International Energy Agency
Photovoltaic Power Systems Programme

Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications: Third Edition

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Executive summary

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As the world looks for carbon-free sources to meet energy demand associated with heat, electrical power, and transport, energy from the sun stands out as the single most abundant energy resource on Earth. Harnessing this energy is the challenge and opportunity for achieving a carbon-free energy supply by 2050 to fulfil the 1.5°C target set by the Intergovernmental Panel on Climate Change[1] and recommended in the 2015 Paris Agreement. Reducing carbon-dioxide emissions per energy unit and rapidly accessing the huge potential of solar energy will have the largest impact on achieving the 1.5°C target.

Photovoltaics (PV), solar heating and cooling, and concentrating solar power (CSP) are the primary forms of energy applications using sunlight. These solar energy systems use different technologies, collect different fractions of the solar resource, and have different siting requirements and production capabilities. Reliable information about the solar resource is required for every solar energy application. This holds true for small installations on a rooftop as well as for large solar power plants; however, solar resource information is of the most critical interest in the latter case because such projects require substantial investment, sometimes exceeding $1 billion in construction costs.

Before such projects can be undertaken, the best possible information about the quality and reliability of the fuel source (i.e., solar radiation) must be made available. That is, project developers need to have reliable data about the solar resource available at specific locations, including historic trends with seasonal, daily, hourly, and (preferably) subhourly variability to predict the daily and annual

[1] See https://www.ipcc.ch/report/ar4/syr/.

performance of a proposed power plant. Without this information or its accuracy requirements, a bankable financial analysis is not possible.

In response to a meeting of prominent CSP developers and stakeholders hosted by the U.S. Department of Energy (DOE) in September 2008, the National Renewable Energy Laboratory (NREL) produced a handbook to provide best practices for the use of solar resource data, which was titled *Concentrating Solar Power: Best Practices Handbook for the Collection and Use of Solar Resource Data*.[2] The content was based on the experiences of scientists and engineers from industry, academia, and DOE for identifying the sources, quality, and methods for applying solar and meteorological data to CSP projects.

During this same time, the International Energy Agency's (IEA's) Solar Heating and Cooling Programme (SHC) was hosting tasks on solar resource knowledge management (Task 36, 2005–2011; Task 46, 2011–2016). This work was then followed by the IEA's Photovoltaic Power Systems Programme (PVPS) Task 16 (2017–2020). These activities also contributed to the Solar Power and Chemical Energy Systems (SolarPACES) Technology program (Task 5). These tasks have brought together the world's foremost experts in solar energy meteorology. This group of experts agrees there is a need to maintain a collective document to disseminate the knowledge that was being developed through these tasks. It was decided that combining the efforts of the experts involved in the IEA and SolarPACES collaboration tasks to build on the information in NREL's original version of the handbook would provide the best use of resources and deliver a handbook of outstanding quality to users. It was also decided that additional solar technologies, such as PV, would be incorporated along with additional aspects of energy meteorology that have become extremely important, such as solar forecasting. As a result, a revised edition of the handbook appeared under the title, *Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications*, published by NREL in 2015[3]. The second edition of the handbook was published in 2017 as the final deliverable of IEA SHC Task 46.[4] An update of that document concludes the work of the first phase of IEA PVPS Task 16 and is presented here as the third edition of the handbook. This edition is available in two different formats, as separate NREL[5] and IEA PVPS reports.

The solar PV industry has developed rapidly throughout the last few years based on ongoing technical evolution and shrinking prices. The size of the installations as well as the penetration levels have grown tremendously—both enhancing the needs for accurate solar data for planning and operation. Induced by these needs, there have been significant enhancements in the body of knowledge in the areas of solar resource assessment and forecasting. This third edition of the handbook updates and enhances the initial versions and presents the state of the art in a condensed form for all of its users.

In the coming years, another stage of solar penetration will be reached: solar energy will not be only a small or growing part of power production but will become a major share of the production. This growth will increase the needs for high-quality and reliable resource data. The data needs for this growing industry are summarized in Figure P-1.

The structure of the handbook has been slightly updated since the previous editions. Chapter 1 lays out the need for high-quality and reliable solar resource data to support the rapidly growing industry, and Chapter 2, as before, provides a basic tutorial on solar resources. Chapter 3 presents a comprehensive overview of best practices for measuring solar radiation, including information gained

[2] See https://www.nrel.gov/docs/fy10osti/47465.pdf.
[3] See https://www.nrel.gov/docs/fy15osti/63112.pdf
[4] See https://www.nrel.gov/docs/fy18osti/68886.pdf.
[5] See https://www.nrel.gov/docs/fy21osti/77635.pdf

under collaborative work completed during Task 16. Chapter 4 summarizes techniques used to develop estimates of solar resources from weather satellite data and numerical model predictions. Chapter 5 is a new chapter describing additional meteorological variables (besides radiation) that are required for accurate performance analysis. Chapter 6 describes an updated list of commonly used data sets available both in the public and private sectors, and Chapter 7 provides important information on both measured and modeled solar data uncertainty. Chapter 8 provides an update on recent developments in the ability to forecast solar resources over time horizons spanning from minutes to hours ahead and days ahead. All this information leads to Chapter 9, which provides data application techniques for the various stages of project development, from prefeasibility to routine operations, as shown in Figure P-1. The outlook for future work is summarized in Chapter 10.

System Size →

Phase ↓

	Small	Medium	Large
1. Prefeasibility and planning	• Long-term averages • Monthly data • Solar cadastres/ maps • Simple shading analysis	• TMY • Hourly data • Shading analysis	• Long-term satellite data • Hourly data
2. Feasibility			• Satellite data • Time series (>10 year) • Ground meas. (> 1 year) • Shading analysis • Further site- and technology- specific meteo. parameters (e.g., albedo, soiling)
3. Due diligence and finance		• Satellite data • Time series (>10 y) • Minute data • Shading • Further site- and technology- specific meteo. parameters (e.g., albedo, soiling)	• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Minute data • Shading analysis • Further site- and technology- specific meteo. parameters (e.g., albedo, soiling)
4. Operation and maintenance	• Simple monitoring	• Local measurements • Forecasts	• Local measurements • Forecasts

Figure P-1. Data requirements for different project phases and system sizes.

Project developers, engineering procurement and construction firms, utility companies, system operators, energy suppliers, financial investors, organizations involved in planning and managing solar research programs, and others involved in solar energy systems planning and development should find this handbook to be a particularly valuable resource for the collection and interpretation of solar resource data. Readers are encouraged to provide feedback to the authors for future revisions and an expansion of the handbook's scope and content.