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IEA PVPS Task 16

Solar resource for high penetration and large scale applications

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www.bfe.admin.ch
energieforschung@bfe.admin.ch

Subsidy recipient:
Meteotest AG
CH-3012 Bern
www.meteotest.ch

Author:
Jan Remund, Meteotest AG, jan.remund@meteotest.ch

SFOE project coordinator:
Stefan Oberholzer, stefan.oberholzer@bfe.admin.ch

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Summary

IEA PVPS Task 16 (2017) is currently in the first extension phase which will go on until June 2023. The extension of the Swiss project at SFOE started officially beginning of 2020. Jan Remund of Meteotest leads the Task as Task Manager on behalf of the PVPS Technology Collaboration Program with support of SFOE. From Switzerland additionally SPF Institute for Solar Technology of the HSR University of Applied Sciences is taking part in Task 16.

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. 50 participating organisations from 19 countries had to be kept together. In 2022 two hybrid Task meetings took place, one workshop and three online webinars have been given.

The main result of the first three year of the Task 16 – the update of the Solar Resource Handbook – was published in May 2021. The work for the 4th edition has been started.

In 2022 three webinars and one workshop have been organised. Two papers have been published and two reports are almost ready to publish.

Seite absichtlich frei

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List of abbreviations

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

Introduction

IEA PVPS Task 16 started in 2017 is currently in the first extension phase – started in July 2020 – which will go on until June 2023.

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. 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 dissemination, in the benchmarking activity as well as in modelling firm PV power, where a separate project in Switzerland was conducted in 2022.

From Switzerland additionally SPF Institute for Solar Technology of the HSR University of Applied Sciences is taking part in Task 16.

1 Workplan

The main goals of extension phase of T16 are: we want 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.

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

- Lowering uncertainty of satellite retrievals and Numerical Weather Prediction (NWP) models for solar resource assessments and nowcasting.
- Develop enhanced analysis of long-term inter-annual variability and trends in the solar resource also induced by climate change.
- Develop and compare methods for
  - Estimating the spectral and angular distributions of solar radiation (clear and all-sky conditions)
  - Describing the spatial and temporal variabilities of the solar resource
  - Modelling point to area forecasts
  - Probabilistic forecasting
- Contribute to or setup international benchmark for data sets and for forecast evaluation.

In this phase the following focus have been defined:

1. Modelling of spectral data (activity 1.2)
2. Providing a public set of quality proofed meteorological data (activity 1.4)
3. Analysing extreme conditions long term trends induced by climate change (activity 2.4)
4. Analysing solar data on urban scales (new activity 2.6)
5. Modelling of meteorological data and albedo for bifacial modules (activity 2.7)
6. Providing models and information for firm power production (new activity 3.5)
7. Delivering code as supplement to reports (new activity 4.5)

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 (2020-2023)

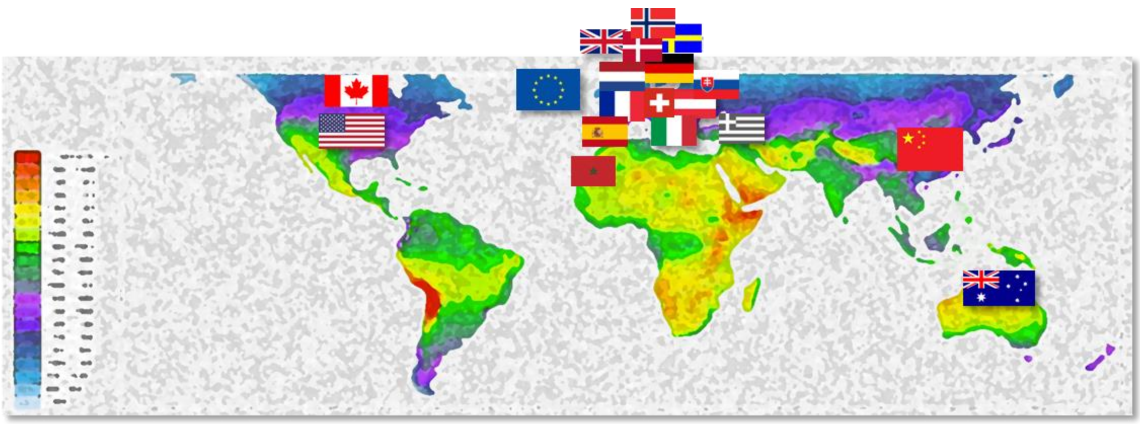
Subtask	Activity
Subtask 1: Evaluation of current and emerging resource assessment methodologies	1.1 Ground based methods
	1.2 Modelling for NWP / satellite data
	1.4 Benchmarking Framework
Subtask 2: Enhanced data & bankable products	2.1 Data quality and format
	2.4 Long-term inter-annual variability
	2.5 Products for the end-users
	2.6 PV at urban scales
	2.7: Data and models for bifacial modules
Subtask 3: Evaluation of current and emerging solar resource and forecasting techniques	3.2 Regional solar power forecasting
	3.3 Probabilistic solar forecasting
	3.4 Forecasts based on all sky imagers
	3.5 Firm power generation
Subtask 4: Dissemination and Outreach	4.2 Produce a periodic Task Newsletter
	4.3 Conduct periodic (annual) Subtask-level webinars and/or conference presentations
	4.4 Update of solar resource handbook
	4.5 Solar Resource Assessment in Python

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

In Table 2 and Figure 1 the Task participants are listed.

Table 2: Participating countries (19) and organizations (51) of Task 16.

Country	TCP	PM	Partners
AUS	PVPS	5	Solcast, University of South Australia, Univ. of NSW (UNSW)
AUT	PVPS	4	Fachhochschule Oberösterreich (FH OOE)
CAN	PVPS	3	Natural Resources Canada
CHE	PVPS	21	Meteotest, HSR (SPF)
CHN	PVPS	4	Public Meteorological Service Center (China Meteorological Administration - CMA)
DEU	PVPS SolarPACES	42	Fraunhofer (ISE & IEE), DLR (both TCP)
DNK	PVPS	18	Danish Meteorological Institute (DMI), Technical University of Denmark (DTU)
ESP	PVPS SolarPACES	51	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	3	JRC
FRA	PVPS	10	CNRS-Promes, MINES ParisTech, Laboratoire PIMENT, Université la Réunion, Univ. des Antilles et de la Guyane, Ecole Polytechnique à Palaiseau, EDF R&D, RTE
ITA	PVPS SolarPACES	7	i-em, RSE, Uni Tor Vergata, ENEA
NLD	PVPS	2	Univ. Utrecht
NOR	PVPS	2	IFE and Met. Norway
SWE	PVPS	5	SMHI, Uni Uppsala
USA	PVPS	17	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	4	Peakdesign Ltd., Rina Consulting, World Energy & Meteorology Council (WEMC), Univ. Glasgow
GRE	SolarPACES	1	Univ. of Patras
MOR	SolarPACES	1	IRESEN
SVK	SHC	2	Solargis



Global horizontal irradiance. Source: www.meteonorm.com Version 8.0

Figure 1: Countries participating in the Task 16.

2 Completed Tasks and achieved results

IEA PVPS Task 16 is among the biggest Tasks in PVPS TCP concerning number of participants (51) and countries (19). 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.

The main result of the first phase of Task is the update of the solar resource handbook. This report has been published in April as NREL version1 and in May in PVPS version2: This report includes all major work done in 2021. In 2022 the Task members worked on five different reports. Two of them are currently in internal review (till December 21st 2022). Two of the reports are scheduled for June 2023. One report – the 4th edition of the Solar Resource Handbook is scheduled for December 2023.

2.1 Papers published

The benchmark of the All Sky Imagers in Almeria, ESP have been concluded in a webinar (see below) and by publishing two papers (Logothetis et al. 2022a and Logothetis et al. 2022b).

2.2 Reports in review

Benchmarking of GHI filling methods

Data gaps in time series of solar irradiance due to missing data due to default during data-logging, sensor failures, maintenance defaults, loss of data, etc. or data excluded with Quality Check (QC) procedures.

Therefore, there is a need of gap filling (GF) methods to create complete dataset (e.g. TMY dataset), complete real-time data, with a lag as short as possible, for post-processing sensitive to missing data, like SCADA-based real time nowcasting and short-term forecasting. These methods are also of crucial interest for the computation temporal aggregations with missing data: intra-daily to daily, daily to monthly and yearly averages.

The objective of this report is to setup and run a benchmark of different GF algorithms for the:

- GF of intra-hourly time series of global horizontal irradiance. The results are exposed for time steps 15-min.
- GF of daily sums of irradiations with intra-day gaps (DSG, daily sums with gaps) with two different main approaches: (1) from the intraday gap-filled intra-day time series with the previous methods and (2) from averaging methods with gaps, without explicit prior intraday gap-filling.

This report is the results of expert discussions during specific sessions of the subtask-2 activity 2.1 of the Task 16 of PVPS and during the dedicated workshop organized during the ICEM 2019 conference: “Workshop on best practices for automatic and expert-based data quality control methods and for gap filling methods.

[1] https://www.nrel.gov/docs/fy21osti/77635.pdf

[2] https://iea-pvps.org/key-topics/best-practices-handbook-for-the-collection-and-use-of-solar-resource-data-for-solar-energy-applications-third-edition/

Firm Power generation

Grid-connected solar power generation, either dispersed or centralized, has developed and grown at the margin of a core of dispatchable and baseload conventional generation. As the penetration of this variable resource increases, the management of the underlying core gradually becomes more complex and costly.

The challenge ahead for grid-connected solar is to evolve beyond the margin and the context of underlying conventional generation management. Activity 3.5 focuses on this challenge where the transformation of intermittent variable renewable energy (VRE) resources such as solar and wind into firm, effectively dispatchable, power generation resources is a prerequisite to the displacement of the underlying conventional generation core.

Substantiated by in-depth case studies, this report infers that nearly 100% VRE power grids firmly supplying clean power and meeting demand 24/365 are not only possible but would be economically sound if VRE resources are optimally transformed from unconstrained run-of-the weather generation into firm generation. VREs are thus capable of entirely displacing all climate disruptive conventional sources economically (provided now emerging grid-forming inverter technology resolves any grid frequency and stability issues resulting from the displacement of conventional rotating power generation). The variable-to-firm transformation enablers include energy storage, the optimum blending of VREs and other renewable resources, geographic dispersion, and supply/demand flexibility. Most importantly this transformation entails overbuilding and operationally curtailing the VREs ─ a strategy we term applying implicit storage. This strategy ensures acceptable VRE production costs.

This report summarizes ten experts' contributions focusing on firm power generation at near 100% renewable energy penetration. In addition, four contributions describe 'entry level' firm power generation objectives, easier to achieve in the short-term, but using the same enabling strategies, where firmness is defined in terms of meeting forecast VRE production instead of full load.

2.3 Workshops / Webinars

Three webinars and one workshop have been organised during the last year. They are listed in chronological order.

The Task was also presented at the following conferences and meetings:

- WMO SG ENE 6th meeting, August 25th 2022 (online)
- Eurosun 2022, September 26-29th 2022 (Kassel)
- WCPEC-8, September 26-29th 2022 (Milano): at this conference a workshop of Task 16 was organised in the framework of the PVPS side events
- IEA PVPS Task 13 kick-off, October 5th 2022 (Frankfurt a.M.)
- PVSEC-33, November 16th (online)

Webinar on "Benchmarking of solar resource data"

June 28th 2022 a webinar was given under the lead of Anne Forstinger (CSP Services GmbH, Germany) about Radiation Data Benchmark Results. A first glimpse on the results have been presented. The results of this benchmark have been presented later at EMS 2022 and WCPEC-8 and will be concluded in a report in 2023.

Speakers were: Jan Birk Kraas, Jan Remund, Stefan Wilbert, Adam R. Jensen and Anne Forstinger.

Webinar on “Firm PV Power”

On August 16th a webinar was given on ISES channel (https://www.ises.org/what-we-do/events/webinar/iea-pvps-task-16-firm-pv-power). In this webinar, the speakers investigated whether photovoltaics (PV) can effectively and economically contribute to a massively renewable energy (RE) power generation future for different regions.

The speakers determined the optimum PV/battery configurations that can meet the country’s electrical demand firmly 24x365 at the least possible cost. The result of the modelling is the optimum between overbuilding and curtailment of PV.

The analyses shows that firm PV power is an enabler of the energy transition and can ease the energy trilemma – regarding security of supply, sustainability and affordability. The speakers will present results for Switzerland, California and different TSO zones in the USA.

Speakers: Richard Perez, Jan Remund, Marc Perez and Patricia Hidalgo-Gonzalez, UC San Diego (USA).

Webinar on "All Sky Imagers Benchmarking"

On December 15th a webinar about the benchmark of all sky imager (ASI) have been held also on ISES channel: https://www.ises.org/what-we-do/events/webinar/iea-pvps-task-16-all-sky-imagers-benchmarking

In this webinar, the existing and advancing solar nowcasting techniques with the use of all-sky imagers (ASIs) have been presented and evaluated. For this, a benchmarking exercise has been carried out, at CIEMATS’s Plataforma Solar de Almería (PSA) in southern Spain, focusing on state-of-the-art surface solar irradiance nowcastings derived from ASIs. The speakers have identified the strengths and the weaknesses of the implemented algorithms and evaluated the ASI-based nowcast performance under various cloud conditions, time horizons, and against typical reference nowcast models. The analyses reveal the feasibility of ASIs to reliably nowcast GHI and estimate solar power at distant times or detect sudden GHI fluctuations.

Speakers: Jan Remund, Bijan Nouri, Stavros Logothetis, Andreas Kazantzidis

2.4 Task meetings

As Task Manager Meteotest organised two meetings in 2022. The spring and autumn meetings were organised as hybrid meetings – with a focus to physical meetings (Figure 4).

- March 29 – 31st, 10th Task meeting, Mines Paristech, Sophia Antipolis, FRA
- September 21 – 23rd, 11th Task meeting, Fraunhofer ISE, Freiburg i. Br., DEU

The hybrid meeting was successful and the upcoming meetings will be organised in a similar form. About 30 persons attended the meeting physically and 30-40 online.

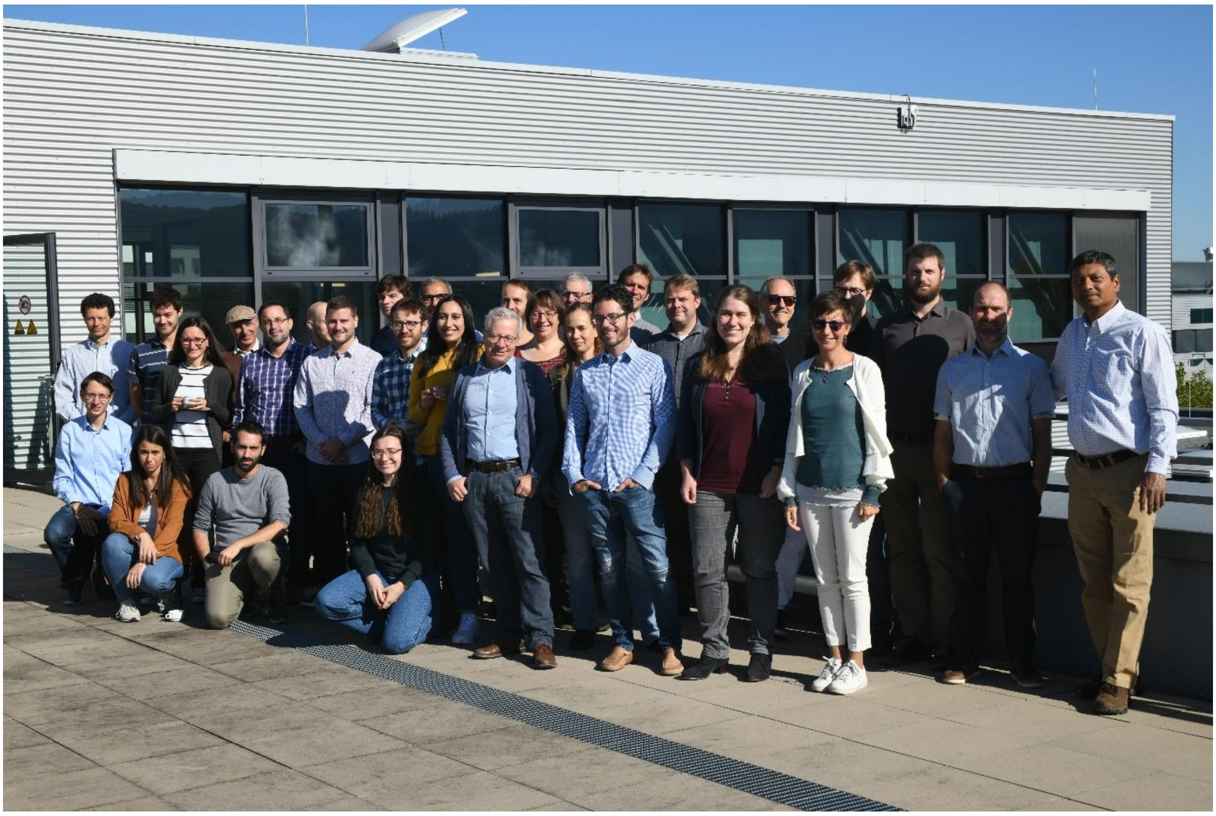


Figure 5: Group photo of the hybrid Task meeting in September 2022 (Fraunhofer ISE, Freiburg i. Br., DEU).

The Task Manager presented the Task at the online Exco meeting in April. In the hybrid Exco meeting end of November the Task was represented by the deputy Task Manager Manajit Sengupta.

3 Collaboration in Switzerland

Aside Meteotest HSR / SPF was part of the Task 16.

In the SFOE (2022) project "Firm PV Power Switzerland" we investigated the concept of Firm PV power in Switzerland (activity 3.5). The results are published on aramis website[3] and disseminated also via energeia[4]: Optimally 10-20% of the energy produced by PV is curtailed. The analysis showed that curtailment lowers the costs of the energy transition significantly.

The knowledge that curtailment is an enabler not a brake of energy transition is spread in the electricity modelling community slowly. Some recently published reports like e.g. «Auswirkungen einer starken Elektrifizierung und eines massiven Ausbaus der Stromproduktion aus Erneuerbaren Energien auf die Schweizer Stromverteilnetze»[5] include curtailment but still on a rather low level. Nevertheless, this report shows that also flexibility options lower grid enhancement costs significantly.

[3] https://www.aramis.admin.ch/Grunddaten/?ProjectID=49486

[4] https://energeiaplus.com/2022/06/27/solarstrom-im-schweizer-stromsystem-effektiv-und-wirtschaftlich-dank-ueberdimensionierung-und-abregelung/

[5] https://www.bfe.admin.ch/bfe/de/home/news-und-medien/medienmitteilungen/mm-test.msg-id-91974.html

4 Outlook

In January 2023 the report about gap-filling methods and about Firm Power generation will be published. Two reports are foreseen for June 2023 (Benchmark of probabilistic forecasts and on Benchmarking of solar resource data). The organisation of the writing of the next (4th) edition of the Solar Resource Handbook has been started. It is foreseen for end of 2023.

If the new work plan is accepted by the Exco the third phase of the Task 16 will start in July 2023.

The main changes of this work plan are:

1. Analyzing additional meteorological parameters like wind, precipitation, soiling or albedo (activity 1.5)
2. Analyzing the results of climate models and describing how to optimally use them (activity 2.4)
3. Modelling of meteorological data for all advanced and integrated and upcoming technologies like agri-PV, floating PV including albedo for bifacial modules (activity 2.7)
4. Contributing content to general public sites like Wikipedia to spread the know-how even faster and outside our core target groups (activity 4.6)

Two Task meetings are planned (March and October). The first as hybrid meeting in Sevilla, ESP – the 2nd as an all-Tasks meeting (all active PVPS Task will meet together) in Adelaide, AUS.

Publications

IEA PVPS Task 16 has an own project site on Researchgate: https://www.researchgate.net/project/IEA-PVPS-Task-16-Solar-resource-for-high-penetration-and-large-scale-applications

Logothetis, Stavros-Andreas, Vasileios Salamalikis, Stefan Wilbert, Jan Remund, Luis F. Zarzalejo, Yu Xie, Bijan Nouri, Evangelos Ntavelis, Julien Nou, Niels Hendrikx, Lennard Visser, Manajit Sengupta, Mário Pó, Remi Chauvin, Stephane Grieu, Niklas Blum, Wilfried van Sark, Andreas Kazantzidis, Benchmarking of solar irradiance nowcast performance derived from all-sky imagers. 2022a. Renewable Energy, Volume 199, 2022, Pages 246-261, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2022.08.127

Logothetis Stavros-Andreas, Salamalikis, V., Nouri, B., Remund, J., Zarzalejo, L.F.; Xie, Y.; Wilbert, S.; Ntavelis, E.; Nou, J.; Hendrikx, N.; Visser, L.; Sengupta, M.; Pó, M.; Chauvin, R.; Grieu, S.; Blum, N.; Sark, W.v.; Kazantzidis, A. 2022b. Solar Irradiance Ramp Forecasting Based on All-Sky Imagers. Energies 2022, 15, 6191. https://doi.org/10.3390/en15176191

SFOE. 2022: Firm PV power generation for Switzerland. SFOE contract number: SI/ 502286-01. https://www.aramis.admin.ch/Grunddaten/?ProjectID=49486