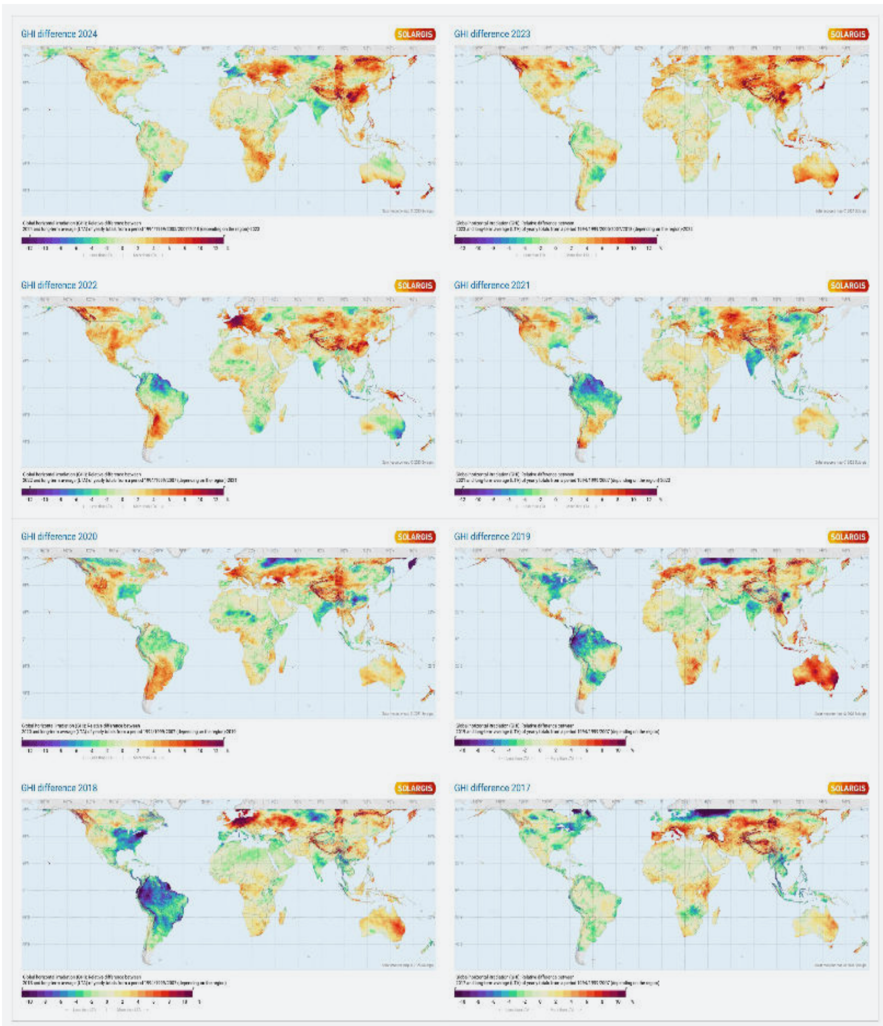
The rising complexity of solar projects requires a new approach to data and modeling

The solar industry is evolving at an unprecedented pace, bringing new challenges that traditional modeling methods can no longer address. As technology advances, climate variability intensifies and financial requirements grow stricter, relying on outdated assumptions and low-resolution data is no longer viable. To ensure the resilience and bankability of solar projects, the industry must adopt higher-resolution datasets, physics-based modeling and standardized PV component verification.

The solar industry has never been more complex. The rapid advancement of solar technology and storage, increasingly unpredictable weather patterns and stricter financial requirements have made many traditional PV system modeling and evaluation methodologies outdated.

We can no longer rely on the same assumptions and legacy approaches that have been used over the last 20 years. The industry must embrace new data standards and modeling techniques to ensure solar projects remain resilient, financially viable and technically sound.

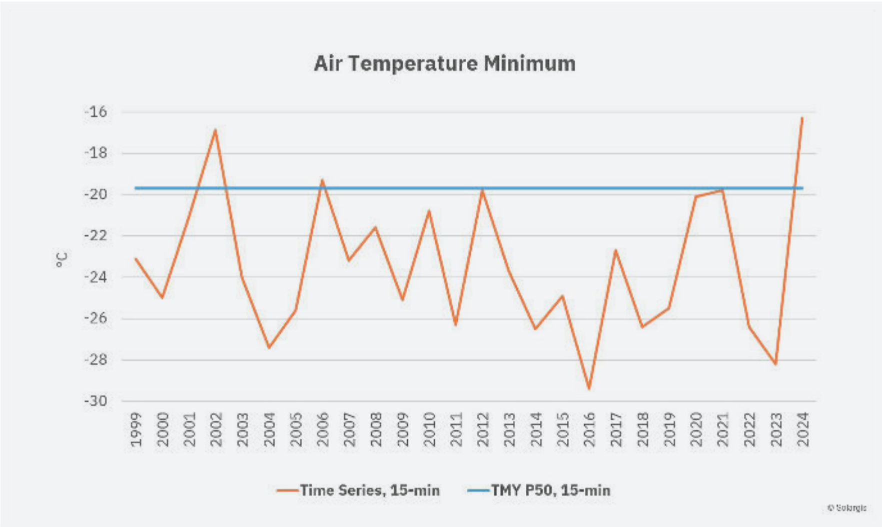
In ensuring projects' bankability and resilience, we must move away from simplified empirical models based on low-granularity data towards sophisticated, real-world simulations using high resolution data.



Solar industry today: more complex technology, more complex weather conditions

The past decade has brought remarkable progress in solar technology. Bifacial modules, intelligent inverters, trackers and battery storage systems have all contributed to the increased efficiency and adaptability of PV systems. At the same time, more complex PV systems have introduced new challenges, requiring deeper expertise, rigorous data analysis and system performance optimization.

Another major factor that is adding to the complexity of PV projects is weather variability and climate change. Not only are they making solar energy production



Site name: Pittsfield, MA, United States, Latitude: 42.447660, Longitude: -73.254160, Elevation: 320.0 m a.s.l., Period: 01/01/1999 - 31/12/2023, Data: Solargis Evaluate

increasingly difficult to predict, but while natural weather cycles have always created some degree of uncertainty, climate change is further distorting these patterns. Extreme weather events are becoming more frequent and more severe, impacting solar project performance across the globe.

In 2024, Europe saw multiple weather events that directly impacted PV performance. France, Belgium and northern Italy recorded notable declines in solar irradiation, while the UK, Norway and Denmark also experienced below average solar conditions. In September and early October, record rainfalls hit central and western Europe, causing widespread flooding and disruption in the area. That same month, we observed the effects of forest fires in Portugal, where ashes from the fires caused a temporary GHI reduction of up to 30%, followed by increased PV module soiling.

These world maps show the difference in Global Horizontal Irradiance (GHI) for the years 2017 to 2024. They compare each year's GHI to a long-term average, highlighting how solar irradiance varies annually and across different regions.

The climate-driven disruptions highlight the need for a more robust approach to the assessment of solar resources and climate conditions, one that accounts for real-world variability rather than relying on long-term averages.

The financial stakes have never been higher

Extreme weather is not just a technical concern, it's a financial risk. There is growing pressure on PV developers to secure steady and predictable energy production or risk financial instability.

In the past, subsidies and guaranteed energy prices provided a safety net. Today, market-driven models mean that any deviation from projected energy yields can have serious financial implications. Without a doubt, financial feasibility and bankability are the most important points of interest for all stakeholders in PV projects. Investors, banks and money lenders are more cautious, responding to the growing complexity of solar projects with stricter funding requirements.

Projects that fail to meet stringent performance criteria risk losing access to financing or facing higher insurance premiums, jeopardizing their economic viability. To secure bankability and long-term profitability, the solar industry must transition to higher-resolution data, physics-based models and methodologies based on new standards.

The following three areas are where new industry standards must be established to drive innovation and enhance efficiency, accuracy and market resilience.

1. High-resolution Time Series data as the new standard

The solar industry has long relied on hourly Typical Meteorological Year (TMY) datasets to assess project feasibility and model PV system performance. While TMY remains useful for quick estimations and the pre-feasibility phase, its limitations are becoming increasingly evident as weather variability needs to be considered.

The industry needs to transition to 15-minute Time Series data to better capture fast-frequency variability, extreme weather events, seasonal fluctuations and climate change.

While TMY aggregates historical weather data into an idealized 'typical' year, high resolution Time Series data at 15-minute resolution provides 15-minute intervals spanning up to 30 years, offering over 1 million data points per parameter.

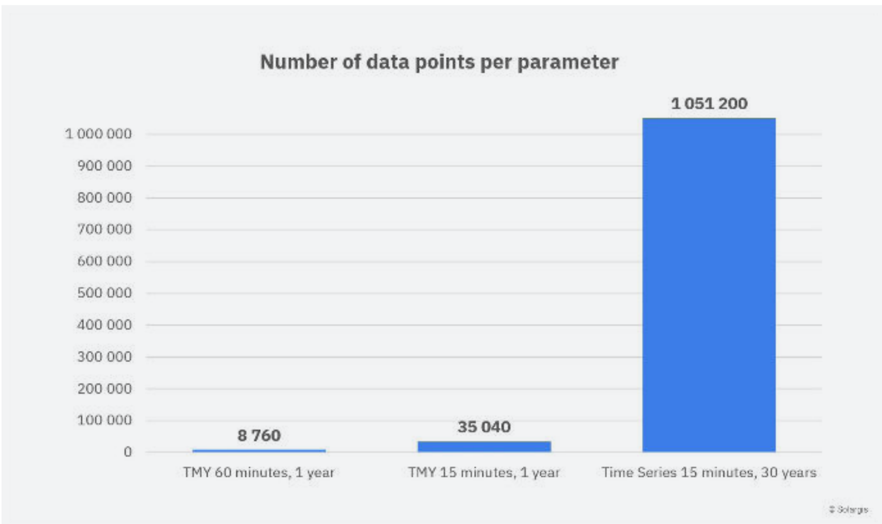
Hourly TMY smooths out variability and ignores short-term (intra-hourly), interannual (year-over-year) and long-term climate fluctuations, presenting only long-term averages. This lack of granularity creates significant blind spots in PV simulations, potentially leading to overly optimistic energy yield projections, unanticipated revenue losses in weaker solar irradiance years and inadequate financial modeling for debt repayment and PPA contracts.

As solar energy production becomes increasingly impacted by extreme weather and climate variability, transitioning from hourly TMY models to sub-hourly Time Series data is no longer optional, it is a necessity for ensuring project accuracy and financial security.

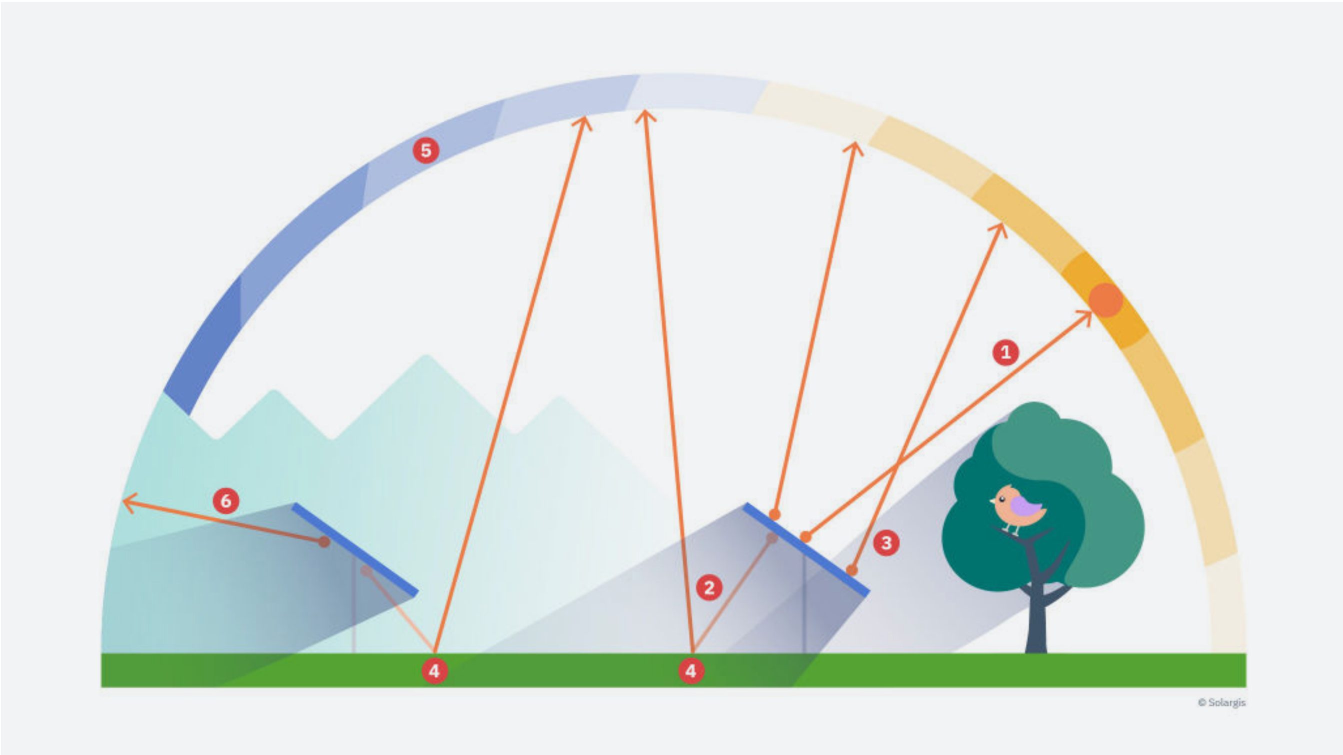
By analyzing year-over-year changes at a 15-minute resolution, developers gain a realistic picture of energy output variability and potential underperformance, ensuring more robust risk assessments and better project bankability.

2. Ray tracing technology as the new standard for bifacial PV modeling

Bifacial PV modules are becoming the standard in the solar industry. By capturing sunlight on both the front and rear sides, they are more effective, increasing energy yields.



As the solar industry advances, so must the methodologies and approaches used to model and evaluate PV performance.



1. Direct light, 2. Diffuse light, 3. Near shading, 4. Ground surface albedo, 5. Anisotropic sky dome, 6. Far horizon

However, most PV modeling tools use the view factor model based on the isotropic sky model, which assumes uniform diffuse radiation across the entire sky dome. This model works well for monofacial PV systems but fails to properly simulate rear-side irradiance, account for shading and reflections from nearby structures and capture dynamic interactions between sunlight and surrounding surfaces. As a result, bifacial yield predictions are often inaccurate, leading to suboptimal system designs and financial losses.

To accurately optimize PV performance for bifacial systems, the industry must adopt ray tracing technology combined with the anisotropic sky model. Unlike the isotropic model, ray tracing simulates how individual light rays interact with the environment, accounting for shading from PV modules, trees, buildings and other structures, variations in surface reflections due to albedo changes and dynamic sky conditions that influence both direct and diffuse light.

Incorporating satellite-derived, site-specific ground albedo data and high-resolution, sub-hourly Time Series datasets offers far greater accuracy than traditional models. Developers that adopt ray tracing can optimize bifacial system designs for real-world conditions, improving both PV performance and investment confidence.

3. The need to standardize PV component data to improve simulations

Another persistent challenge in the industry is the lack of standardization in technical specifications of PV components, which can easily introduce errors and inconsistencies into PV simulations.

Many developers still rely on unverified PAN and OND files, which are often incomplete or tampered with and shared across the internet without validation. This inconsistent data leads to multiple versions of the same component, resulting in flawed PV designs and distorted energy yield calculations.

The lack of PV component data verification leads to several issues, including inconsistent technical specifications that create confusion and inefficiencies, errors in energy yield estimates that increase financial uncertainty and overly optimistic performance predictions that result in underperforming projects.

To ensure consistent and reliable simulation results, the PV industry needs a new approach to managing technical information for PV modules, inverters and trackers. Accurate and validated specifications of PV components would also significantly improve transparency and efficiency in due diligence, reduce risk for developers and investors and streamline PV design.

Implementing a verification system for specifications of PV components and introducing a confidence rating to PV components based on data quality and level of validation would provide industry with trusted information for performance modeling.

The future of PV project modeling: from assumed to validated, from empirical to scientific

As the solar industry advances, so must the methodologies and approaches used to model and evaluate PV performance. Complexities of new technology and more frequent demonstrations of climate change cannot be tackled using outdated, low-resolution datasets and legacy approaches.

Investors in the solar energy sector demand higher precision of PV simulations and rightfully so. By embracing data-driven, physics-based modeling approaches, solar developers can build projects that meet both performance and financial expectations, even in an era of weather uncertainty and evolving market trends.

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