

this  
**webinar** is powered by

PI Berlin

20 November 2023

5:00 pm – 6:00 pm | CET, Berlin, Madrid

11:00 am – 12:00 pm | EST, New York City

pv magazine  
**webinars**

# Glass breakage – a growing phenomenon in large-scale PV



**Mark Hutchins**

Editor  
pv magazine



**Thomas Weber**

Senior Project Manager  
PI Berlin



**Steven Xuereb**

Executive Director  
PI Berlin




**Tristan Erion-Lorico**

VP of Sales and Marketing  
PV Evolution Labs (PVEL)

# Welcome!

Do you have any questions? ? 

Send them in via the Q&A tab.  We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 

We'll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience.  



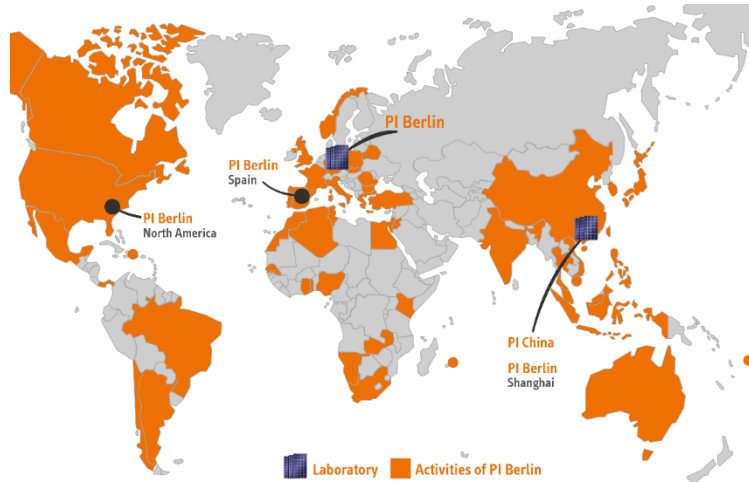
# Glass Breakage

## A Growing Phenomenon in Large-scale PV

Thomas Weber, Muktaparna Boruha, Redemption Agada, Jerry Pyles, Matthew Lu, Steven Xuereb; PI Berlin  
Tristan Erion-Lorico, Jean-Nicolas Jaubert; PVEL  
Susann Radicke, Dominique Brun, kiwa GmbH

# Trusted Experts Worldwide

Wherever and Whenever You Need Us



## Key PV Services Around the World

From roofs on industrial buildings in central Europe to utility plants in desert regions, our experts are there for you.

- Specialized Factory Auditors
- PV Systems Engineers
- Accredited Testing Laboratories

# PI Berlin's Services Within Kiwa

We Help You Improve



Certification



Testing



Inspection



Consultancy



Training



Data  
services



Radio and  
Wireless



Construction



Industry



Renewable  
Energy



Fire



Water



Many  
more

- Motivation
- Glass Breakage Pattern
- Background
- Mitigation Approaches Along the Value Chain
- Investigating Damage and Making a Claim
- Case Studies



1850

2022

## Warming Stripes

1850 to 2022

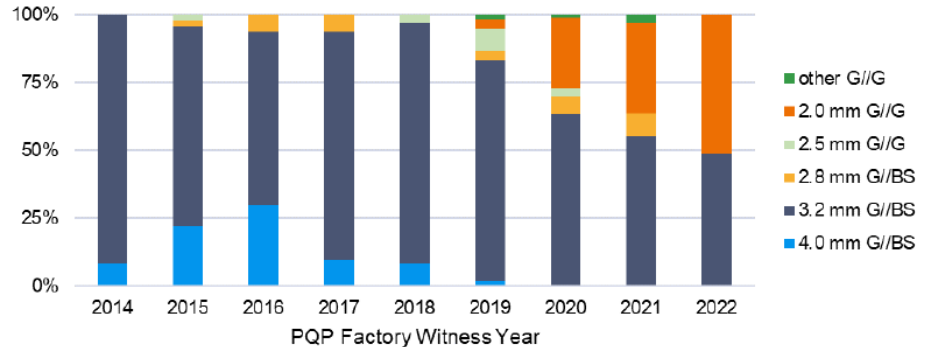
Each color (8 blue und 8 red) = 0,1 K

mean: 1971 – 2000

by Ed Hawkins

- Tackling climate change
- Dramatic growth rates for PV necessary and to be expected (1 to 3 TW per year)
- 200 - 400 GW of glass/glass (G/G) modules have been already produced and deployed
- For some projects, we observed breakage rates of 1; 3 and even 10 %

PVEL PQP Test Population by Glass/Module Type



**Conclusion 1: Raise awareness immediately**

G: glass  
BS: backsheet



## What can be distinguished / What does it look like?

- Type of glass (heat strengthening process)
- Front or rear side
- Clear impact (edge or plane induced)
- Thermal or mechanical induced
- Origination with clamps or junction box

## Problems

- Frame covered edge
- Superimposed by secondary breakage

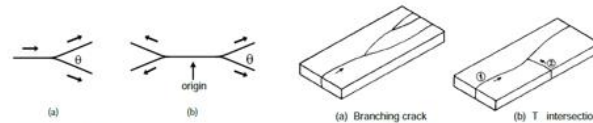
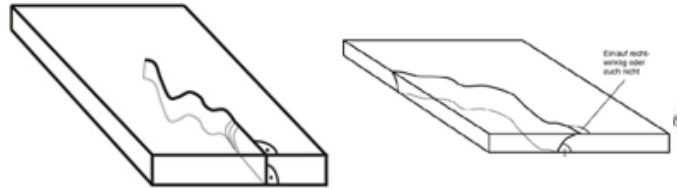
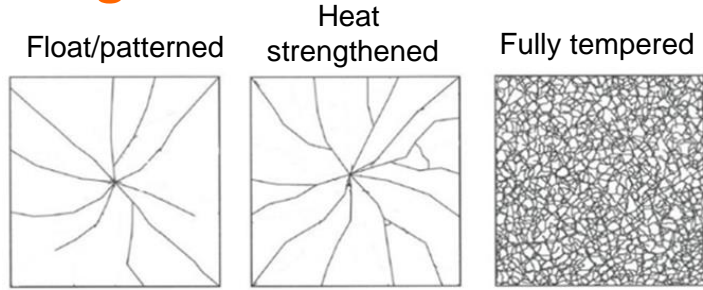


Figure 4.6 Crack branching indicates the direction of crack propagation.

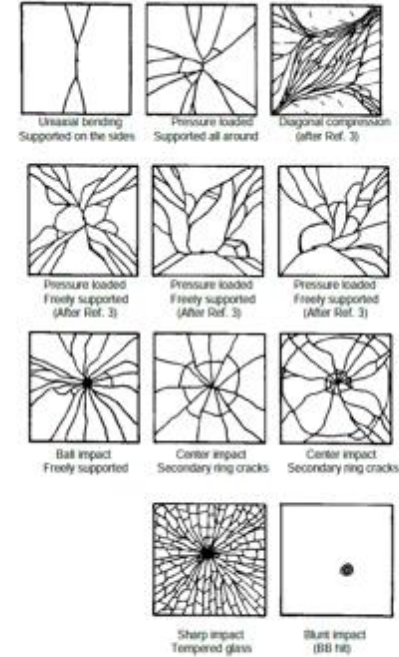
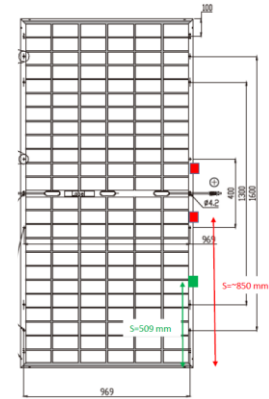


Figure 4.20 Plate and window fracture patterns. Figure 4.17b shows an example of a center impact plate with secondary ring cracks.

# 4. Background – More Breakage

## Four Reasons

- Module design
- Glass quality / supply shortage
- Gaps in testing and certification of modules (glass, system)
- Other reasons
  - Module failures
  - Installation/mounting, O&M



## 4. Background – More Breakage

### Module design

Thinner frames and larger module areas while also shortening the mounting rail

- G/BS -> G/G
- The modules have almost doubled in size compared to 10 years ago
- Half-cut cell-modules:  
3 holes in the rear glass

→ Relying on the glass to bear a significant portion of the load



## Reduced glass quality:

### Thickness reduction and tempering process

2.0 mm glass used in dual-glass modules is only heat-strengthened, not fully tempered [2]

- Heat-strengthened glass has a reduced thermal-change resistivity and bending strength
- Impact of glass shortages
  - Use of non-solar glass for the backside
  - Speeding up the lines leads to lower glass strength
  - Technological improvements

Material	Standard	Flexural strength	Temperature change resistance
Float glass	DIN EN 572	45 N/mm <sup>2</sup>	40 K
Heat strengthened glass (HS, TVG)	DIN EN 1863-1	70 N/mm <sup>2</sup>	100 K
Tempered glass (FT, ESG)	DIN EN 12150	120 N/mm <sup>2</sup>	200 K

Share

Daqo New Energy CEO Longgen Zhang has announced another impressive set of quarterly results for the Chinese polysilicon producer but also noted a recent shortage of glass for solar panels.

Echoing [comments](#) made by Canadian Solar chief Shawn Qu, Zhang noted: "In recent weeks, because of strong solar module and installation demand, we began to see solar glass capacity shortage becoming a bottleneck for the solar industry and limiting module production." Like his counterpart at Canadian, the [Daqo](#) chief executive predicted the situation would ease in "coming months" as more solar glass production capacity comes online.

There was little else to be gloomy about for Daqo investors in a sprightly third-quarter earnings

[5]

### Gaps in testing and certification of modules and the glass? (1/2)

- Missing specification and quality control
  - No PV specific tests exists; only in the construction industry \*
- Current safety factors do not provide enough design margin for additional stresses
- Minimum test loads of 2400 Pa are often not met
  - Henry Hieslmair, DNV: “The module has become a load-bearing element” but is a rather flimsy material that breaks more easily [6]
  - Daniel Chang, RETC: “Test for inhomogeneous loads missing” [8]



[2]

\* DIN-EN 18008-1,  
ASTM C1048-12 & C1036  
GB-T 17841 & 34328

### Gaps in testing and certification of modules and the glass? (2/2)

- SML test (UL2703/IEC 61215:2021 within module type qualification) relies on only **one** module [4] and is provided as evidence of ‘compatibility’ between module and mounting
- Retesting guideline and certificates ignored: often the testing is done only on a few clamps/module combinations and not for every combination of clamp and tracker
- Alf Oschatz, SBP Sonne: “The module in the simulation is only considered as load element but no load-bearing element”; “usability issues are missing [...tracker, Resonance] the module is the weakest part in the chain” [7]



**Conclusion 2:** Current climate-specific testing, triple-IEC, hail, SML and DML are all in detail insufficient and were not able to avoid the current glass breakage issue



### 1) Other module failures

- Hot-Spots (shunting, soldering, cell breakage)
- Reverse currents

### 2) Installation / Aggressive mounting

### 3) Extreme weather / events

- Hail, Heavy snow and wind
- Flood, Earthquake

**Conclusion 3:** Work with experts from other fields for interdisciplinary cooperation as solar industry is currently lacking the necessary standards and approaches

**Teresa Barnes:**  
"Cost-driven industry – not  
[focused on] robustness"



<https://solarquarter.com/wp-content/uploads/2022/02/image1-1.jpg>



[8]



## Contracting Support

- Specifications
- Load analysis
- QA-Service
- AQL levels
- Criteria



## Auditing and Oversight

- Incoming goods inspection
- Check of specifications
- Edge and drill/laser-hole control!



## QA Testing during production

- Glass & module manufacturing



## Module testing

- Current standards
- SML, DML, Hail, MB
- Advanced testing, like PVEL's PQP
- Beyond standards, R&D



## Root-Cause Analysis

- See over-next slide
- Desktop
- On-Site
- Lab-Testing
- Expert Opinion



## Testing beyond standards, R&D-level

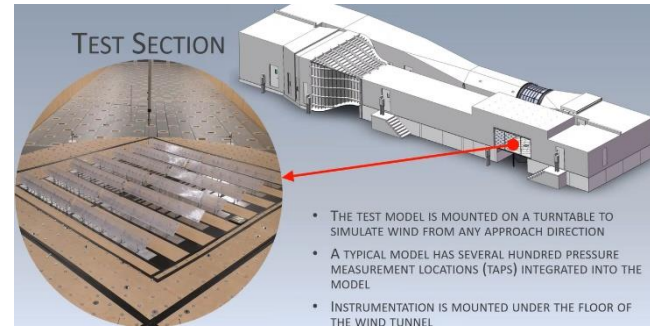
- PVEL PQP mechanical and hail stress test sequences
- NREL, **DMX**: Mill. of small pressure cycles drive damage in cracked solar cells; [9]
- Imbalanced test loads [8]
- TÜV-Rheinland: IEC 62938:2020 Non-uniform snow load testing [10]
- Swiss Hail Register: More stringent than IEC [11]
- Shaker Test: IEC 60068-2-64:2008 + A1:2019

## Others: see [8]

- Static simulations of complete systems including load bearing modules
- Wind-tunnel testing

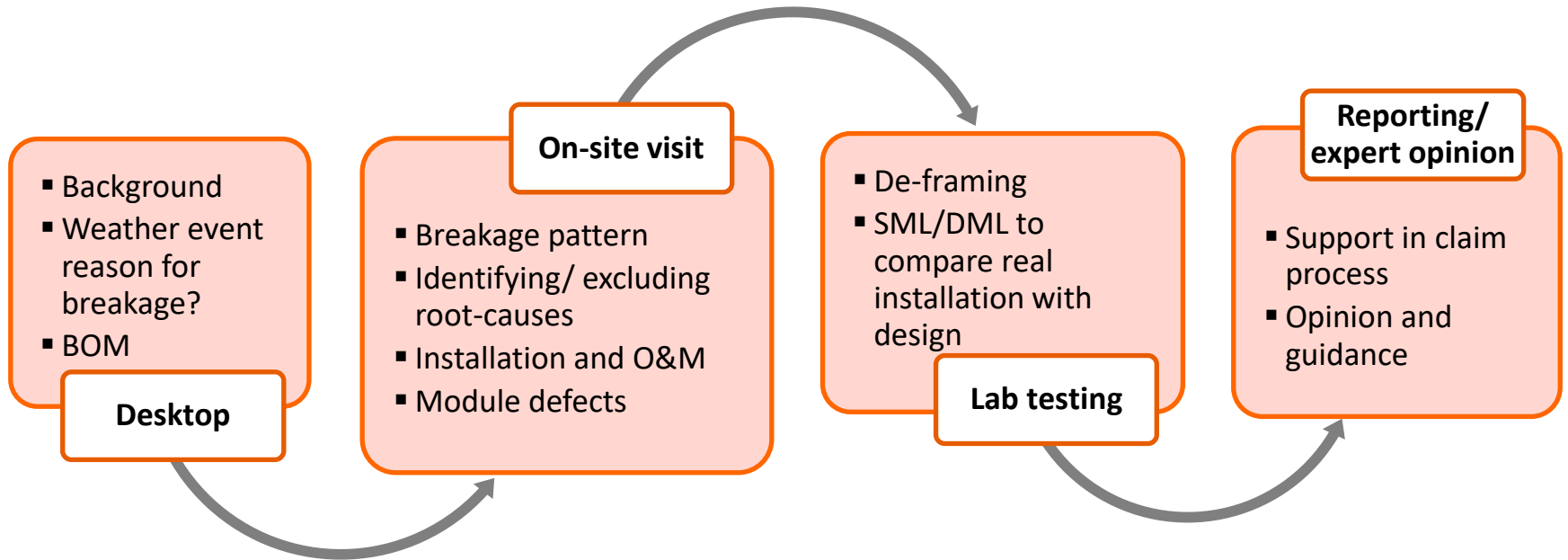


<https://www.solarpowerworldonline.com/wp-content/uploads/2016/07/snow-load.jpg>



[8]

# 6. Investigating Damage and Making a Claim



# 7. Case Study

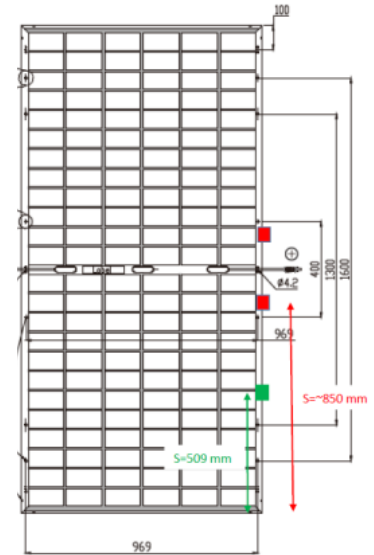
**Location** Texas, US

**Project size** 200 MW

**Date** 2023

**Issue / Services**

- On-site inspection: Visual, RCA
- Expert Opinion
- Issue: rear glass breakage
  - 1) Too narrow clamp position
  - 2) Low quality glass installed in 2019 which is derated from a mechanical test point of view



- Approved test load from module manufacturer with the tracker-system: 1600 Pa (test load)

# 7. Case Study

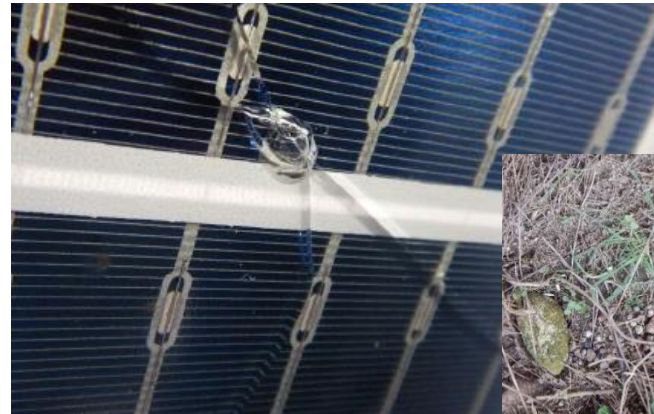
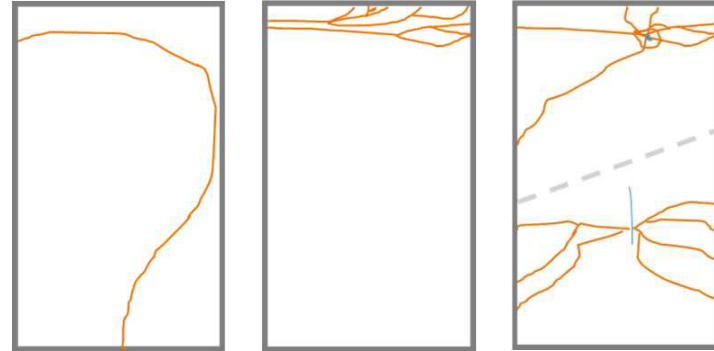
**Location** Poland

**Project size** 20 MW

**Date** 2023

**Issue / Services**

- On-site inspection: Visual, RCA
- Reporting
- Issue: rear glass breakage < 1%
  - 1) wrong clamp position, deviating torques
  - 2) impact from pebbles during mowing



**Location**     England

---

**Project size**   10 MW

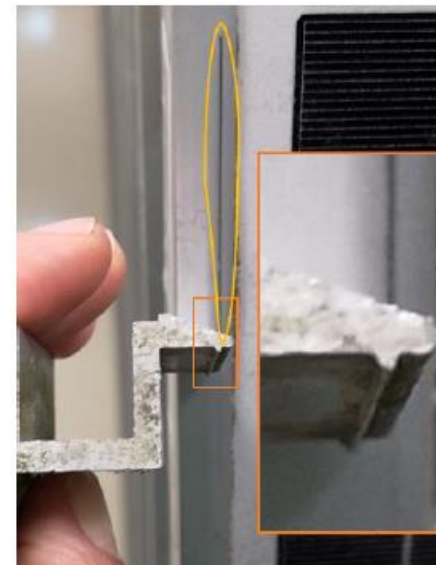
---

**Date**            2021

---

**Issue /  
Services**

- Module type A broke, type B not due to wrong clamp
  - Desktop work
  - Root Cause Analysis
    - On-site inspection: Visual and EL
    - Laboratory: de-framing, SML
  - Expert Opinion
- 



# 7. Case Study

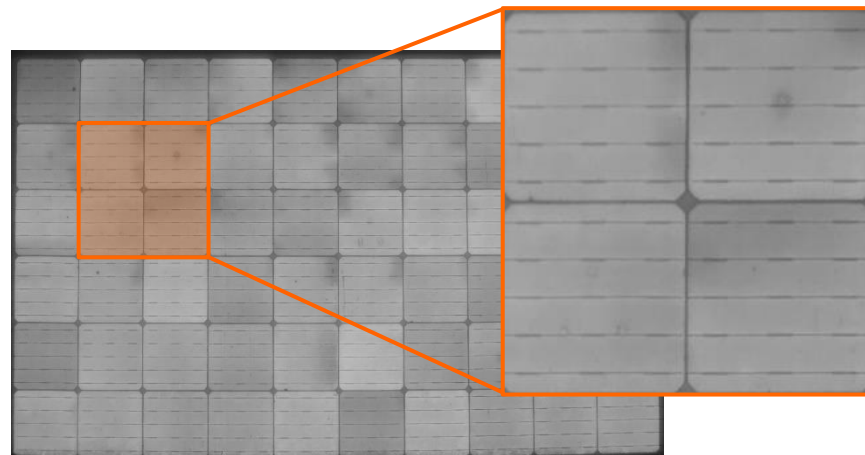
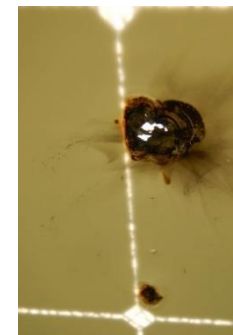
**Location** France

**Project size** 10 MW

**Date** 2021

**Issue / Services**

- On-site inspection: IR, Visual and EL
- Expert Opinion and Claim support
- Issue: Soldering defect on BB



- [1] <https://showyourstripes.info/stripes/GLOBE---1850-2022-MO.png>
- [2] Jean-Nicolas Jaubert, "The risk of breakage in thinner, not-fully tempered glasses, NREL-PVMRW 2023-02, Denver, CO, USA
- [3] George D. Quinn; NIST Recommended Practice Guide: Fractography of Ceramics and Glasses, 2020-09
- [4] Ekkehard Wagner, "Glasschäden,,", 5. Auflage, 2020
- [5] pv magazine: November 24, 2020 Max Hall
- [6] "Stress concentrators"; H. Hieslmair, DNV, 2023
- [7] Statement from Alf Oschatz, SBP Sonne; 18.09.2023
- [8] pv magazine Webinar | Module wind load resistance: Standards vs. reality, 30 August 2021, RETC
- [9] Silverman, Timothy & Bosco, Nick & Owen-Bellini, Michael & Libby, Cara & Deceglie, Michael. (2022). Millions of Small Pressure Cycles Drive Damage in Cracked Solar Cells. IEEE Journal of Photovoltaics. 12. 1-4. 10.1109/JPHOTOV.2022.3177139.
- [10] <https://www.tuv.com/>, IEC 62938:2020
- [11] <https://www.hagelregister.ch/bauherren-architekten/klassifikation/vkf-pruefbestimmungen.html#anchor-test-specifications-in-english>



- Raise awareness immediately
- → Today the glass bear a significant portion of the load
- Current climate-specific testing, triple-IEC, hail, SML and DML are all in detail insufficient and were not able to avoid the current glass breakage issue
- Cooperate with interfaces and experts from other fields for interdisciplinary cooperation as long as industry is lacking the necessary standards and approaches







Member of Group



**Your trusted solar advisers!**

**PI Berlin can help with this problem.**

**Contact us**

PI Berlin

[info@pi-berlin.com](mailto:info@pi-berlin.com)

[weber@pi-berlin.com](mailto:weber@pi-berlin.com)

[www.pi-berlin.com](http://www.pi-berlin.com)

this  
**webinar** is powered by

PI Berlin

20 November 2023

5:00 pm – 6:00 pm | CET, Berlin, Madrid

11:00 am – 12:00 pm | EST, New York City

pv magazine  
**webinars**

# Glass breakage – a growing phenomenon in large-scale PV

## Q&A



**Mark Hutchins**

Editor  
pv magazine



**Thomas Weber**

Senior Project Manager  
PI Berlin



**Steven Xuereb**

Executive Director  
PI Berlin



**Tristan Erion-Lorico**

VP of Sales and Marketing  
PV Evolution Labs (PVEL)

# The latest news | print & online



**10% off**  
your subscription  
with  
**Webinars10**

## [New MPPT approach for multi-string PV systems under partial shading](#)

by Blior Kahana



**Most-read online!**

## [Agrivoltaic system achieves 9.9% efficiency, LCOE of \\$0.033/kWh](#)

by Emilliano Bellini



# Coming up next...

**Wednesday, 29 November 2023**

6:00 am – 7:00 am CET, Berlin, Paris, Madrid  
4:00 pm – 5:00 pm AEDT, Sydney

**Wednesday, 13 December 2023**

11:00 am – 12:00 pm EDT, New York City  
5:00 pm – 6:00 pm CET, Berlin, Paris, Madrid

**Many more to come!**

**Balancing the  
books on big  
solar's  
weather risk**

**Achieving  
domestic  
content with  
solar trackers**

In the next weeks, we will continuously add further webinars with innovative partners and the latest topics.

Check out our pv magazine Webinar program at:

[www.pv-magazine.com/webinars](http://www.pv-magazine.com/webinars)

Registration, downloads & recordings are also be found there.





**pV magazine**

**roundtables**   
**EUROPE** 

---

**DEC 5 & 6, 2023**

**REGISTER NOW**



this  
**webinar** is powered by  
PI Berlin

pv magazine  
**webinars**



**Mark Hutchins**  
Editor  
pv magazine

**Thank you for  
joining today!**