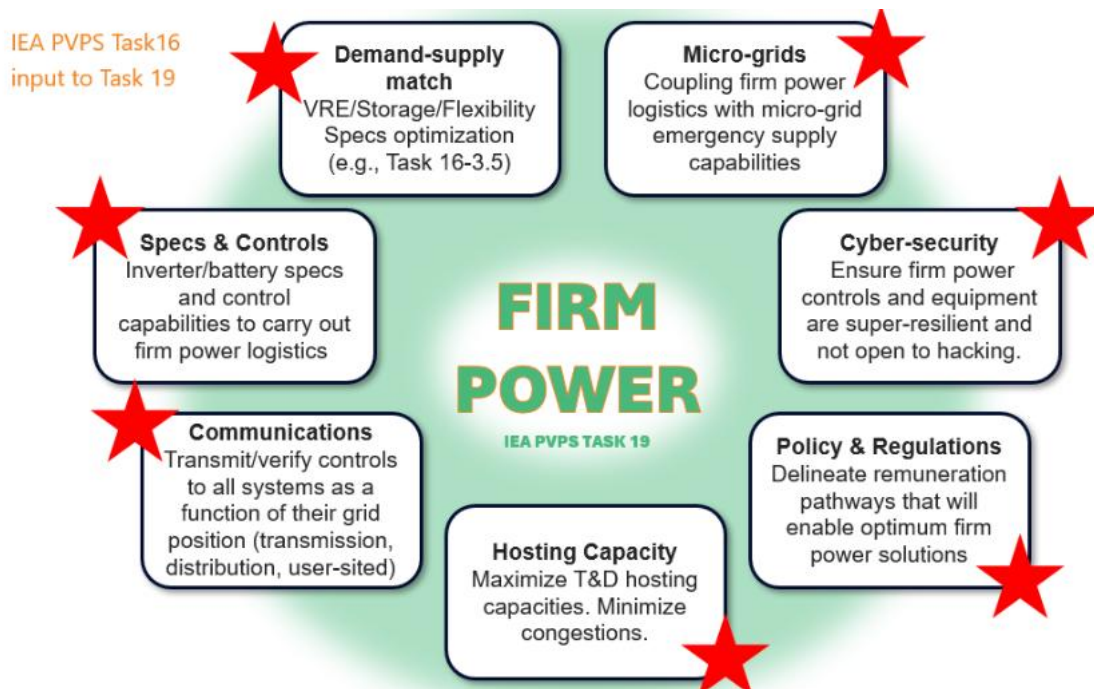




Interim report from 16 January 2026

IEA PVPS Task 19

Photovoltaic Integration in Electricity Networks and Markets 2025-2028



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



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List of abbreviations

DER	Distributed energy resources
DG	Distributed generation
DG	Distributed generation
DMS	Distribution management system
DSO	distribution system operator
E.DSO	European Distribution System Operators
ENTSO-E	European Network of Transmission System Operators for Electricity
HV	high voltage
ICT	Information and communication technologies
IEA	International Energy Agency
LV	low voltage
MV	medium voltage
NCP	network connection point
NWP	Numerical weather prediction
PCC	point of common coupling
PV	photovoltaics
PVPS	Photovoltaic Power Systems Programme
RES	Renewable energy sources
TSO	transmission system operator



1 Introduction

IEA PVPS Task 19 (T19) main topics are integration of PV in electricity networks and in markets. T19 started in Spring 2025 as successor of Task 14. It will go on until 2028. Meteotest was nominated in August 2025. This report covers the period of August – December 2025.

T19 is organised in a more agile and flexible way compared to other PVPS Tasks. Main work areas are defined as Joint Research Activities (JRA), which go on for 2 years. Activities are started when enough partners (from different countries) are participating.

Meteotest is collaborating in the two active JRA-24 and 40.

- JRA-24: Understanding Firm Power in a National Level. Topic: National PV Targets Versus Grid Capacity and Peak Load
- JRA-40: PV in Energy, Capacity and Balancing Markets. Topic: Energy Economy in a 100% RES Based Power System

The main work of Meteotest was to prepare and attend a first in-person meeting, linking the Firm Power topic to Task 16 and ongoing writing two conference papers.

2 Workplan

The integration of photovoltaics into the power system is central to the energy transition. Although there are now ambitious targets in many countries, the implementation of high shares of PV in the total energy supply is often slowed down by the fact that the grids cannot absorb large amounts of solar electricity at all times. Worldwide, there are already many concepts and methods under discussion on how photovoltaics can become a main source of energy and what role the electricity grids play in this. What technical and regulatory measures need to be taken locally and supra-regionally, what role digitalization plays, what role the interplay with the heating and mobility sectors takes. Technical, legal regulatory and economic effects are examined in this task based on international best practices and scientific analyses to give recommendations for planning and operation of the electricity grids, but also to give recommendations for local energy management measures that optimally relieve the electricity grids.

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 19 (2025-2028). Bold: Activities with participation of Meteotest. Only running JRA's are listed (with defined leads and at a certain number of participants).

Subtask	Activity
Subtask 1: National PV Targets versus Grid Capacity	JRA-43: Definition of Overpowered Networks
	JRA-21: Grid Hosting Capacity Rules
	JRA-22: Grid Hosting Capacity Status
	JRA-24: Understanding Firm Power in a National Level
Subtask 2: Rights and Obligations of Prosumers	JRA-41: Designing a new Social Contract for Customers to Grids Dominated by DER
	...
Subtask 3: PV in Smart Grids	JRA-17: Comparability of DER Communication Standards
	JRA-16: Talking to Inverters – Cybersecurity Aspects
Subtask 4: Approval and Commissioning for Interconnection of PV Systems	...
	...
Subtask 5: Curtailment Power Management	JRA-05: Control Strategies for Highly Overpowered Grids
	JRA-23: How do Countries deal with very high PV Penetration?
Subtask 6: New Inverter Capabilities	JRA-01: Grid Forming Inverter – Market Overview
	...
Subtask 7: Aggregators, Local Markets and Energy Communities	JRA-45: Investigation of the Feasible Solution for the Over-Installation of PV System in LV grid
	JRA-28: Role of PV in a Microgrid Resilience Strategy
	...
Subtask 8: Local Energy Management	JRA-03: Overview on Capabilities of Local Energy Management Systems
Subtask 9: Energy Economy in a 100% RES Based Power System	JRA-40: PV in Energy, Capacity and Balancing Markets
Workshops and Webinars & new disseminations Approach	

Currently 14 countries and 20 participants with Notification of Participation are taking part.



3 Completed Tasks and achieved results

IEA PVPS Task 19 just started in summer 2025. Therefore, no official results are available.

1.1 Ongoing work on Task Report

JRA-40 is a mirrored Task of IEA PVPS Task 16 – Activity 3.5 about Firm Power. Both Activities are led by Richard Perez, SUNY, Albany, NY, USA.

In autumn 2025 the team prepared an update of the first Firm Power report (Perez et al., 2023). It will be published in February 2026.

1.2 Ongoing work on Conference Papers

Two IEA PVPS Task 19 papers were being prepared.

Remuneration models for a system with 100% renewables

Authors: Jan Remund, Gerd Heilscher, Christof Bucher, Richard Perez

Conference: Tagung Zukünftige Stromnetze, 28-29 January 2026, Berlin, Germany.

Abstract: Based on in-depth analyses and case studies, we conclude that electricity systems powered almost entirely by renewable energies, supplying clean electricity around the clock and meeting demand, are not only possible but also economically viable almost everywhere in the world.

Solutions include energy storage, the optimal mix of variable renewables (VRE) and other renewable resources, geographical distribution, and methods to limit feed-in. In most of the regions studied, the optimum economic cost is achieved with a curtailment of 10-20% of the electricity generated. Storing and using every potential kilowatt hour would significantly increase the overall costs. However, this optimum is not achieved with today's market and remuneration systems.

Curtailment thus reduces the overall costs of the energy system (and thus the average electricity production costs). However, the losses incurred by curtailment must be compensated for electricity producers in some form so that the incentive for further expansion remains.

Previous models have been developed without taking grid expansion costs into account. It can be assumed that, if these costs are included, curtailment could be even higher, as flexible feed-in could eliminate the need for a considerable portion of grid expansion, primarily at the distribution grid level.

In many countries, VRE electricity production is also exceeding demand in recent years. This is reflected, among other things, in the increasing number of hours with negative electricity prices. The “duck” curve is increasingly becoming a “canyon.” This, too, means that remuneration systems need to be adjusted.

At a workshop in Neuchâtel (CH) on October 17, 2025, experts from the electricity industry, science, and administration met as part of IEA PVPS Tasks 16 and 19 to discuss possible solutions. In this article, we briefly present the various inputs and focus in particular on compensation measures to maintain investment security despite curtailment.



Integrating Solar PV into Energy, Capacity and Balancing Markets: An International Comparison of Market Models, Regulatory Frameworks, and System Flexibility

Authors: Manuela McCulloch, Stine Fleischer Myhre, Jan Remund, Sami Jouttjärvi, Marta Irena Murkowska, Ayat-Allah Bouramdame, Vincent Krakowski, Léa Courcier, Giovanna Adinolfi, Dietmar Graeber, Gerd Heilscher

Conference: 22nd International Conference on the European Energy Market (EEM26), 22-24 June 2026, Trondheim, Norway

Abstract: As solar photovoltaics (PV) expand at an unprecedented pace worldwide, countries are re-thinking how their electricity markets (the organized systems where electricity is bought and sold between producers, retailers and consumers) and regulations (the rules set by public authorities that govern how energy is produced, traded, and connected to the grid) must evolve to reliably integrate this fast-growing source of variable renewable energy.

This study explores how solar photovoltaics are being integrated into energy markets, capacity markets, and balancing markets around the world.

As global PV deployment continues to accelerate, driven by cost reductions and strong policy support highlighted in the IEA Renewables 2025 outlook, energy systems face new challenges. The central issue is how to effectively integrate large volumes of variable renewable energy (VRE), whose output fluctuates with weather conditions, into electricity markets that were originally designed for controllable power plants.

Against this backdrop, the study aims to identify which market models (the different ways in which electricity buying and selling are organized), and which regulatory frameworks (the legal and technical rules that govern how the power system operates), best support PV participation; what barriers (technical, economic, or administrative obstacles) still remain; and what lessons can be drawn from international comparison.

The study begins by clarifying the fundamental concepts of renewable-energy market integration, including the six phases of VRE integration (a staged framework describing how power systems adapt as renewable penetration rises) and the roles of main actors such as regulators, transmission system operators (TSOs), distribution system operators (DSOs), aggregators, and prosumers. It then outlines the regulatory tools and market-design approaches used internationally to accommodate PV in different market segments.

Methodologically, the research is guided by a comparative framework built on six analytical dimensions: market, price-formation, PV participation, remuneration models, flexibility options, and the broader regulatory context. The study relies on a mix of legal and regulatory documents, market data, and academic literature.

The core of the analysis provides an overview of market-design typologies, followed by in-depth country case studies covering Germany, Switzerland, Norway, Italy, Finland, Denmark, France, and Morocco. For each country, the study examines governance structures, market-access conditions for PV and other distributed renewables, the development of local and regional markets, as well as market barriers and entry restrictions.

Overall, the study offers a comparative understanding of how different countries are enabling PV to participate not only in energy markets but also in capacity markets (which ensure sufficient available power) and balancing markets (which maintain real-time grid stability). By highlighting effective practices and persistent obstacles, it provides insights for policymakers and system operators seeking to design market frameworks capable of supporting high levels of solar energy while maintaining a reliable and efficient electricity system.



1.3 Workshops / Webinars

One workshop was organized by Meteotest: The workshop on invitation about "VRE remuneration models adequate for firm power" held in Neuchatel, Switzerland, in collaboration with IEA PVPS Task 16 (Activity 3.5, Firm Power) (October 17th 2025).

1.4 Task meetings

As Task participant Meteotest took part in one online and one in-person meeting.

- January 31st, online: Kick-off meeting
- October 20 – 21st, 2nd Task meeting, Puerto de la Cruz, Tenerife, ESP

4 National and international cooperation

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

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