1 Why Solar Resource Data Are Important to Solar Power

Richard Meyer[1] and Manajit Sengupta[2]

1. *Suntrace GmbH*
2. *National Renewable Energy Laboratory*

Sunlight is the fuel for all solar energy generation technologies. For any generation source, knowledge of the quality and future reliability of the fuel is essential for accurate analyses of system performance and to determine the financial viability of a project. For solar energy systems, the variability of the supply of sunlight probably represents the single greatest uncertainty in a solar power plant's predicted performance. Solar resource data and modeling factor into three elements of a solar project's life:

- Historical long-term data for site selection during feasibility studies
- Prediction of power plant output for plant design and financing
- Real-time measurement and solar forecasting for plant and grid operations.

Site selection includes numerous location properties, including current land use, grid access, and proximity to load centers, but a top priority is determining if an adequate solar resource exists for a proposed project. For site selection, average solar irradiation at the site is the first selection criterion. Geographical latitude is also considered because sites close to the equator have advantages such as lower geometrical losses and lower shadowing. Lower seasonal variability at locations near the equator could also be advantageous because of a more consistent match to the power demand. As weather patterns may change from year to year, many years of data are required for determining reliable average irradiation conditions and inter-annual variability. For this purpose, satellite-derived, high-quality historic solar radiation data sets covering over 10 years are usually considered necessary for site selection, although site-specific climate conditions or design criteria may allow a shorter period.

As flat-priced electricity feed-in-tariff regulations get phased out, the economic yield of solar power systems depends more and more on the solar production during various times of the year as well as on its availability during specific parts of the day. Thus, for solar projects with variable prices, the temporal distribution of solar irradiance may be critical, even during site selection, to estimate potential yields among alternative sites. At this early stage of project development, it is sufficient to study the temporal variability of the energy output throughout the year and typical daily cycles. As an alternative to multiple-year data sets, typical meteorological year (TMY) data for each site may be sufficient at this stage, although the TMY will not characterize inter-annual variability.

If a site is found to be feasible and a power project is to be developed, more precise and detailed data sets are required. For the site-specific techno-economic optimization of a solar system, availability of higher time resolution data is always beneficial. Advanced modeling techniques allow developing such data based on satellite-derived time series. For financing large solar plants, data sets that are validated by ground measurements on or near the site become essential to lower the yield risk. In addition to precise solar radiation measurements, specialized

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meteorological stations usually provide additional environmental parameters that help to optimize the sizing and proper selection of plant components.

Precise solar and meteorological stations are also valuable during plant commissioning; reliable measurements are the base for acceptance testing to demonstrate proof of fulfillment of technical specifications for heat or electric output. Although temporary measurement equipment may be used for acceptance testing, reliable measurements are essential for estimating real-time plant output to assure high efficiency of the plant throughout its service life. Evaluation of plant output as a function of solar irradiance is the most important indicator of power plant performance. A drop in overall efficiency implies a degradation of one or more power plant components or poor maintenance or operation. Although remotely sensed data may be used for smaller rooftop systems where performance accuracy can be relaxed, larger solar systems usually rely on ground-based measurements, which may be combined with near-real-time satellite-derived solar radiation data. Local ground measurements also assist in site-specific model validation and improvements of solar forecasting.

Proper and accurate solar forecasts are important for ideal use of solar plants both economically and operationally. They help to improve system operations such as optimal use of a storage tank in a solar thermal water heating system, a molten salt system for high-temperature applications, or a battery system in an off-grid photovoltaic (PV) system. With the fast growth of grid-connected solar electrical systems, solar radiation forecasts have become highly important for safe grid operations and efficient operations among power plants, which might be necessary to balance solar fluctuations.

This handbook covers all pertinent aspects of solar radiation, which are relevant for the planning and operation of solar thermal heating and cooling systems, as well as for concentrating solar thermal and PV plants. Chapter 2 explains the basic concepts and terms, which are essential for understanding subsequent chapters. Chapter 3 describes the state of the art in measuring solar radiation on the Earth's surface and offers methods and protocols to produce a data set that withstands the scrutiny of due diligence. Chapter 4 focuses on modeling solar radiation. It provides an introduction to the theory of radiative transfer in the atmosphere, aiming to provide an understanding of current practices for deriving solar radiation values at the Earth's surface. Several examples of solar resource data sets derived from satellites and ground-measured data are presented in Chapter 5. It is important to understand the uncertainty of any data set produced by either measurement or modeling. Chapter 6 provides an understanding of how to estimate and interpret uncertainty in both measured and modeled data sets. Today, many data sets are retrieved from operational meteorological satellites applying radiative theory. Radiative transfer calculations, similar to those described in Chapter 4, are used to forecast the intensity of solar radiation, which is described in Chapter 7. Nowcasting a few hours ahead by extrapolating satellite and ground-mounted observations is now state of the art, while solar radiation forecasts beyond the first few hours are estimated by numerical weather prediction models. Chapter 8 summarizes the various techniques and data sets and recommends best practices for the various stages of a solar power project. Significant work remains to improve the accuracy, reliability, and level of detail of solar resource products. It is recognized that many open questions remain in the field of solar resource assessment. Chapter 9 gives an overview of how these outstanding issues may be solved in the future through the development of new or improved techniques and

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applying new measurement techniques, new meteorological satellites, improved weather models, or, ideally, a smart combination of these approaches.

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