Task 13 Performance, Operation & Reliability of Photovoltaic Systems

Performance and Reliability of PV Modules and Systems – an IEA PVPS Perspective

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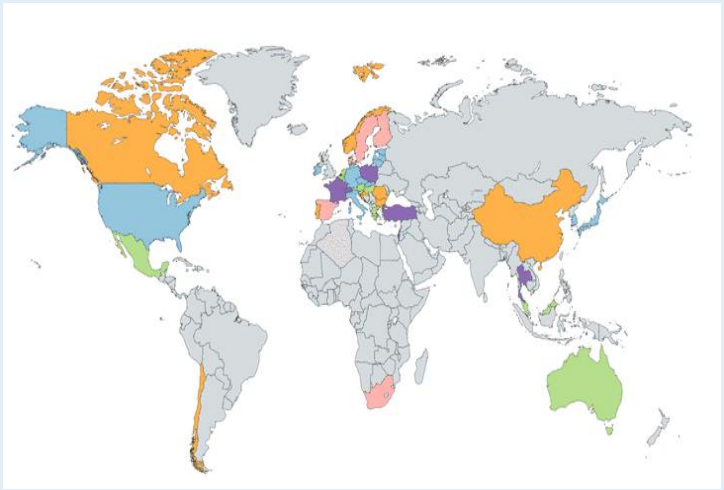
Outline

- IEA PVPS network & expertise
- Published reports of Task 13 (Highlights)
- Focus of New Work Programme
- Conclusions

The IEA PVPS Programme

- The IEA Photovoltaic Power Systems Programme (PVPS) is one of the collaborative R&D Agreements established within the IEA
- **Global network of expertise, independent, objective, neutral**
- 32 members: 26 countries, European Commission, SolarPower Europe, SEPA, SEIA, Copper Alliance
- Activities are carried out collaboratively on a country basis along a number of technical and non-technical subjects
- Currently, 8 Tasks are active



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- Global network of expertise
- Broad variety of stakeholders
- Independent, objective, neutral
- Country based, task-shared

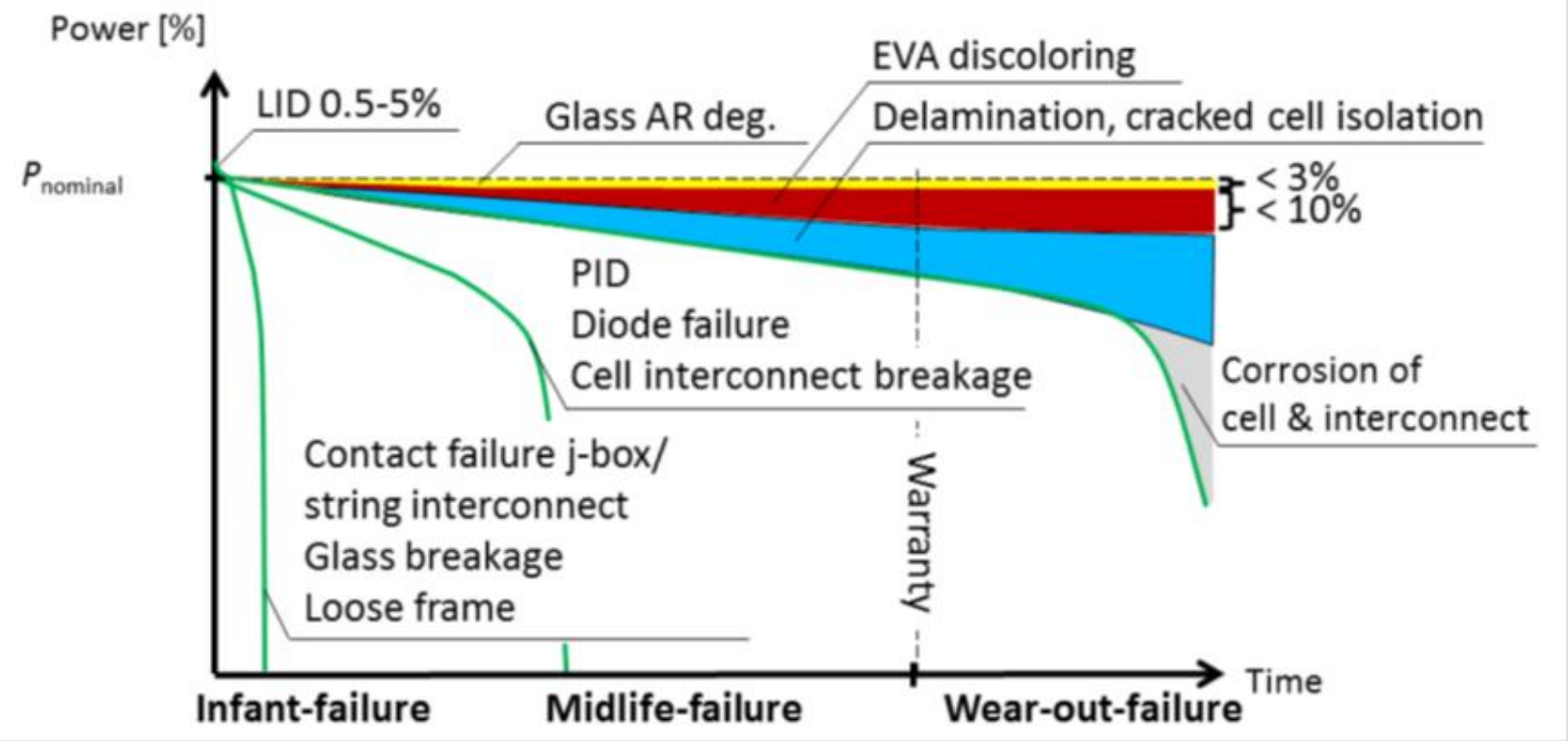
- Analysis
- Recommendations
- Communication & interaction

IEA PVPS Tasks

- Task 1 - Exchange and dissemination of information on PV power systems
- Task 8 - Very large scale PV power generation systems (closed)
- Task 9 - PV Deployment in emerging countries
- Task 12 - PV environmental, health & safety activities
- **Task 13 - PV performance, operation and reliability**
- Task 14 - High Penetration PV in Electricity Grids
- Task 15 - Enabling framework for the acceleration of BIPV
- Task 16 - Solar resource for high penetration and large-scale applications
- *Task 17 - PV and Transport*

IEA PVPS Task 13: Failure Modes for PV Modules

Time evolution of PV module failures



Infant failure or early failure occur in the beginning of the working life of a PV module.

Origin: Defective construction, faults in production and non-conforming materials.

Mid-life failure occurring up till 10-15 years of operation are termed as midlife failures.

Wear-out failure occurring late in PV module lifetime.

Source: IEA PVPS Task 13
http://www.iea-pvps.org/index.php?id=57

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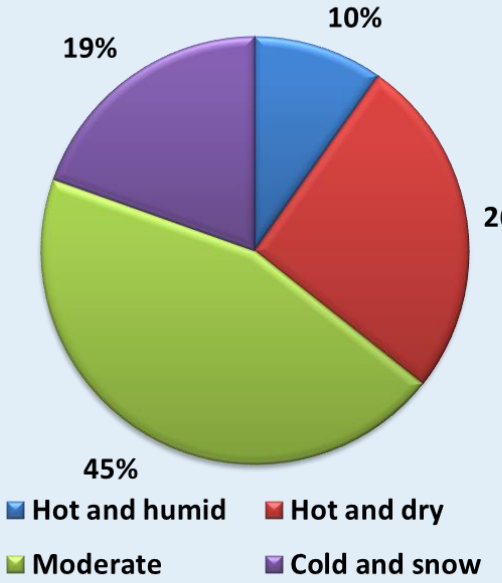

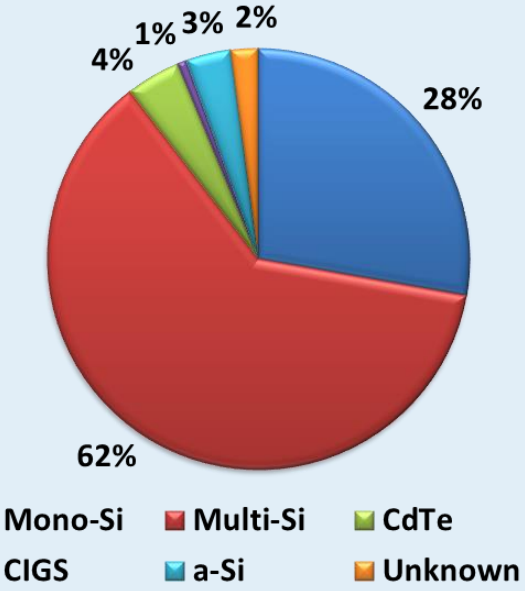

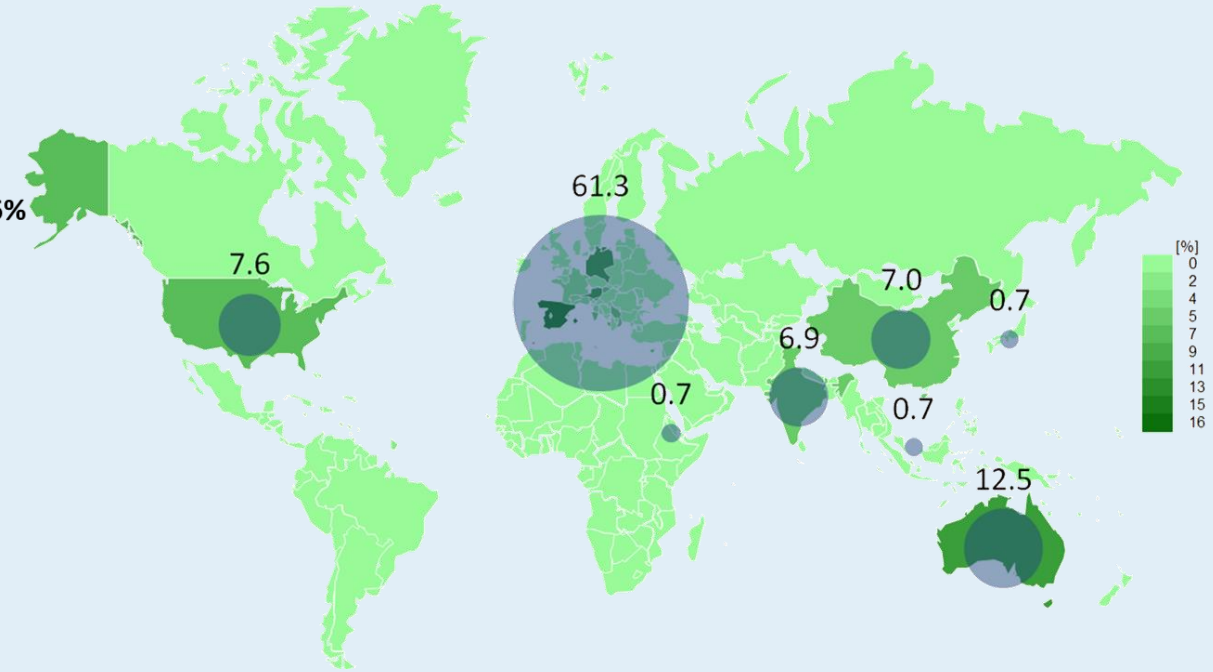

- Main survey data from Europe
- Moderate climate dominates data.
- Technology distribution equal to market distribution
- 150 failure-survey-data sets from 18 countries

IEA PVPS Task 13: Data collection tool
http://iea-pvps.org/index.php?id=344

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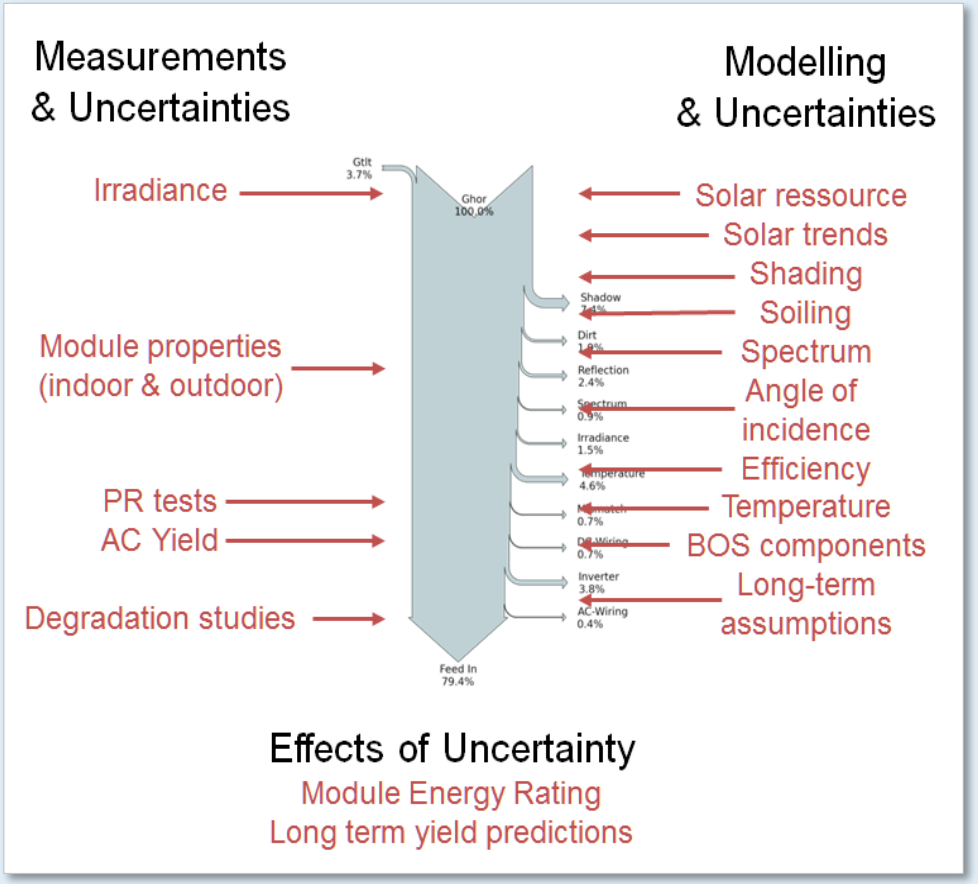
Uncertainties in PV System Yield Predictions and Assessments

Technical Report IEA-PVPS T13-12:2018

We provide insights into the field of uncertainties of several technical aspects of PV system yield prediction and assessment:

- The solar resource, including long-term trends
- PV module properties
- PV system output and performance, again including long-term effects.

Our effort is to standardize the procedure of uncertainty calculation of predicted PV energy yields in order to properly estimate financial investment risks.

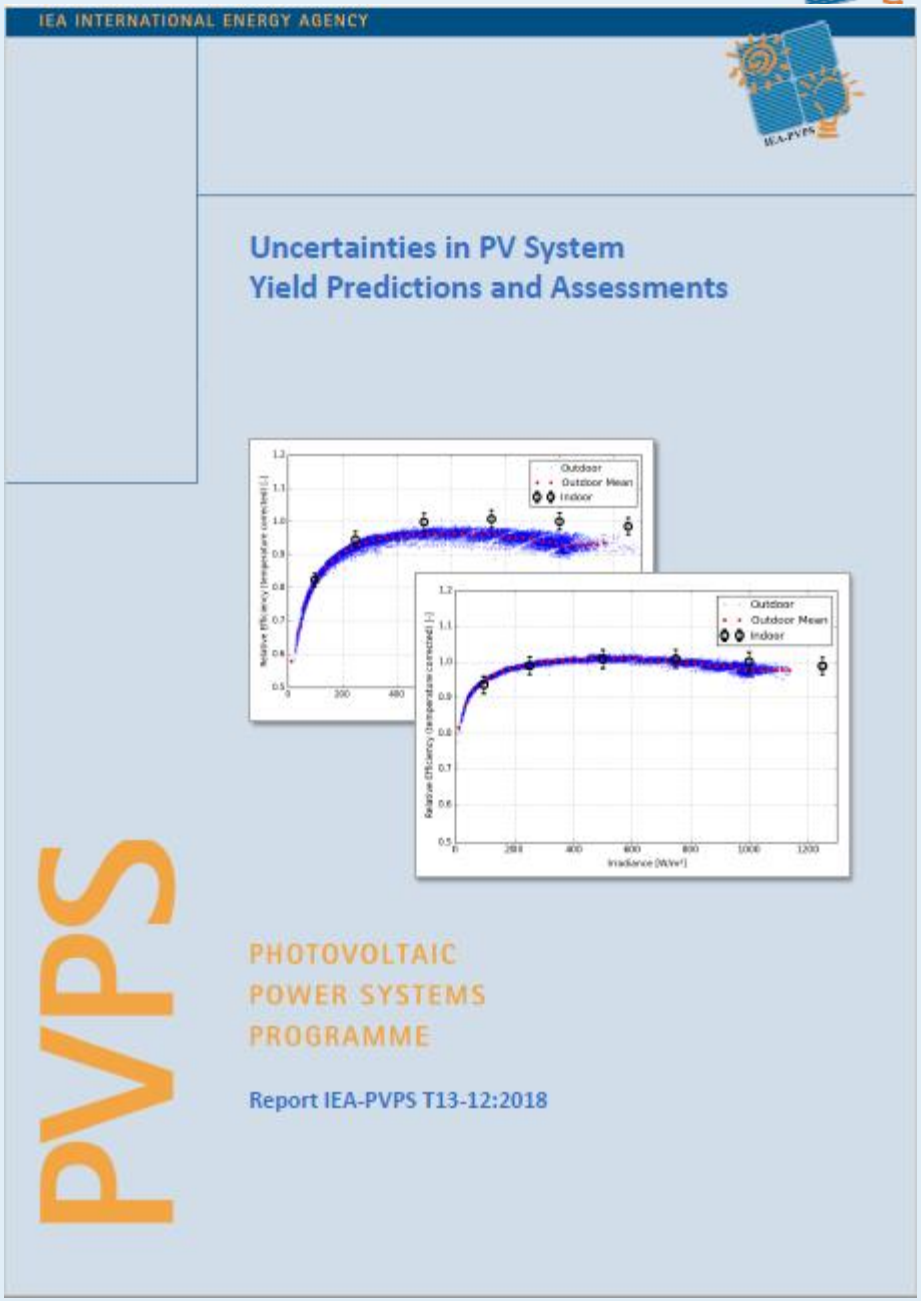


ST 2.3 & 3.1 Report

The first main section lists typical measurements, dealing either with a PV system component's properties or with PV system performance.

The second major section investigates several of the modelling steps for gains and losses in a PV system.

Following the investigation of uncertainties in measurements (Section 2) and in modelling (Section 3), the combination of the knowledge gained is demonstrated for two application cases in Section 4.



3.3 Review on Infrared and Electroluminescence Imaging for PV Field Applications

Technical Report
IEA-PVPS T13-10:2018

This report provides a comparison of the relative merits of EL and IR imaging techniques .

- We present the current practices for infrared (IR) and electroluminescence (EL) imaging of PV modules and systems, looking at environmental and device requirements, and on the interpretation of sample patterns with abnormalities.
- Our goal is to provide recommendations and guidelines for using IR and EL imaging techniques to identify and assess specific failure modes of PV modules and systems in field applications.

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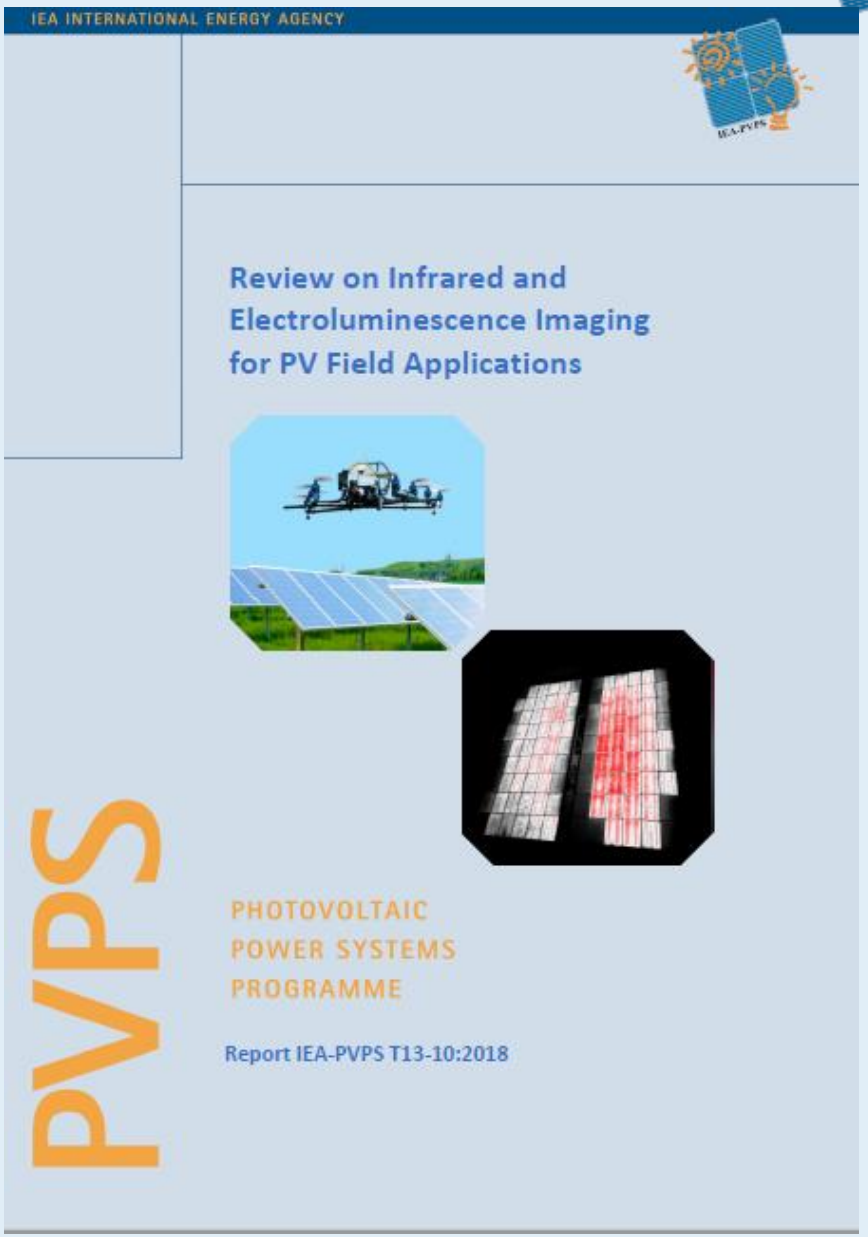
ST 3.3 Report

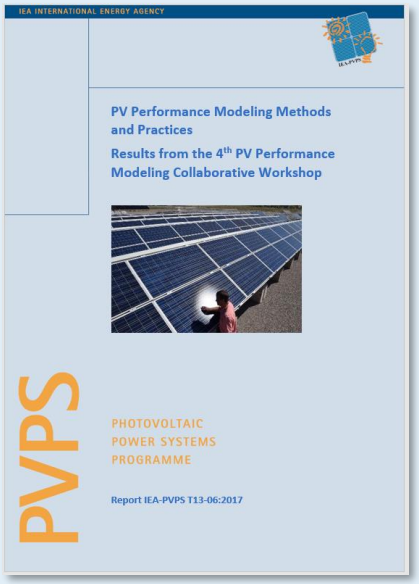
An introduction on IR imaging, test requirements and examples as well as the-state-of-art technology and techniques are given.

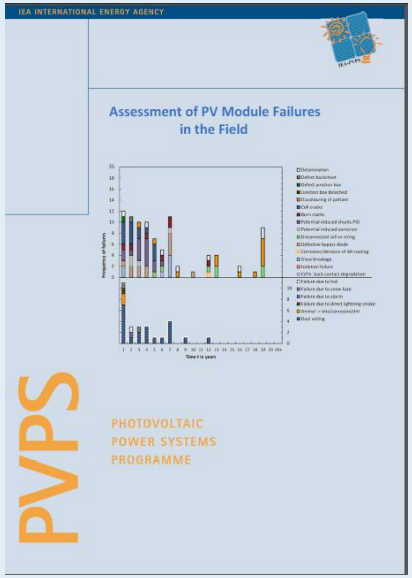
The same approach is taken for EL imaging in the field.

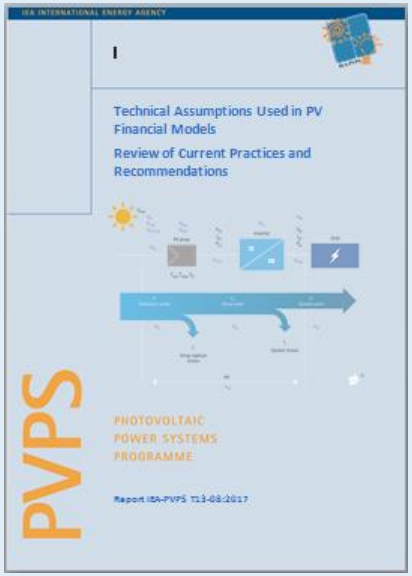
A combination of both techniques allows to detect the most common defects in a PV module with high accuracy and provides a good indication of the health and reliability of the modules within a PV plant.

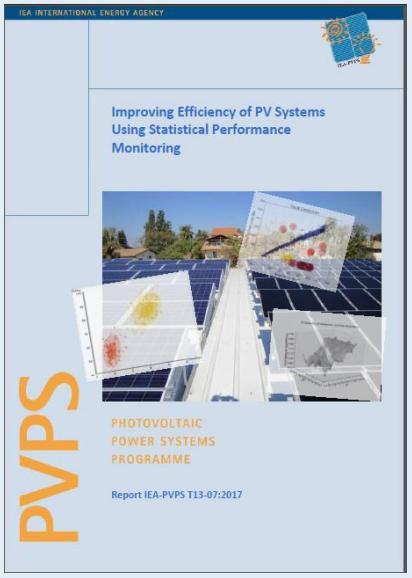


IEA PVPS Task 13 Deliverables: Published 2017









4 Technical Reports

For Download at: www.iea-pvps.org

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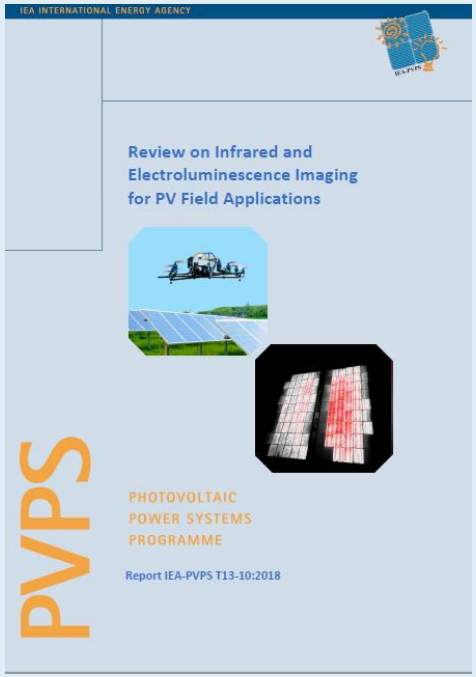
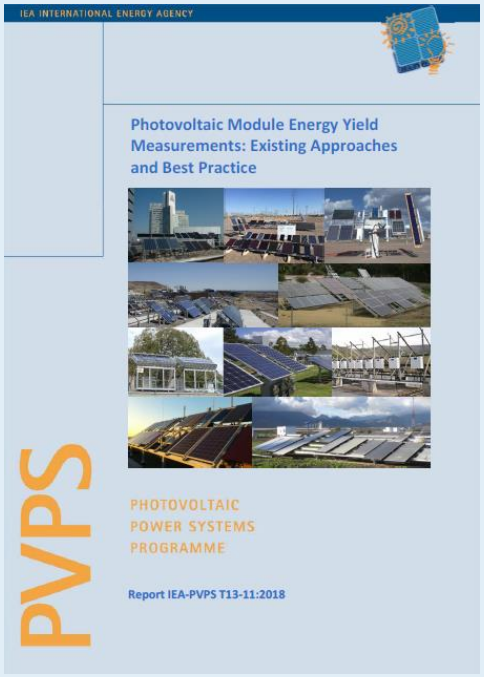
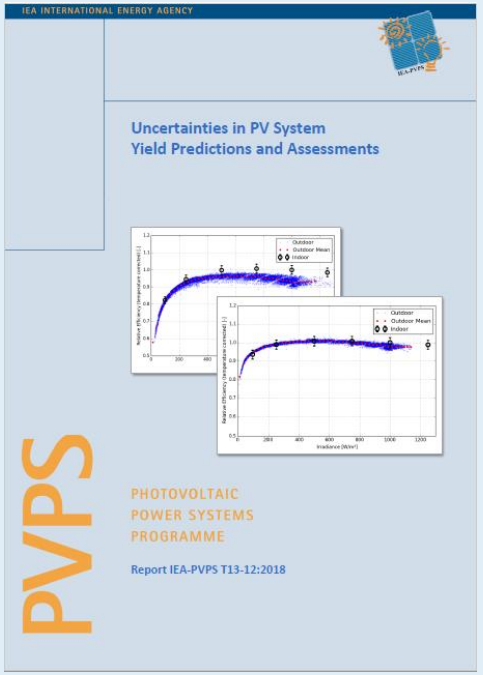
IEA PVPS Task 13 Deliverables: Published 2018







3 Technical Reports

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PVPS Task 13 Structure 2018 – 2021

Subtask 1: New Module Concepts and System Designs

Subtask 2: Performance of Photovoltaic Systems

Subtask 3: Monitoring - Operation & Maintenance

Subtask 4: Dissemination

- 1st period: May 2010 – April 2014
- 2nd period: Sep 2014 – Dec 2017
- **3rd period: Sep 2018 – Sep 2021**

Performance, Operation & Reliability of PV Systems

Subtask 1: New Module Concepts and System Designs
1.1 New Module-Concepts, -Designs and -Materials
1.2 Bifacial Photovoltaic Modules and Concepts
1.3 Performance of New Photovoltaic System Designs
1.4 Service Life Prediction

Subtask 2: Performance of Photovoltaic Systems
2.1 Uncertainty in Yield Assessments and PV LCOE
2.2 Predictive Monitoring
2.3 Climatic Rating of Different Technologies for Different Countries
2.4 Impact of Soiling on PV System Performance and Reliability
2.5 Assessment of Performance Loss Rate

Subtask 3: Monitoring - Operation & Maintenance
3.1 Quantification of Technical Risks during O&M
3.2 Characterization of PV Power Plants using Mobile Devices
3.3 Guidelines for O&M Procedures in Different Climates/Countries

Subtask 4: Dissemination / Outreach

PVPS Task 13 Motivation

- What is the range of degradation rates of PV systems?
- What is the uncertainty in PV plant performance predictions?
- Does the degradation rate depend on the methodology used to calculate it?
- What is the occurrence of failures in PV systems?
- Which failures have a significant impact?
- How can we rapidly detect failures or even predict when they may occur?

The reliability of PV power plants and modules has been, and will continue to be an issue for investors, owners and utilities.

Subtask 1: New Module and System Designs

Motivation

- PV is utilizing new materials, manufacturing methods, module and systems designs in order to lower costs and hopefully increase or maintain reliability.
- This activity will collect data from member countries on the emerging state of the art in PV modules and systems.
- The activity will provide recommendations on characterization methods for new technologies.

Possible Task Focus Areas

- **New Module Materials and Constructions** (e.g., encapsulants, coatings, back sheets, cover sheets, adhesives, bifacial modules, shingled cells with conductive adhesive, lightweight modules (no glass), edge seals, frameless modules, integrated mounting, module power electronics)
- **New System Concepts** (e.g., coupled PV with energy storage, high dc voltage systems, advanced power electronics, tracking technologies, vertical bifacial systems, etc.)

1.1 New Module Materials and Constructions

- Encapsulants
- Bifacial module designs
- Shingled cells with conductive adhesive
- Glass-glass, frameless
  - Clip design
  - Integrated support structure
  - Composite frames
- Lightweight modules (no glass)
- Coatings
  - Anti soiling, reflection
  - Aesthetic
- Megamodules
  - May increase installation efficiency?

Task 13: PV Performance, Operation & Reliability

Subtask 2: Performance of Photovoltaic Systems
2.1 Uncertainty in Yield Assessments and PV LCOE
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Task 13: PV Performance, Operation & Reliability

Impact on Life Cycle Analysis & Levelized Cost of Electricity

$$LCOE_{PV} = \frac{I_{PV} + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t} + R_n}{\sum_{t=1}^{n} \frac{M_{el} \times (1-d_{PV})^t}{(1+i)^t}}$$

I_{PV}: investment costs
A_t: annual total costs
R_n: removal costs
n: lifetime in years

M_{el}: electricity output
d_{PV}: degradation rate
i: discount rate
t: operating year

- Efficiency performance irradiation
- Maintenance recycling
- wafer, cell, module Balance of systems
- financing
- Lifetime reliability

Cost and Quality of the PV System (planning)

- *T13-08:2017 Technical Assumptions of PV Financial Models*

System Lifetime

- *T13-01:2014 Review of Failures of Photovoltaic Modules*
- *T13-07:2017 Statistical Performance Monitoring*
- *T13-09:2017 Assessment of Photovoltaic Module Failures in the Field*

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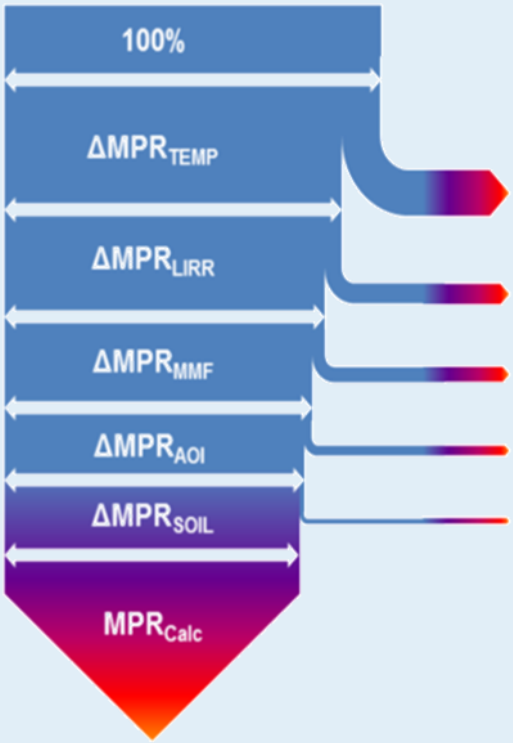
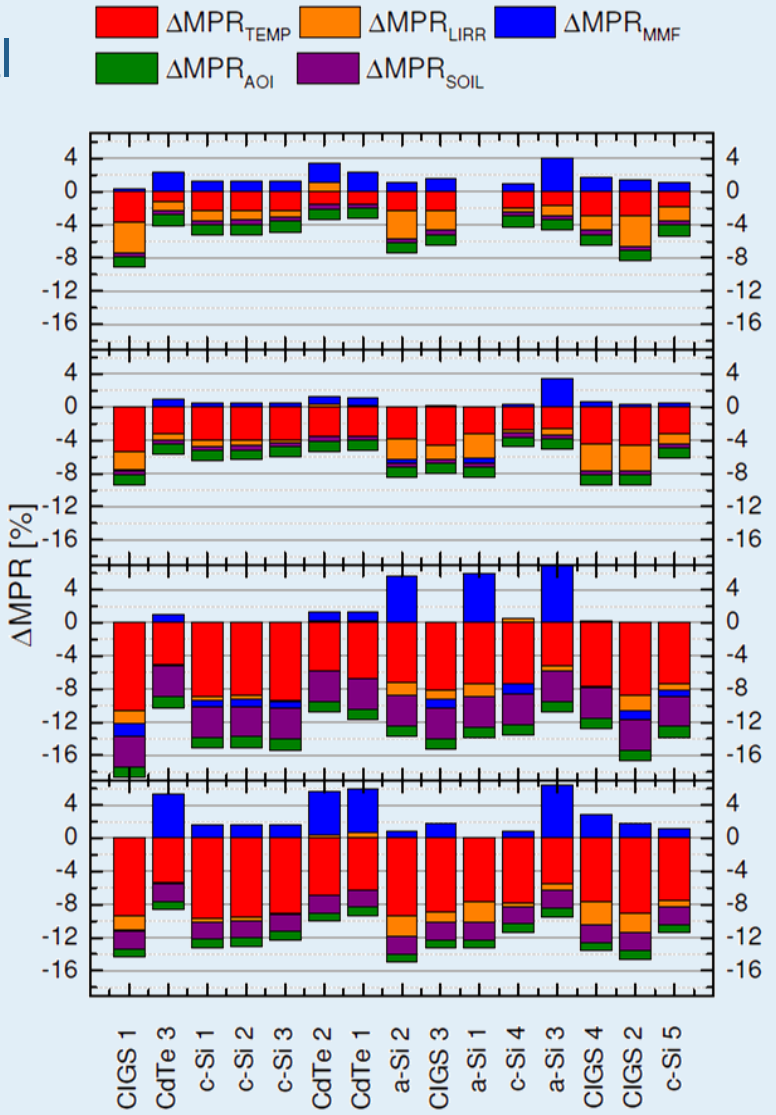
ST 2.3: Climatic Rating of Different Technologies for Different Countries

Separating and quantifying meteorological impact factors on energy yield delivery to compare between different PV module types in various climates:



c-Si 1	Cologne	Ancona	Tempe	Chennai
	-2.3%	-3.9%	-8.9%	-9.6%
	-1.2%	-0.8%	-0.4%	-0.5%
	+1.3%	+0.5%	-0.8%	+1.6%
	-3.5%	-2.4%	-2.0%	-2.9%
	-0.5%	-0.5%	-3.7%	-2.1%
	-6.2%	-7.2%	-15.9%	-13.5%
	93.9%	92.8%	84.1%	86.5%



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Task 13: PV Performance, Operation & Reliability

Subtask 3: Monitoring - Operation & Maintenance
3.1 Quantification of Technical Risks during O&M
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3.3 Guidelines for O&M Procedures in Different Climates/Countries

ST 3.2: Characterization of PV Power Plants using Mobile Devices

Motivation

- Provide good practice on methods and devices to qualify PV power plants in the field
- Evaluate uncertainties of mobile devices for characterizing PV power plants and comparison to laboratory data
- Legal framework for using

Target Audience

- PV industry, test equipmer
  inspectors, O&M providers

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Task 13 Collaboration with other Organizations

- PV ETIP dedicated Working Group on Quality
- IEC TC 82 & IEC-RE
- IRENA's Report on Quality Infrastructure
- Output of H2020 Solar Bankability project
- SOLAR UNITED's White Paper on Quality
- EU Cost Action on large data analysis - Pearl PV
- PVQAT

Conclusions

- **Task 13 extension 2018-2021**: Global network required to improve the quality and reliability of PV systems and components by collecting, analyzing and disseminating information on their technical and financial performance.
- New focus areas and challenges: “New Module Materials and Constructions” and “New System Concepts”.
- PV is utilizing new materials, manufacturing methods, module and systems designs in order to lower costs and hopefully increase or maintain reliability.
- PV performance analysis and monitoring will lead to more qualified assessments of PV plants and thus lower risk in PV investments.

Task 13 Technical Reports at www.iea-pvps.org

14th Task13 Meeting in Bolzano, Italy, 06-08 April 2016

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International Collaboration IEA PVPS Task 13:

22+ IEA countries, 38+ institutions

⇒ 45 participants, 80+ members

Thank You for Your Attention!