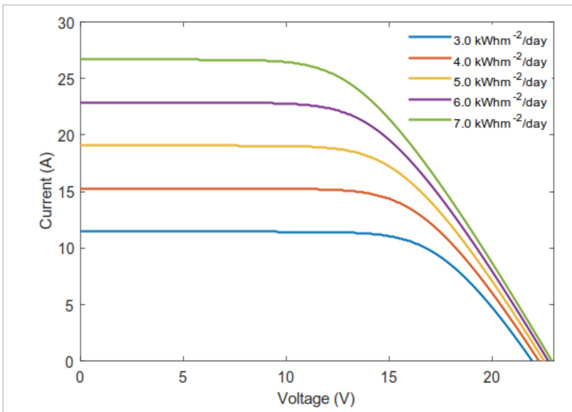

Figure 5: V current generated at 25 °C, at different geographical region of Nepal on the basis of irradiance level

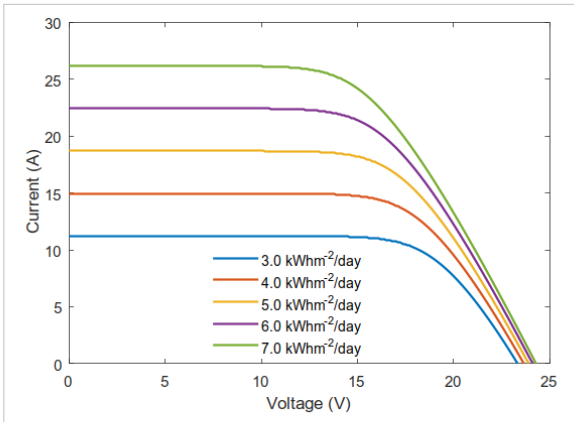

Figure 6: PV current generated at 0 °C, at different geographical region of Nepal on the basis of irradiance level

The findings show solar irradiation and temperature variations across Nepal significantly influence PV current output. High-irradiance areas like Mustang and Jomsom (6–6.5 kWh/m²/day) generate higher currents (19–27.5 A), making them ideal for solar PV system installation. In contrast, regions with lower irradiation, especially in the east and west, produce less current and require more efficient system design. Additionally, lower temperatures enhance voltage, improving system performance. These support researchers, developers, and installation organizations in selecting optimal locations, designing efficient systems, and planning region-specific solar energy projects in Nepal.

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3.3 Power generated by PV at various irradiation levels in Nepal

The solar photovoltaic module's power output varies greatly across different geographical region of Nepal, particularly in the Himalayan region demonstrating significantly better power generation potential. Specifically, in Mustang, Kehami, as well as Jomsom, solar PV generated electricity is substantially higher than in other places, ranging up to 250 W, as illustrated in figure 7. The maximum electrical output of a solar PV module is often observed within a specified voltage range, usually between 10 and 15 V. This range shows the best working circumstances under which the PV module may produce the most power effectively. This improves the performance of solar PV system for energy extraction in specific region of Nepal.

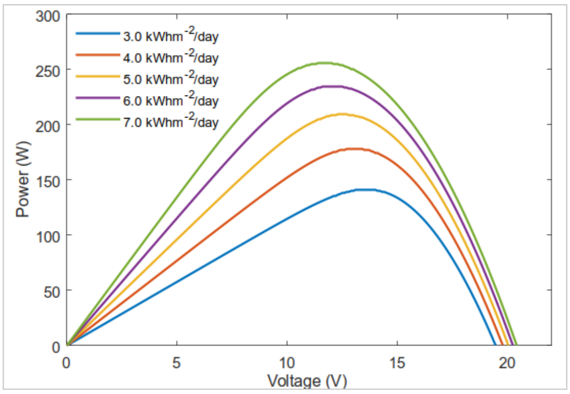

Figure 7: Solar PV generated power at 45 °C, at different geographical region of Nepal at difference irradiance level

Considering different possible temperature in context of Nepal the solar power generated by PV module generated as shown in Figures 7–9. On comparing the power generated across the different region of Nepal with solar irradiance (figure 3 as references). The observation shows at 45°C, power generation in western part of Butwal can produce up to 150 W across the terai and up to 200 W across hilly region of different places of Nepal. Similarly, in the region of the Himalayas, solar PV systems generate significantly more power than terai and hilly region i.e. up to 250 W. The difference in power generated by solar PV is due to higher solar irradiation in the western Himalayas compared to the eastern region, leading to greater power generation.

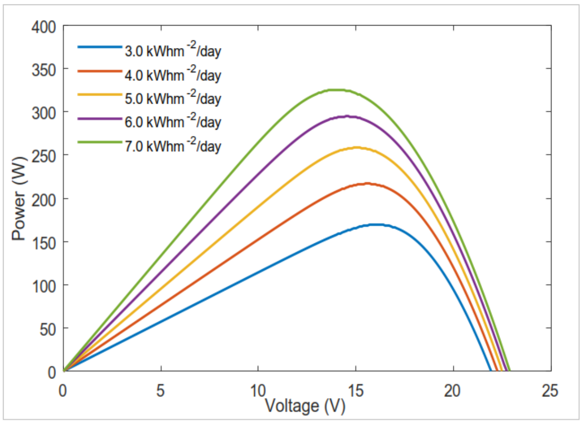

Figure 8: Solar PV generated power at 25 °C, at different geographical region of Nepal at difference irradiance level

On comparison of higher irradiance level in Himalayan region of Nepal, especially Mustang, Kehami, as well as Jomsom region photovoltaic solar energy generation is significantly higher than in other regions of Nepal and observed up to 345 W as shown in figure 8. Power output is higher in the western Himalayas due to greater solar irradiation, peaking at 345 W compared to 270 W in the east. This shows how geographic differences in sunlight directly affect solar PV performance, less pollution, sunshine peak hour, good orientation of solar panel, etc.

In general, the solar PV power generation differs between the western along with eastern Himalayas shows western Himalayan region maximum at 375 W, whereas in the eastern Himalayan region it can reach 300 W at considered temperature. The examination of the effect temperatures have on power generation finds a consistent pattern across many regions and conditions. With decreasing temperature, power output increases, accompanied by a shift to higher voltages. Figures 7–9 show that the power convergence occurs approximately 20 V at 45°C, 22 V at 25°C, along with 24 V at 0°C. These findings are consistent with prior studies [8,13], supporting the observed phenomenon of power generation increasing voltage under varied irradiation. Studying these dynamics is critical for optimising the deployment as well as efficiency of solar PV systems across various geographical locations, hence supporting the country's sustainable energy development.

3.4 Impact of Global Horizontal Irradiance on Photocurrent

Figure 10 shows, how global horizontal irradiance effect photocurrent generated by solar PV module at different temperature in Nepal (the region is consider for Nepal from figure 3). On the absis of real data the three temperature scenarios (-40°C, 25°C, along with 45°C) were used to measure photocurrent fluctuation. The study analysed photovoltaic cells' photocurrent production at various worldwide horizontal radiation levels, which varied from 3 kWh/m^2/day to 7 kWh/m^2/day. The observation shows photocurrent was linear with regard to the global horizontal irradiance as shown in figure 10. Photocurrent readings ranged from 9 to 19 A at different irradiance level. Also, at higher temperature the yield in photocurrent higher than lower temperature as example amount of photocurrent at 45°C is greater than that at 25°C and -40°C, emphasising the effect of temperature on the photocurrent generation.

3.5 Impact of Cell Temperature on Photocurrent

Figure 11 depicts the fluctuation in photocurrent depending on cell temperature, which ranges from 10.7 A to 11.5. The observation shows as the cell temperature increase photocurrent also increases. However, the fluctuation was small, and photocurrent values remained within a narrow range. Also, the global irradiance has impact on photocurrent at different irradiance level means higher the level of irradiance higher the production of photocurrent. This shows that both irradiance and temperature have effects on photocurrent and consider panel generated current up maximum at the region of Nepal where irradiance as well as temperature is both high.

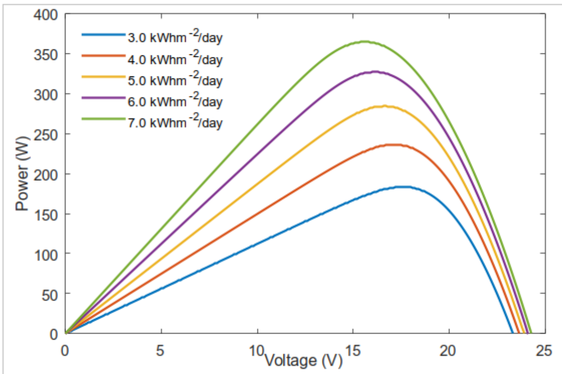

Figure 9: Photocurrent generate with global horizontal irradiance at differential temperature

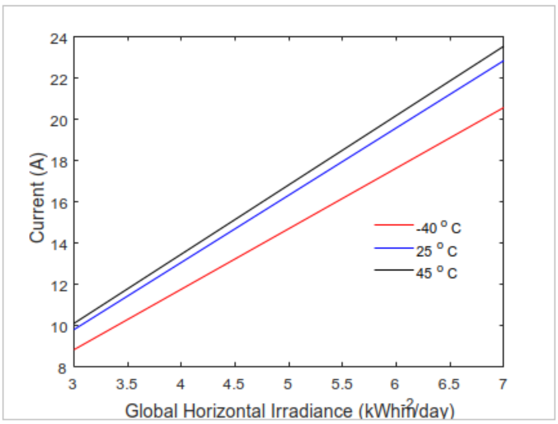

Figure 10: Photocurrent generate with global horizontal irradiance at differential temperature

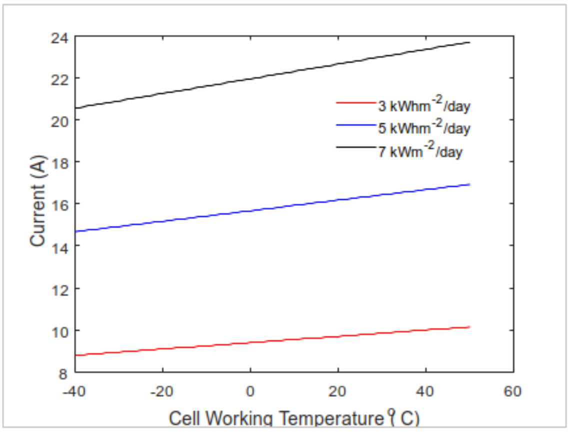

Figure 11: Cell Working Temperature vs Photocurrent

3.6 -benefit analysis of deploying PV systems in different regions

For cost-beneficial analysis of different geographical region of Nepal on the basis of solar irradiances and power generation. A solar system setup consists of a 365 W panel costing NPR 57,300, an MPPT controller priced at NPR 12,190, and installation expenses of NPR 2,000. A battery system with a lifespan of 8 years, requiring three replacements over the 25-year system lifespan, adds NPR 156,900 to the cost (3 batteries × NPR 52,300 each). The total investment amounts to NPR 228,390. The system assumes a performance ratio of 0.8, with average Peak Sun Hours (PSH) of 6.5 kWh/m^2/day at Himalayan region location and 4.4 kWh/m^2/day at Himalayan region location. Electricity is valued at 15 NPR/kWh, and the system is designed to operate over a 25-year lifespan. The annual energy output of a 365 W solar panel is calculated using the formula: $E = 0.365 \times PSH \times 365 \times 0.8$, where 0.8 is the assumed performance ratio. For the Himalayan region place, with Peak Sun Hours (PSH) of 6.5 kWh/m^2/day, the panel generates approximately 693.31 kWh/year, while for the Eastern half place, with 4.4 PSH, it produces 469.46 kWh/year. Over a 25-year system lifespan, the total energy output is 17,332.75 kWh for Himalayan region and 11,736.5 kWh for Eastern half. The Levelized Cost of Energy (LCOE) is then calculated as the total system cost divided by the lifetime energy output. With a total investment of NPR 228,390, the LCOE is 13.18 NPR/kWh for Himalayan region and 19.46 NPR/kWh for Eastern half.

The solar system, equipped with a 365 W panel and designed for daily use, can effectively support a combination of common household appliances. These include five 9W LED bulbs (totaling 45W), five 5W mobile chargers (totaling 25W), and two 60W laptops (totaling 120W), resulting in a combined power demand of 190W. Since the panel provides 365W of peak power and generates approximately 693.31 kWh/year (1.9 kWh/day) at Himalayan region location and 469.46 kWh/year (1.29 kWh/day) at Eastern half location, it can comfortably run these 190W loads for several hours daily—around 10 hours/day at Himalayan region and about 6–7 hours/day at Eastern half — demonstrating its suitability for basic residential or off-grid use. To meet a daily energy consumption of 950 Wh (0.95 kWh) for 5 hours of use, a battery capacity of about 1,140 Wh is needed after adding a 20% buffer for losses and cloudy days. For a 12V system, this equals roughly 95 Ah, but considering a 50% depth of discharge (DoD) for lead-acid batteries, the total required capacity becomes 190 Ah at 12V. This setup can reliably power 5 LED bulbs, 5 mobile chargers, and 2 laptops running for 5 hours daily.

Table 2 compares the electricity prices between solar systems and government-supplied electricity in different regions. While the Levelized Cost of Energy (LCOE) from the solar system ranges from 13.18 to 19.46 NPR/kWh—higher than the urban government rate of 10 NPR/kWh—it is notably cheaper than the rural-hilly government rate of 21 NPR/kWh, especially in the Himalayan region where solar is about 37% cheaper. Despite the higher per-unit cost of solar electricity in some areas, the overall investment in extending the government grid to remote, geographically challenging locations like mountainous villages in Nepal is significantly greater. This is because the difficult terrain and dispersed settlements increase infrastructure costs, making solar systems a more viable and cost-effective solution for electrification in such off-grid areas.

Table 2: Comparison of electricity price.

Location	LCOE from Solar System (NPR/kWh)	NEA Rural-Hilly (NPR/kWh)	NEA Normal Urban (NPR/kWh)	Cost Difference (Solar and Govt) Urban	Compare Urban (Solar - Govt)	Cost Difference Rural-Hilly (Solar - Govt)	Compare Rural-Hilly (Solar - Govt)
Himalayan region	13.18	21	10	+3.18	31.8% more	-7.82	Cheaper by 37%
Eastern half	19.46	21	10	+9.46	94.6% more	-1.54	Cheaper by 7%

3.7 Payback period

Payback Period is defined as the amount of time required for an investment to generate enough savings or revenue to recover the initial cost. It is calculated using the formula: Payback Period=Initial Investment/Annual Savings. where Initial Investment is the total upfront cost of the system, and Annual Savings represents the yearly financial benefit or revenue generated from the investment. A shorter payback period indicates quicker recovery of the invested capital. The solar system, with a total investment of NPR 228,390, demonstrates different payback periods depending on location. In the Himalayan region, the system generates 693.31 kWh/year, resulting in annual savings of NPR 14,559.5 based on an electricity rate of 21 NPR/kWh. This leads to a payback period of approximately 15.7 years. In the Eastern Half, with a lower annual output of 469.46 kWh/year, the annual revenue is NPR 9,858.66, resulting in a longer payback period of around 23.2 years. These figures highlight that the system is more financially favorable in locations with higher solar radiation like the Himalayan region.

3.8 Return on Investment

Return on Investment (ROI) measures the profitability of an investment by comparing the net gain to the initial cost. It is calculated as:

$$ROI = \frac{Total\ Savings\ over\ lifetime - Investment}{Investment} \times 100\%$$

where Total Savings over Lifetime is the cumulative financial benefit gained from the investment, and Investment is the initial cost. ROI expresses the percentage return relative to the original investment, indicating how much profit (or loss) was made. The Return on Investment (ROI) of the solar system varies significantly between regions due to differences in solar energy availability. In the Himalayan region, the system generates a total of 17,332.75 kWh over 25 years, translating to a total revenue of NPR 364,000 at the rural electricity rate of 21 NPR/kWh. This results in an ROI of approximately 59.4%, indicating a substantial gain over the initial investment of NPR 228,390. In contrast, the Eastern Half yields a lower total energy output of 11,736.5 kWh, generating NPR 246,465 in revenue over the same period, which gives an ROI of only 7.9%. This means the system is much more economically beneficial in high-irradiance areas like the Himalayan region, where energy production is higher and payback is quicker, while returns are minimal in lower-irradiance regions like the Eastern Half.

3.9 Net Present Value

Net Present Value (NPV) evaluates the profitability of an investment by calculating the present value of future cash flows discounted at a specific rate. Assuming a discount rate r=6%, NPV is calculated as:

$$NPV = \sum_{t=1}^{25} \frac{Annual\ Saving}{(t+0.6)^t} - Inverstemnt$$

Assuming a discount rate of 6%, the Net Present Value (NPV) analysis reveals that the solar system yields negative returns in both locations over the 25-year lifespan. In the Himalayan region, with an annual cash flow of NPR 14,559.5, the NPV is calculated as 14,559.5 × 11.9247 228,390 = NPR 54,727.5, indicating that the system does not recover its initial investment in today's monetary terms. Similarly, in the Eastern Half, the lower annual cash flow of NPR 9,858.66 results in an even more negative NPV of NPR 110,850. These findings suggest that while the system performs better in high-irradiance areas like the Himalayas, it still falls short of being financially viable when discounted future earnings are considered, highlighting the need for either cost reduction or subsidy support for greater feasibility.

3.10 Limitations of research

This study is subject to several limitations. Solar irradiance in Nepal varies significantly by season and region, ranging from 4.5 kWh/m^2 in December to 7.2 kWh/m^2 in May, with the Himalayan regions such as Mustang, Kehami, and Jomsom exhibiting higher irradiance (6–6.5 kWh/m^2/day) compared to the eastern half, which remains below 4.4 kWh/m^2/day. These variations, along with temperature fluctuations that affect current output and voltage, directly impact solar PV performance. However, the financial analysis in this study—covering Payback Period, ROI, and NPV—was conducted based solely on a single 365 W solar panel, MPPT controller, installation, and battery replacement over a 25-year lifespan. Furthermore, the simulation of power generation and energy output relied on secondary data rather than real-time field measurements, which may limit the accuracy and generalizability of the results across diverse geographic and climatic conditions in Nepal.

4 Conclusion

The observation shows Nepal's enormous possibilities for solar energy harnessing, specifically in the Himalayan region with high irradiation levels. Also, findings indicate a clear relationship between solar irradiance, the outside temperature, along with PV system performance. That means greater irradiance along with lower temperatures producing larger current and power outputs. The linear relationship between horizontal global irradiance and photocurrent demonstrates the predictability of PV system performance under changing environmental condition. These findings can help policymakers and stakeholders promote renewable energy adoption while encouraging sustainable development activities in Nepal. The Himalayan region is the more favorable location for solar PV deployment due to greater solar energy availability, resulting in faster cost recovery and higher returns. Although both regions exhibit negative NPVs, the system is more economically viable in the Himalayas, while cost reductions or subsidies may be needed to improve feasibility in lower-irradiance areas like the Eastern Half. Further study might concentrate on enhancing PV system models and incorporating energy storage options to improve grid resilience as well as stability when faced with of climate change risks.

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