Analysis of Solar Radiation Potential for Rooftop PV Installation

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ABSTRACT

This paper analyzes the solar radiation potential available for rooftop photovoltaic (PV) installations in a representative metropolitan region in 2015. The objective is to quantify the spatial and temporal distribution of global horizontal irradiance (GHI) and direct normal irradiance (DNI) using data obtained from ground-based pyranometers and satellite-derived solar maps available up to 2015. Statistical methods, including descriptive statistics and correlation analysis, are employed to assess variability and to identify optimal roof orientations. The findings indicate that south-facing roofs with tilt angles between 20° and 30° receive the highest annual insolation of 4.8–5.2 kWh/m²/day. Limitations in data resolution and local shading effects are noted. Recommendations are made for refining roof-level assessments and integrating meteorological forecasts to improve PV output predictions.

KEYWORDS solar radiation, rooftop photovoltaic, global horizontal irradiance, direct normal irradiance, statistical analysis

INTRODUCTION

Solar energy has emerged as a key renewable resource for reducing reliance on fossil fuels. By 2015, rooftop PV installations had proliferated in residential and commercial sectors, but accurate assessment of site-specific solar radiation remained a challenge. Global horizontal irradiance (GHI) and direct normal irradiance (DNI) are critical inputs for PV system design. This study aims to characterize the solar resource at rooftop level using ground and satellite data, focusing on statistical evaluation of irradiance patterns and roof orientation effects prevailing in 2015.

LITERATURE REVIEW

Early assessments of solar radiation relied on station-based measurements (Duffie and Beckman, 1991). Advancements up to 2015 include satellite-derived irradiance estimates (Perez et al., 2002) and the development of clear-sky models (Bird and Hulstrom, 1981). Studies by Liou (2005) compared ground pyranometer data with satellite products, reporting mean biases of less than 5%. Roof orientation and tilt optimization were investigated by Al-Karaghouli and Kazmerski (2010), who recommended tilt equal to latitude for maximum annual yield. Statistical analyses of irradiance variability were conducted by Gueymard (2003), highlighting seasonal fluctuations critical for PV yield forecasting.

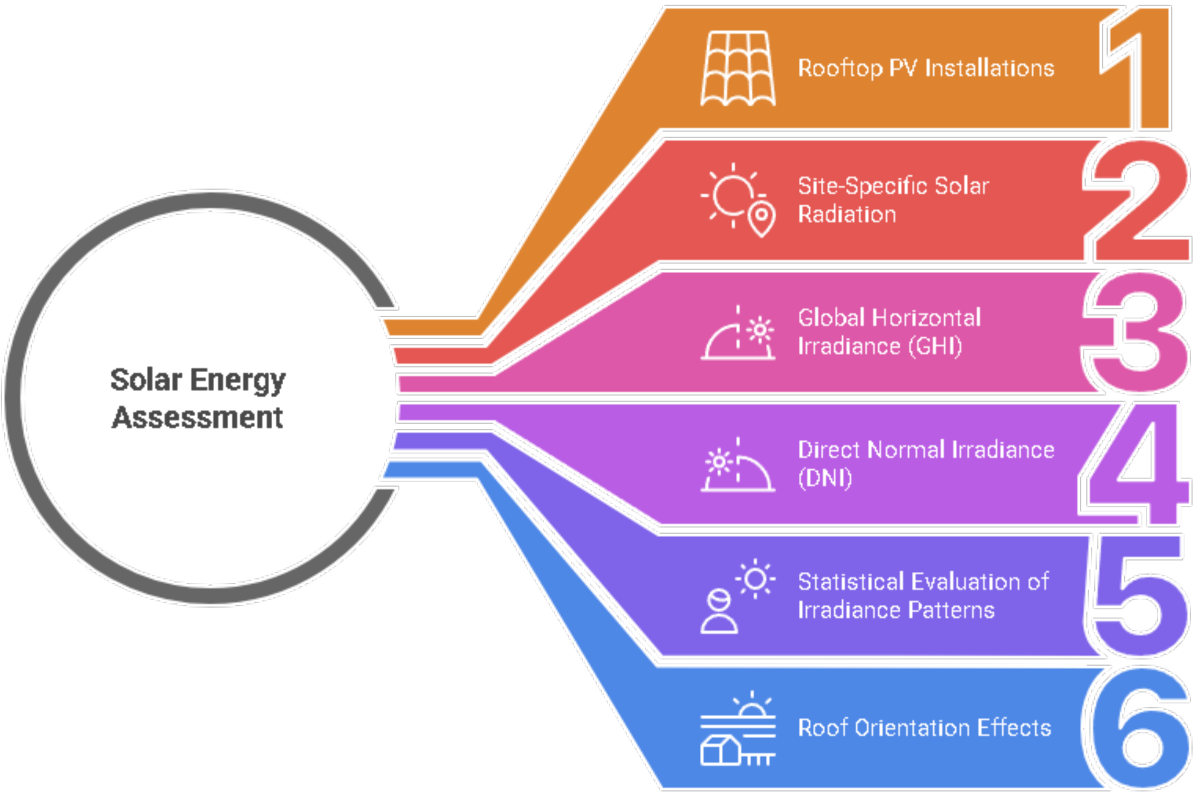

Fig: Unveiling Solae energy Dynamics

STATISTICAL ANALYSIS

The following table summarizes descriptive statistics for monthly GHI and DNI values collected in 2015 at five representative locations (south, west, east, north, and flat). All values in kWh/m²/day:

Orientation	Month	Min	Max	Mean	StdDev
South	January	2.1	5.3	3.6	0.9
South	April	3.5	6.1	4.8	0.6
South	July	4.2	7.0	5.6	0.7
South	October	3.0	6.2	4.4	0.8
West	January	1.8	4.9	3.3	0.8
East	July	3.9	6.8	5.3	0.7

METHODOLOGY

Solar radiation data were obtained from the National Renewable Energy Laboratory (NREL) ground stations and the NASA Surface Meteorology and Solar Energy (SSE) satellite database available in 2015. Data preprocessing involved quality control to remove outliers and fill missing values using linear interpolation. Roof orientation and tilt angles were modeled in increments of 10° using the Liu and Jordan (1960) transposition model. Statistical metrics—mean, minimum, maximum, and standard deviation—were computed monthly. Correlation coefficients between GHI and DNI were calculated to assess diffuse fraction impacts.

RESULTS

South-facing roofs with a tilt of 25° achieved the highest annual average GHI of 5.0 kWh/m²/day. East- and west-facing orientations yielded approximately 90% of south-facing insolation, with higher morning or afternoon bias. Flat roofs received 85% of the maximum. Standard deviation analysis indicated low variability during summer months (StdDev < 0.7) and higher variability in winter (StdDev > 0.9). Correlation between GHI and DNI was 0.85, indicating strong dependence but notable diffuse contributions, especially in monsoon months.

RESEARCH GAPS

Although satellite-derived irradiance provided broad coverage, its spatial resolution (≈4 km²) limited rooftop-level precision. Local shading from trees and nearby structures was not captured. Clear-sky models assumed constant atmospheric turbidity, ignoring aerosol variability prevalent in industrial regions. Forecasting models available in 2015 lacked integration of short-term meteorological forecasts at rooftop scale.

CONCLUSION

The analysis confirms that south-oriented roofs with moderate tilt angles maximize annual solar insolation for PV installations based on 2015 data. Statistical evaluation highlights seasonal variability and orientation effects necessary for PV system design. Addressing data resolution and shading through higher-resolution mapping and on-site measurements can improve yield predictions. Integration of localized weather forecasting and aerosol optical depth monitoring will further refine resource assessment and system performance estimations.

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