IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, July 2026
Impact Factor: 8.2

# Impact of Climatic Parameters on Solar Radiation Availability and Photovoltaic Energy Generation

**Patil Nitinkumar Surgonda[1] and Dr. Brijendra Mishra[2]**
[1]Research Scholar, Department of Electrical Engineering
[2]Research Guide, Department of Electrical Engineering
Vikrant University, Gwalior, M.P, India

**Abstract:** *Solar photovoltaic energy generation is strongly influenced by the availability and variability of solar radiation and by atmospheric and climatic conditions at the installation site. Although solar irradiance is the primary determinant of PV electricity production, parameters such as ambient temperature, relative humidity, cloud cover, wind speed, precipitation, atmospheric aerosols, and dust can substantially modify the amount of radiation reaching the module and the electrical efficiency of the PV system. This research paper examines the relationship between climatic parameters, solar radiation availability, and photovoltaic energy generation through a systematic analytical framework. Previous research indicates that irradiance has the strongest direct influence on PV output, while elevated module temperature generally decreases electrical efficiency. Cloud cover and humidity can reduce incident radiation, whereas wind can provide a cooling effect and partly offset temperature-related losses.*

**Keywords:** Solar Radiation, Photovoltaic Energy, Climatic Parameters, Temperature, Humidity, Cloud Cover, Wind Speed, Solar Irradiance.

## I. INTRODUCTION

The increasing demand for clean and sustainable energy has accelerated the deployment of photovoltaic technology across different climatic and geographical regions. Solar photovoltaic systems convert incident solar radiation directly into electricity, making solar irradiance the fundamental resource controlling PV generation. However, the amount of electricity actually generated by a PV module is not determined by solar radiation alone. Atmospheric conditions continuously alter the intensity, spectral characteristics, and distribution of radiation reaching the module, while temperature and wind conditions influence the operating temperature and electrical efficiency of the PV cells.

Solar irradiance varies considerably according to time of day, season, geographical location, atmospheric conditions, cloud movement, and solar position. Consequently, PV generation exhibits substantial temporal variability. AlSkaif et al. (2020), using meteorological and PV-output data, demonstrated that variables including temperature, relative humidity, wind speed, cloud cover, precipitation, and other meteorological characteristics can be useful in explaining PV output variability.

Temperature is particularly important because the electrical efficiency of conventional crystalline-silicon PV modules generally declines as cell temperature increases. Reviews of PV temperature behavior report temperature coefficients that commonly correspond to approximately 0.4–0.5% power loss per °C increase for crystalline-silicon systems, although the precise coefficient depends on module technology and operating conditions (Skoplaki & Palyvos, 2009).

Cloud cover is another major climatic parameter. Clouds can reduce direct solar radiation and alter the balance between direct and diffuse irradiance. Thick cloud cover can cause substantial reductions in PV output, while rapidly moving clouds can produce short-term fluctuations in generation. Recent reviews identify solar irradiance as the dominant factor while emphasizing the important effects of clouds, temperature, aerosols, humidity, dust, and wind.

Humidity also influences PV performance through atmospheric scattering, water droplets, condensation, and enhanced adhesion of dust particles to module surfaces. High humidity may therefore reduce the radiation reaching the cells and contribute to long-term module degradation. Wind speed has a more complex effect: stronger airflow can cool PV

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, July 2026
Impact Factor: 8.2

modules and reduce temperature-related efficiency losses. A field study at Westmill Solar Park found that, after solar radiation, relative humidity and cloud cover were important controls of PV electricity output, while wind conditions also affected generation through panel cooling.

## II. PROBLEM STATEMENT

Solar PV systems are often assessed primarily on the basis of available solar radiation. However, two locations receiving similar annual solar irradiance may produce different amounts of electricity because of differences in temperature, humidity, cloudiness, wind, precipitation, aerosols, and dust. High solar radiation accompanied by high module temperature, for example, may not result in proportionally high electricity production.

The major research problem is therefore to determine how climatic parameters influence solar radiation availability and how changes in these parameters subsequently affect photovoltaic energy generation. A systematic understanding of these relationships can improve PV system planning, performance prediction, seasonal energy assessment, and climate-resilient renewable-energy development.

## III. OBJECTIVES OF THE STUDY

The study has the following objectives:

1. To examine the influence of climatic parameters on solar radiation availability.
2. To determine the relationship between solar irradiance and photovoltaic electricity generation.
3. To investigate the effect of ambient temperature on PV energy generation.
4. To evaluate the influence of relative humidity and cloud cover on solar radiation and PV output.
5. To assess the role of wind speed in modifying PV module operating conditions and energy generation.
6. To compare climatic effects on PV generation across different seasons.
7. To develop a statistical framework for predicting photovoltaic energy generation from climatic variables.

## IV. RESEARCH QUESTIONS

1. What is the relationship between climatic parameters and solar radiation availability?
2. Which climatic parameter has the strongest influence on PV electricity generation?
3. How does ambient temperature affect PV output?
4. To what extent do humidity and cloud cover reduce solar radiation availability?
5. Does wind speed improve PV performance through module cooling?
6. How does the relationship between climatic parameters and PV generation vary seasonally?
7. Can climatic variables be used to reliably predict photovoltaic energy generation?

## V. HYPOTHESES

1. **$H_1$:** Solar irradiance has a significant positive relationship with photovoltaic electricity generation.
2. **$H_2$:** Ambient temperature has a significant relationship with photovoltaic energy generation.
3. **$H_3$:** Relative humidity has a significant negative relationship with solar radiation availability and PV energy generation.
4. **$H_4$:** Cloud cover has a significant negative relationship with solar radiation availability and PV energy generation.
5. **$H_5$:** Wind speed significantly influences photovoltaic energy generation.
6. **$H_6$:** Climatic parameters jointly provide a significant prediction of photovoltaic energy generation.
7. **$H_7$:** The relationship between climatic parameters and photovoltaic generation differs significantly across seasons.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, July 2026
Impact Factor: 8.2

## VI. REVIEW OF RELATED LITERATURE

### 1. Solar Irradiance and PV Generation

Solar irradiance is the most important environmental factor affecting photovoltaic electricity production. PV output generally increases with increasing incident irradiance because greater radiation provides more energy for conversion into electricity. However, the relationship may become nonlinear under low-light conditions, high temperatures, shading, or other environmental constraints.

Hasan et al. (2022) emphasize that PV performance is influenced by irradiance, temperature, dust, wind, shading, humidity, and other environmental variables. They further note that irradiance varies with weather conditions, geographical location, season, time of day, and solar position.

### 2. Temperature

Temperature affects PV performance primarily through its influence on cell voltage and module efficiency. As module temperature increases, the voltage of crystalline-silicon cells generally decreases, causing a reduction in maximum power output. Skoplaki and Palyvos (2009) reviewed mathematical relationships between module temperature and electrical performance and demonstrated the importance of operating temperature in PV-system modeling.

The effect can be expressed approximately as:

$$\eta_T = \eta_{ref}[1 - \beta(T_c - T_{ref})]$$

Where:

1. $\eta_T$ = efficiency at cell temperature $T_c$.
2. $\eta_{ref}$ = reference efficiency
3. $\beta$ = temperature coefficient
4. $T_{ref}$ = reference temperature, normally 25°C.

Thus, high ambient temperatures may reduce PV efficiency even when solar radiation is abundant.

### 3. Relative Humidity

Relative humidity affects PV generation through several mechanisms. Water vapor and droplets can scatter or reflect incoming radiation, while high humidity can increase dust adhesion and contribute to condensation and module degradation. Hasan et al. (2022) report that humidity can reduce the radiation incident on PV cells and may contribute to long-term material degradation.

Therefore, humidity should not simply be considered an independent meteorological variable; it can interact with dust, cloud formation, temperature, and radiation.

### 4. Cloud Cover

Cloud cover is one of the most important short-term causes of solar-radiation variability. Thick clouds reduce direct normal irradiance, while broken clouds may generate rapid fluctuations between direct and diffuse radiation.

Recent research shows that cloud characteristics including cloud coverage, optical thickness, and physical structure can strongly influence PV output.

### 5. Wind Speed

Wind speed can have a positive indirect effect on PV generation because moving air removes heat from the module surface. Consequently, higher wind speed can lower module temperature and partially compensate for temperature-related electrical losses.

AlSkaif et al. (2020) included wind speed and wind direction among the meteorological variables relevant to PV-output estimation.

### 6. Combined Climatic Effects

The influence of climatic variables is not independent. For example, high irradiance can increase module temperature, while strong wind can reduce that temperature. Similarly, high humidity may be associated with cloud development and reduced solar radiation. Therefore, multivariable statistical models are more appropriate than simple single-variable analyses.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, July 2026
Impact Factor: 8.2

A systematic meteorological study found that a combination of variables can be used to estimate PV output while avoiding unnecessary dimensionality in predictive models.

## VII. RESEARCH METHODOLOGY

**1. Research Design**

A quantitative, descriptive, correlational, and analytical research design is recommended. The design allows the researcher to examine relationships among climatic variables, solar radiation, and PV energy generation.

**2. Variables**

**Table 1. Variables Used in the Proposed Study**

| Category | Variable | Unit | Role |
|---|---|---|---|
| Solar resource | Global Solar Irradiance | $W/m^2$ | Independent |
| Climate | Ambient Temperature | °C | Independent |
| Climate | Relative Humidity | % | Independent |
| Climate | Cloud Cover | % or oktas | Independent |
| Climate | Wind Speed | m/s | Independent |
| Climate | Rainfall | mm | Independent |
| PV system | Module Temperature | °C | Intervening |
| PV system | PV Power Output | kW | Dependent |
| PV system | Energy Generation | kWh | Dependent |

**3. Data Collection**

The study may use hourly or sub-hourly observations of:

- Global horizontal irradiance (GHI)
- Ambient temperature
- Relative humidity
- Wind speed
- Cloud cover
- Rainfall
- Module temperature
- DC power output
- AC power output
- Daily/monthly energy generation.

For a field-based study, climatic measurements should preferably be obtained from an on-site automatic weather station and PV monitoring system. Where on-site measurements are unavailable, validated meteorological/reanalysis and solar-resource datasets can be used, followed by calibration against available PV-generation records.

## VIII. PROPOSED STATISTICAL ANALYSIS

The following statistical techniques are appropriate:

**1. Descriptive Statistics**

Mean, minimum, maximum, standard deviation, coefficient of variation, and seasonal averages should be calculated.

**2. Pearson Correlation**

Pearson's correlation coefficient can determine the strength and direction of relationships between climatic parameters and PV generation.


DOI: 10.48175/568

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 6, Issue 5, July 2026 Impact Factor: 8.2

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2\sum(Y-\bar{Y})^2}}$$

**3. Multiple Regression**

The proposed regression equation is:

$$PV = a + b_1G + b_2T + b_3RH + b_4C + b_5W + b_6R + \epsilon$$

Where:

- $PV$ = photovoltaic power generation
- $G$ = solar irradiance
- $T$ = ambient temperature
- $RH$ = relative humidity
- $C$ = cloud cover
- $W$ = wind speed
- $R$ = rainfall
- $a$ = intercept
- $b1 \ldots b6$ = regression coefficients
- $\epsilon$ = error term.

**4. Seasonal Analysis**

The year can be divided into:

| Season | Typical Months | Major Climatic Characteristics |
|---|---|---|
| Winter | December–February | Lower temperature, shorter daylight |
| Pre-monsoon/Summer | March–May | High temperature, high irradiance, dust |
| Monsoon | June–September | High humidity, cloud cover, rainfall |
| Post-monsoon | October–November | Moderate temperature, declining humidity |

Seasonal differences can be tested using one-way ANOVA where appropriate.

**5. Expected Relationship Between Climatic Parameters and PV Generation**

**Table 2. Expected Direction of Relationships**

| Climatic Parameter | Expected Effect on Solar Radiation | Expected Effect on PV Generation | Expected Direction |
|---|---|---|---|
| Solar irradiance | Strong increase | Strong increase | Positive |
| Ambient temperature | Indirect/limited | Usually decreases efficiency at high temperature | Negative at high temperature |
| Relative humidity | Often reduces radiation transmission | Generally decreases output | Negative |
| Cloud cover | Reduces direct radiation | Decreases output | Negative |
| Wind speed | Little direct effect | Cooling can improve efficiency | Positive/conditional |
| Rainfall | Temporary reduction during rainfall | Usually negative during event; cleaning may benefit later | Mixed |
| Dust/aerosols | Reduces radiation reaching module | Reduces output | Negative |

These expected relationships are consistent with published reviews and empirical investigations of environmental influences on PV systems.

## IX. CONCLUSION

The impact of climatic parameters on photovoltaic energy generation is complex and multidimensional. Solar irradiance remains the dominant factor determining the amount of solar energy available for electricity production, but the final PV output is substantially modified by temperature, cloud cover, humidity, wind, rainfall, aerosols, and dust. Existing research consistently indicates that high module temperature reduces PV electrical efficiency, while cloud cover and atmospheric moisture can decrease the solar radiation reaching photovoltaic cells. Wind can have a beneficial indirect effect by cooling PV modules.

Consequently, assessment of solar-energy potential should move beyond simple annual irradiance estimates and incorporate the complete climatic environment of the installation site. A multivariable statistical framework involving correlation, regression, and seasonal analysis can identify the relative importance of individual climatic parameters and their combined effects. Such an approach can contribute to more accurate PV energy forecasting, improved system design, better maintenance planning, and more reliable renewable-energy development.

## REFERENCES

1. AlSkaif, T. A., Dev, S., Visser, L. R., Hossari, M., & van Sark, W. G. J. H. M. (2020). A systematic analysis of meteorological variables for PV output power estimation. *Renewable Energy, 153*, 12–22.
2. Hasan, A., Al-Juboori, A. M., & Al-Douri, Y. (2022). Effects of different environmental and operational factors on the PV performance: A comprehensive review. *Energy Science & Engineering, 10*.
3. Rehman, T., Qaisrani, M. A., Shafiq, M. B., Baba, Y. F., Aslfattahi, N., Shahsavar, A., Cheema, T. A., & Park, C. W. (2025). Global perspectives on advancing photovoltaic system performance. A state-of-the-art review. *Renewable and Sustainable Energy Reviews, 207*, 114889.
4. Skoplaki, E., & Palyvos, J. A. (2009a). On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations. *Solar Energy, 83*(5), 614–624.
5. Skoplaki, E., & Palyvos, J. A. (2009b). Operating temperature of photovoltaic modules: A survey of pertinent correlations. *Renewable Energy, 34*(1), 23–29.
6. Jones, A. D., & Underwood, C. P. (2001). A thermal model for photovoltaic systems. *Solar Energy, 70*(4), 349–359.
7. Dubey, S., Sarvaiya, J. N., & Seshadri, B. (2013). Temperature dependent photovoltaic efficiency and its effect on PV production: A review. *Energy Procedia, 33*, 311–321.
8. Zaghba, L., & Djeffal, F. (2024). The environmental factors affecting solar photovoltaic output. *Renewable and Sustainable Energy Reviews, 207*, 115073.
9. Al-Housani, M., Bicer, Y., & Koç, M. (2019). Experimental investigations on PV panel performance under different environmental conditions. *Renewable Energy, 134*, 111–123.
10. Makrides, G., Zinsser, B., Norton, M., Georghiou, G. E., & Werner, J. H. (2010). Performance of photovoltaic systems under different climatic conditions. *Proceedings of the 25th European Photovoltaic Solar Energy Conference*, 3974–3978.