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Interim report from 16 January 2026

IEA PVPS Task 16

Solar resource for high penetration and large scale applications

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The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

Summary

IEA PVPS Task 16 is currently in the third phase which started in June 2023 and will go on until June 2026. Jan Remund of Meteotest leads the Task as Task Manager on behalf of the PVPS Technology Collaboration Program with support of SFOE.

The main goals of the Task are to lower barriers and costs of grid integration of PV and lowering planning and investment costs for PV by enhancing the quality of the forecasts and the resources assessments. The work is organised in four subtasks:

– Subtask 1: Evaluation of current and emerging resource assessment methodologies
– Subtask 2: Enhanced data & bankable products
– Subtask 3: Evaluation of current and emerging solar resource and forecasting techniques
– Subtask 4: Dissemination and Outreach

Meteotest is mainly involved in leading, presenting and organizing the Task (Subtask 4). This intermediate report of the Swiss supporting project includes the overview of the work done in the last year. 52 participating organisations from 21 countries had to be kept together.

The main result of the first three year of the Task 16 – the update of the Solar Resource Handbook – has been published in October 2024 and presented at different conferences. Three official reports, a factsheet on soiling and six additional peer reviewed paper were published in 2025.

In 2025 two hybrid Task meetings took place in Palaiseau, France and Neuchâtel, Switzerland – with support from EPFL and SFOE. Two workshops were organized at the end of the Task meetings.

Zusammenfassung

Der IEA PVPS Task 16 befindet sich derzeit in der dritten Phase, die im Juni 2023 begann und bis Juni 2026 andauern wird. Jan Remund von Meteotest leitet den Task als Task Manager im Namen des PVPS Technology Collaboration Program mit Unterstützung des BFE.

Die Hauptziele des Tasks sind die Senkung der Hindernisse und Kosten für die Netzintegration von PV und die Senkung der Planungs- und Investitionskosten für PV durch die Verbesserung der Qualität der Prognosen und der Ressourcenbewertung. Die Arbeit ist in vier Unteraufgaben gegliedert:

- Subtask 1: Bewertung aktueller und neuer Methoden der Ressourcenbestimmung
- Subtask 2: Verbesserte Daten und bankfähige Produkte
- Subtask 3: Bewertung aktueller und neuer Verfahren für Solarvorhersagen
- Subtask 4: Verbreitung und Öffentlichkeitsarbeit

Meteotest ist hauptsächlich an der Leitung, Präsentation und Organisation des Tasks (Subtask 4) beteiligt. Der vorliegende Zwischenbericht des Schweizer Unterstützungsprojekts gibt einen Überblick über die Arbeit des letzten Jahres. 52 teilnehmende Organisationen aus 21 Ländern mussten unter einen Hut gebracht werden.

Das Hauptergebnis des Task 16 - die Aktualisierung des Solar Resource Handbook - wurde im Oktober 2024 veröffentlicht und auf verschiedenen Konferenzen vorgestellt. Ausserdem wurden drei Reports, ein Factsheet und sechs zusätzliche Papers veröffentlicht.

Im Jahr 2024 fanden zwei hybride (online & physisch) Sitzungen statt. Eines davon dank Unterstützung des BFE und der EPFL in Neuchâtel. Zudem wurden zwei Workshops – beide im Anschluss an die offiziellen Task-Meetings- organisiert.

Contents

List of abbreviations

FOV	Field of view
GHI	Global horizontal irradiance
IEA	International Energy Agency
PVPS	Photovoltaic (PV) Power Systems TCP
RHI	Reflected horizontal irradiance
SFOE	Swiss Federal Office of Energy
SHC	Solar Heating and Cooling TCP
SolarPACES	Solar Power and Chemical Energy Systems TCP
SFOE	Swiss Federal Office of Energy
TCP	Technology collaboration programme
TMY	Typical Meteorological Year

1 Introduction

IEA PVPS Task 16 (T16) started in June 2017 is currently in the 3rd phase which will go on until June 2026. This report covers the period of January – December 2025.

T16 is a joint Task with the TCP SolarPACES (Task V). It will keep also minimal collaboration with the Solar Heating and Cooling (SHC) – the Technology Collaboration Programme of the preceding solar resource and forecast Tasks.

Meteotest leads the Task as Task Manager on behalf of the PVPS TCP with support of Swiss Federal Office of Energy (SFOE). Manuel Silva of Univ. of Sevilla, Spain leads the Task V since summer 2018 on behalf of SolarPACES. Manajit Sengupta from NLR (Golden, CO, USA) is the deputy Task Manager.

The main work of Meteotest was to organise to ongoing work of the Task – meetings, workshops and reports – and informing the Exco about the updates. Meteotest works actively for dissemination, in the benchmarking activity as well as in modelling firm PV power, where a separate project in Switzerland was conducted in 2021, 2022, 2023 and 2024.

2 Workplan

The main goals of third phase of T16 are to lower barriers and costs of grid integration of PV and to lower planning and investment costs for PV by enhancing the quality of the forecasts and the resources assessments.

To reach this main goal the Task has the following objectives:

- Lower uncertainty of satellite retrievals and Numerical Weather Prediction (NWP) models for solar resource assessments and nowcasting
- Develop enhanced analysis of long-term variability and trends in solar resource with an additional focus on effects of climate change.
- Develop and compare methods for
    - Estimating the spectral and angular distributions of solar radiation (clear and all-sky conditions)
    - Modelling point to area forecasts
    - Probabilistic forecasting
- Organize international benchmarks of solar resource and forecast datasets.

In this phase the following focus have been defined:

1. Analysing long term trends and variability changes induced by climate change (activity 2.4)
2. Modelling of meteorological data and albedo for bifacial modules (activity 2.7)
3. Providing models and information for firm power production (new activity 3.5)

The scope of the work in Task 16 concentrates on meteorological and climatological topics needed to plan and run PV, solar thermal, concentrating solar power stations and buildings. As in the preceding Task solar resource assessment and forecasting are the main focus.

To handle this scope the work programme is organized into three main technical subtasks (subtasks 1 – 3) and one dissemination subtask (Subtask 4) (Table 1):

Table 1: Subtasks and Activities of Task 16 (2023-2026)

Subtask	Activity
Subtask 1: Current methodologies for solar data generation	1.1 Radiation measurements
	1.2 Radiation models
	1.4 Benchmarking solar data
	1.5 Additional meteorological parameters
Subtask 2: Enhancement of data & value-added products	2.1 Data quality and format
	2.4 Climate change and long-term variability
	2.5 Products for the end-users
	2.7: Products for upcoming, integrated technologies
Subtask 3: Solar forecasting	3.2 PV power forecasting at different spatio-temporal scales
	3.3 Probabilistic solar forecasting
	3.4 Cloud image based nowcasting (0-6 hours)
	3.5 Firm power generation
Subtask 4: Dissemination and Outreach	4.3 Webinars, workshops, publications and trainings
	4.4. Update of solar resource handbook
	4.5. Program Toolbox
	4.6. Update basic knowledge for a broad public (e.g. Wikipedia)

Whereas Subtasks 1 and 3 are mainly focused on ongoing scientific work, Subtasks 2 and 4 are mostly focused on user aspects and dissemination.

In Table 2 the Task participants are listed.

Table 2: Participating countries (21) and organizations (52) of Task 16.

Country	TCP	Partners
AUS	PVPS	Univ. of South Australia (UniSA), Univ. of NSW (UNSW)
AUT	PVPS	Fachhochschule Oberösterreich (FH OOE)
CAN	PVPS	CanmetENERGY (Ottawa and Varennes)
CHE	PVPS	Meteotest, OST (SPF)
CHN	PVPS	Public Meteorological Service Center (China Meteorological Administration - CMA)
DEU	PVPS SolarPACES	Fraunhofer (ISE & IEE), DLR (both TCP), CSP Services
DNK	PVPS	Danish Meteorological Institute (DMI), Technical University of Denmark (DTU)
ESP	PVPS SolarPACES	CIEMAT, CENER, Public University of Navarra, Univ. Almeria, Univ. Jaen, Univ. Malaga, University of Seville (US), Univ. des Las Palmas de Gran Canaria, Mactech
EU	PVPS	JRC
FRA	PVPS	MINES Paris PSL, Laboratoire PIMENT, Université la Réunion, Ecole Polytechnique à Palaiseau, EDF R&D, RTE, TotalEnergies, ESA
IND	PVPS	National Institute of Solar Energy (NISE)
ITA	PVPS SolarPACES	i-em, RSE, Uni Tor Vergata, ENEA and EURAC
NLD	PVPS	Univ. Utrecht
NOR	PVPS	IFE and Met. Norway
POR	PVPS	Faculty of Sciences University of Lisbon
SWE	PVPS	SMHI and Univ. Uppsala
USA	PVPS	Dep. of Energy/National Renewable Energy Laboratory (NREL), National Aeronautics and Space Administration (NASA), State Univ. of New York at Albany (SUNY), University of Oregon, Clean Power Research (CPR), Solar Consulting Services (SCS)
GBR	SHC	Peakdesign Ltd.
GRE	SolarPACES	Univ. of Patras
MOR	SolarPACES	IRESEN
SVK	SHC	Solargis

The network grew by three new participants from India (NISE), Portugal (Univ. Lisbon) and Canada (CanmetENERGY Ottawa).

3 Completed Tasks and achieved results

IEA PVPS Task 16 is among the biggest Tasks in PVPS TCP concerning number of participants (52) and countries (21). Additionally financial resources are not adequate in many countries. Both issues made operating the Task not an easy topic. Missing resources as well as changes of staff of participants led also to re-organisation and changes of activity and subtask leads.

1.1 Reports published

As in the first two phases also for the 3rd phase the main result of Task is the update of the Solar Resource Handbook. This last version (4th edition) has been published in October 2024. It includes the major results of the collaboration during the years 2020 - 2024 (Sengupta et al., 2024a and Sengupta et al., 2024b).

Four publications – downloadable from the PVPS website were published in 2025 (see references):

1. The added value of combining solar irradiance data and forecasts: A probabilistic benchmarking exercise
2. SolarStations.org—A global catalog of solar irradiance monitoring stations
3. A Set of New Tools to Measure the Effective Value of Probabilistic Forecasts of Continuous Variables
4. Fact Sheet: Understanding, Measuring, and Mitigating Soiling Losses in PV Power Systems

The list consists of three journal articles and a fact sheet.

An IEA PVPS fact sheet on PV soiling was prepared together with Task 13. It covers fundamentals of PV soiling, the role of soiling data for project development and monitoring, as well as soiling forecasting and mitigation options (Fig. 1). Furthermore, the influence of different particulate matter data sets on the accuracy of modelled soiling data was investigated.

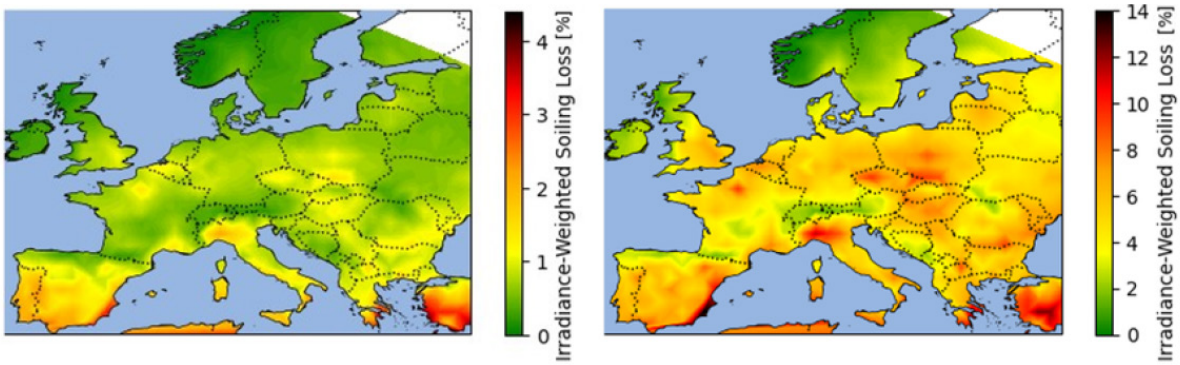

Fig. 1. Average soiling loss maps assuming two different cleaning effects of rain. Left: full cleaning; right: only 10% cleaning above a threshold.

1.2 Papers published

Three official IEA PVPS papers were published. All three were transformed in reports – see links om chapter 1.1.

The added value of combining solar irradiance data and forecasts: A probabilistic benchmarking exercise

Despite the growing awareness in academia and industry of the importance of solar probabilistic forecasting for further enhancing the integration of variable photovoltaic power generation into electrical power grids, there is still no benchmark study comparing a wide range of solar probabilistic methods across various local climates. Having identified this research gap, experts involved in the activities of IEA PVPS T16 agreed to establish a benchmarking exercise to evaluate the quality of intra-hour and intra-day probabilistic irradiance forecasts. The tested forecasting methodologies are based on different input data including ground measurements, satellite-based forecasts and Numerical Weather Predictions (NWP), and different statistical methods are employed to generate probabilistic forecasts from these. The exercise highlights different forecast quality depending on the method used, and more importantly, on the input data fed into the models. In particular, the benchmarking procedure reveals that the association of a point forecast that blends ground, satellite and NWP data with a statistical technique generates high-quality probabilistic forecasts. Therefore, in a subsequent step, an additional investigation was conducted to assess the added value of such a blended point forecast on forecast quality. Three new statistical methods were implemented using the blended point forecast as input. To ensure a fair evaluation of the different methods, we calculate a skill score that measures the performance of the proposed model relative to that of a trivial baseline model. The closer the skill score is to 100%, the more efficient the method is. Overall, skill scores of methods that use the blended point forecast ranges from 42% to 46% for the intra-hour scenario and 27% to 32% for the intra-day scenario. Conversely, methods that do not use the blended point forecast exhibit skill scores ranging from 33% to 43% for intra-hour forecasts and 8% to 16% for intra-day forecasts. These results suggest that using (a) blended point forecasts that optimally combine different sources of input data and (b) a post-processing with a statistical method to produce the quantile forecasts is an effective and consistent way to generate high-quality intra-hour or intra-day probabilistic forecasts.

A global catalog of solar irradiance monitoring stations

Abstract: Ground-based measurements remain the most accurate method for determining solar surface irradiance despite continuous improvements in satellite-derived and reanalysis models. However, identifying and accessing high-quality irradiance measurements is challenging, largely due to incomplete information on available stations. Consequently, many studies use low-quality data or have poor geographical coverage, reducing the scientific outcomes. To address this issue, a global catalog of multi-component solar irradiance monitoring stations has been created, streamlining the identification of relevant stations. Each station entry includes the following metadata: station name, location, elevation, owner, network, period of operation, data availability, instrumentation, and climate zone. The station catalog and an interactive map are available for free at www.SolarStations.org. As of April 2025, the catalog contains information on 808 stations, of which 440 are currently active. Only half of the active stations share data freely, highlighting a widespread issue of data availability. The catalog and website are developed openly on GitHub and welcome community contributions.

A Set of New Tools to Measure the Effective Value of Probabilistic Forecasts of Continuous Variables

Abstract: In recent years, the prominence of probabilistic forecasting has risen among numerous research fields (finance, meteorology, banking, etc.). Best practices on using such forecasts are, however, neither well explained nor well understood. The question of the benefits derived from these forecasts is of primary interest, especially for the industrial sector. A sound methodology already exists to evaluate the value of probabilistic forecasts of binary events. In this paper, we introduce a

comprehensive methodology for assessing the value of probabilistic forecasts of continuous variables, which is valid for a specific class of problems where the cost functions are piecewise linear. The proposed methodology is based on a set of visual diagnostic tools. In particular, we propose a new diagram called EVC ("Effective economic Value of a forecast of Continuous variable") which provides the effective value of a forecast. Using simple case studies, we show that the value of probabilistic forecasts of continuous variables is strongly dependent on a key variable that we call the risk ratio. It leads to a quantitative metric of a value called the OEV ("Overall Effective Value"). The preliminary results suggest that typical OEVs demonstrate the benefits of probabilistic forecasting over a deterministic approach

Additional papers by Task experts

Additionally, six peer reviewed papers were published from Task participants covering work of the Task.

Blum, Niklas, et al., 2025: "Geometric calibration of all-sky cameras using sun and moon positions: A comprehensive analysis." Solar Energy 295 (2025): 113476.

Bonanno, R. and E. Collino, 2025: Assessing the impact of climate change on solar energy production in Italy, Reg. Environ. Change, vol. 25, fasc. 3, p. 78, July 2025, doi: 10.1007/s10113-025-02417-6.

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Sohani, Ali, Marco Pierro, David Moser, and Cristina Cornaro, 2025: Comparison of Physical Models for Bifacial PV Power Estimation. Journal Energy Conversion and Volume 327, 2025, 119515, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2025.119515.

1.3 Workshops / Webinars

Two workshops were organized:

1. A public workshop organized by LMD, Univ. Palaiseau, was held in the conjunction with the Task meeting. Topic: " Journée De meilleures données solaires pour booster le photovoltaïque" (Paris, April 4th 2025)
2. A workshop on invitation about "VRE renumeration models adequate for firm power" was held in Neuchatel, Switzerland, in collaboration with IEA PVPS Task 19 (JRA-40) (October 17th, 2025).

Many presentations have been given at conferences like EU PVSEC 2025, SolarPACES 2025 and other regional conferences.

1.4 Task meetings

As Task Manager Meteotest organised two (hybrid) meetings in spring and autumn 2024 (Figure 2).

- April 1-3rd, Paris, 16th Task meeting, Palaiseau (Paris), France
- October 15 – 17th, 17th Task meeting, EPFL Neuchatel, Switzerland

The hybrid meetings were successful. About 35-40 persons attended the meetings physically and 30 online. The meeting in Neuchatel was possible due to support from EPFL (rooms) and SFOE (catering, online conference tool).

Figure 1: Group photo of the IEA PVPS Task 16 at Neuchatel, Switzerland (October 2025).

4 National and international cooperation

This work has been presented at the following conferences:

- 1. All Sky Imager Workshop, Rosenheim, Germany (hybrid), February 25th 2025
- 40. PV-Symposium, Bad Staffelstein, Germany, March 12th 2025
- 53. IEEE PVSC, Ottawa, Canada, June 8-13th 2025
- 24. Wind&Solar Integration Workshop, Berlin, Germany, October 9th 2025

Task 16 was collaborating additionally with the Agrivoltaics Action Group of PVPS, with IEA Wind Task 51 and with WMO (framework for a Global Partnership for weather, water and climate services for a clean energy transition).

The workshop in Neuchatel (October 17th) the following Swiss organisations (aside Task participants) were presenting or participating: Gerd Heilscher (TH Ulm, Task 19 Manager), Ch. Bucher (BFH), Michael Beer (BKW), Wieland Hintz (SFOE), Stefan Oberholzer (SFOE), Pierre-Jean Alet and Nicolas Wyrsch (CSEM), Gracia Brückmann (Uni Bern) and Florent Jaqmin (Planair).

The collaboration with the 2nd Task 16 participant from Switzerland - OST (SPF) - was on hold due to missing projects and finances on their side.

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