Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 13 Reliability and Performance of Photovoltaic Systems

PVPS

FACT SHEET

Overview and Performance of Agrivoltaics

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What is Agrivoltaics?

Agrivoltaics refers to the **simultaneous use of the same land area for agricultural production and PV electricity generation.** It aims to optimise land-use efficiency, enhance agricultural resilience, and enable sustainable PV deployment where land competition is a barrier.

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To qualify as agrivoltaics, a project must include agriculture and PV electricity generation, with agricultural relevance ensured through criteria such as land-use efficiency, agricultural intensity, solar sharing, and synergies between agricultural and PV activities.

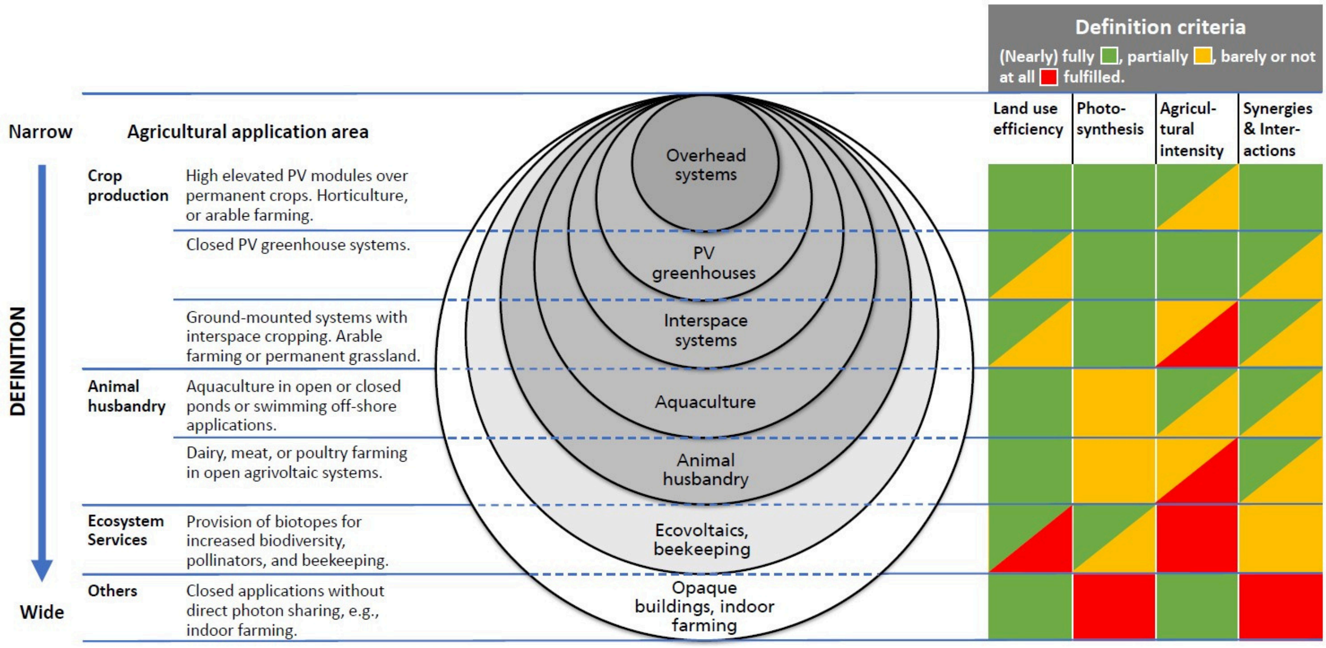


Figure 1: Hierarchy of narrower to broader agrivoltaics definitions, showing how different system types vary in land-use efficiency, agricultural intensity, photosynthetic involvement, and agriculture–PV interactions.

The Development of Agrivoltaics

The development of agrivoltaics spans more than four decades, evolving from a conceptual idea to a rapidly expanding field of research and commercial deployment.

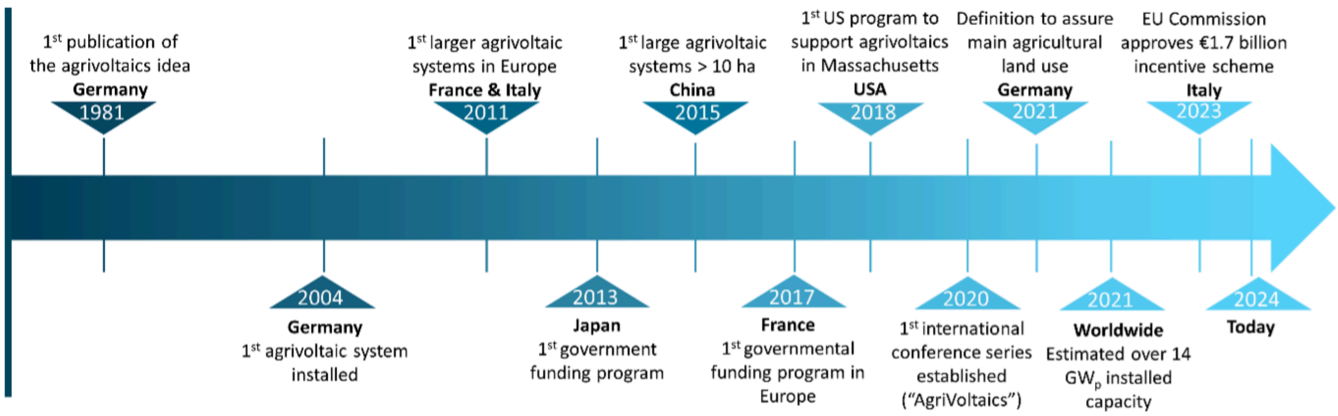


Figure 2: Timeline of key milestones in the evolution of agrivoltaics, from the 1981 conceptual origin and Japan's 2003 "solar sharing" systems to the scientific adoption of the term in 2011 and the rapid global expansion and regulatory development since 2020. © Fraunhofer ISE

Classification of Agrivoltaics

This classification helps structure the diverse agrivoltaic system types and supports consistent comparison of their technical and agricultural characteristics.

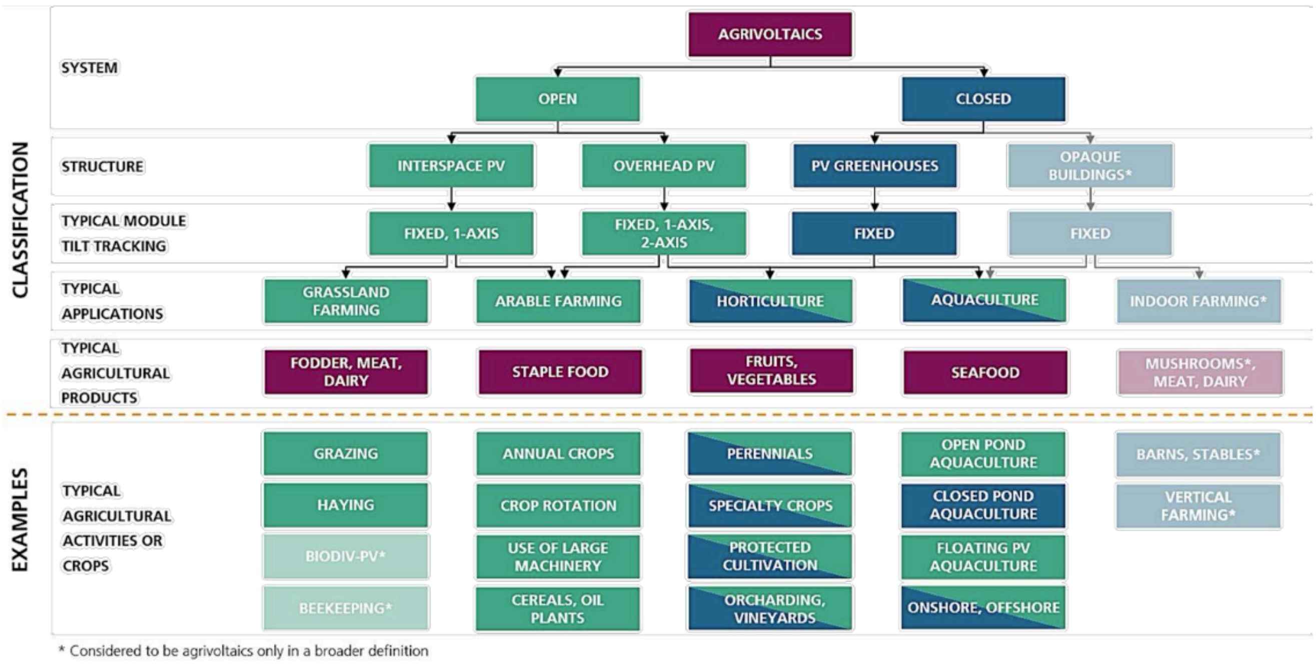


Figure 3: Overview of agrivoltaic system types and applications, based on Gorjian et al. (2022).

Modelling and Simulation

- Agrivoltaics requires the **simultaneous evaluation of crop yield and PV power production**, as shading and microclimate changes affect both. **Integrated modelling** is essential to design systems that are agronomically viable, technically efficient, and compliant with regulatory requirements.
- **Agrivoltaics modify irradiance, temperature, soil moisture, wind, and albedo**, creating conditions that influence both crop growth and PV performance – especially for bifacial modules. Conventional PV or crop models alone cannot capture these interactions.
- **Reliable modelling depends on high-quality, multi-year meteorological data and specialised tools for irradiance, microclimate, and crop simulation.** New integrated platforms are emerging that combine these components to support system optimisation and robust performance assessment.

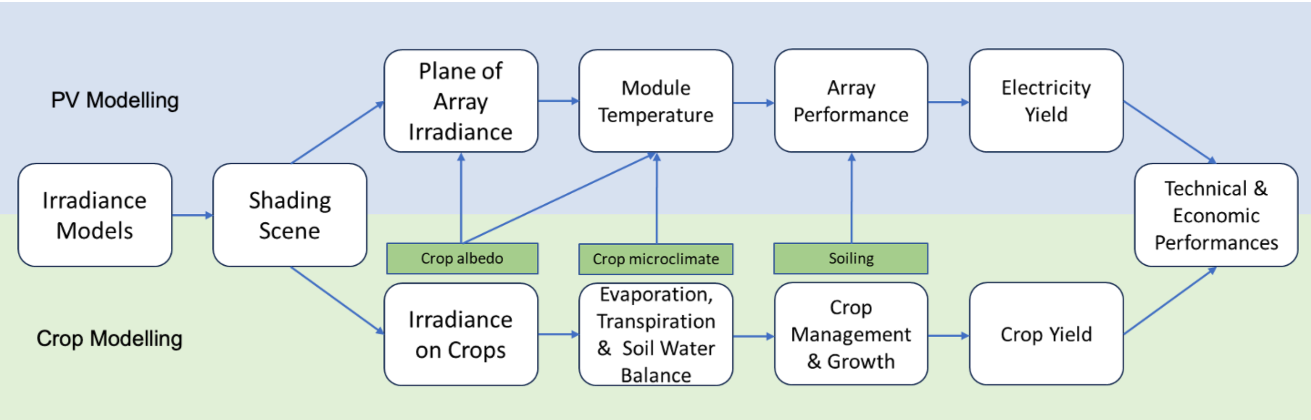


Figure 4: Simplified workflow for agrivoltaic systems simulation

Operation and Maintenance (O&M)

Monitoring microclimatic parameters and the agricultural and PV performance is key to better understand interactions and synergies between the agricultural and PV land use.

Overview of actions and their importance in the general O&M framework for agrivoltaics

Agriculture

- Vegetation Management
- Irrigation System Maintenance
- Fertilization and Pest / Disease Control
- Soil Preparation

PV System

- Regular PV Module Cleaning
- Inspection of Mounting Structures
- Preventive Maintenance / Checks of Balance of Systems (BOS, inverters, cabling)

Both

- Training and Education
- Community Engagement and Communication
- Regulatory Compliance and Safety Measures
- Weather-Related Resilience and Preparedness
- Data Management, Monitoring, and Analysis
- Documentation and KPIs Follow-up

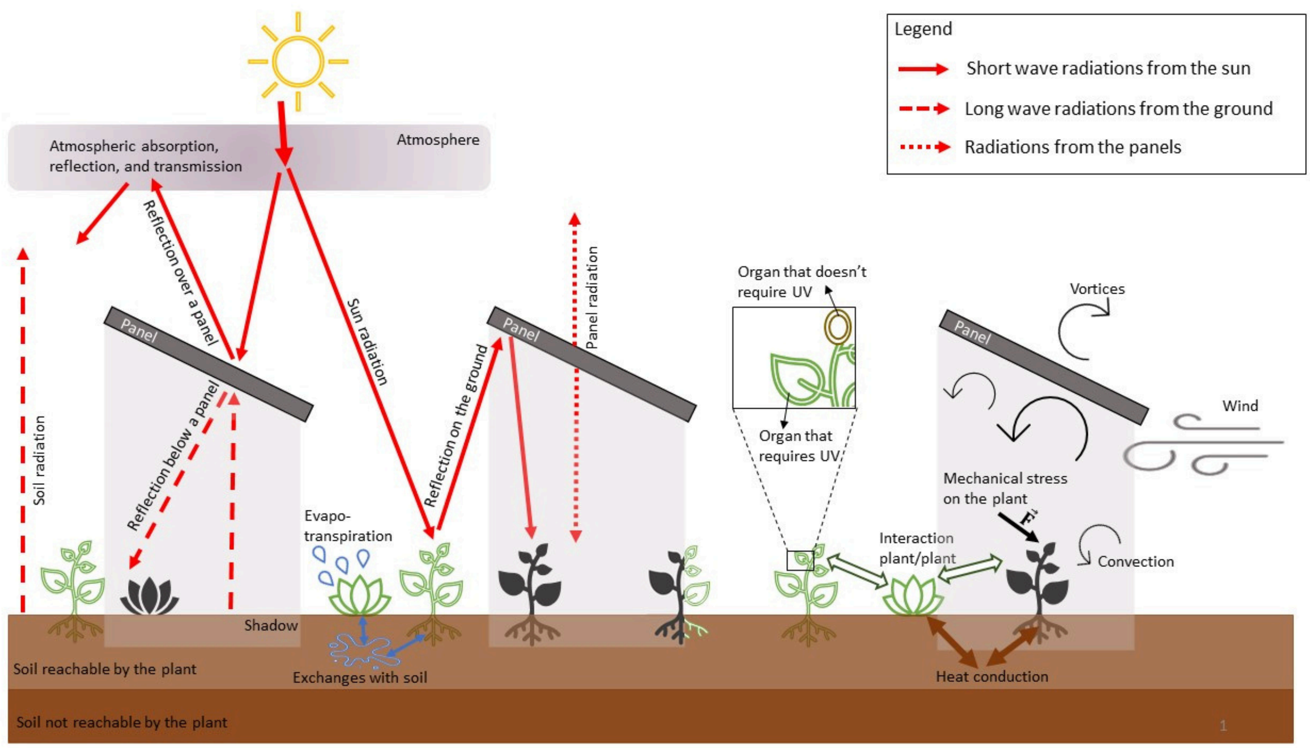


Figure 5: Diagram of the main physical phenomena within an agrivoltaic system and how they interact. Colour code: red (irradiance); blue (evapotranspiration); black (displacement of air, sensible heat); brown (heat conduction in the soil). Note that relevant weather phenomena, like rain, or energy removal by electric cables, are not shown here (Vernier, 2023).

Legal Definitions

Agrivoltaics requires clear legal definitions to distinguish it from conventional ground-mounted PV and to ensure that agriculture remains an active, primary land use. Regulations often set criteria such as minimum crop yields, shading limits, or farmer involvement. Coherent frameworks are essential to provide planning certainty and support responsible system deployment. In a recent study, Solar Power Europe finds that only 5 out of 18 EU Member States have a legal definition for agrivoltaics, showing the regulatory fragmentation across Europe (Solar Power Europe 2025).

Examples of Policy Frameworks

(Campana et al, 2025.)

Japan enabled an early, widespread adoption of agrivoltaics – over 4,000 farms by 2021 – through feed-in tariffs tied to crop-yield reporting. Deployment slowed due to inconsistent local permitting, limited incentives, and stricter structural standards.

France's 2023–2025 legislation defines agrivoltaics strictly, requiring ≥90% agricultural yield, ≤10% uncultivable area, and demonstrable agricultural benefits. Strong local oversight and new national standards make France one of Europe's most demanding regulatory environments.

The US has no unified national framework; agrivoltaics depends on fragmented state and local permitting. States such as Massachusetts, Illinois, and New York offer incentives or bid preferences, but broader uptake requires alignment across federal funding, state energy policy, and local zoning.

Germany anchors agrivoltaics regulation in DIN SPEC 91434, which requires agriculture to remain the primary land use and sets a minimum criterion of 66% agricultural yield. Updates to the EEG and the Building Act provide incentives and privileged permitting, creating a clear and stable national framework.

Because agricultural land cannot be converted without rezoning, agrivoltaics progressed slowly until new unified criteria were developed to enable dual land use. Current regulation requires ≥70% agricultural yield and strict enforcement, allowing over 180 pilot projects across diverse crops.

Italy supports agrivoltaics through national guidelines and incentives, including fast-track permitting in designated zones and strong support for "advanced" systems. Growth is hampered by regional restrictions, pending national mapping of suitable areas, and complex eligibility rules for incentives.

Social Aspects

- **Agrivoltaics can increase local acceptance when agricultural activity remains visible** and farmers retain a clear, leading role in the land-use decision.
- **Projects can strengthen rural communities** by supporting farm viability, enabling generational renewal, and creating new cooperation models with energy developers.
- Well-designed agrivoltaic **projects can improve climate resilience for farms**, reducing the social and economic stress associated with extreme weather.
- **Concerns often arise when revenue distribution is perceived as unfair or when agricultural benefits are unclear**, reducing trust among local stakeholders.
- **Landscape changes and fears of "energy over agriculture"** remain key social barriers, particularly where community involvement in planning is limited.
- **Transparent communication, participatory design processes, and long-term monitoring commitments** are essential for building and maintaining social licence.

Economic Aspects

Agrivoltaics reshapes the economic logic of land use by combining two revenue streams on the same parcel. Figure 6 compares the economic implications of conventional ground-mounted PV (GMPV) and agrivoltaics, showing higher investment is needed to enable dual-land use particularly for mounting structures and surface preparation and installation.

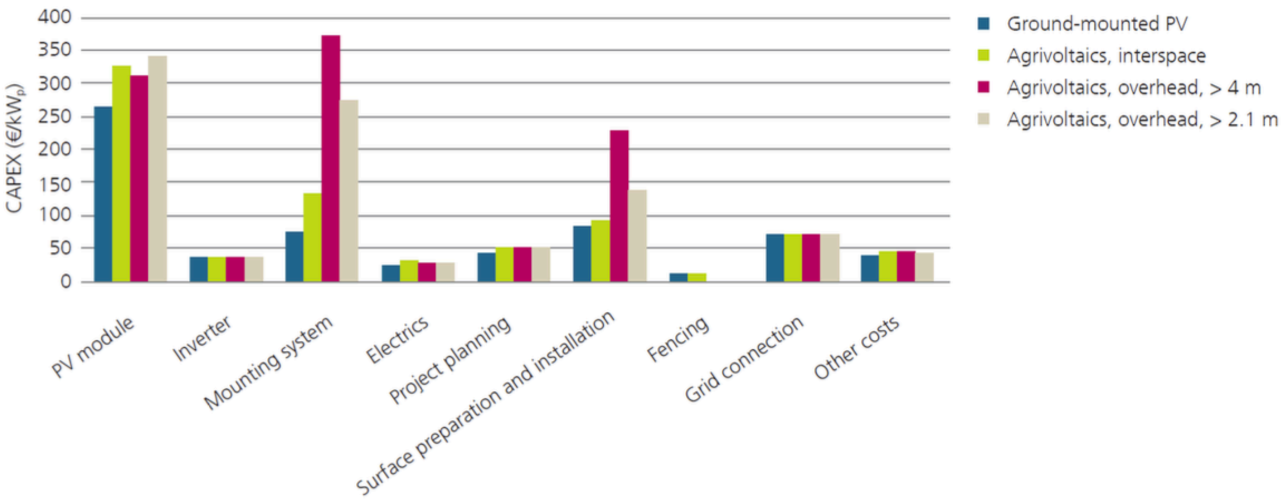


Figure 6: Estimated CAPEX for GMPV and three different agrivoltaic systems. © Fraunhofer ISE

Figure 7 illustrates typical revenue shares across different agrivoltaic applications, highlighting that electricity generation often contributes the majority of income, while agricultural value varies strongly by crop type, market structure, and system design. These distributions emphasise the need for regulation that protects meaningful agricultural activity and avoids designs where farming becomes marginal compared to energy production.

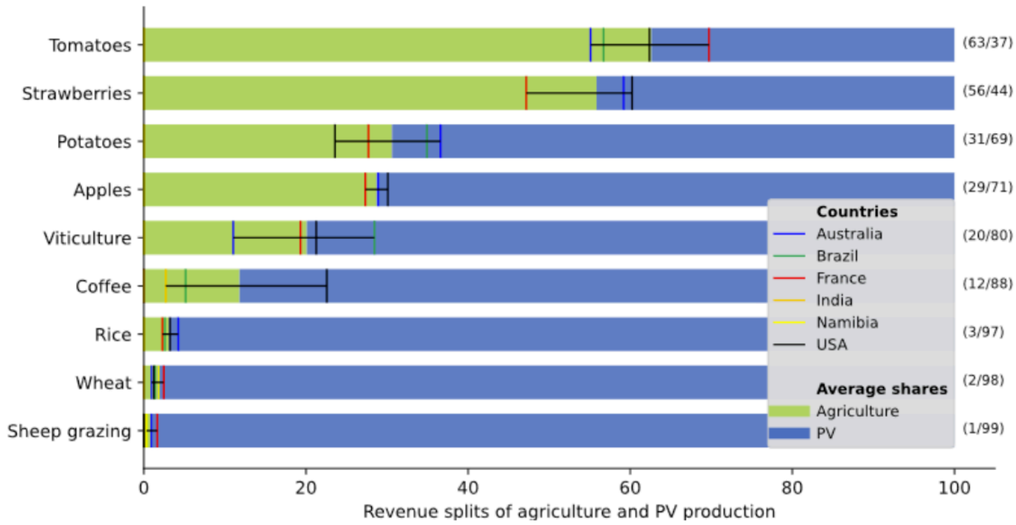


Figure 7: Revenue splits of agriculture and PV production according to Trommsdorff et al. (2024). Coloured lines indicate the variations of considered countries. Agriculture data: FAO Stat.; PV data: Solar GIS.

Conclusion and Perspectives

- Agrivoltaics offers a **strategic response to land-use conflicts between agriculture and PV deployment**, enabling climate-friendly energy generation while maintaining productive farmland. By mitigating heat, drought, and extreme weather impacts, agrivoltaics can strengthen agricultural resilience and contribute to broader climate-adaptation goals.

- **Global deployment has accelerated**, driven by supportive policies in pioneer countries such as Japan, China, France, the USA, Italy, Israel, Korea, and Germany. Market growth is expected to continue as land becomes scarcer, PV costs fall, and the need for weather-resilient food production increases.

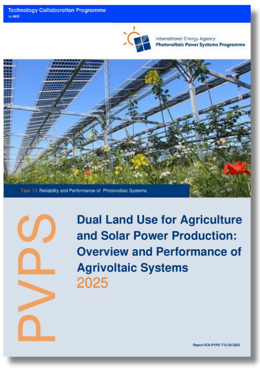
- **Key technical challenges remain: i**ntegrated modelling tools capable of simulating PV yield, crop yield, and microclimate together are still limited, and operational experience with long-term monitoring, O&M, and compliance with agricultural-yield requirements is only beginning to emerge. Ensuring data availability, refining system design, and addressing insurance and regulatory risks will be essential for maturing the sector.

- Looking ahead, **agrivoltaics is likely to diversify,** with standardised system designs for broad deployment and specialised configurations for crop-specific needs. Early and transparent engagement with local communities will remain crucial to secure acceptance. With appropriate policies and robust technical development, agrivoltaics can become a central tool for combining renewable-energy expansion with climate-resilient and productive agriculture.

PVPS Activities on Agrivoltaics

If you are interested in more details and data, download our report *Dual Land Use for Agriculture and Solar Power Production: Overview and Performance of Agrivoltaic Systems*, which offers a comprehensive overview of agrivoltaic definitions, system types, modelling & simulation methods, performance data, socio-economic aspects, and recommendations.

IEA PVPS has also established an Agrivoltaics Action Group, launched in 2024. Its mission is to synthesise existing research, harmonise definitions and metrics, and identify gaps in agrivoltaics research and implementation.



About IEA PVPS Task 13

Task 13 aims to enhance the quality, performance, and reliability of PV modules and systems by summarizing technical aspects, gathering global data, and disseminating results through reports, workshops, webinars, and web content. Task 13's expertise ensures relevant analysis for stakeholders, contributing to technology advancement, risk mitigation, and standardization in PV research and industry.

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