



Enhancing solar PV performance through weather monitoring insights

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As solar power scales globally and technologies like bifacial modules and smart trackers redefine performance expectations, real-time weather monitoring is fast becoming the backbone of intelligent PV operations. From forecasting and fault detection to yield optimization and cost control, accurate environmental data is reshaping how solar assets are designed, maintained and maximized, laying the foundation for smarter, greener energy systems.

The solar photovoltaic sector continues to expand at an unprecedented pace. Global installed capacity surpassed 1.6 TW by the end of 2023, growing from about 1.05 TW in 2021, a 32 % two-year increase, with 2022 alone seeing around 228 GW of new capacity and 24 % year-on-year growth. With deployment accelerating worldwide, operators and developers face growing complexity: system optimization, maintenance cost control, energy forecasting and grid integration.

A core, but sometimes under-emphasized, enabler in meeting these challenges is real-time environmental monitoring. Advanced meteorological stations tailored for solar PV sites, often called PV-oriented weather stations, now play an essential role in unlocking value across the project lifecycle.

Why environmental monitoring matters

Solar PV output is inherently tied to environmental conditions. Global irradiance is the primary driver of energy generation, while temperature, wind, humidity, precipitation,

and atmospheric pressure influence performance, soiling, and equipment health.

A precise understanding of local irradiance via pyranometers is fundamental for accurate yield modeling and panel orientation decisions. Temperature data, both ambient and module rear, helps detect overheating, maintain module efficiency and trigger preventive actions.

Wind data informs cooling effects as well as structural risk management during high-wind events. Rain and soiling metrics are increasingly critical: according to a 2025 research review published on arXiv and industry insights from Nor-Cal Controls, average annual soiling losses now account for 4–7 % of global PV output, equating to an estimated USD 7 billion in annual revenue losses.

Accurately tracking and interpreting these impacts through data enables timely cleaning and maintenance decisions, avoiding unnecessary cost or yield loss.

Industry momentum: monitoring technologies and market growth

The monitoring ecosystem within solar is rapidly evolving. The global PV monitoring technologies market was valued at around USD 39.14 billion in 2023 and is forecast to reach USD 56.93 billion by 2030, growing at a CAGR of approximately 5.5 %. Meanwhile, specific attention to weather station-based systems is growing globally, driven by demand for real-time data analysis and predictive modeling capabilities.

Additionally, the broader monitoring segment, incorporating hardware, software, and transmission technologies, is witnessing sustained innovation, with research into advanced data processing architectures and communications protocols supporting smarter system designs.

For plant operation and maintenance (O&M), a related sector sees strong momentum: the global solar panel O&M market was valued at USD 14.51 billion in 2024 and is expected to more than double to around USD 32.63 billion by 2034, at about 8.4 % CAGR (Precedence Research). Environmental monitoring lies at the heart of efficient O&M, providing the data drivers for predictive maintenance, fault detection and yield analysis.

Real-world applications: forecasting, faults, and efficiency

Accurate forecasting across time horizons is increasingly essential, both for internal dispatch optimization and for grid predictability. Onsite irradiance and weather measurements enable more precise short-term generation forecasts, reducing reliance on less accurate distant or model-based sources.

Fault detection is enhanced via correlation of electrical performance with environmental conditions: if irradiance is high but output is low, this suggests soiling, shading, module degradation, or tracker misalignment and targeted intervention can follow swiftly.

Environmental data also supports operational efficiency. For example, by understanding when rain might naturally clean panels, cleaning schedules become smarter, avoiding unnecessary labor when rain suffices. Temperature and wind data help understand passive cooling effects, meaning that maintenance or derating decisions can be finely timed.

Broader market and strategic context

In the European Union, installed PV capacity has soared from 164 GW at the end of 2021 to approximately 260 GW by late 2023, representing an impressive nearly 60% increase, a leap supported by accelerating adoption and policy support.

On the employment side, the EU photovoltaic workforce expanded from 466,000 full-time equivalent (FTE) jobs in 2021 to around

648,000 FTEs by the end of 2022, marking a robust 39% growth year-on-year, according to the EU Solar Jobs Report 2023 from SolarPower Europe.

Against this backdrop, innovations such as tracker systems combined with bifacial modules are reshaping yield expectations. In the US, 94 % of new utility-scale PV added in 2022 employed single-axis trackers, and combining trackers with bifacial modules can reduce the levelized cost of electricity (LCoE) by about 16 % compared to conventional systems.

As bifacial module adoption grows globally, with expectations that they may dominate more than 70 % of the market by 2033, the role of fine-grained environmental data grows too, because rear-side irradiance, albedo, and wind impact bifacial performance in ways not seen with monofacial panels.

The pathway to 'smart, green, efficient' solar operations

Putting weather stations at the core of monitoring architecture is no longer optional; it's strategic. As described by industry sources, photovoltaic weather detection stations serve as a bridge to smart PV plant operations, providing power generation

forecasting, performance optimization and enabling low-carbon strategies.

Concretely, high-precision sensors, including pyranometers, temperature probes, wind instruments, rain gauges and sometimes barometers, work together to provide real-time inputs. Combined with onsite data processing and modern communications, these underpin AI-enabled anomaly detection, dynamic scheduling and system diagnostics.

Delivering insight without over-selling

Integrating advanced weather monitoring is essential for optimizing performance, improving reliability and supporting informed decision-making in PV operations. In large-scale plants, fine-grained data supports better forecasting, adaptive operations, predictive cleaning and maintenance, asset protection in extreme events and yield optimization in complex environments. In smaller sites, too, the same data flow supports better ROI, even if at a different scale.

Operators who understand and act on real-time environmental conditions gain improved uptime, lower maintenance costs and more accurate energy production measurement. These capabilities improve

financial modeling, regulatory compliance reporting and facilitate investor confidence, all crucial as solar PV becomes a dominant global generation source.

Evolving from reactive to intelligent operations

The solar industry is entering a phase shift. With over 1.6 TW of global capacity and growing, and with PV monitoring technologies increasingly essential, weather-linked systems are at the heart of smarter, greener, more efficient solar deployment. These systems provide the data foundation for optimization, from irradiance-based forecasting and energy yield correlation to maintenance scheduling, system protection, and even bifacial module performance tuning.

For any serious PV operator, utility-scale or distributed, the integration of environmental monitoring is foundational. As markets grow and technologies evolve, those who deploy and harness fine-grained weather data will lead in operational efficiency, reliability, forecasting accuracy and financial performance.

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