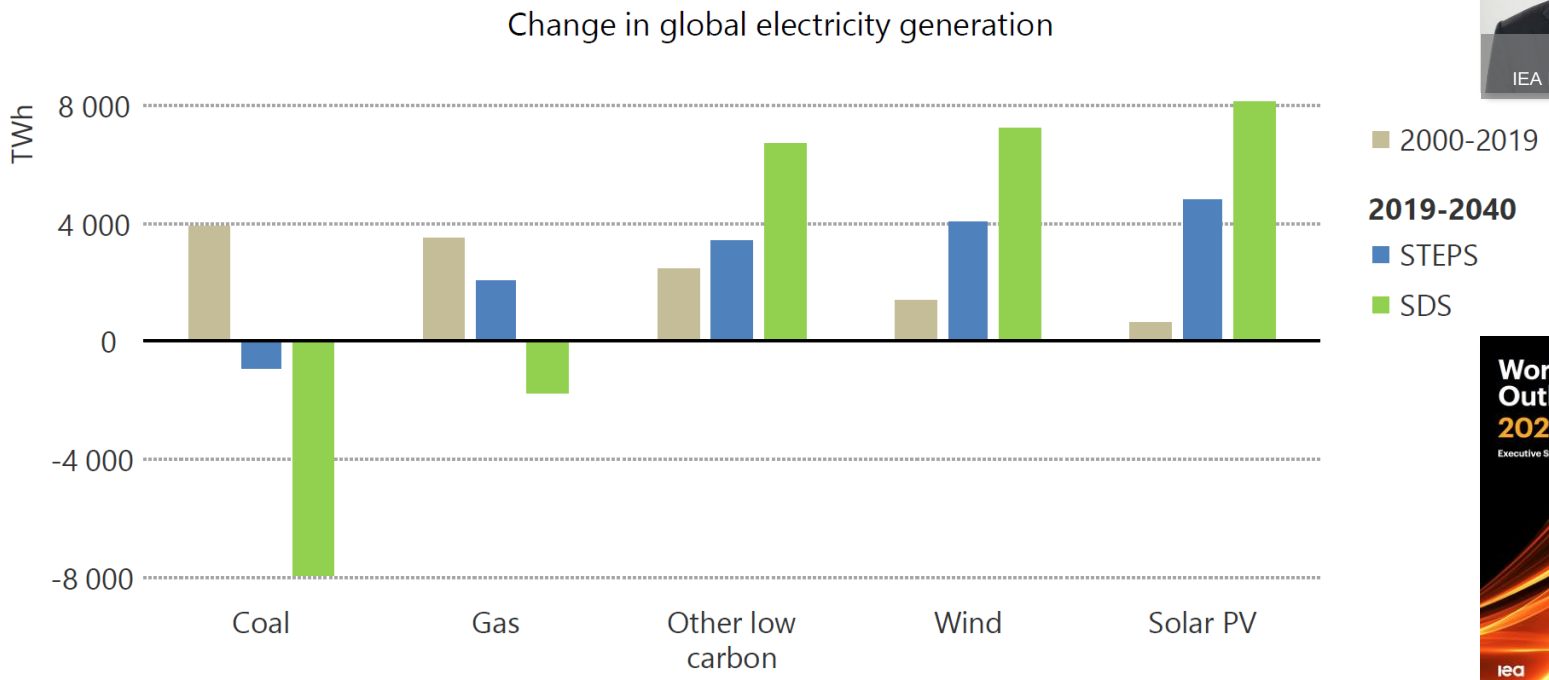
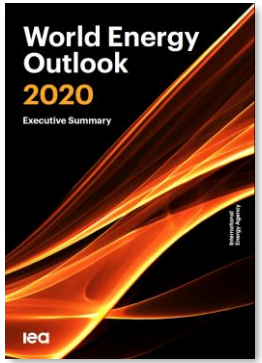
A Quest for Quality – From Technology to Energy Systems

Becquerel Prize Acceptance - Ulrike Jahn

38th EU PVSEC, 6th September 2021

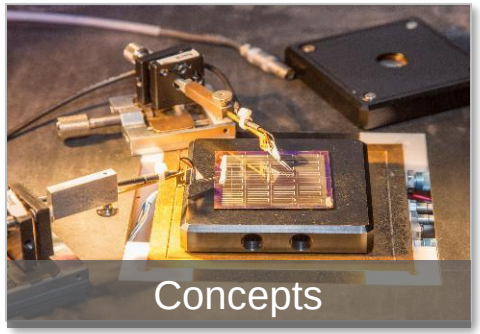
Solar PV is becoming the ‘new king’ of electricity

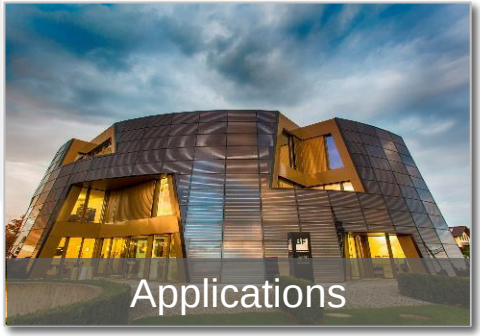




Solar PV is now the cheapest source of electricity in most countries in part due to low cost financing and is set to triple before 2030 under current and proposed policies, with the potential to grow much faster

Working along the value chain

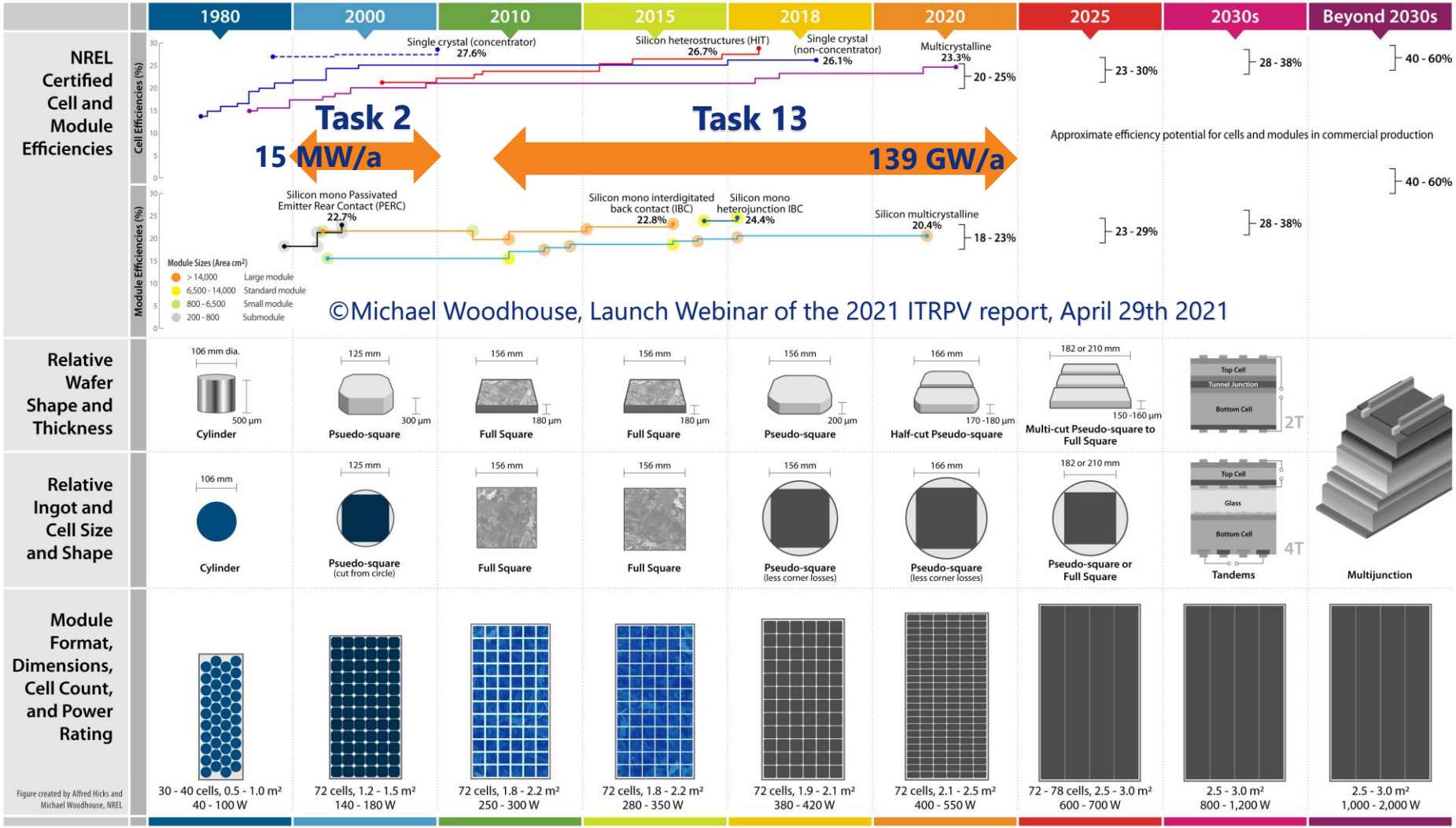




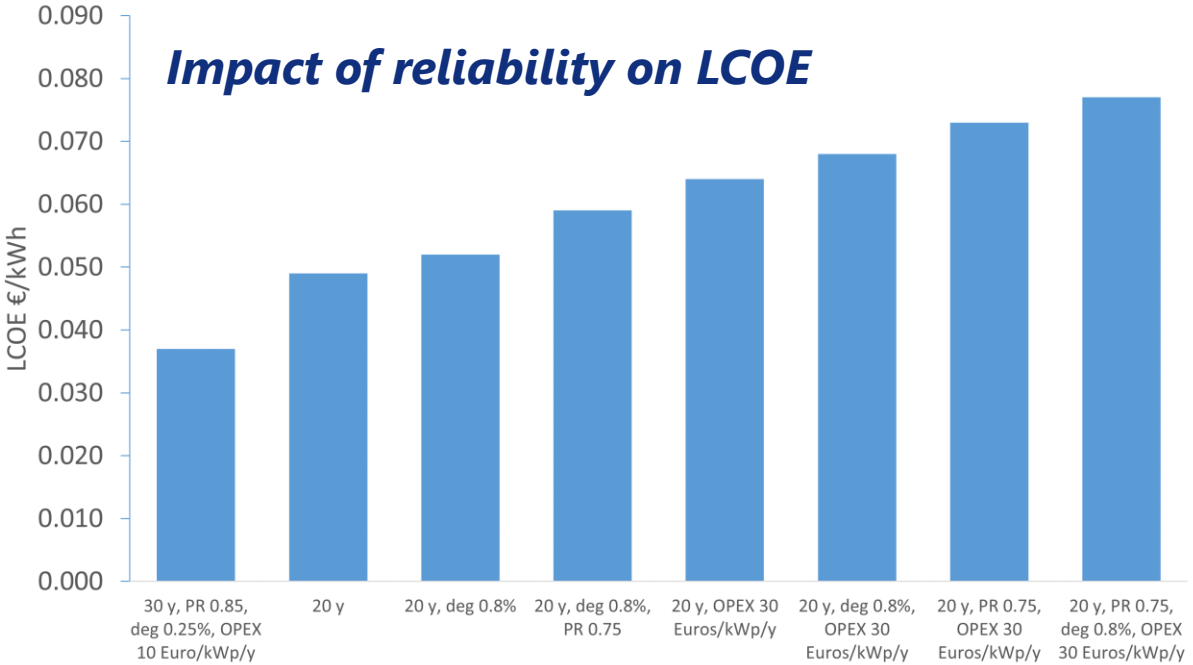
PVPS

Research | Components | Systems | Integration | Market

PVPS expertise & outreach


1980
2000
2010
2015
2018
2020
2025
2030s
Beyond 2030s
NREL Certified Cell and Module Efficiencies
Cell Efficiencies (%)
Single crystal (concentrator) 27.6%
Silicon heterostructures (HIT) 26.7%
Single crystal (non-concentrator) 26.1%
Multicrystalline 23.3%
20 - 25%
23 - 30%
28 - 38%
40 - 60%
Task 2
15 MW/a
Task 13
139 GW/a
Approximate efficiency potential for cells and modules in commercial production
Module Efficiencies (%)
Silicon mono Passivated Emitter Rear Contact (PERC) 22.7%
Silicon mono interdigitated back contact (IBC) 22.8%
Silicon mono heterojunction IBC 24.4%
Silicon multicrystalline 20.4%
18 - 23%
23 - 29%
28 - 38%
40 - 60%
Module Sizes (Area cm²)
> 14,000 Large module
6,500 - 14,000 Standard module
800 - 6,500 Small module
200 - 800 Submodule
©Michael Woodhouse, Launch Webinar of the 2021 ITRPV report, April 29th 2021
Relative Wafer Shape and Thickness
106 mm dia.
500 µm
Cylinder
125 mm
300 µm
Psuedo-square
156 mm
180 µm
Full Square
156 mm
180 µm
Full Square
156 mm
200 µm
Pseudo-square
166 mm
170 -180 µm
Half-cut Pseudo-square
182 or 210 mm
150 -160 µm
Multi-cut Pseudo-square to Full Square
Top Cell
Tunnel Junction
Bottom Cell
2T
Relative Ingot and Cell Size and Shape
106 mm
Cylinder
125 mm
Psuedo-square (cut from circle)
156 mm
Full Square
156 mm
Full Square
156 mm
Pseudo-square (less corner losses)
166 mm
Pseudo-square (less corner losses)
182 or 210 mm
Pseudo-square or Full Square
Top Cell
Glass
Bottom Cell
4T
Tandems
Multijunction
Module Format, Dimensions, Cell Count, and Power Rating
30 - 40 cells, 0.5 - 1.0 m²
40 - 100 W
72 cells, 1.2 - 1.5 m²
140 - 180 W
72 cells, 1.8 - 2.2 m²
250 - 300 W
72 cells, 1.8 - 2.2 m²
280 - 350 W
72 cells, 1.9 - 2.1 m²
380 - 420 W
72 cells, 2.1 - 2.5 m²
400 - 550 W
72 - 78 cells, 2.5 - 3.0 m²
600 - 700 W
2.5 - 3.0 m²
800 - 1,200 W
2.5 - 3.0 m²
1,000 - 2,000 W
Figure created by Alfred Hicks and Michael Woodhouse, NREL

PV towards decreasing record prices and LCOE



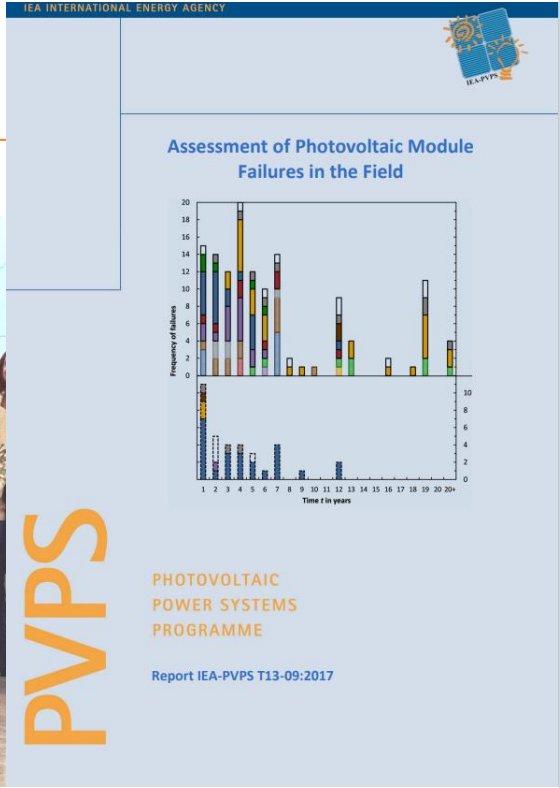
Which are the drivers for cost-effective increase of performance & reliability?

Eero Vartiainen, Gaëtan Masson, Christian Breyer, David Moser, Eduardo Román Medina, PIP 2019 https://doi.org/10.1002/pip.3189
Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility-scale PV levelised cost of electricity

Graph courtesy of Dr. David Moser, Eurac research

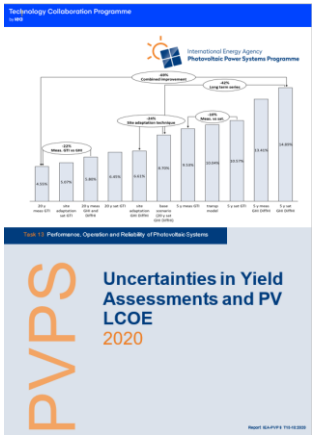
5th IEA PVPS Task 2 Experts' Meeting
Yokohama, Japan, 19-22 September 2001:
10 experts from 6 countries

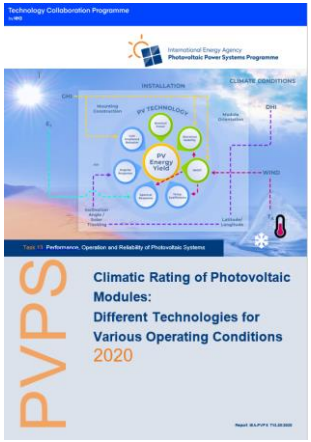
… Task 13 delivering technical reports

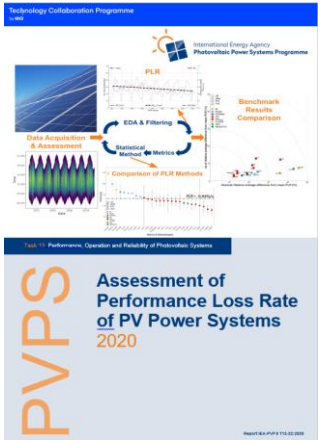


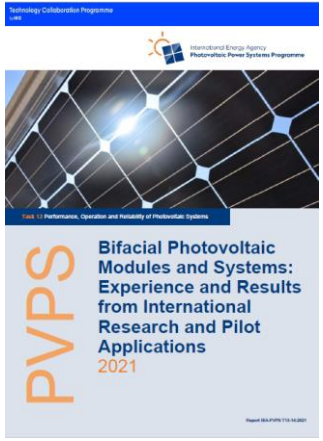
17th IEA PVPS Task 13 Experts' Meeting, Cologne, Germany, October 2017:
45 experts from 20 countries

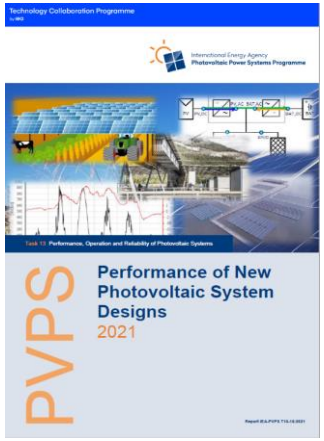
Technical Reports (2018-2021)

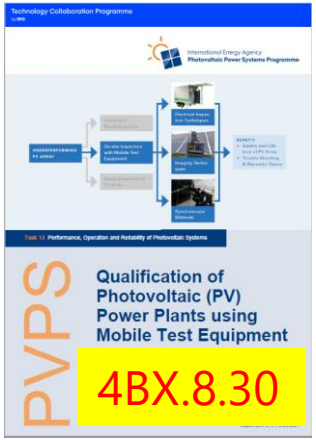


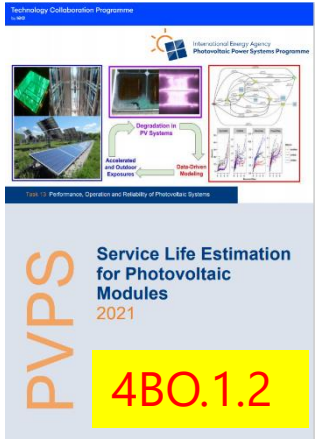


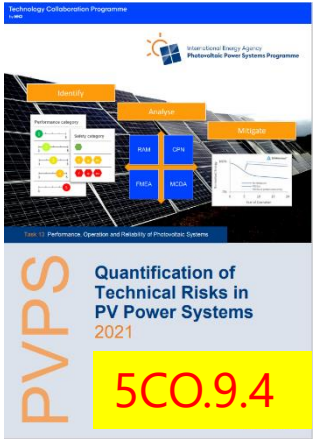


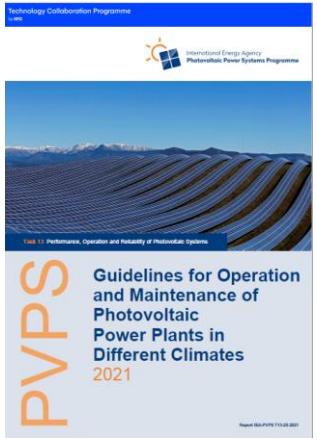






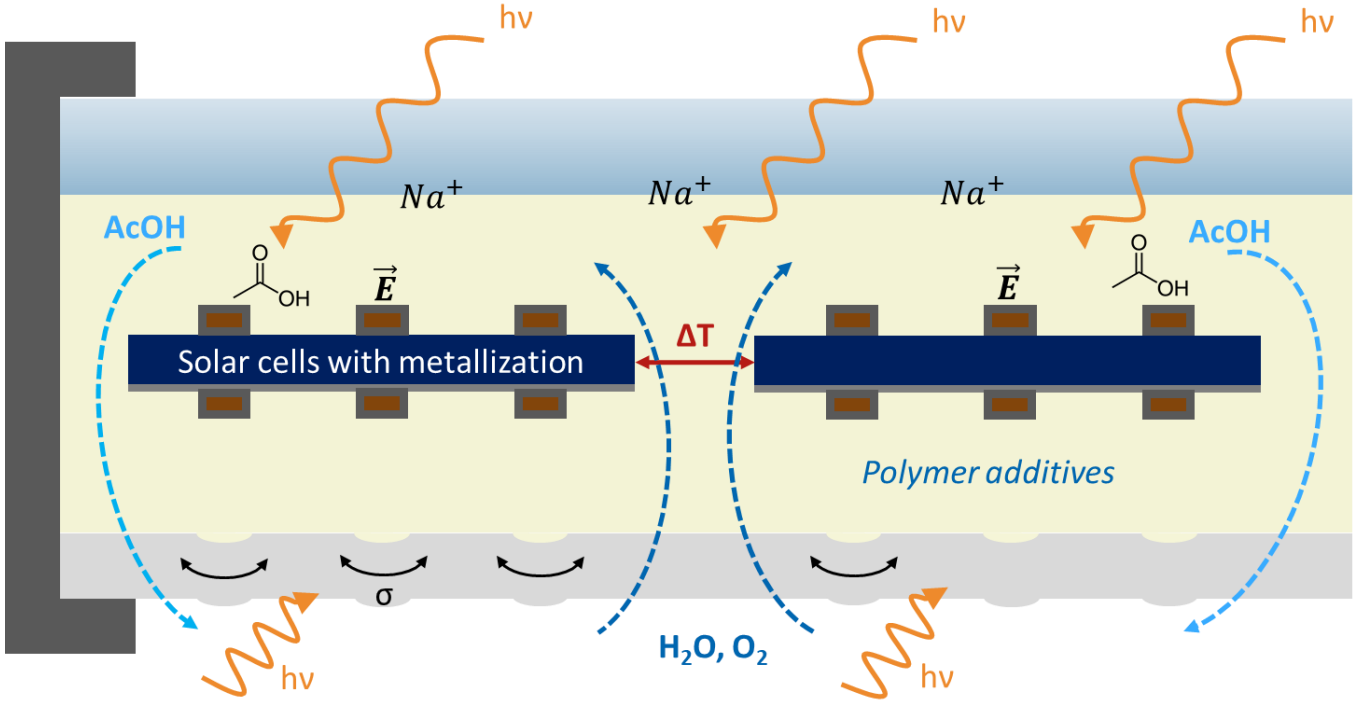


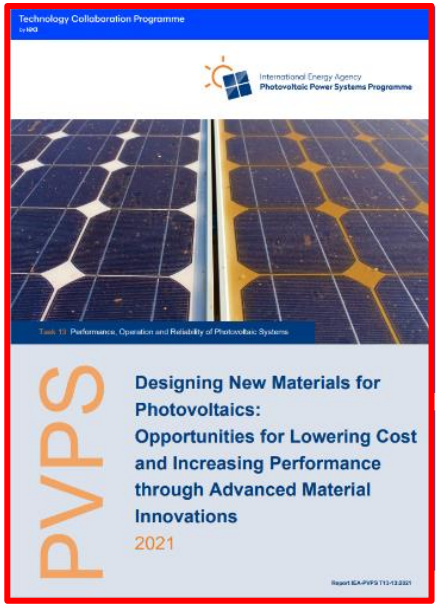




https://iea-pvps.org/research-tasks/performance-operation-and-reliability-of-photovoltaic

Challenges for new materials and components





PVPS

- External and internal stress factors influence performance and long-term reliability of PV modules
- The materials in PV modules have to withstand extremely challenging micro-climatic conditions.

G. Oreski, J.S. Stein, et al. "Designing New Materials for Photovoltaics: Opportunities for Lowering Cost and In-creasing Performance through Advanced Material Innovations". Report IEA-PVPS T13-13:2021. ISBN 978-3-907281-02-4.

Challenges for new materials and components

Adhesion - delamination

Backsheet yellowing

Corrosion

- Long-term stability is determined by bill of materials and their material interactions.
- Each material combination to be tested thoroughly before introduction into the market
- Single stress testing does not reveal certain degradation modes observed in the field.

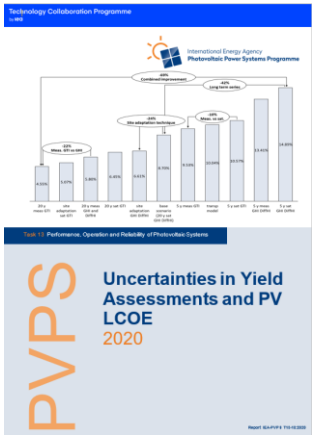
Constant need for adaption of test methods and standards

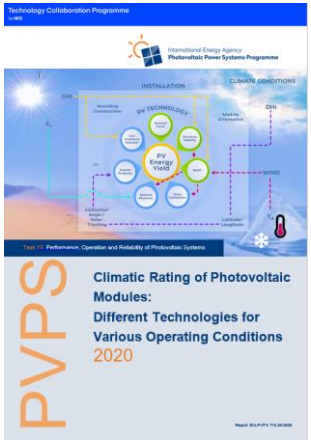
PVPS

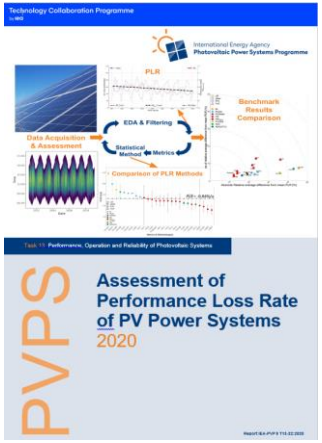
4CO.1.1 & 4.AV.1.24

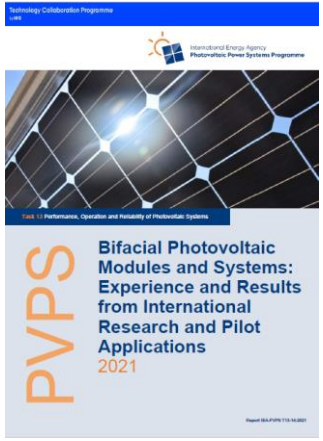
G. Oreski, ... ics: Opportunities for Lowering Cost and In-creasing Performance through Advanced Material Innovations". Report IEA

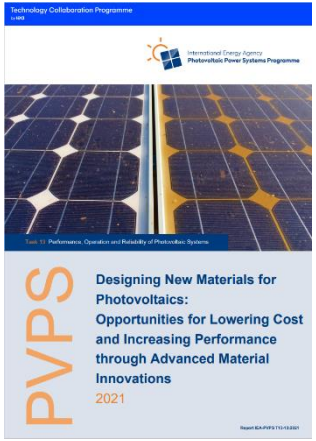
Technical Reports (2018 - 2021)

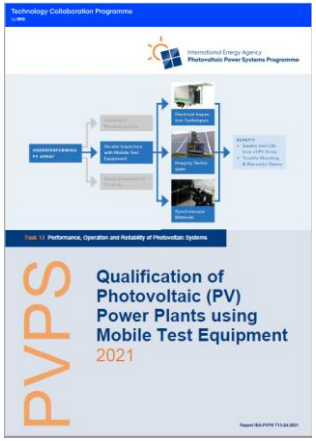


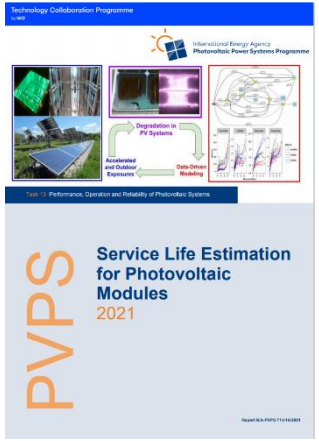


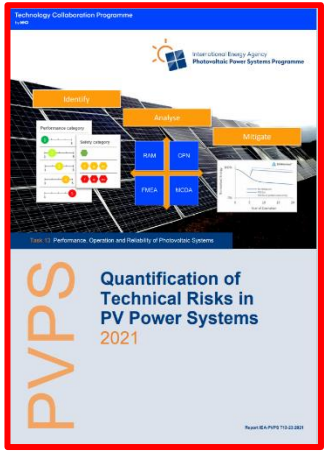


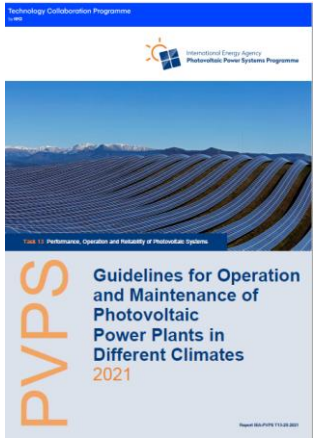












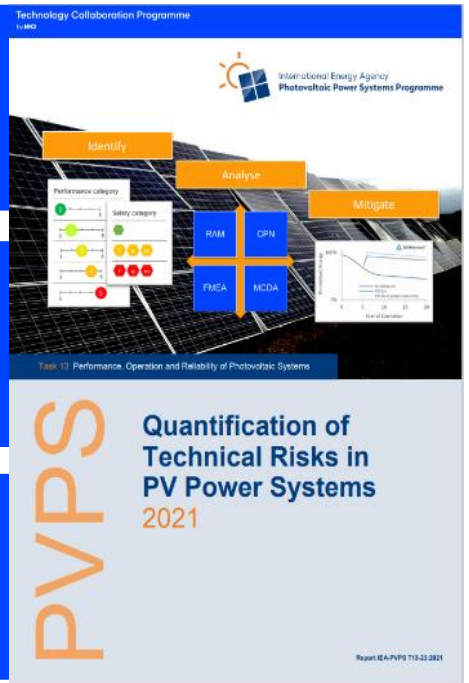
https://iea-pvps.org/research-tasks/performance-operation-and-reliability-of-photovoltaic

Quantification of Technical Risks

Review methods to compare and assess common practice

- Key Definitions
- Semi-Quantitative Methods
- Quantitative Methods
- Risk Mitigation Measures
- Limitations and Challenges

- Common Practice
- Risk Analysis
- Cost-Benefit Analysis



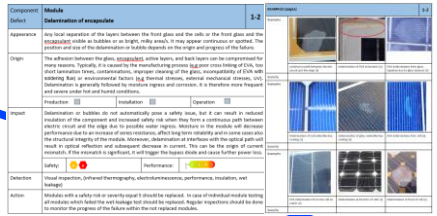
PVPS

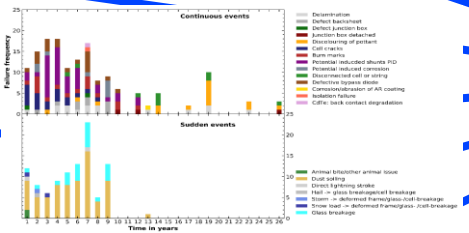
D. Moser, M. Del Buono, U. Jahn, M. Herz, M. Richter, K. De Brabandere, Identification of technical risks in the photovoltaic value chain and quantification of the economic impact, Progress in Photovoltaics: Research and Applications 25 (7), 592-604, 2017

Quantification of Technical Risks

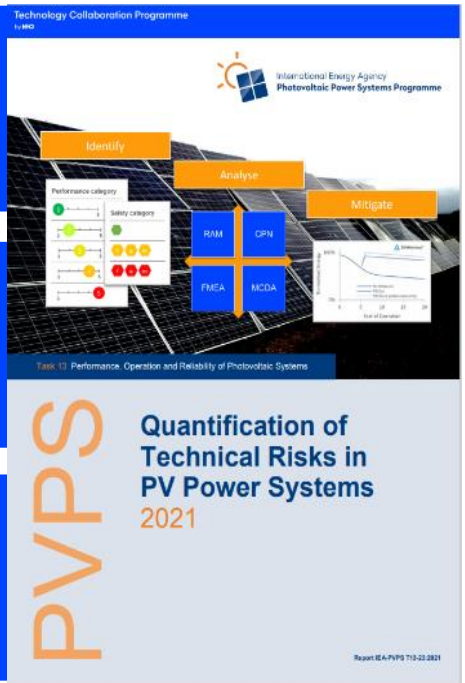
Create and maintain a technical risk database

- Overview of technical risks
- Definition of failure fact sheets (PVFS)
- Empirical risk data
- Statistical risk data
- Modeling approaches





- Common Practice
- Risk Analysis
- Cost-Benefit Analysis



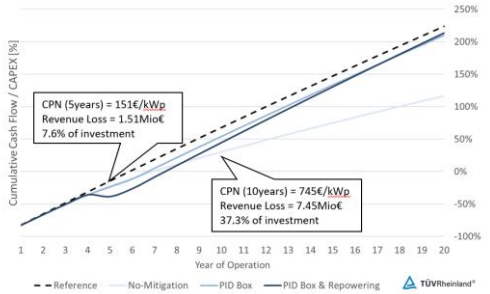
PVPS

M. Köntges, G. Oreski, U. Jahn, M. Herz, P. Hacke, K. A. Weiss, G. Razongles, M. Paggi, D. Parlevliet, T. Tanahashi and R. H. French, "Assessment of Photovoltaic Module Failures in the Field". Report IEA-PVPS T13-09: 2017

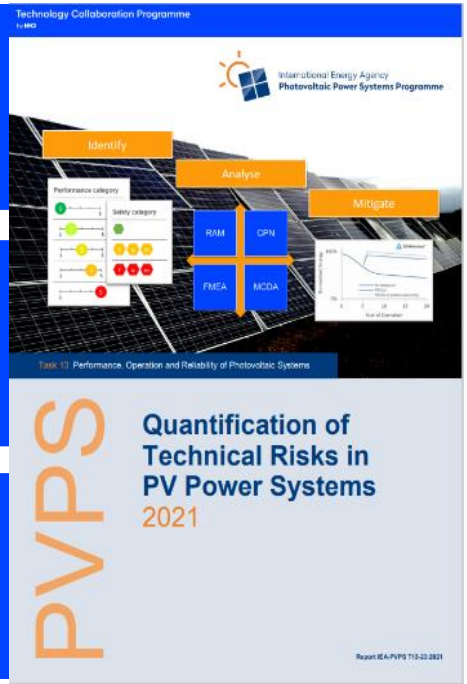
Quantification of Technical Risks

Assess the economic impact of risks and the effectiveness of mitigation measures

- Overview of O&M measures
- Costs of O&M measures
- Strengths and weaknesses
- Quantification of the effectiveness



- Common Practice
- Risk Analysis
- Cost-Benefit Analysis

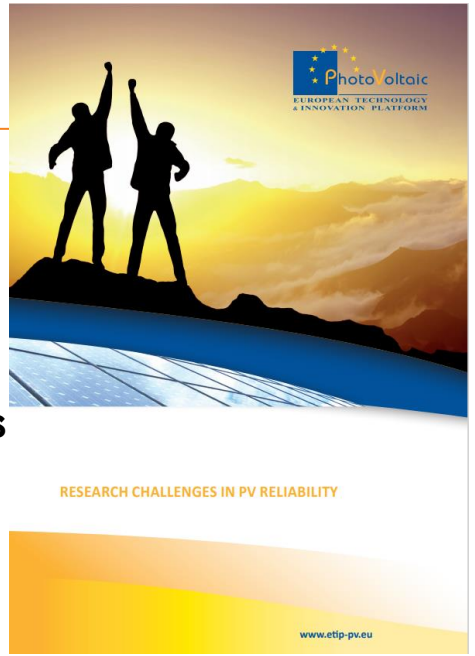


PVPS

M. Herz, U. Jahn, D. Moser, S. Lindig, K.A. Berger, M. Richter, M. Köntges, G. Friesen, J. Paradis Ärlebäck, R.H. French, and J. Vedde. "Quantification of Technical Risks during Operation and Maintenance". Report IEA-PVPS T13-23:2021. ISBN 978-3-907281-11-6.
U. Jahn, M. Herz, D. Moser, G. Belluardo and M. Richter, Managing technical risks in PV investments: Prog Photovolt Res Appl. 2018; 26: 597– 607. https://doi.org/10.1002/pip.2970.


Solar Bankability must be data-driven
Digitalization is the driver to ensure cost-effective increase of quality
Data-driven evaluation of techno-economic performance indicators

Strategic Research & Innovation Agenda for



Challenge 2 – Lifetime, reliability and sustainability enhancements

- **Reliable generation of TWh of electricity for an extended lifetime.**
- **Ensure sustainability from energy, environmental and investment viewpoint.**
- **Circular economy and renewable, clean energy need to go hand in hand.**
- **Higher performance and reliability in the field is a constant demand from the industry.**
- **Updated solutions and services to capture innovation trends.**
- **New technologies may introduce new degradation modes once in the field.**

Lead: David Moser, Andreas Wade

6CP.1.5 Wed

Thank You

Federal Ministry
for Economic Affairs
and Energy

European
Commission

Horizon 2020
European Union funding
for Research & Innovation

VDE

TÜVRheinland®
Precisely Right.

ZAE BAYERN

ISFH

IEA
PVPS

PhotoVoltaic
EUROPEAN TECHNOLOGY
& INNOVATION PLATFORM

PVPS

Thank You

IEA PVPS

Thoughts to share

- A crucial time when PV really matters
  - for climate change ⇒ climate neutrality by 2050
  - for future generations ⇒ 100% Renewables (Act NOW!)

- PV is the key for the sustainable energy transition:
  - support the development of production capacities "made in Europe"
  - develop circularity of the PV systems' various components
  - make solar PV readily available for a range of applications

- "Solar Energy = the Citizen's Energy…" [1)]

[1)] Prof. A. Goetzberger; Keynote Speech of Becquerel Prize awardee, 1997

PV to bring electricity to rural and urban households

Electricity is a crucial for

- poverty alleviation
- economic growth
- improved living standards

PV to provide minimum level of electricity for

- health facilities
- small enterprises
- education & information

770 million people without access to electricity in 2019 (10%)

Thank You

Ulrike Jahn

ulrike.jahn@vde.com

www.iea-pvps.org

https://etip-pv.eu/