COMPREHENSIVE ASSESSMENT OF PERFORMANCE AND FEASIBILITY OF SELECTED GRID-CONNECTED ROOFTOP SOLAR PV PLANTS IN MYSURU, KARNATAKA, INDIA

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Abstract:

With its abundant solar energy resources, India holds immense potential to integrate solar power into its renewable energy goals. This study evaluates the technical feasibility and performance of grid-connected rooftop solar photovoltaic (PV) systems in Mysuru, Karnataka, using PVsyst software across seven sites. The analysis spans academic, industrial, and residential sectors, highlighting discrepancies between projected and actual energy outputs. Sites 3, 5, and 6 show room for improvement through better shading management, equipment upgrades, and maintenance, while high-performing sites like Site 7 offer capacity expansion opportunities. A survey of 2,000 participants identified cost and awareness as adoption barriers. Recommendations focus on education, infrastructure, and supportive policies to promote sustainable energy.

1 Introduction

The interrelated problems of climate change and the need for energy security have made this shift toward renewable energy sources important to international attention. Among several renewable alternatives, solar energy stands out due to its wide availability, sustainability, and potential for use in highly populated areas through rooftop photovoltaic (PV) installations [1][2]. It's more promising for meeting the energy demand of urban cities through reduced consumption of nonrenewable energy sources [3]. India has proven to be more proactive in mainstreaming solar power into its energy system, which the National Solar Mission has taken the initiative and already has programs aiming to achieve a total solar capacity of 280 gigawatts by 2030. Rooftop solar power helps in achieving that because it will decentralize generation and stabilize the grid [4][5]. Karnataka, the renewable energy leader state in India, has established the Renewable Energy Policy (2022–2027), targeting of 1,000 MW of rooftop solar capacity. Net metering, feed-in tariffs, and capital subsidies have served as a catalyst in its adoption. Karnataka is being seen as a model for renewable energy implementation [6][7]. Mysore is one of the ideal settings in southern Karnataka for rooftop solar PV systems. Its consistent solar radiation, moderate climatic conditions, and urban infrastructure provide a strong foundation for renewable energy initiatives [8][9]. Regional factors like solar insolation, shading, and module orientation have been shown in studies to impact rooftop PV performance significantly; hence, site-specific analysis is necessary [10] [11]. Simulation tools like PVsyst have changed the face of rooftop PV system evaluation in assessing energy yields, system efficiency, and economic viability [12] [13]. Ahmed et al. showed the effectiveness of PVsyst in optimizing the design of a system incorporating tilt angle, azimuth, and shading [14]. Kumar and Gupta also demonstrated the ability of the tool to model climatic influences on energy production in Indian conditions [15]. These studies prove that PVsyst is a valuable tool for planning and decision-making in solar energy [16] [17]. Economic viability remains the bedrock for rooftop solar adoption. The payback period, internal rate of return, and levelized cost of electricity are sensitive to electricity tariffs, system costs, and government subsidies

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[18][19]. Patel et al. and Mehta et al. showed that net metering policies improve financial viability significantly by reducing the electricity prices and accelerating cost recovery [20][21]. Further, intermittency. Incorporating energy storage has further enhanced the merits of rooftop photovoltaic systems by overcoming intermittency issues and improving grid reliability [22][23]. Government incentives have been the driving force behind technology adoption. Reports from the Ministry of New and Renewable Energy (MNRE) and Karnataka Renewable Energy Development Limited (KREDL) reflect the importance of effective clearance procedures, fiscal benefits, and promotional campaigns for raising consumer awareness to encourage the installation of rooftop solar technologies [24][25].

The Karnataka Electricity Regulatory Commission (KERC) has been instrumental in the implementation of net metering policies that enable the flow of surplus energy generation back into the electricity grid [26][27]. Worldwide, the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA) have also acknowledged the role of rooftop solar systems in the pursuit of energy sustainability targets [28][29]. However, there are performance issues, including grid stability, system degradation, and seasonality-driven variability in energy payback. Joshi et al. and Rajasekar et al. identify the importance of performance challenges, which could only be mitigated through localized assessments and capacity-building programs [30][31]. Das et al. also discussed the integration challenges of rooftop PV systems in high-density urban grids and recommended innovative solutions to overcome infrastructural bottlenecks [32]. Despite these developments, the adoption of rooftop solar systems in Mysore remains underexplored, and a comprehensive analysis of technical and economic feasibility is required. This study will bridge this gap by analyzing the operational efficiency and economic feasibility of grid-connected rooftop solar photovoltaic systems in Mysore, Karnataka, using the PVsyst software. It will incorporate local climatic data, applicable government policies, and energy pricing regimes to provide real-world recommendations to stakeholders such as policymakers, investors, and end-users [33][34]. India's renewable energy industry has grown substantially in recent years, with particular interest in rooftop solar photovoltaic (PV) systems, due to positive policies, technological advancements, and increased sensitization toward sustainability. Different studies comparing PVsystems for different climates within India have found that climates within India have found that the solution of the solar system varies largely with different climatic conditions. These studies found that temperature, humidity, and many other environmental factors affect the efficiency of the rooftop solar systems' energy production [35]. With the increasing popularity of rooftop solar PV systems, efforts have been made to identify ways of improving their efficiency. Notably, this has been done by improving the general system design and optimizing its various components to best suit the local climatic conditions. Efficiency improvement measures have targeted increasing the energy output from the system and overall performance [36]. Besides the technological advancement, the policy implications have been significant in making the rooftop solar systems more acceptable. With net metering, consumers can feed surplus solar energy into the electrical grid, which tends to make the installation of the solar system more financially viable. Studies based on net metering policies identified that such policies are significant for increasing the large-scale adoption of rooftop solar photovoltaic systems in India [37]. Moreover, studies on regional adoption, like Karnataka, have offered deeper,more profound insights into what drives rooftop solar PV adoption.

The most prominent factors are state-level policies, financial incentives, and the availability of suitable infrastructure [38]. Secondly, lifecycle analyses of rooftop solar PV systems revealed long-term environmental and economic benefits of solar energy. The following analyses evaluate rooftop solar installations' carbon abatement and economic payback over their operating life cycle to support India's overall sustainability goals [40]. Despite these benefits, there are still challenges to the integration of rooftop solar systems into urban electrical grids. Technical issues such as grid stability and energy storage need to be addressed to ensure these systems can operate smoothly in urban environments [41][42]. Regional evaluation of solar potential has become an important strategy in boosting rooftop solar installations in India. For instance, regional evaluation of rooftop solar capacity in Karnataka has identified locations with high solar irradiance and available rooftops, which has enabled targeted policy interventions to maximize solar energy generation [49]. Policy structures for achieving renewable energy targets will be necessary for promoting rooftop solar installations in India. These policy structures enhance the implementation of solar energy within both the urban and rural areas, hence the realization of renewable energy targets in India [45]. To improve rooftop solar system design and performance, PVsyst is a widely used simulation software. These devices allow the evaluation and enhancement of the overall performance of solar systems based on the local environmental conditions, thus making the solar power installations more efficient [46]. Integrating rooftop solar energy into the Indian grid is a long-term challenge. Policy initiatives, technological advancement, and better infrastructure should be adopted to deal with the inherent fluctuating nature of solar energy so that the country can achieve its energy demands through renewable resources [43] [44] [50].

2 Methodology

2.1 Assumptions and limitations of studies

Assumptions

- *Standard Weather Data:* The simulation relies on typical meteorological year (TMY) data, assuming consistent irradiance and temperature conditions.
- *Ideal Panel Performance:* PV modules are considered to operate under manufacturer-specified conditions, with minimal degradation over time.
- *Constant System Efficiency:* This assumption assumes that inverters, wiring, and other components perform at rated efficiency without significant losses due to aging.
- *No Unexpected Shading:* This policy considers shading only from predefined obstacles and not from seasonal changes, dirt accumulation, or temporary obstructions.
- *Stable Grid Conditions:* Grid voltage and frequency are assumed to remain within acceptable limits for optimal power injection.
- *Uniform Module Aging:* PV module degradation follows a predictable rate (~0.5% per year), ignoring potential failures or irregular degradation.
- *Accurate Economic Inputs:* Financial analysis assumes fixed electricity tariffs, subsidy policies, and stable maintenance costs.

Limitations

- *Weather Variability:* Actual solar radiation, temperature, and wind speed fluctuations may differ from modeled data, affecting performance predictions.
- *Unaccounted Real-World Losses:* Dust accumulation, module mismatches, and irregular shading can cause higher losses than estimated.
- *Simplified Electrical Modeling:* This method assumes uniform current-voltage characteristics, which may not hold true under partial shading or temperature variations.
- *Grid Instability Effects:* Does not fully account for voltage fluctuations, power outages, or curtailment due to grid constraints.
- *Limited Aging Considerations:* Long-term performance is estimated based on linear degradation, ignoring potential component failures or efficiency drops.
- *Economic Uncertainties:* Electric price changes, policy incentives, and financing costs may impact financial viability.
- *Software Constraints:* PVsyst simulations are based on predefined models and databases, which may not accurately capture all site-specific conditions.

Novelty of work:

- *Comprehensive Multi-Sector Analysis* – This study uniquely evaluates the performance and feasibility of rooftop solar PV across academic, industrial, and residential sectors in Mysuru, providing a diverse perspective on solar adoption.

- *Real vs. Simulated Performance Comparison*—Unlike many studies that focus only on theoretical simulations, this work compares real-world energy generation data with PVsyst simulations, identifying discrepancies and areas for improvement.
- *Localized Feasibility Study* – The research incorporates site-specific climatic, economic, and policy factors, making it highly relevant to Karnataka's renewable energy landscape.
- *Survey-Based Consumer Insights* – A large-scale survey of 2,000 participants assesses public awareness, adoption barriers, and policy effectiveness, offering a data-driven perspective on consumer behavior.
- *Actionable Policy and Optimization Recommendations*—The study analyzes performance gaps and provides targeted recommendations on shading management, system upgrades, and maintenance strategies to improve PV efficiency.

2.2. Site Details

The site details are illustrated in Table 1.

Table 1. Site details.

Attribute	Details
Location	Mysuru, Karnataka, India
Latitude	12.2958°N
Longitude	76.6394°E
Population (2023)	~1.281 million
Climate Type	Tropical Savanna (Tending to Semi-Arid)
Annual Rainfall	70 - 110 mm
Average Temperature	~27.04°C

Solar energy potential, the Global Horizontal Irradiation (GHI) map for India and the selected area for the study, Mysuru, is presented in Figure 1.

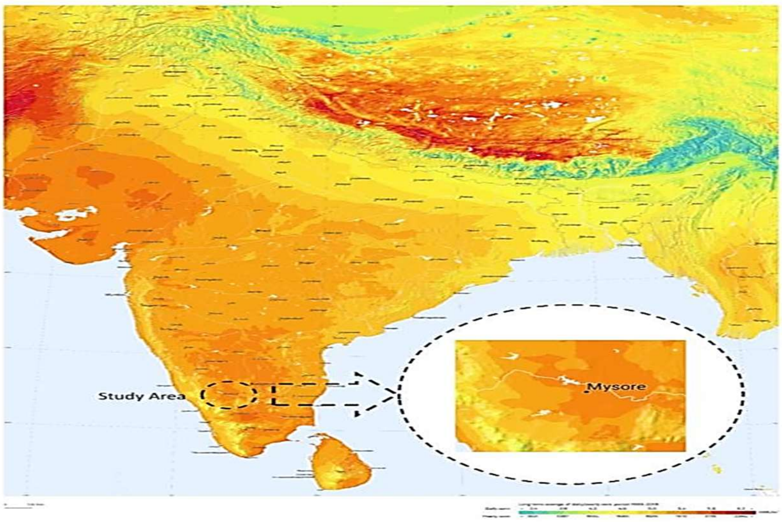

Figure 1. GHI Map of India [42].

This study includes examining data from seven distinct commercial rooftop solar photovoltaic (PV) projects in Mysuru. These projects, featuring rooftop installations with capacities ranging from 45 kW to 200 kW, are situated within a 287 km^2 (approximately a 10 km radius) around Mysuru. Each of these installations operates in areas sharing similar climatic conditions and topographical features and serves communities with comparable socio-economic backgrounds. The selection of these seven rooftop solar grids was influenced by the fact that they are managed by two different types of entities: academic institutions and manufacturing industries. This diversity in management allows for an in-depth study of varying operational, management, and policy issues. Detailed information on these seven solar PV plants is listed in Table 1, while the locations and satellite photographs of the plants are shown in Figure 2.

Table 2. Details of 7 rooftop solar PV power plants.

Solar PV plant number	Geographical coordinates	Type of entity	Total installation capacity (kW)
1	12.33634812083643 °N, 76.61886456719172 °E	Academic	**170**
2	12.371227185096894 °N, 76.58494455851539 °E	Academic	**82.9**
3	12.283800185267436 °N, 76.64121697985024 °E	Academic	**180**
4	12.361802258861957 °N, 76.62893974200182 °E	Academic	**198**
5	12.314539522441722 °N, 76.77052190359102 °E	Academic	**94.5**
6	12.354036852626814 °N, 76.59455008262935 °E	Manufacturing industry	47.8
7	12.36512271700577 °N, 76.63456708123125 °E	Manufacturing industry	198

Plant 1: 12.33634812083643 °N, 76.61886456719172 °E

Plant 2: 12.371227185096894 °N, 76.58494455851539 °E

Plant 3: 12.283800185267436 °N, 76.64121697985024 °E

Plant 4: 12.361802258861957 °N, 76.62893974200182 °E

Plant 5: 12.314539522441722 °N, 76.77052190359102 °E

Plant 6: 12.354036852626814 °N, 76.59455008262935 °E

Plant 7: 12.36512271700577 °N, 76.63456708123125 °E

Figure 2. Satellite pictures of 7 selected rooftop solar PV power plants in Mysuru.

2.3 Justification for Site Selection: Academia vs. Industry

Academic Institutions

- *Large Rooftop Availability:* Ideal for solar PV installation without extra land requirements.
- *Consistent Energy Demand:* Supports classrooms, labs, and administrative buildings.
- *Sustainability & Research:* Aligns with green campus initiatives and is a learning tool.
- *Government Incentives:* Many institutions qualify for subsidies and grants.

Manufacturing Industries

- *High Energy Consumption:* Solar PV offsets electricity costs and reduces grid dependency.
- *Large Rooftop/Open Space:* Industrial facilities have ample areas for solar panels.
- *Operational Efficiency:* Helps manage peak demand and ensures a stable power supply.
- *Environmental Compliance:* Reduces carbon footprint, supporting CSR and regulatory goals.

2.4 Simulation Methodology

PVsyst 7.2 is powerful software for photovoltaic systems' design, simulation, and performance analysis. It helps users model different types of PV systems, evaluate their energy production, and assess their financial and environmental feasibility.

The methodology for using PVsyst 7.2 in designing and analyzing PV systems is illustrated in Figure 3.The simulation approach to the grid-connected rooftop solar photovoltaic system is systematic , as seen in the flowchart.

A brief overview is given below:

- Project Initialization
  a) Establish a new grid-connected facility.
  b) Choose the geographical location and submit the pertinent information.
  c) Set project specifications.
  d) Photovoltaic System Configuration
- Define tilt angles (summer, winter, and fixed).
  Define azimuth direction and angle.
  Set seasonal tilt if needed.
  Define planned PV power and available PV area.
  Photovoltaic Array and System Design
- Select photovoltaic modules and inverters.
- Design the array structure and the system.
- Consider shading conditions (no shading or near shading).
- Run the simulation.
- Performance Analysis and Results
- Compute nominal and generated energy.
- Evaluate energy delivered to the network:.
- Track PV module temperature and system losses.
- Calculate the normalized energy yield and performance ratio.
- Study global irradiation on collector and horizontal planes. Create a system loss diagram.

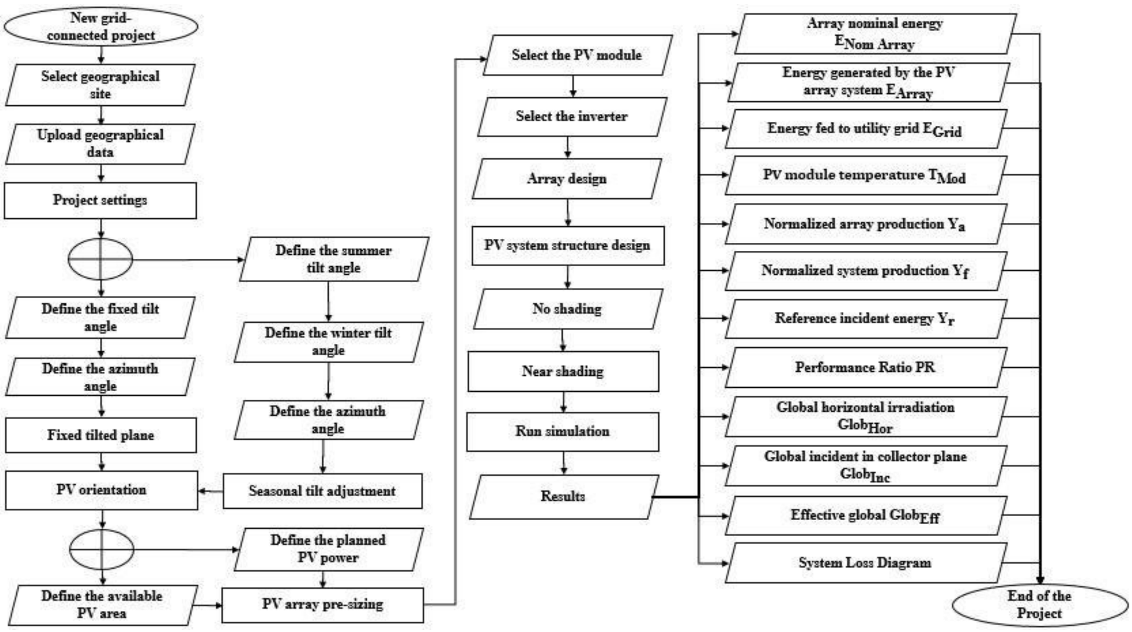

Figure 3. Flowchart for using PVsyst 7.2 in designing and analyzing PV systems.

2.3 Solar PV System Configuration

Table 3. Solar PV System configuration.

Solar PV plant number	Geographical coordinates	Type of entity	No. of PV array's modules	No. of inverters	Total installation capacity (kW)
1	12.33634812083643 °N, 76.61886456719172 °E	Academic	523	3	170
2	12.371227185096894 °N, 76.58494455851539 °E	Academic	255	3	82.9
3	12.283800185267436 °N, 76.64121697985024 °E	Academic	555	5	180
4	12.361802258861957 °N, 76.62893974200182 °E	Academic	630	4	198
5	12.314539522441722 °N, 76.77052190359102 °E	Academic	300	4	94.5
6	12.354036852626814 °N, 76.59455008262935 °E	Manufacturing industry	184	2	47.8
7	12.36512271700577 °N, 76.63456708123125 °E	Manufacturing industry	760	2	198

The provided data in table 3 on solar PV systems across various academic and manufacturing locations reveals diverse configurations and capacities. Academic institutions typically have larger arrays with more modules, ranging from 255 to 630 modules, and capacities ranging from 82.9 kW to 198 kW, suggesting these systems are designed for sustainable energy generation and educational purposes. In contrast, manufacturing industries, though having fewer modules (184 and 760), focus on higher-capacity systems (47.8 kW and 198 kW) to meet the higher energy demands of industrial operations. The number of inverters, ranging from 2 to 5 per plant, is generally scaled to balance the energy output and system efficiency. These solar PV systems help reduce grid dependency, with larger systems suited to industry demands and more modular setups catering to academic institutions.

3 Solar PV System Real Time power generation V/s Simulated power generation

Table 4. Solar PV System Real Time generation data V/s Simulated dana.

Solar PV plant Site number	Geographical coordinates	Total installation capacity (kW)	Yearly Actual Power Output (MWhr) over 5 Years (2017-2023)	Yearly Simulated Power Output (MWhr)
1	12.33634812083643 °N, 76.61886456719172 °E	170	21.72	24.21
2	12.371227185096894 °N, 76.58494455851539 °E	82.9	10.24	11.62
3	12.283800185267436 °N, 76.64121697985024 °E	180	21.21	25.23
4	12.361802258861957 °N, 76.62893974200182 °E	198	24.59	27. 62
5	12.314539522441722 °N, 76.77052190359102 °E	94.5	8.48	13.32
6	12.354036852626814 °N, 76.59455008262935 °E	47.8	3.85	6. 69
7	12.36512271700577 °N, 76.63456708123125 °E	198	15.73	28.14

The dataset in table 4 provides a detailed performance overview of seven solar PV plants, highlighting their geographical coordinates, installed capacities, and yearly power outputs (both actual and simulated) over five years from 2017 to 2023. The analysis consistently shows a difference between the simulated and yearly power outputs. Such differences would imply operational inefficiencies, environmental impacts, or limitations in the accuracy of the simulation models. Such performance disparities would call for closer scrutiny of plant operations, site-specific conditions, and the assumptions used in the simulation process. Efficiency in actual to simulated outputs is quite high at most sites with considerable variation between sites. Site 2 is the most efficient, reaching 88.15% of its targeted power generation, while Site 5 is the least efficient, achieving only 63.67%. The reasons for the differences in efficiency could be site-specific issues such as shading, maintenance schedules, equipment quality, or differences in microclimates. Although the sites are geographically close to each other, differences in their environmental settings and operation strategies could significantly impact their performance. For example, Site 6 is one of the biggest gaps: with a capacity of only 47.8 kW, it could have achieved an actual output of only 57.55% of its calculated maximum.

This points to potential operational or design inefficiencies that need immediate attention. The relationship between installed capacity and power output also provides valuable insights. Sites with higher installed capacities, such as Site 4 (198 kW), naturally generate more energy in absolute terms, but their efficiency does not consistently align with capacity. For example, Site 1, with a moderate capacity of 170 kW, achieves a strong actual-to-capacity ratio of 12.78%, underscoring the importance of effective operational practices. Conversely, Site 5, with a capacity of 94.5 kW, underperforms significantly, generating only 8.48 MWhr annually compared to a simulated value of 13.32 MWhr. The persistent gap between simulated and actual outputs across all sites suggests that the models may not fully account for real-world variables such as equipment aging, environmental factors (e.g., dust or shading), and system downtime. This highlights the need for recalibrating simulation models using historical performance data to improve their predictive accuracy. Additionally, of advanced monitoring systems could provide real-time insights into operational issues, enabling timely interventions to reduce inefficiencies.

4 Other Simulated Results

4.1. Produced energy, Specific production and performance ratio

Table 5. Produced energy, Specific production and performance ratio.

Solar PV plant Site number	Geographical coordinates	Produced Energy(MWhr/year)	Specific Production (kWh/kWp/year)	Performance ratio
1	12.33634812083643 °N, 76.61886456719172 °E	279.6	1645	81.46
2	12.371227185096894 °N, 76.58494455851539 °E	1077	1667	82.41
3	12.283800185267436 °N, 76.64121697985024 °E	289.4	1604	79.49
4	12.361802258861957 °N, 76.62893974200182 °E	320.8	1623	80.22
5	12.314539522441722 °N, 76.77052190359102 °E	157.1	1663	82.46
6	12.354036852626814 °N, 76.59455008262935 °E	78.89	1649	81.43
7	12.36512271700577 °N, 76.63456708123125 °E	332.5	1676	82.80

Table 5 represents summary of performance metrics of seven solar PV plants: Geographical coordinates, annual energy generation (MWhr/year), specific production (kWh/kWp/year), and performance ratios. The performance metrics describe the operational efficiency and energy generated by the plants, which form the basis for evaluating their efficiency and identifying their improvement areas.

4.2 Annual Energy Production (MWhr/year)

Annual energy output varies significantly between plants; Site 7 is at the top of production with 332.5 MWhr/year, followed by Site 4 with 320.8 MWhr/year. The lowest one is Site 6 at 78.89 MWhr/year. Production obviously depends on installed capacity, site-specific conditions, like shading or dust, and operating practice.

4.3 Specific Production (kWh/kWp/year):

Specific production represents a fair measure of the plant's efficiency of using installed capacity. Sites 2, 5, and 7 recorded the highest specific productions, within the range of 1663 to 1676 kWh/kWp/year, which leaves an impression of having optimized performance with regard to their installed capacity. On the other end of the scale, Site 3 has the lowest specific production of 1604 kWh/kWp/year, indicating inefficiency and a matter for improvement through optimization on sites or through better maintenance practices.

4.4 Performance Ratio (PR):

The performance ratio represents the overall efficiency of a solar PV plant, considering losses from the system, environment, and other factors. PRs for all the sites lie in a narrow band of 79.49% to 82.80%, implying that the plants are performing pretty uniformly. Site 7 has achieved the highest PR at 82.80%, which implies very good operation efficiency with almost negligible energy losses. On the other hand, Site 3 has the least PR at 79.49%, indicating improvement potential to decrease losses.

4.5 Comparative Insights

High Performers:

Site 7: This plant has the best overall performance with the highest energy production (332.5 MWhr/year), specific production (1676 kWh/kWp/year), and PR (82.80%). This means it has an efficient mix of optimal design, location, and operational efficiency.

Site 2: This is another high performer with a PR of 82.41% and a specific production value of 1667 kWh/kWp/year, which means that it is effectively using its installed capacity.

Low Performers:

Site 3: Lowest specific production = 1604 kWh/kWp/year combined with PR of 79.49% presents inefficiencies potentially due to an inappropriate design or shading and the lack of adequate maintenance.

Site 6: Specific production, 1649 kWh/kWp/year, along with PR = 81.43%, is within a realistic range. Low energy is produced at 78.89 MWhr/yr, which must be due to its smaller capacity. A capacity increase must be considered depending on site conditions.

Geographical Influence:

This may indicate that sites' geographical proximity has minimal effect on solar irradiance. Therefore, performance differences must be due to factors such as equipment quality, maintenance schedules, and site-specific conditions like dust accumulation or shading.

4.6 Recommendations for Improvement

- *Targeted Optimization:* In detail, audit sites with low performance, especially Sites 3 and 6, for design inefficiencies, shading, or operational practice issues. Address site-specific problems such as better panel cleaning and reducing shading to improve these sites' performance.
- *Capacity Enhancement:* Determine if the capacity of good performers, like Site 7, can be expanded to capitalize on superior efficiency and potential energy yield.
- *Performance Monitoring:* Implement advanced monitoring systems to monitor real-time performance metrics, allowing for timely identification and resolution of inefficiencies.
- *Maintenance Practices:* Standardize maintenance protocols across all sites to ensure consistent practices that minimize performance degradation and maximize energy production.
- *Performance Benchmarking:* High-performing sites like Sites 2 and 7 are used as benchmarks for operational excellence, and their successful practices are applied to underperforming plants.
- *PR Optimization:* For sites with lower PR, focus on reducing system losses through measures like inverter optimization, cable loss reduction, and periodic system checks.

5 Energy balances and main Simulation results [Yearly average]

Table 6. Energy balances and main Simulation results.

Site No	Global Horizontal kWh/m²	Diffuse Horizontal kWh/m²	T_ Amb °C	Glob Incident kWh/m²	Glob Effective radiation kWh/m²	Energy produced by Solar Array MWh	Energy Supplied to grid MWh	Performance Ratio
1	1957.2	819.76	24.23	2019.1	1966.3	290.53	279.56	0.815
2	1962.8	816.72	24.31	2022.7	1965.0	1097.9	1077.4	0.824
3	962.0	815.19	24.51	2018.2	1960.7	302.72	289.35	0.795
4	1964.4	810.72	24.25	2023.6	1965.8	331.70	320.75	0.802
5	1960.7	811.98	24.44	2016.4	1971.8	159.82	157.13	0.825
6	1965.3	803.74	24.25	2025.0	1967.3	80.389	78.887	0.814
7	1964.4	810.78	24.25	2023.5	1965.8	337.61	332.52	0.828

The table 6 provides an in-depth analysis of the solar energy data across seven sites. The key parameters studied include solar radiation (global and diffuse), ambient temperature, global incident and effective radiation, energy production, grid supply, and the performance ratio. Below is a detailed examination:

5.1. Solar Radiation Analysis

Global Horizontal Radiation(GHR) represents the total solar radiation received on a horizontal plane. It significantly impacts the potential energy a solar system can generate. Most sites exhibit high GHR values around 1957–1965 kWh/m², suggesting favorable solar exposure. Site 3 deviates sharply with a GHR of only 962.0 kWh/m², indicating less solar availability. Possible causes include geographical location, seasonal variations, or shading.

5.2 Diffuse Horizontal Radiation (DHR)

DHR measures scattered sunlight, a component of GHR. High DHR values can indicate overcast conditions or atmospheric scattering.DHR values are consistent, with minimal variation across sites, ranging between 803.74 kWh/m² (Site 6) and 819.76 kWh/m² (Site 1).
The relatively stable DHR suggests atmospheric conditions are similar for all sites, making it less likely to be a significant differentiator.

5.3. Ambient Temperature

The ambient temperature can affect the efficiency of solar panelsexcessive heat may reduce panel performance.The temperature across all sites remains within a narrow range of 24.23°C to 24.51°C.
With such consistent temperatures, this parameter is unlikely to influence performance differences between sites significantly.

5.4. Global Incident and Effective Radiation

GIR measures the total solar radiation received on the tilted plane of the solar panels, which reflects the effect of panel orientation and tilt optimization.GIR values are consistently high, ranging from 2016.4 kWh/m² (Site 5) to 2025.0 kWh/m² (Site 6).Site 5 has the lowest GIR despite having high GHR, potentially due to suboptimal panel tilt or orientation.
Global Effective Radiation (GER)GER accounts for the usable radiation after accounting for system losses like shading, dirt, and reflection.
GER values closely follow GIR, with minor reductions (e.g., Site 5 shows a GER of 1971.8 kWh/m², slightly lower than its GIR). The minimal difference between GIR and GER across sites suggests good maintenance and minimal losses.

5.5 Energy Production and Grid Supply

Energy Produced by Solar Arrays

The energy produced is a function of available solar radiation and system efficiency.**Site 2** has the highest energy production at 1097.9 MWh, reflecting its high GIR and efficient system.**Site 6**, in contrast, produces only 80.389 MWh, likely due to its smaller system size or operational constraints.Sites 1, 3, 4, 5, and 7 demonstrate moderate energy outputs ranging from 159.82 MWh (Site 5) to 337.61 MWh (Site 7).

Energy Supplied to Grid

Due to in-house consumption and transmission losses, energy supplied to the grid is slightly lower than the total energy produced.The difference between energy produced and supplied to the grid is minimal, suggesting efficient energy transfer.The highest grid supply occurs at Site 2 (1077.4 MWh), while the lowest is at Site 6 (78.887 MWh).

5.6. Performance Ratio (PR)

PR measures the efficiency of a solar energy system, with values closer to 1.0 indicating better performance.PR values range from 0.795 (Site 3) to 0.828 (Site 7), demonstrating good overall efficiency across sites. Site 3 has the lowest PR, likely due to low GHR and potential inefficiencies in the system or environment. Sites 5 and 7 achieve the highest PR (0.825 and 0.828, respectively), indicating optimized operation and minimal losses.

5.7. Comparative Insights

Table 7. Comparative insights on Energy balances and main Simulation results.

Site	Key Strengths	Key Weaknesses
1	High GHR (1957.2 kWh/m²), consistent energy production	Moderate PR (0.815), indicating room for operational improvement
2	Highest energy production (1097.9 MWh) and grid supply (1077.4 MWh)	PR (0.824) slightly lower than top-performing sites
3	Moderate GER (1960.7 kWh/m²) despite low GHR (962.0 kWh/m²)	Lowest PR (0.795), indicating inefficiencies
4	High energy output (331.70 MWh)	PR (0.802) could be improved
5	Highest PR (0.825) and efficient energy supply	Lower energy output (159.82 MWh) due to small system size
6	High PR (0.814) and consistent GER	Lowest energy production (80.389 MWh)
7	Highest PR (0.828) and significant energy output (337.61 MWh)	No major weaknesses

5.8. Recommendations for Improvement

- *Optimize Panel Orientation and Maintenance:*
  - Sites with low PR, especially **Site 3**, should focus on optimizing panel orientation and regular cleaning to maximize usable radiation.
- *Expand Capacity at High-Performing Sites:*
  - Sites with high PR and moderate energy output, like **Sites 5 and 7**, could benefit from expanding system capacity to leverage their efficiency.
- *Investigate Low Radiation at Site 3:*
  - Conduct shading analysis or explore geographical/meteorological factors contributing to the low GHR at **Site 3**.
- *Reduce Losses Across All Sites:*
  - Even top-performing sites (e.g., Site 7) can further enhance PR by minimizing transmission losses and improving operational practices.

6 Feasibility analysis

This survey, consisting of 24 well-defined was designed to provide panoramic information regarding the characteristics of domestic properties, choices of energy sources, and utilization of solar energy systems. The responses gathered from 2,000 participants alone provided rich data encompassing quantitative metrics and qualitative feedback. The questionnaire covered a range of areas of interest, starting with general property details, such as housing type, geographical location, and rooftop features. It further examined critical factors that influence energy choices, including potential barriers to adopting renewable energy and familiarity with solar technologies and policies. Respondents were also asked about their perspectives on solar arrays, the impact of rooftop installations on communal life, and the perceived benefits of switching to solar energy. For those already utilizing solar panels, the survey collected details about installation capacity, the manufacturing company, metering systems, and observed changes in energy expenses. It also addressed maintenance issues and associated costs. Finally, the survey explored participants' willingness to transition to solar energy, even in scenarios where government policies provide free electricity. This thorough approach offered valuable insights into the factors shaping renewable energy adoption and sustainable energy practices.

6.1 Survey analysis on adoptability of Rooftop Solar PV Technology

Based on survey results, the chart provides insights into key barriers to adopting renewable energy. The most significant concern, cited by 12.25% of respondents, is the high cost associated with renewable energy systems. Closely following this, 11.90% highlighted the inefficiency of transportation systems reliant on renewable energy and difficulties in finding trustworthy suppliers. Concerns about outdated technology (10.65%), the aesthetic appeal of renewable devices (10.75%), prolonged return on investment (10.95%), and lack of information on renewable energy (10.50%) also emerged as notable challenges. These findings suggest a need for cost reduction, better infrastructure, trustworthy suppliers, and greater awareness to promote renewable energy adoption.

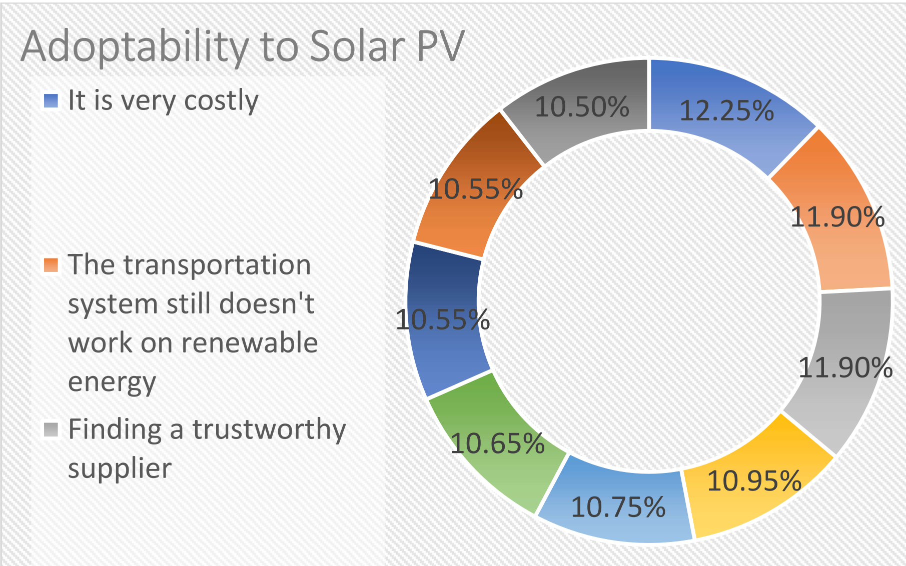

Figure 4. Survey analysis on adoptability of Rooftop Solar PV Technology.

6.2 Survey Analysis based on familiarity of Solar PV system

The chart reflects varying levels of familiarity with solar energy and related policies among respondents. The largest group, 21.35%, is slightly familiar, indicating they have heard about solar energy but lack detailed knowledge. Those unfamiliar with solar energy account for 20.80%, suggesting a significant portion of the population lacks basic awareness. Moderately familiar respondents make up 19.35%, showing some understanding but not of operational details. Meanwhile, 19.40% are very familiar with solar energy and its policies, such as net metering and financing. Finally, 19.10% are uncertain about their familiarity. These results suggest a need for targeted education at the school level,university level, and community level to bridge gaps in understanding and awareness of solar energy technologies and policies.

It is also required to carry out community engagement events on Television and news papers for more awarness and familarity about rooftop solar technology.

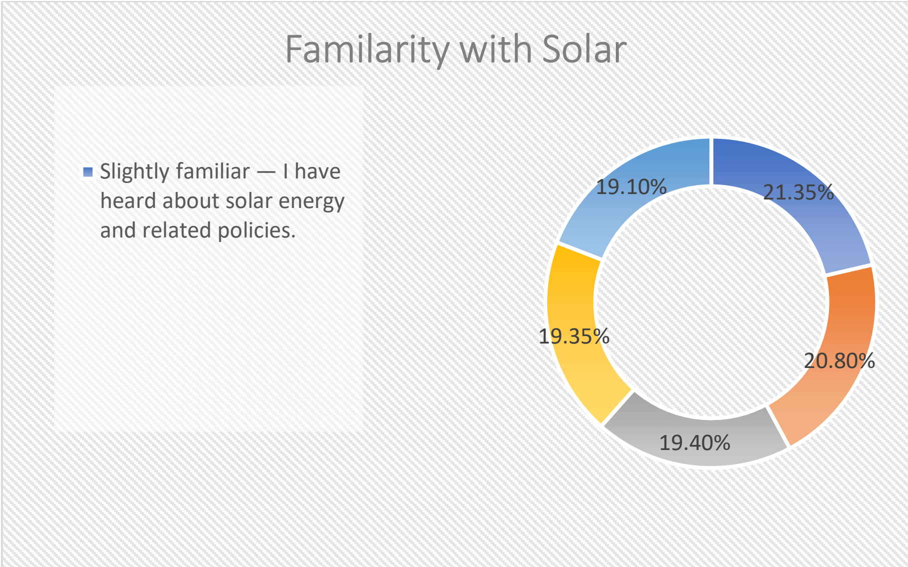

Figure 5. Survey analysis on familiarity of Rooftop Solar PV Technology.

6.3. Survey Analysis based on Interest in Solar PV

The chart below analyzes the barriers to adopting solar PV technology based on responses. The highest concern, indicated by 12.25% of respondents, is the high cost of solar PV systems. Another strong barrier, with a share of 10.95% of the responses, pertains to the lengthy period of return on investment, which reveals the financial feasibility of the option. The level of infrastructure constraints is 11.90%, with respondents indicating that the transport system is not yet optimally suited for renewable energies. Equally, 11.90% found it hard to get credible suppliers. Concerns related to technological obsolescence comprised 10.55% of the responses, while 10.50% said there is insufficient information on RE options. Amazingly, 10.75% of the respondents felt that the unsightly appearance of renewable energy gadgets is a turn-off. Overall, the findings suggest that addressing cost, financial returns, infrastructure, and education could go a long way in improving public interest and adoption of solar PV technology.

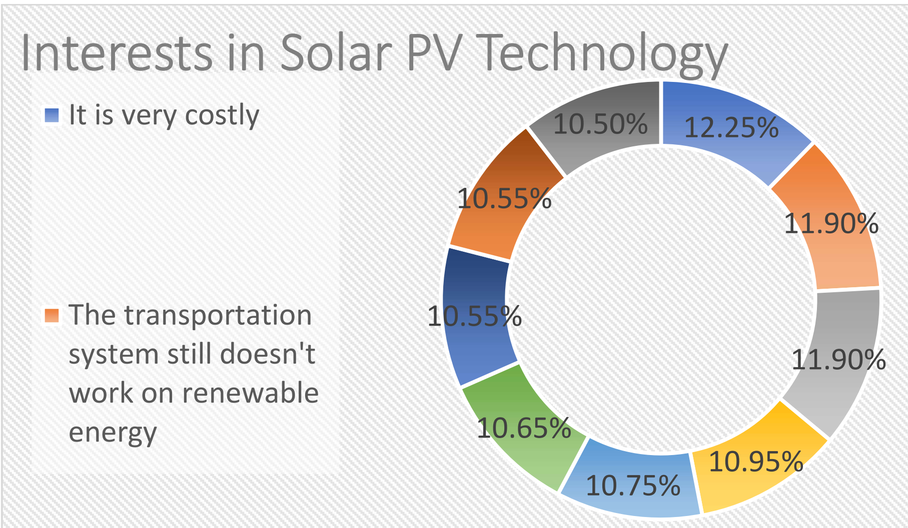

Figure 13. Survey Analysis based on Interest in Solar PV.

6 Environmental impacts

Implementing rooftop solar photovoltaic systems in Mysore City significantly contributes to reducing CO_2 emissions. Assuming an average monthly electricity consumption of 300 kWh per household and grid electricity emitting 0.92 kg of CO2 per kWh, properties using solar panels save around 209.87 kg of CO2 emissions monthly. Given a solar adoption rate of 10.65% among 2,000 surveyed properties, approximately 213 properties are equipped with solar systems.
These properties collectively save an estimated 44,701.49 kg of CO2 per month, which equates to a reduction of about 536,417.88 kg of CO2 emissions annually. This showcases the substantial environmental benefits of transitioning to solar energy, including decreased reliance on fossil fuels, lower greenhouse gas emissions, and reduced pollution. These findings highlight the role of renewable energy in mitigating climate change and promoting sustainability.

7 Conclusion

An analysis of the solar PV system at different research and industrial setups clearly shows scope for optimization in energy production and eliminating inefficiencies. However, despite its promising growth rate, the solar energy adoption market is still underlined by significant performance gaps between simulated and actual outputs, reflecting the need to improve equipment maintenance, system design, and operation practices. This inefficiency could be addressed with targeted interventions to improve shading management and performance monitoring.
The survey results show increasing awareness of solar energy, but there are still barriers to its use: it is pricey to get started with, and one is not informed about it. In addition, the adoption of solar PV has an important environmental impact in reducing CO2 emissions. Thus, refining operational strategies and enhancing public awareness can make solar energy play a pivotal role in advancing sustainability and reducing dependency on fossil fuels.

8 Conflict of Interest

The authors declare that they have no conflict of interest.

9 Acknowledgements

None.

10 Appendix

The questionnaire, comprising 24 questions, spanned multiple areas of interest and successfully gathered 2000 data points, encompassing quantitative and qualitative dimensions.

Number	Questions/Information
1	Timestamp
2	What is the type of property?
3	In which type of geographical area is your residence located?
4	What is the type of house?
5	The floor on which the family is residing?
6	Do you rent or own the property?
7	Do any large trees shade your home from the afternoon summer sun?

8	What type of roof do you have?
9	Do you have any arrangements/bodies on the rooftop that cause shading?
10	Can you please tell us how big your plot area of the building's rooftop is?
11	To what extent are the following barriers to switching from fossil fuels to renewable energy to you?
12	How would you feel about having a large solar array near your home?
13	Do you feel installing solar arrays on the terrace will affect your communal life?
14	How familiar are you with solar energy (i.e., solar panels or solar PV) and policies related to solar development?
15	Which benefits of solar energy (i.e., solar panels or solar PV) are most important to you?
16	Which among the following influence your decision to switch to green energy?
17	Have you installed solar panels?
18	What is the installation capacity of the solar panel system? (in kW)
19	Which company manufactured the solar panels used in the installation?
20	In what year was the solar panel system installed?
21	Is your solar panel system connected to a net or gross metering system?
22	By what percentage have you noticed a reduction in your energy bills since installing the solar panel system?
23	Have you experienced any maintenance issues with your solar panel system?
24	Have you incurred any maintenance costs for your solar panel system? If so, please mention the costs in INR
25	Finally, do you want to switch to Solar PV energy though the electricity is free as per the government's policy of free electricity

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