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pv magazine webinars

UVID: Risks, detection, and impact on solar projects

25 March 2026

8:00 am – 9:00 am | PDT, Los Angeles
11:00 am – 12:00 pm | EDT, New York City
4:00 pm – 5:00 pm | CET, Berlin, Paris

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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. 👀 💡

UVID in N-Type Modules

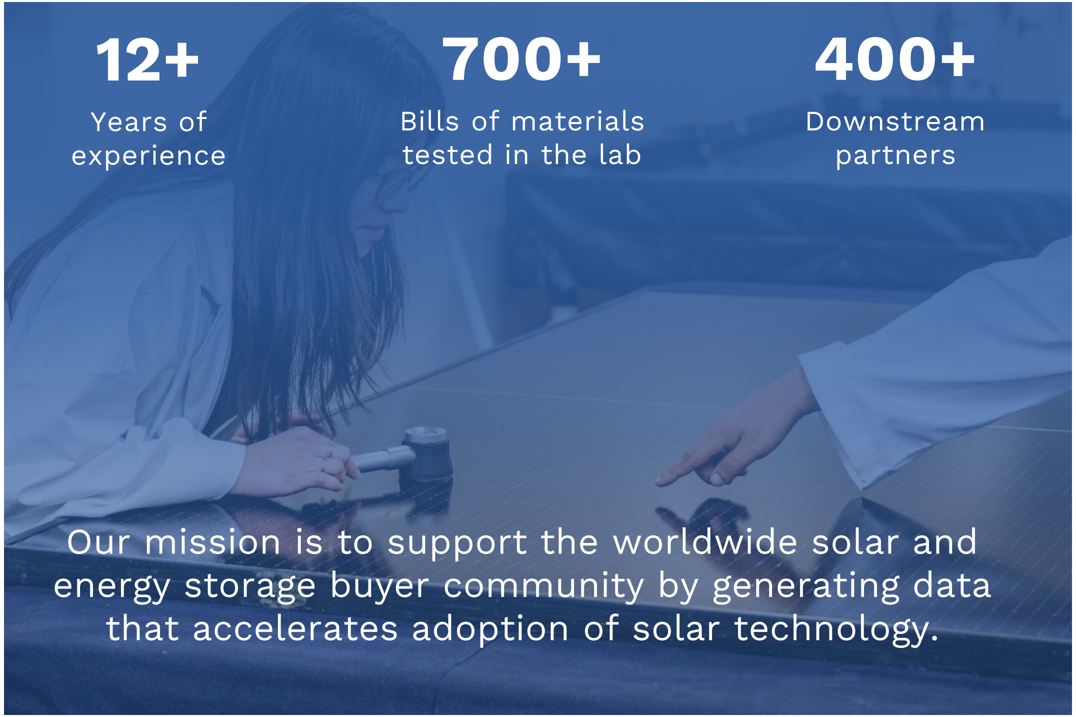
Degradation, Stabilization and Mitigation

Tristan Erion-Lorico, VP of Sales & Marketing
Kiwa PVEL

kiwa

*creating trust, **driving progress***

Kiwa PVEL is the Independent Lab of the Downstream Solar Market



12+
Years of experience

700+
Bills of materials tested in the lab

400+
Downstream partners

Our mission is to support the worldwide solar and energy storage buyer community by generating data that accelerates adoption of solar technology.

Services at a glance:

- Extended reliability and performance testing for PV modules
- Batch testing of PV modules
- Outdoor testing of PV modules, inverters and energy storage
- Data services for PV buyers and investors

See more details at kiwa.com/pvel

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Industry leading reports, from analysis of key solar and energy storage components pricing, technology trends, policy updates, as well as custom data and reporting.

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We support investors, developers, EPC contractors, asset managers to procure high quality equipment, optimize system performance and conduct technical due diligence.

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Independent, industry-leading performance testing of PV modules, inverters, battery energy storage, and other key solar equipment.

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Factory audits and inspections benchmarking manufacturing quality based on our expertise in processes, materials, and technologies to ensure the long-term performance, reliability, and safety of key equipment.

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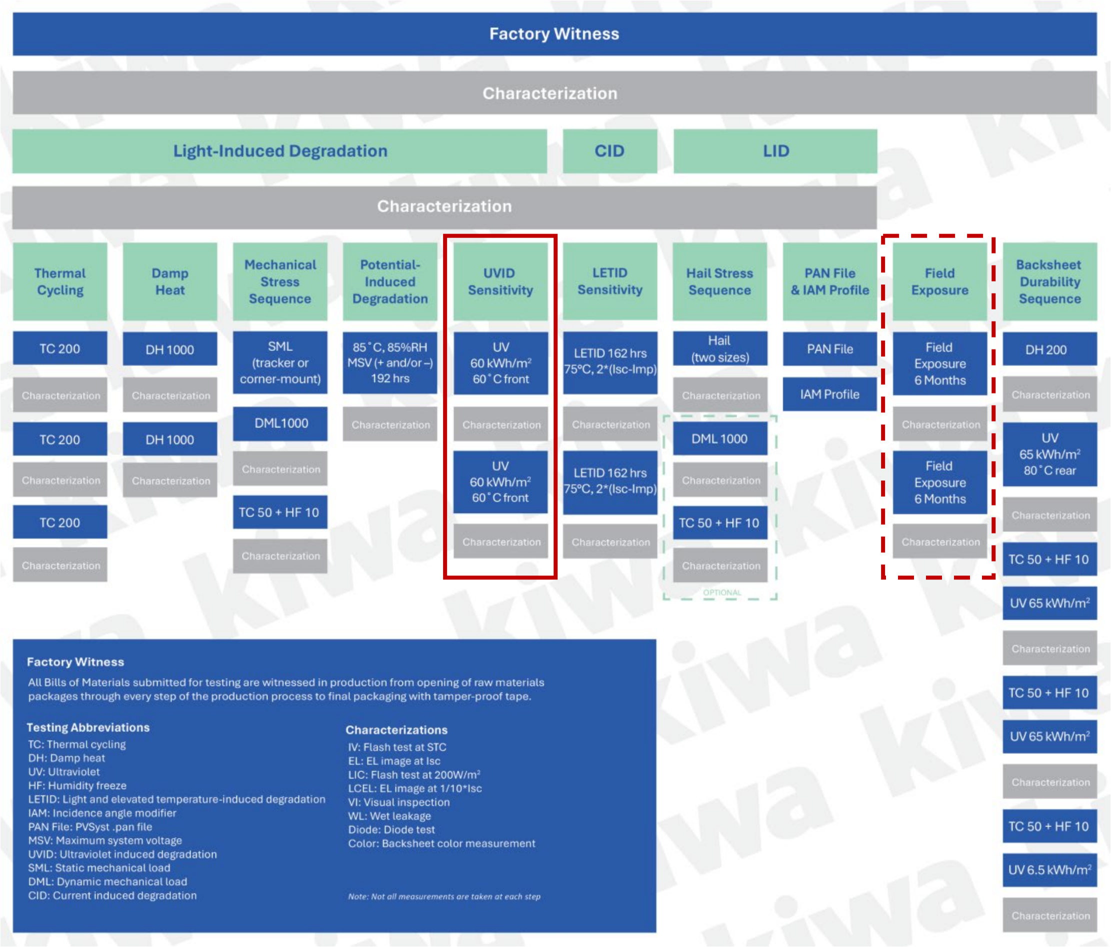
See kiwa.com/solar for more

PQP Test Sequence

The PQP evolves every few years based on feedback from Kiwa PVEL’s downstream partners, module manufacturers, and the industry’s collective understanding of module failure modes and test mechanisms.

The previous update introduced the new UVID test and streamlined many of the tests leading to faster execution of PQP projects.

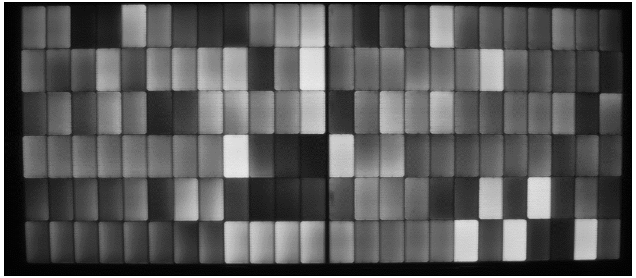
Learn more at: kiwa.com/pvel/pqp.



UVID – Why is it a Concern

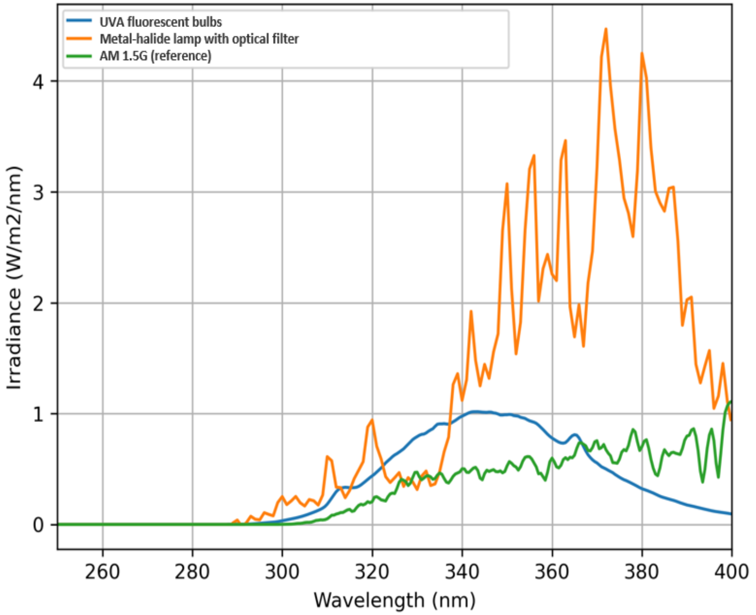
- TOPCon is today's predominant module technology.
- It offers greater resilience to LID and LETID and higher power.
- But it has a higher **vulnerability to UV-induced degradation (UVID)** due to increased cell sensitivity to UV radiation (280-360 nm).
- Degradation occurs at cell level with a direct impact on the system performance, reliability and warranty.

UVID 120 kWh/m^2 power loss = 16.6%



UVID Test Method

- 120 kWh/m² of UV equates to 1~2 years in the field, dependent on location.
- UVID results are influenced by the light source and module condition during testing.
- Kiwa PVEL uses **120 kWh/m²** of UV (280-400 nm) **when using metal-halide lamps** or 53 kWh/m² when using UV fluorescent lamps.
- Kiwa PVEL has standardized on using short-circuit conditions, for additional acceleration. This deviates from the draft UV testing specification: IEC TS 63624-1



UVID Sensitivity

UV 60 kWh/m²
60°C front

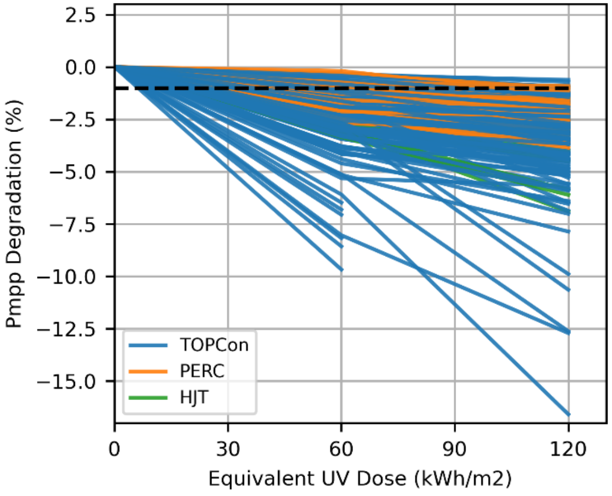
Characterization

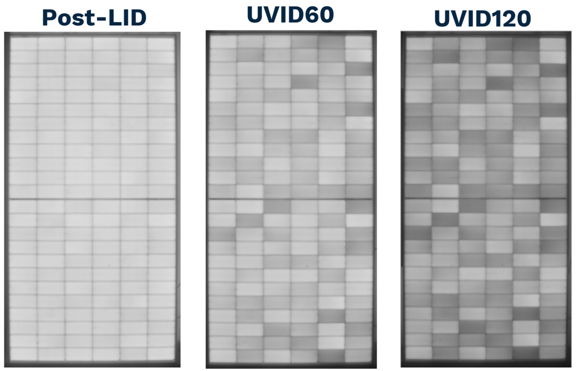
UV 60 kWh/m²
60°C front

Characterization

Kiwa PVEL's UVID Test Results

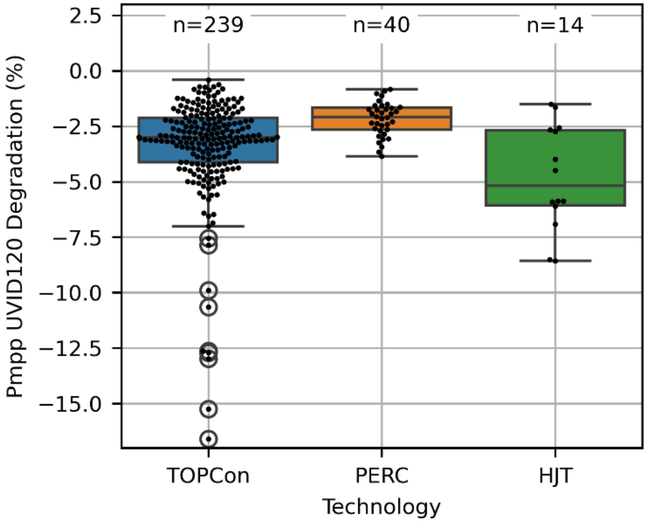
- Largest "public" dataset:
  - Total **586 modules** (~293 BOMs) evaluated.
  - 82% TOPCon modules.
- **N-type modules more susceptible to UVID**.
  - TOPCon and HJT modules showed a broad range of susceptibility (0.4% to 16.6%), indicating the variability in bill of materials, cell architecture, and process non-uniformities.
  - UVID-stable TOPCon BOMs are available.
  - Some BOMs show quasi-stabilization after UVID60.
- **Characteristic "checkerboard" pattern in EL images**.
  - Similar to PID or LETID sensitive modules.
  - Testing based on one-cell sample is not sufficient.

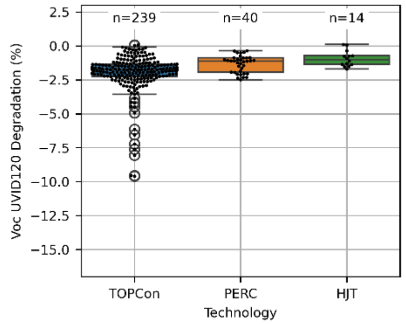


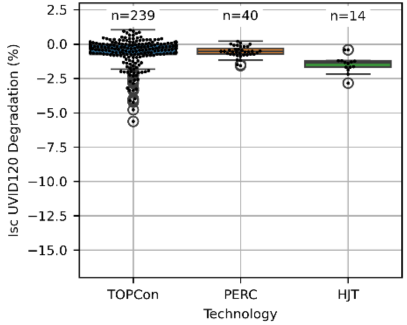


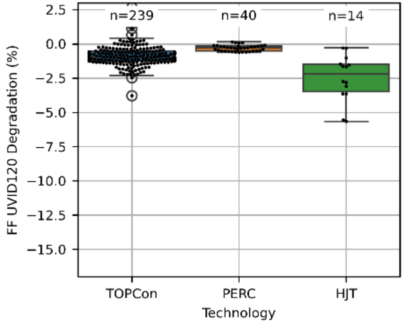
Degradation Pathways

- **TOPCon:** 0.4-16.6% deg, median 3.0%
  - **Voc most affected →** cell ARC or passivation degradation
  - Greater Isc & FF losses in few BOMs → mismatch loss
- **HJT:** 1.5-8.6% deg, median 5.2% (limited sample size)
  - **Isc and FF losses are significant →** front TCO/a-Si interface degradation
  - Voc is fairly stable
- **PERC:** lower degradation, median 2.1%









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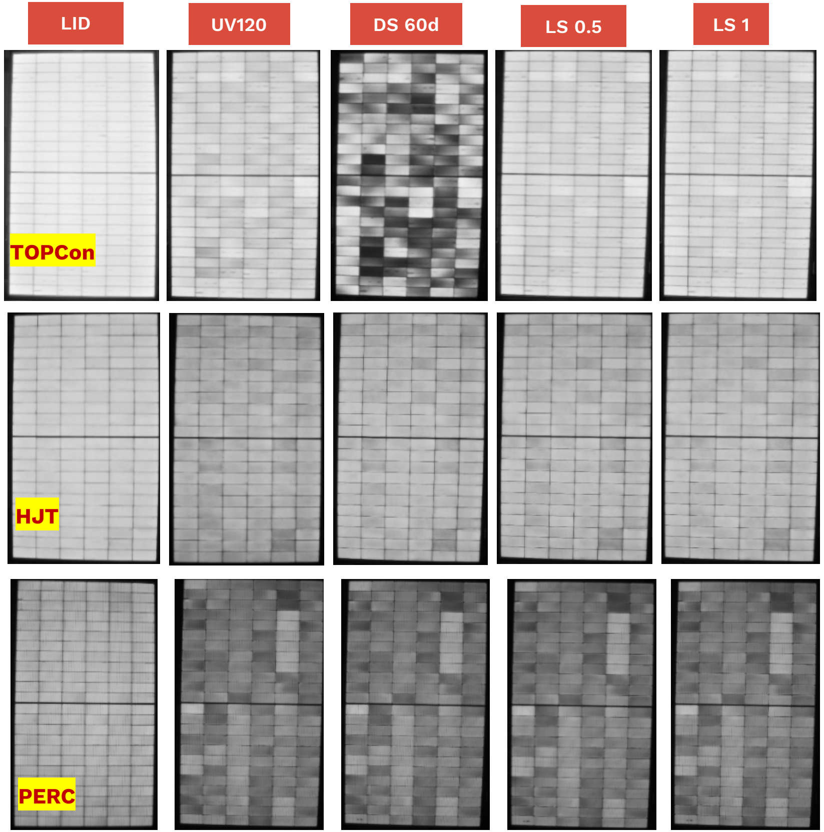
Dark Storage Metastability & Stabilization

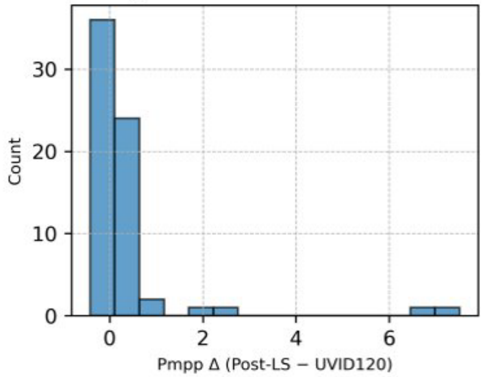
- UVID-sensitive modules can suffer from dark storage (DS) degradation (metastability).
  - The longer the dark-storage period, the higher the degradation.
- **DS degradation is partially/fully recoverable under full spectrum light soak (LS).**
  - TOPCon - Fast and effective recovery.
  - HJT - Obvious recovery but at slower rate.
  - PERC - No obvious degradation or recovery.

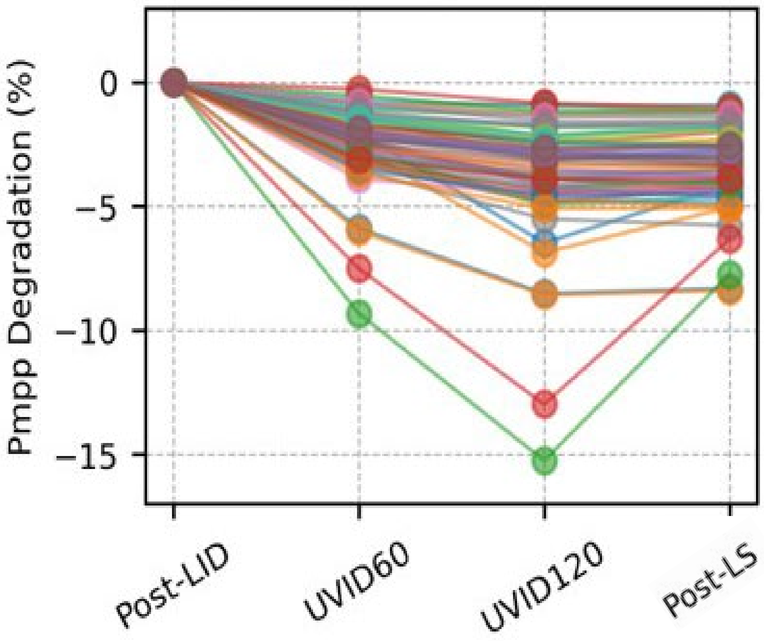
	LID	UVID120	Dark Storage (60 days)	LS 0.5kWh/m^2	LS 1kWh/m^2
Bad TOPCon	0.40%	-5.60%	-12.30%	-5.70%	-5.60%
Good TOPCon	-0.10%	-1.40%	-2.60%	-2.40%	-2.30%
HJT	0.10%	-4.50%	-6.30%	-6.00%	-5.50%
Bad PERC	0.00%	-3.00%	-3.80%	-3.80%	-3.70%
Good PERC	0.00%	-1.90%	-2.30%	-2.40%	-2.30%



Light Soak Stabilization

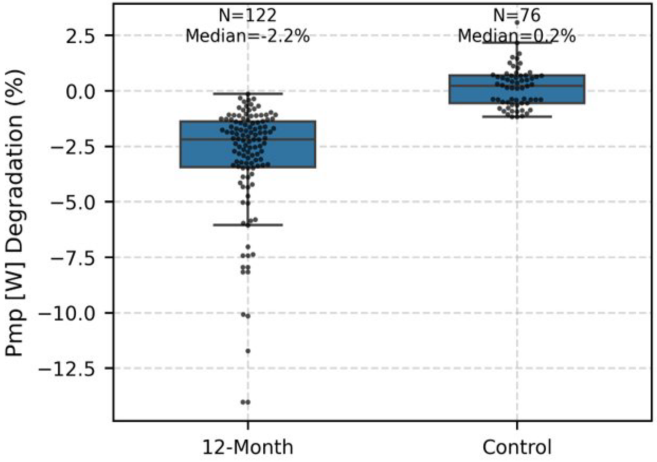
- Kiwa PVEL's characterization window to flash test UVID modules is controlled within 48 hours after test completion.
- Kiwa PVEL implemented a LS stabilization step post-UVID120 (via ~0.5 kWh/m² of light exposure).
- **For UVID-sensitive samples light soak is crucial to get accurate results.**
  - Many test samples are not affected by LS (change is <0.4%), but some are very affected.

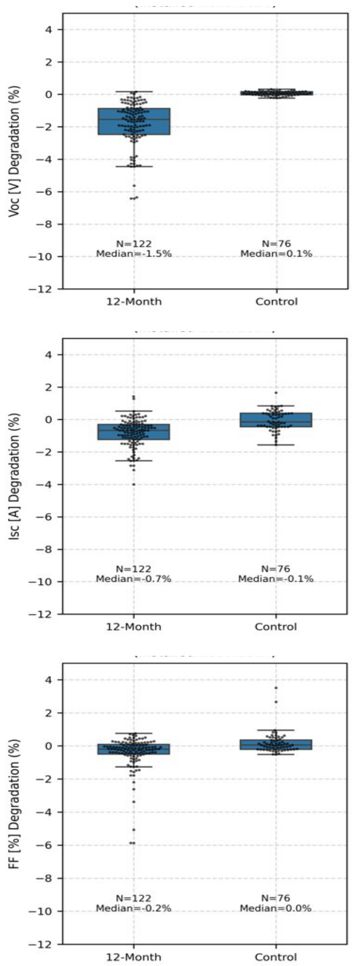




Field Degradation (for TOPCon only)

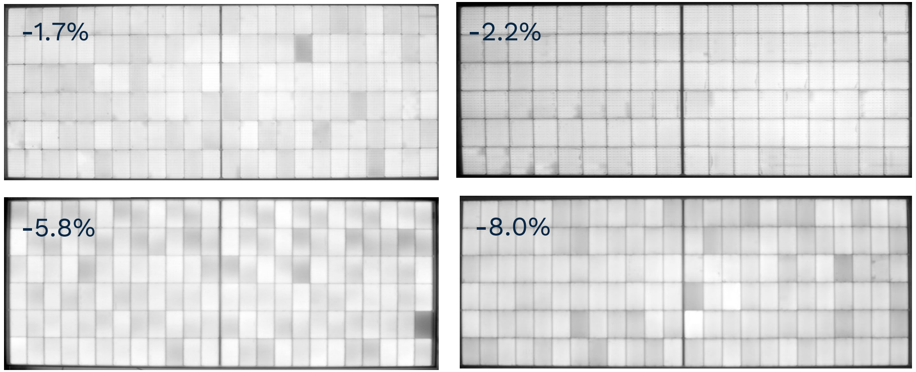
- 1-year outdoor exposure in Davis, CA. Modules installed in 2023 and 2024.
- **Significant degradation (median of 2.2%) in fielded modules.**
  - **Mainly due to UVID**. Pmp degradation is driven by Voc and Isc losses, while FF is generally stable.
  - UVID checkerboard pattern in FE modules.
  - Combined LID and LETID Pmpp loss <1%.
  - Control modules exhibited stable performance.
- **Most FE modules did not meet a <1.0% degradation warranty in the first year.**

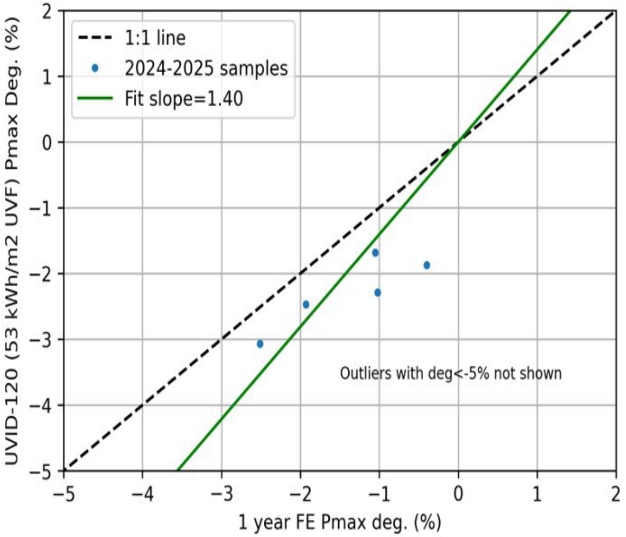




Correlation of UVID and FE

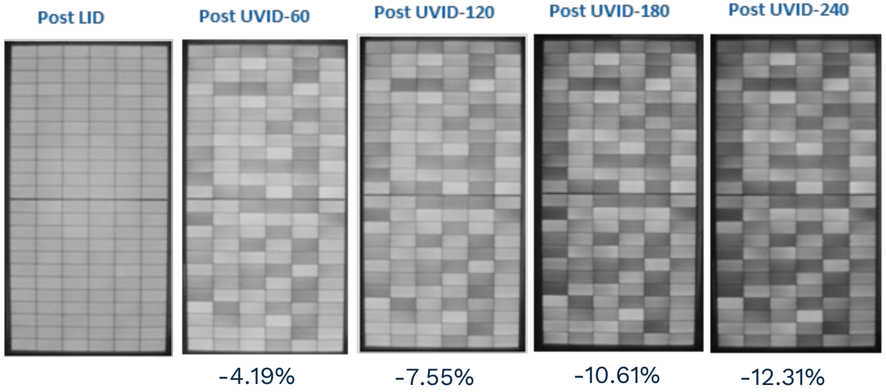
- Average of 2 modules data from UVID120 test and 1-year outdoor exposure in Davis CA.
- Observed higher degradation in UVID testing as compared to field. Possibly due to:
  - Short-circuit condition in UV chamber
  - Light stabilization in FE modules
- **UVID signature is clearly visible in EL images of several FE modules, post 1-yr exposure.**

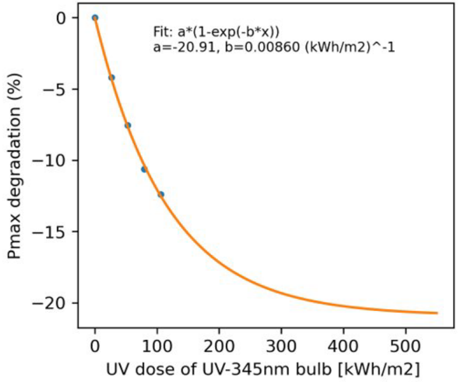




Extended UVID Testing

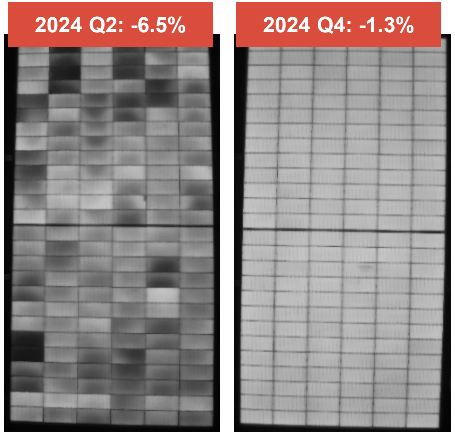
- Kiwa PVEL chose a commercial TOPCon module with high UV sensitivity for extended UV testing.
- Degradation continued up to UV240, without stabilization.
- Results were then extrapolated using exponential fit showing that saturation/ **stabilization occurs after approx. 15 years of field aging** (550 kWh/m^2 of UV-345nm bulbs).
- The updated PQP will have an option to extend UV testing to UV360 for UV-susceptible modules.

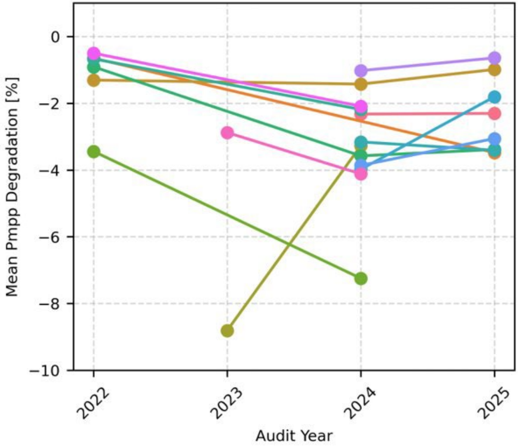




UVID Mitigation at Cell Level

- Cell design improvements:
  - Front cell ARC/passivation layer process controls (thicker AlOx, optimized refractive index, passivation and ARC stack uniformity, quality of passivation layer, etc.)
  - **These fixes can come at the cost of cell efficiency and/or higher production costs.**
- Example: A TOPCon project tested in 2024 Q2 with a retest in 2024 Q4 using same BOM.
  - Original samples: deg 6.5% (average), strong checkerboard pattern.
  - Retest samples: deg 1.3% (average), no EL anomalies.

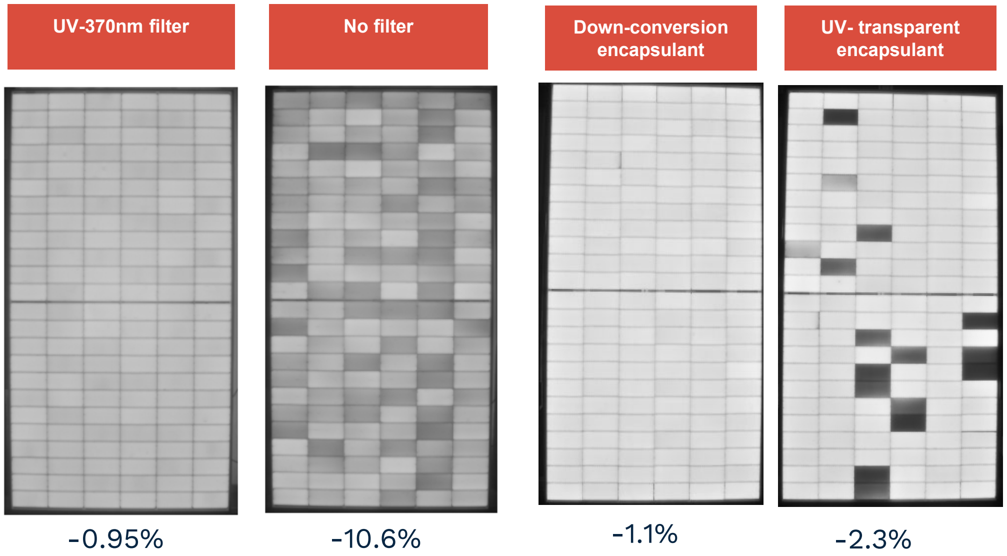




Note: Each line is an individual cell supplier.

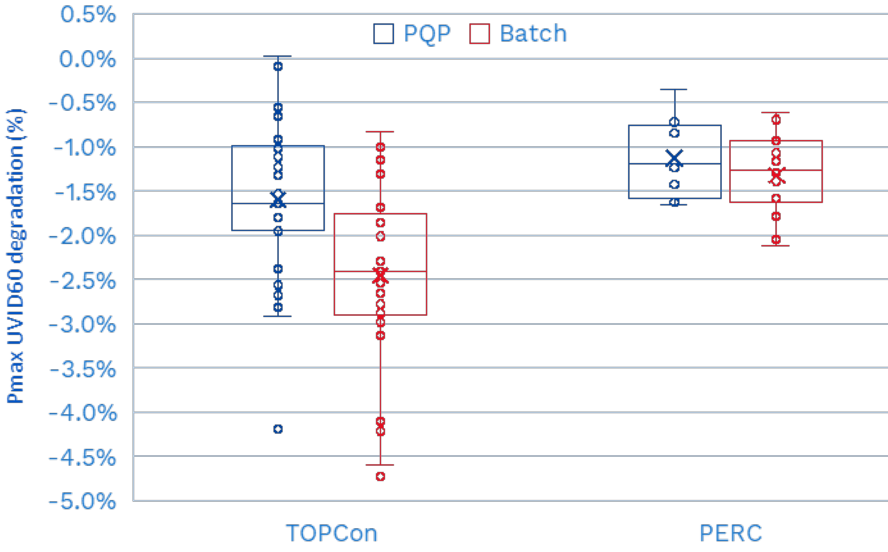
UVID Mitigation at Module Level

- Additives and UV cut-off wavelength can help mitigate UVID.
- Cut-off wavelength of front encapsulant varies in the range of 220-380 nm.
  - **Higher degradation below 350nm cut-off**.
  - UVID extent can be lowered when tailoring the encapsulant cut-off band.
- **UV down-conversion encapsulants.**
  - Currently used in HJT module designs, not much in TOPCon.
  - UVID effects can be mitigated.
  - Other reliability issues may trigger, need to be tested further to validate stability.



UVID Stability is Improving, But is Not Solved! Batch Testing Results

- Downstream customers batch testing vs manufacturer PQP testing results:
  - Projects tested during 2024 Q4 – 2025 Q3 period
  - TOPCon and PERC
  - Post-UVID60 Pmax loss comparison
- UVID not yet solved in mass production:
  - **Higher Pmax losses for TOPcon** in batch testing.
  - Both PERC (~1.3%) and TOPcon (~2.4%) median degradations **likely exceeding year-one degradation warranties after UV60**.

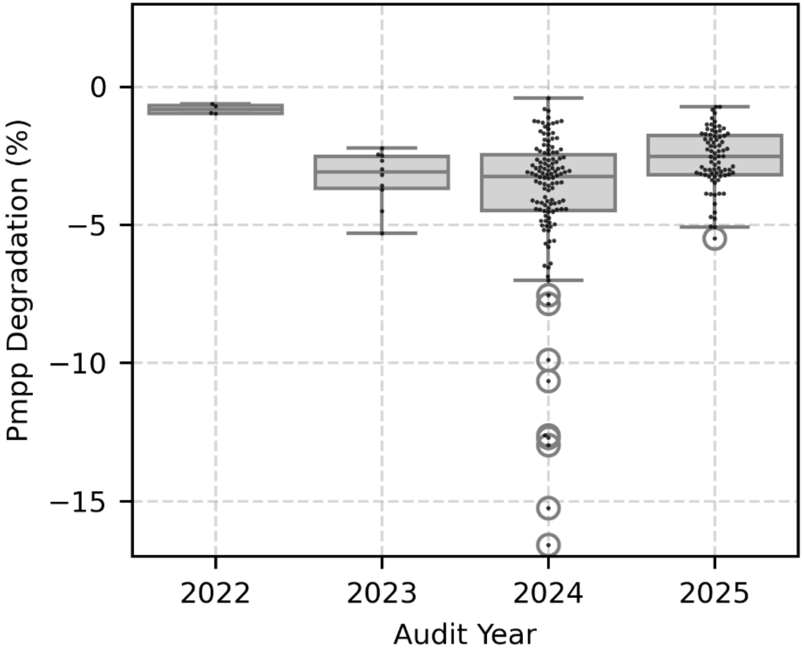


	PQP	Batch	PQP	Batch
Median	-1.6%	-2.4%	-1.2%	-1.3%
Average	-1.6%	-2.4%	-1.1%	-1.3%
Samples	41	45	8	18

Key Takeaways

- UV is a reliability concern for n-type modules, detected both in the lab and the field.
- UVID is likely driven by a combination of UV-transparent encapsulants and thinner cell ARC.
- Front cell ARC/passivation layer process controls and better encapsulant additives selection can help in mitigating UVID.
- Recent UVID testing on PQP samples show a significant improvement in UV susceptibility.
- UV mitigation can come at a cost (higher production cost and/or lower efficiency). Batch testing is useful to detect UV susceptibility on random samples.
- A short light soak under full spectrum (indoors or outdoors) can stabilize modules following UV exposure and dark storage.

Kiwa PVEL's UVID test results (TOPCon only)



Note: some big outliers are partially a result of dark metastability.

Thank you!

Funding provided by the Durable Module Materials Consortium 2 (DuraMAT 2), an Energy Materials Network Consortium funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Solar Energy Technologies Office agreement number 38259. The views expressed in this presentation do not necessarily represent the views of the DOE or the U.S. Government.

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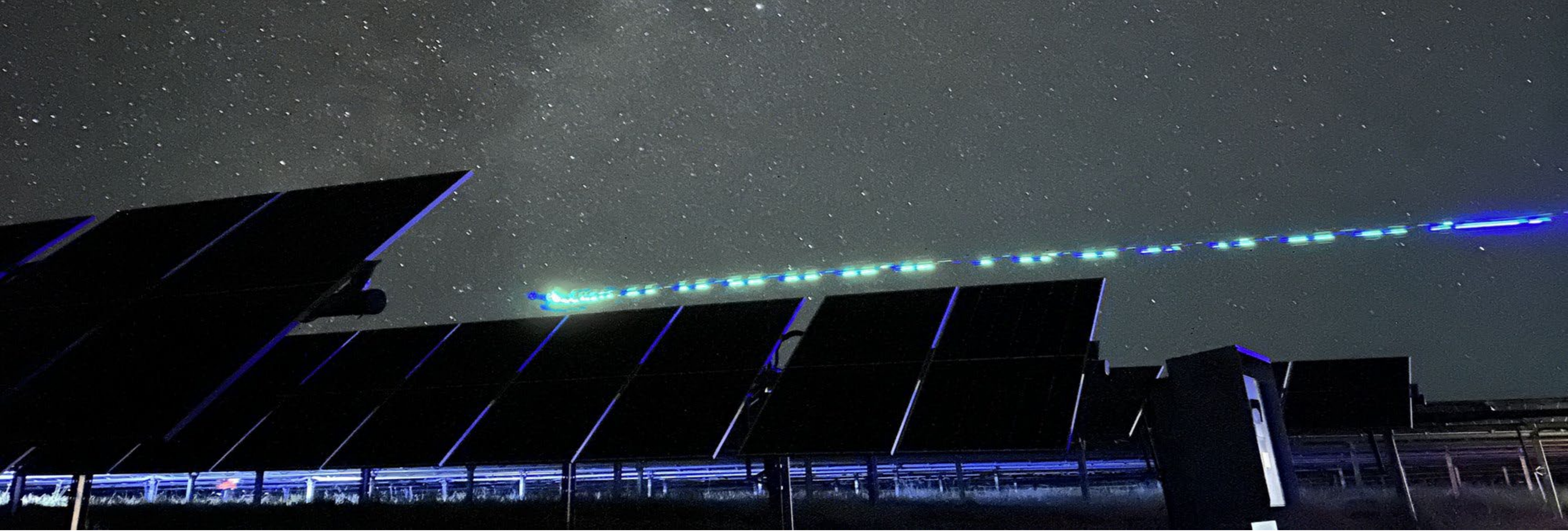


UVID in the Field: Detection and Quantification in Operating PV Assets

From field EL diagnosis to quantified power-loss assessment

Quantified Energy

Dr. Yong Sheng KHOO, COO & Co-Founder
Dr. Johnson Wong, Chief Scientist
March 2026

Quantified Energy (QE) is an AI-driven innovator shaping the future of solar farm asset management.

1

Helmed by a team of solar PV professionals from SERIS/NUS

NUS National University of Singapore | SERIS Solar Energy Research Institute of Singapore

2

QE secured investment from top-tier VCs and investment banks

vertex VENTURES

ADB Ventures

青松集团 QINGSONG GROUP

beacon venture capital

Substantial investments into solar PV carry increasing **risks**. Damages have resulted in significant losses for both owners and insurance providers.

1) Natural disasters

The frequency and severity of hailstorms, typhoons, flooding, etc., are increasing

2) Man-made damages

Rushing to meet EPC deadlines and improper O&M practices may introducing fire incidents

3) Under performance

Price reductions driven by overcapacity may lead to poor product quality

It requires holistic risk management and efficient handling of insurance claims

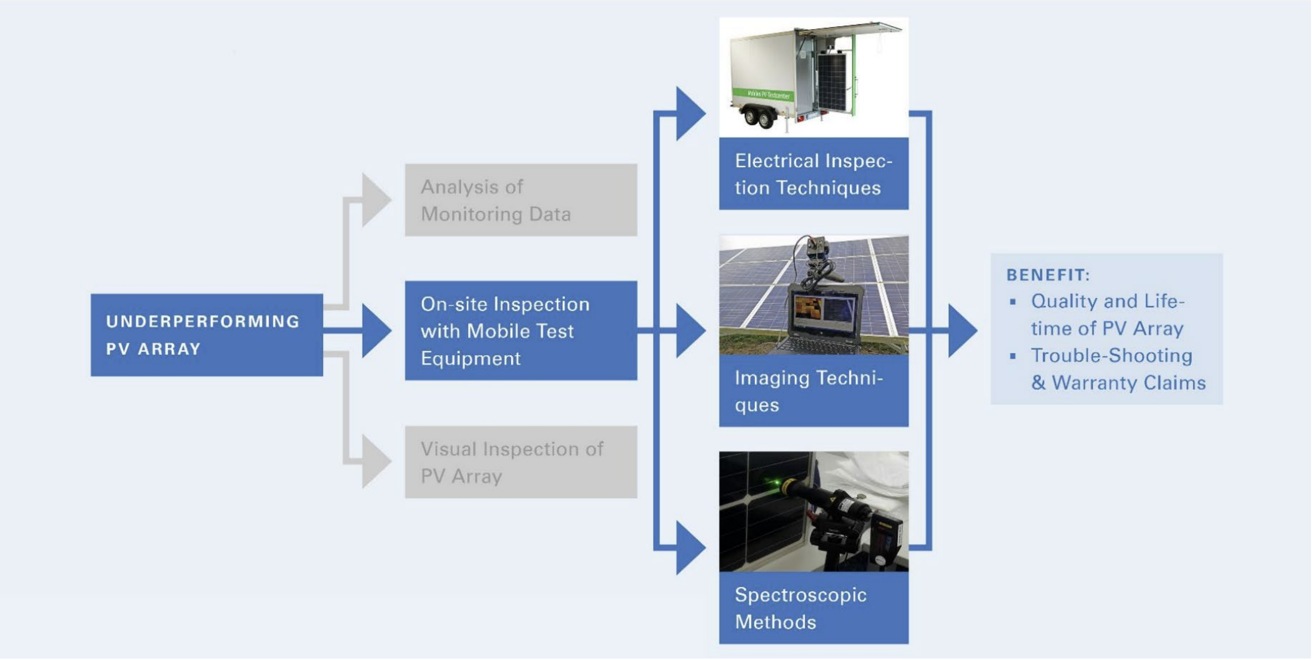
Inspection in the field is crucial for mitigating risks in solar investments. It ensures that potential issues are identified and addressed early.

Allianz

International Energy Agency
Photovoltaic Power Systems Programme

Liabilities

Inspections are vital for de-risking warranties and the potential risks of all kinds of premature degradation. These should be conducted annually from an early stage of operation, in order to detect warning signs that are not discernible without specialist equipment. Inspections will enhance safety, harvested energy, return on investment, and asset lifetimes.



https://commercial.allianz.com/news-and-insights/reports/emerging-risk-solar-power.html

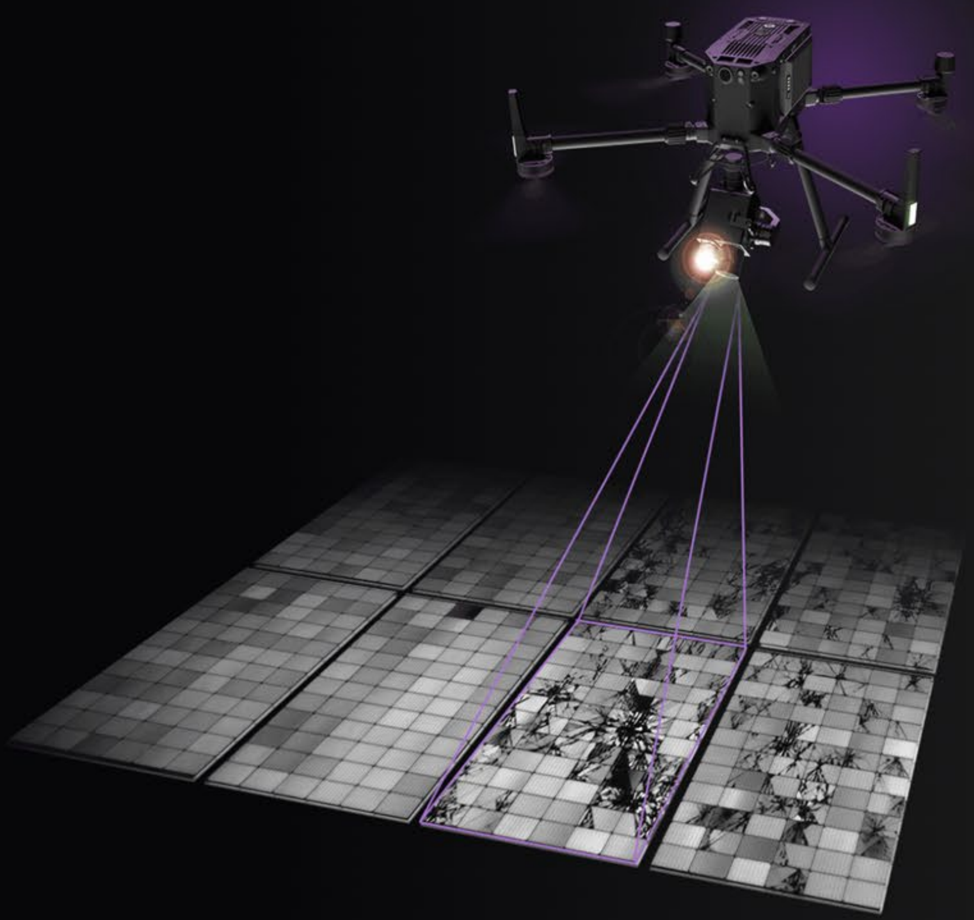
https://iea-pvps.org/key-topics/qualification-of-pv-power-plants-using-mobile-test-equipment/

Patented (SG/EU/US/JP, CN/AU pending) Autonomous Drone EL Mapping Technology

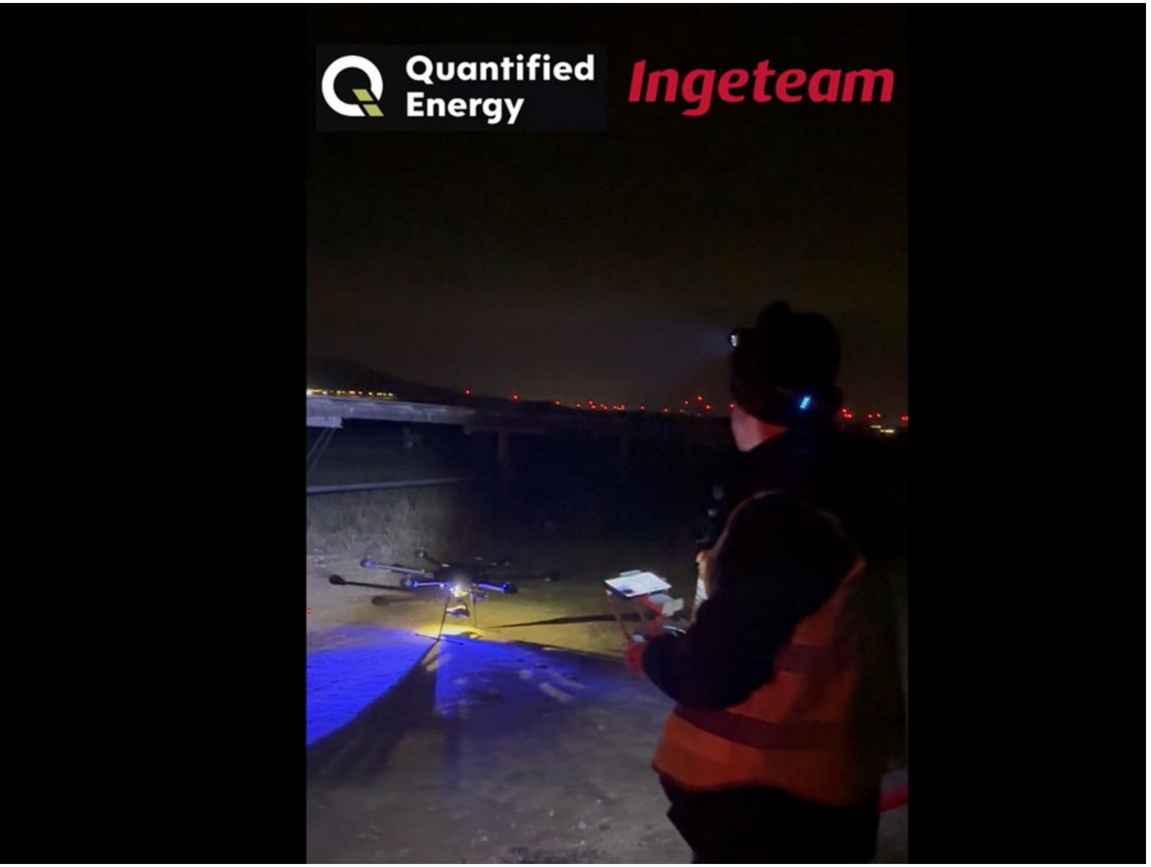
Our mission is to make sure all PV systems operate at full potential

through autonomous drone EL mapping solutions

EL imaging is a critical tool for ensuring the long-term reliability and performance of your PV systems. This versatile inspection method is applicable at every key stage of the PV lifecycle, providing detailed insights that help maintain system integrity, prevent energy losses, and support informed decision-making.



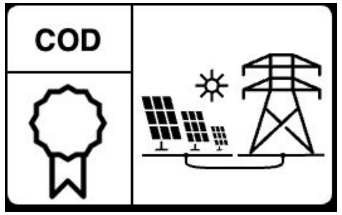
QE collaborates with central inverter partners to enable contactless drone EL at scale, achieving up to **40,000 modules** per 8-hour night shift (**~25 MW**).



https://www.linkedin.com/feed/update/urn:li:activity:7267514967803723777/?actorCompanyId=74745561

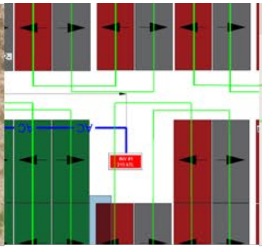
https://www.acenrenewables.com/project/stubbo-solar/

QE is **solar domain expert** acting as the trusted **third-party inspector** to conduct full scope IEC62446 standard testing in the post-installation stages.

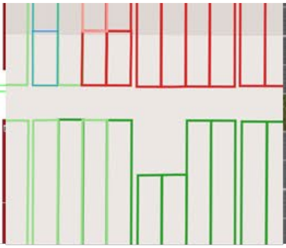


Mechanical installation → Electrical commissioning → Intermediate acceptance test → Commercial operation → Defect liability period (2years) → Final acceptance test

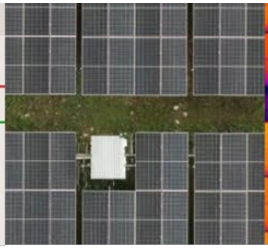
Satellite image



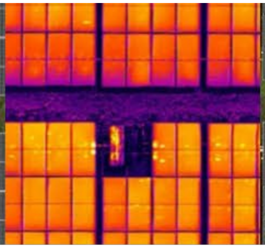
As-design drawing



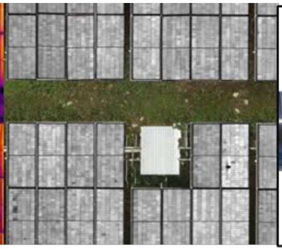
As-build drawing



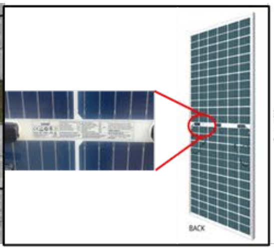
Visual inspection



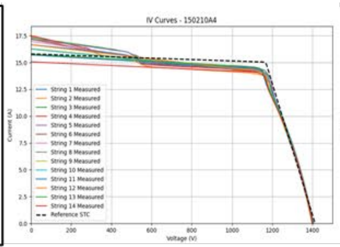
Thermal IR inspection



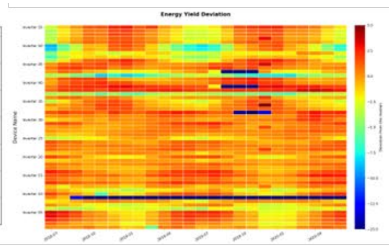
EL inspection



ID mapping



String IV test



PR/Yield heatmap

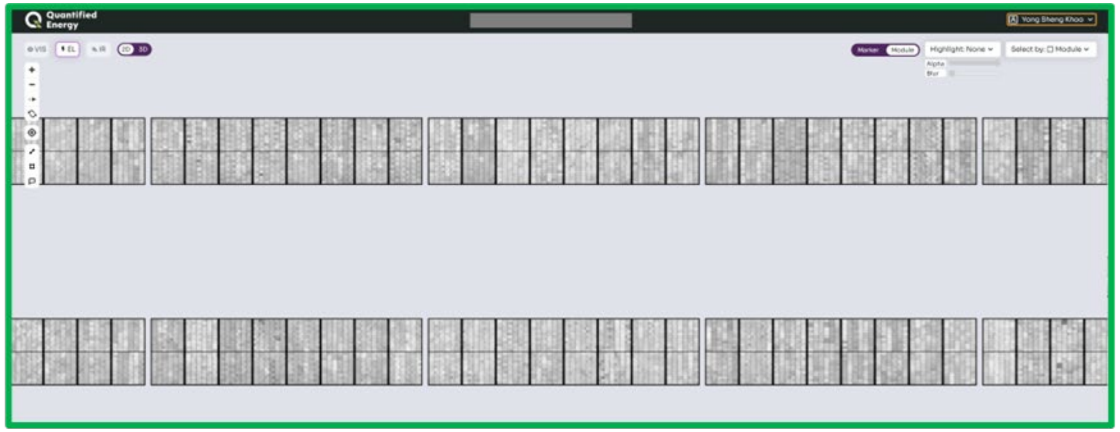
What do we observe when EL is applied systematically in the field?

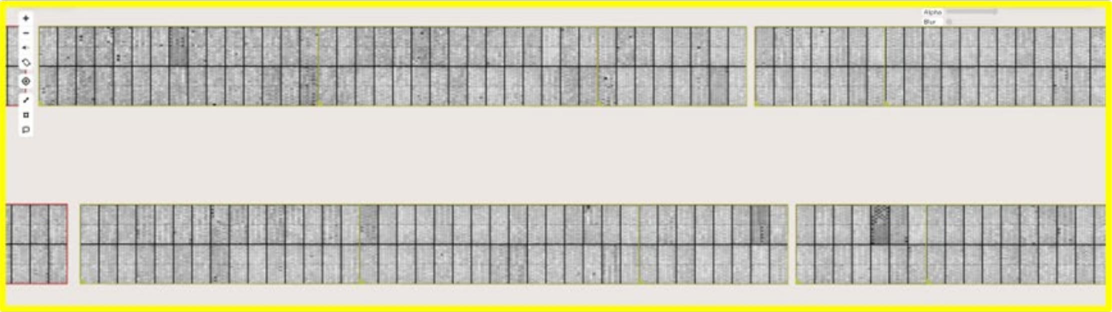
- ❑ QE has inspected hundreds of solar farms across multiple PV technologies:
  - ➢ > 4million PV modules analyzed to date, including
  - ➢ > 2million TOPCon modules.

- ❑ For TOPCon sites, we observed a wide range of dark-cell patterns in EL imaging:
  - ➢ Sites with no visible dark-cell patterns
  - ➢ Sites with low to moderate occurrences
  - ➢ Sites where a large majority of modules exhibited dark-cell patterns, even >90% across the site

- ❑ While EL dark-cell patterns can be any degradation, combining EL with controlled lab testing points to UVID-related degradation

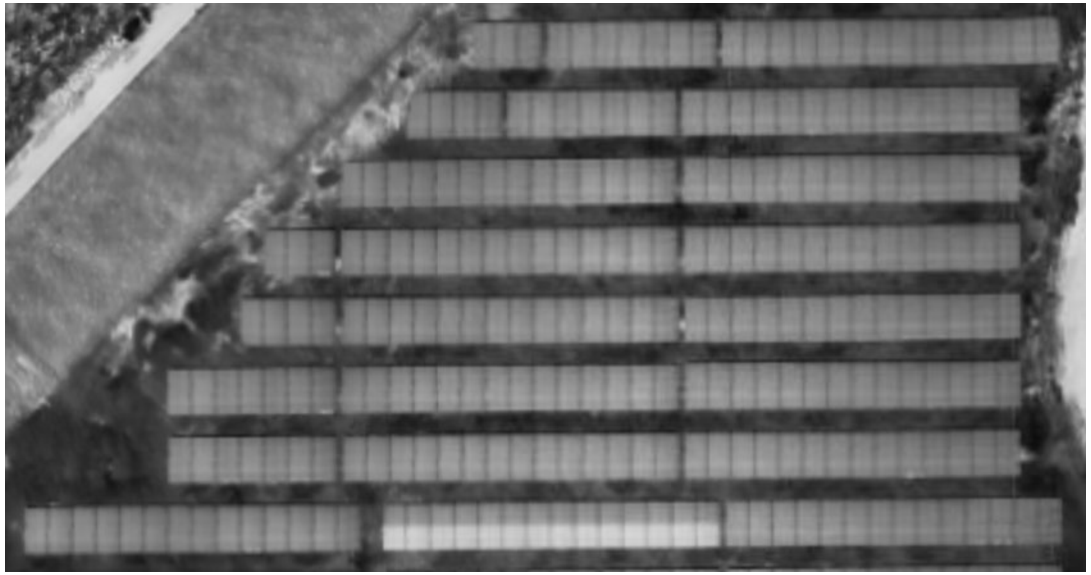
- ❑ Observed across independent projects → technology related degradation mechanism



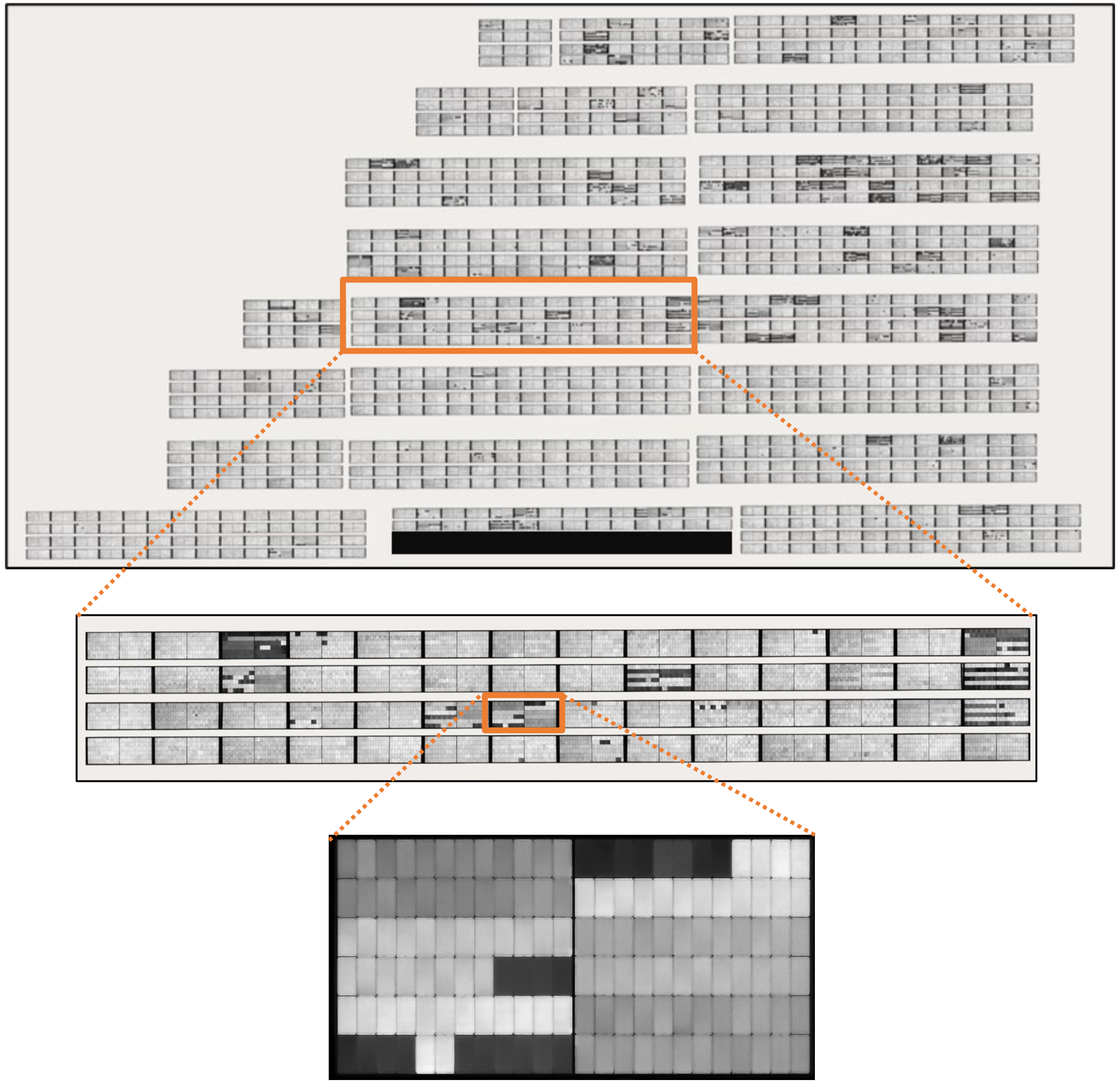


Case study – Utility Scale Topcon PV Plant with unexplained yield loss

IR imaging – unclear where the problem is

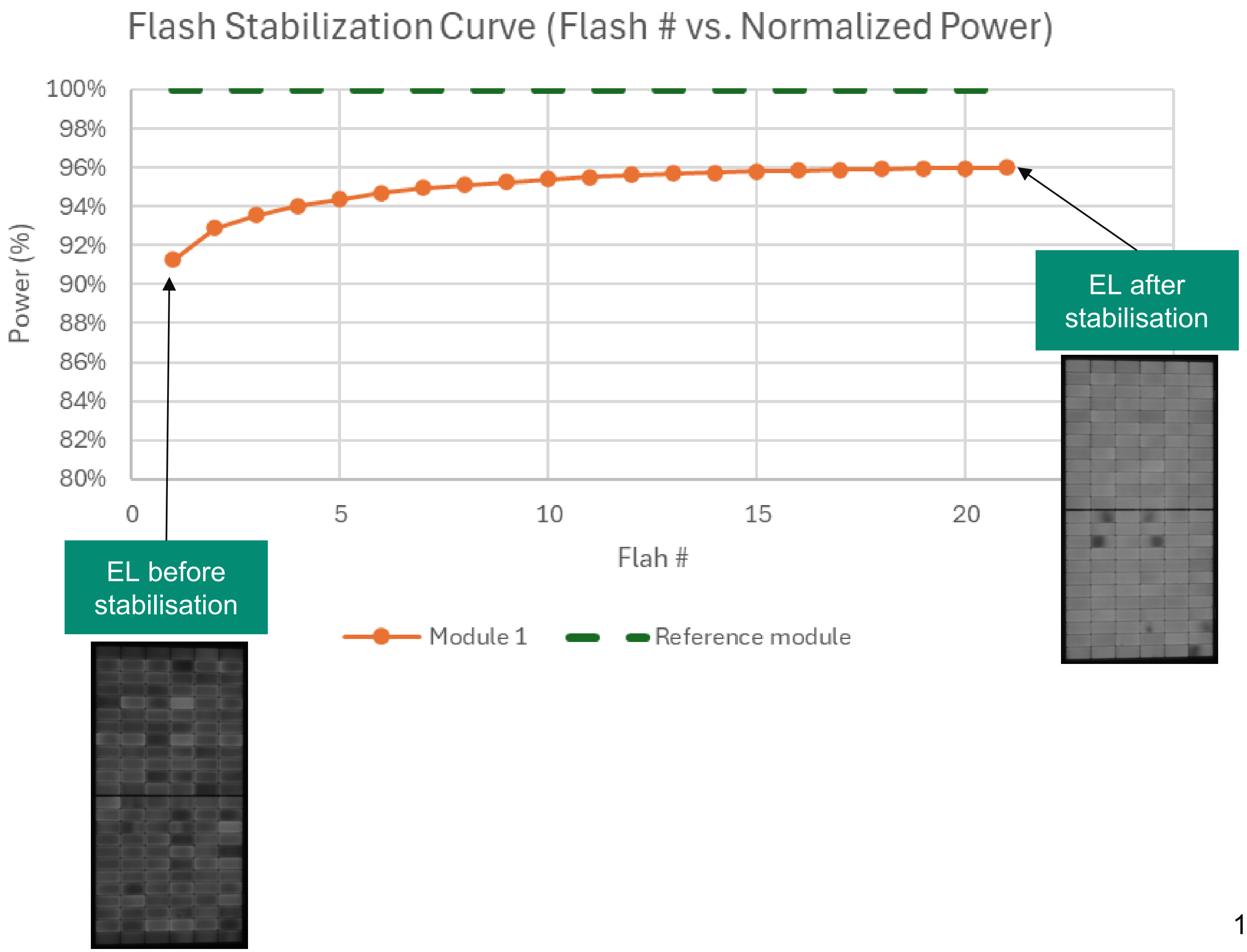


EL imaging – clear location of bad modules



Lab testing confirms UVID

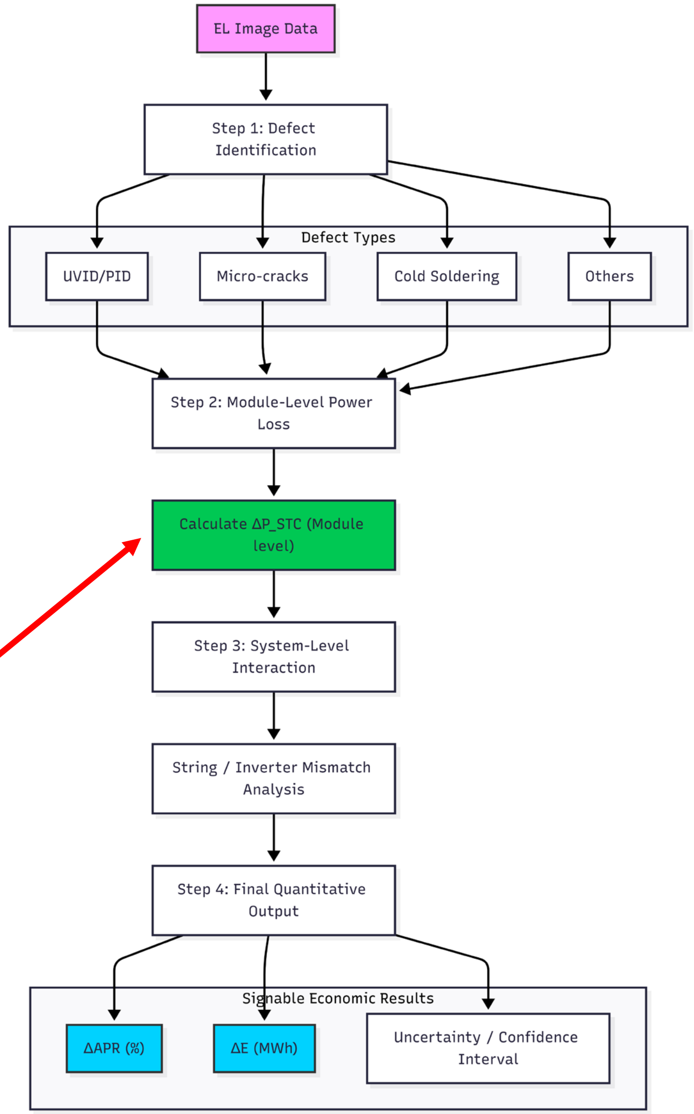
- ❑ Flash testing showed characteristic UVID metastability → power increased with successive flashes before stabilizing
- ❑ Controlled light stabilization removed metastability and dark-storage effects
- ❑ Stabilized STC measurements showed ~4% average power loss



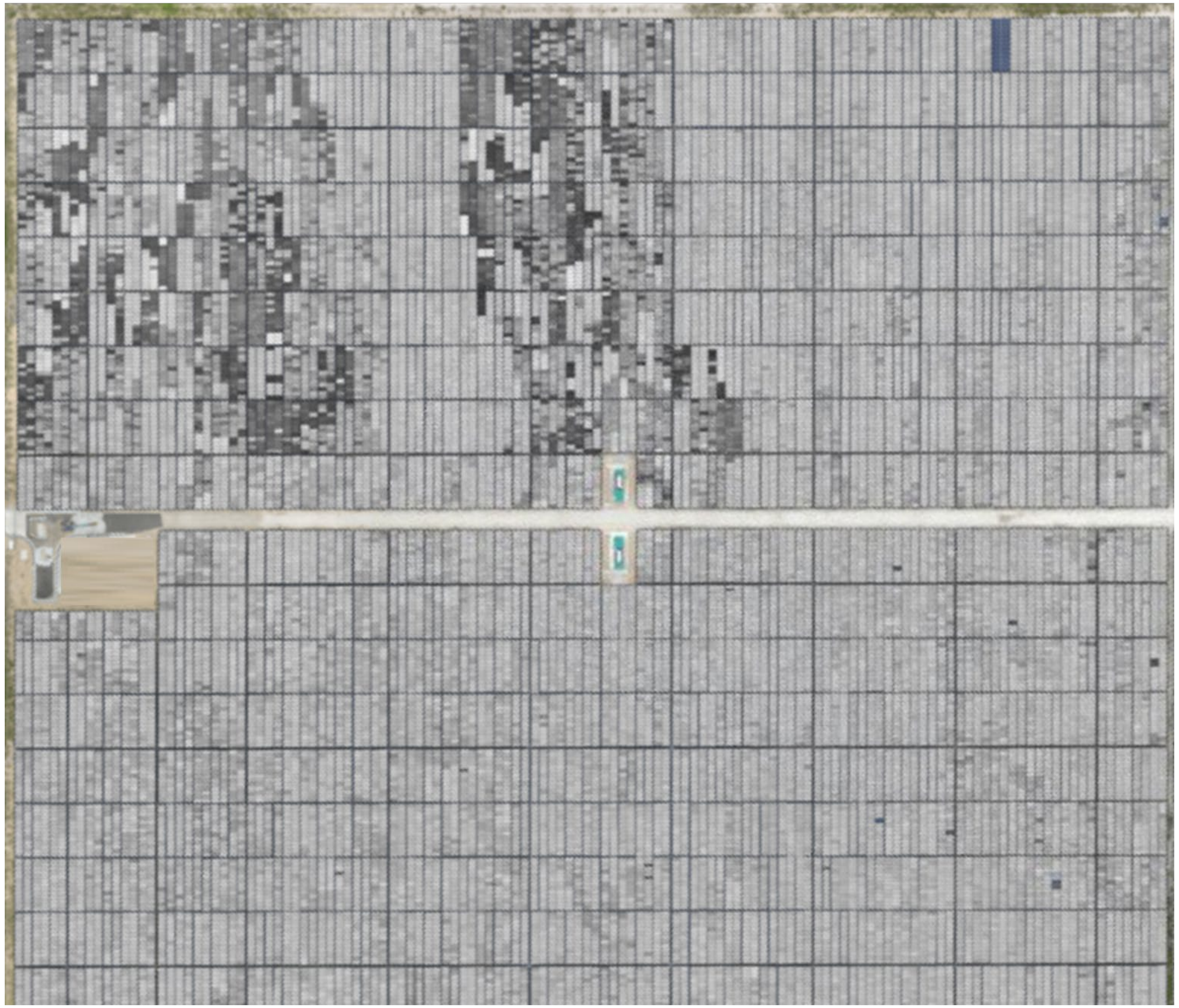
QE provides auditable data and analysis on its evidence-native decision platform for Owner/OE/EPC to sign: **We See it, Price it, Secure it.**

$$\mathrm{APR} = \frac{\sum_{i=1}^{j} E_{act,i}}{\sum_{i=1}^{j} \mathrm{GPOA}_i \left[1 + \beta\left(T_{mod,m} - T_{meas,i}\right)\right]} \cdot \frac{G_{STC}}{P_{mod}}$$

Variable	Definition
APR	Actual Performance Ratio during the testing period.
$E_{act,i}$	Electrical Energy Delivered (kWh) over each one-hour metering interval i.
$GPOA_i$	Global irradiation at the plane of the PV array (kWh/m^2) for interval i.
β	The absolute temperature coefficient for the module's nominal power output ($\%/°\mathrm{C}$).
$T_{mod,m}$	Projected Monthly Average Module Temperature ($°\mathrm{C}$).
$T_{meas,i}$	Actual average module temperature measured during interval i ($°\mathrm{C}$).
G_{STC}	Irradiance at Standard Test Conditions ($1\ \mathrm{kW/m^2}$).
P_{mod}	Sum of the nameplate ratings of the PV modules at STC conditions.
i	Index of the one-hour metering interval.
j	Total number of hours (intervals) during the testing period.



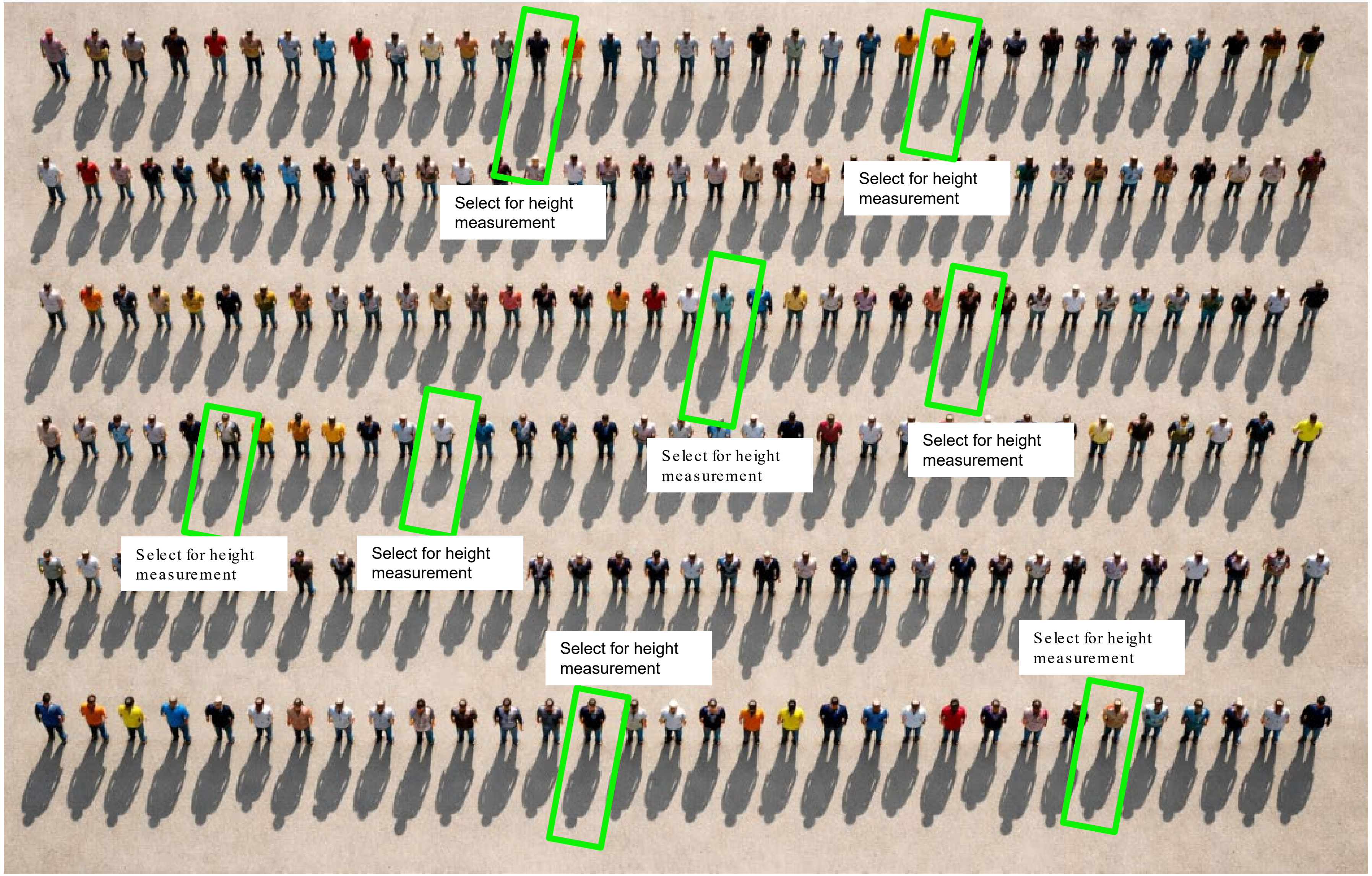
Connecting Lab and Field Data: Quantitative EL Analysis (QELA)



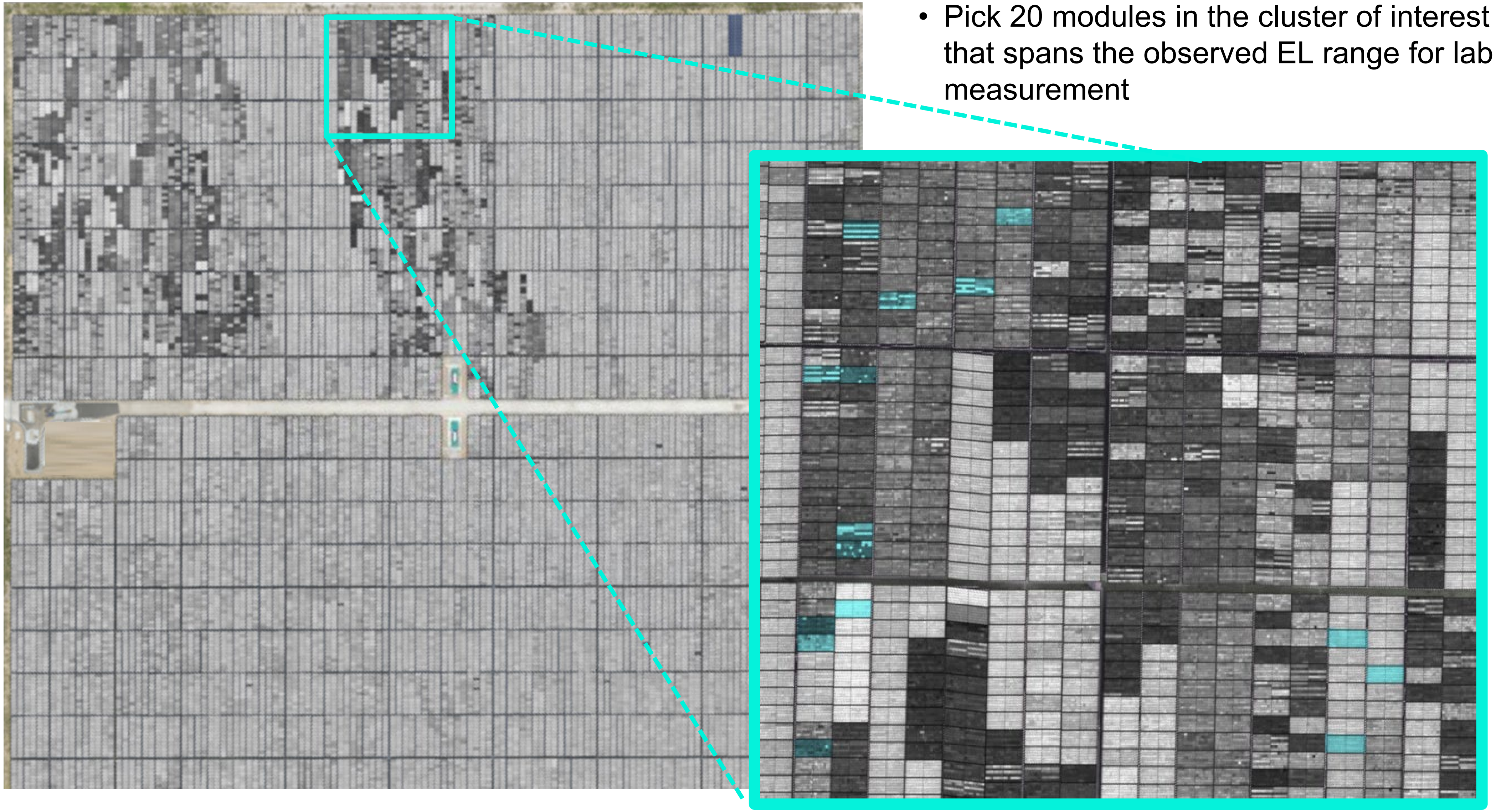
- About 30,000 modules at one plot as an example
- Early degradation is highly clustered
- How to infer the module power loss based on the EL images?

Analogy: Given an aerial photo of people's shadows, how to infer their height?

Calibration: Select a few people spanning the height distribution for reference measurement



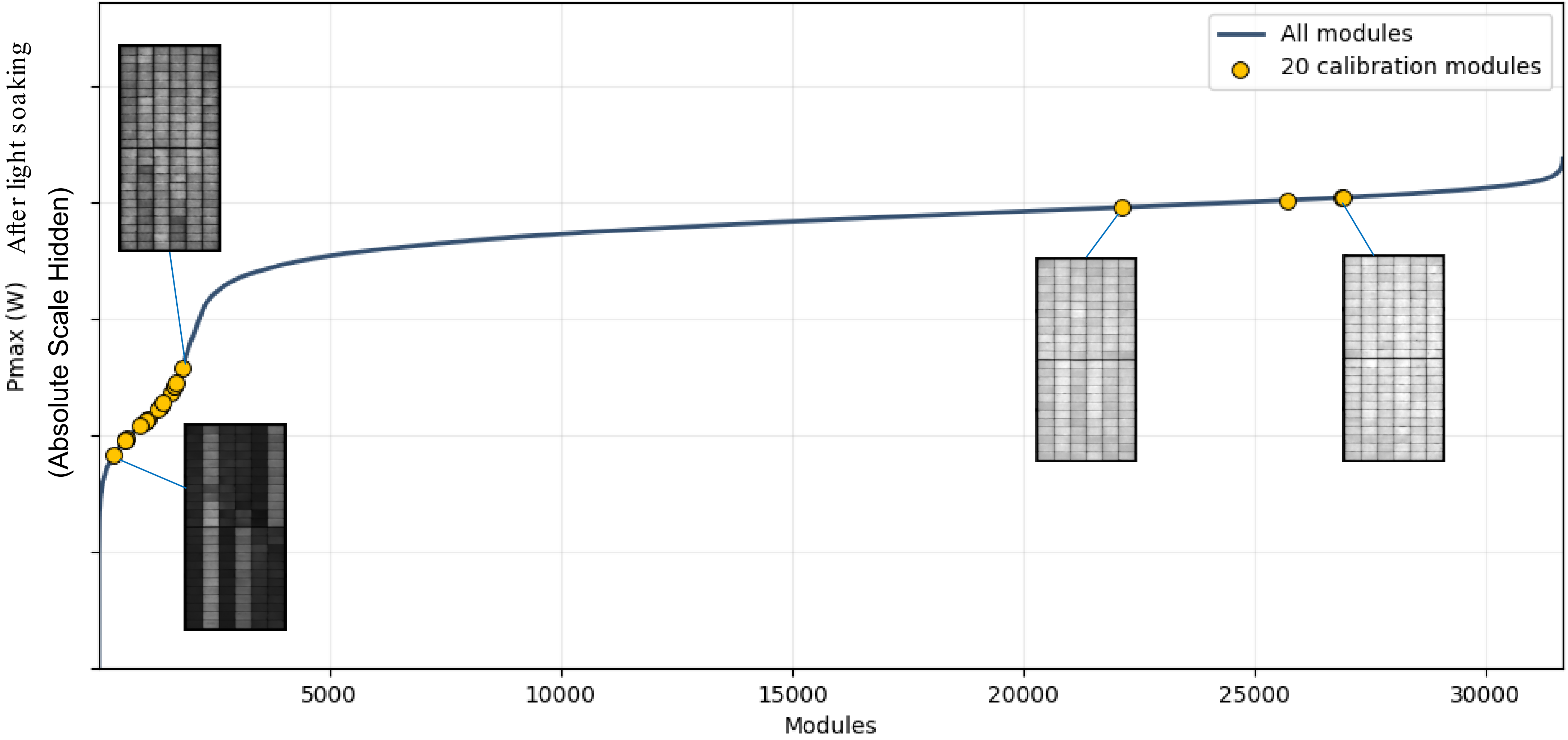
Connecting Lab and Field Data: Quantitative EL Analysis (QELA)



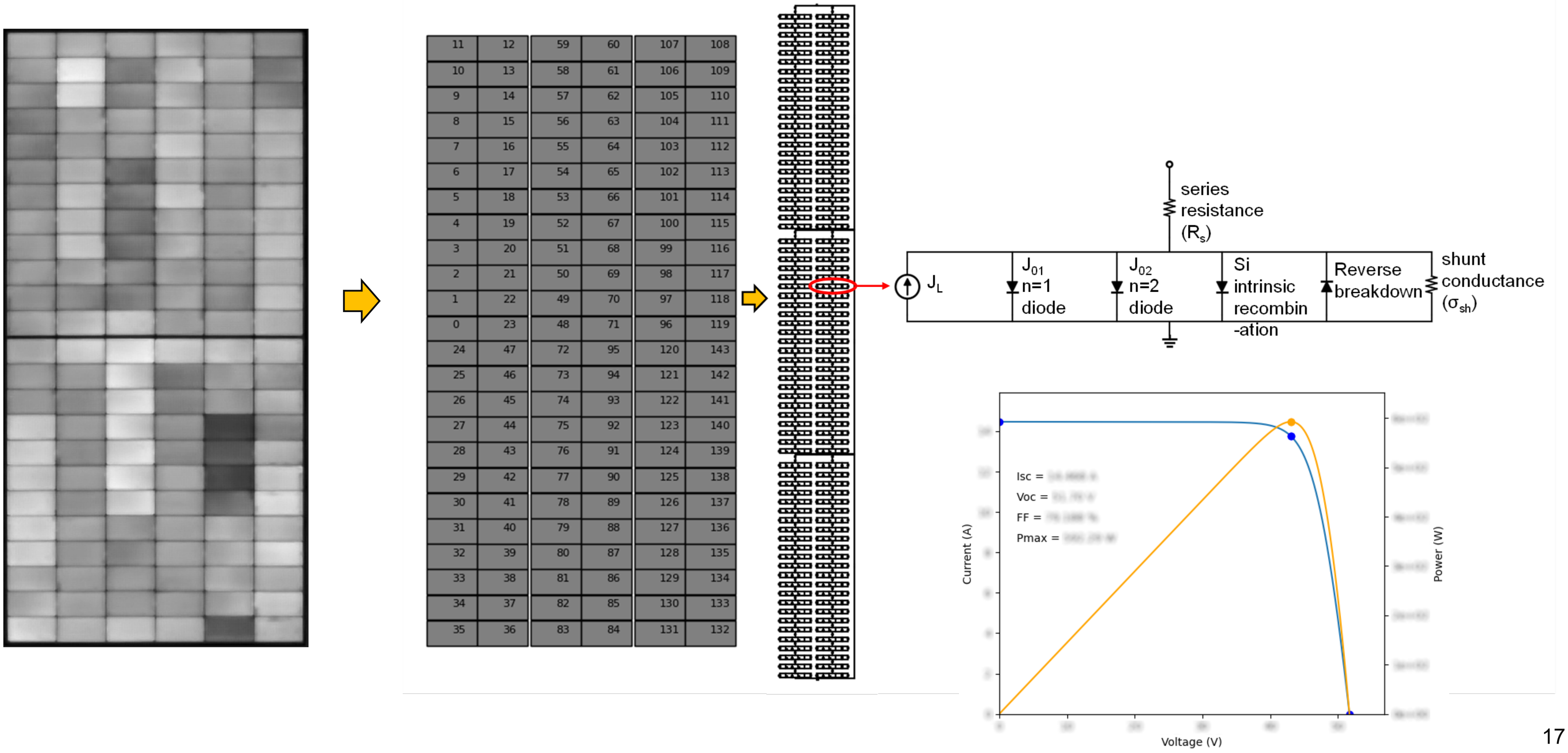
- Pick 20 modules in the cluster of interest that spans the observed EL range for lab measurement

Connecting Lab and Field Data: Quantitative EL Analysis (QELA)

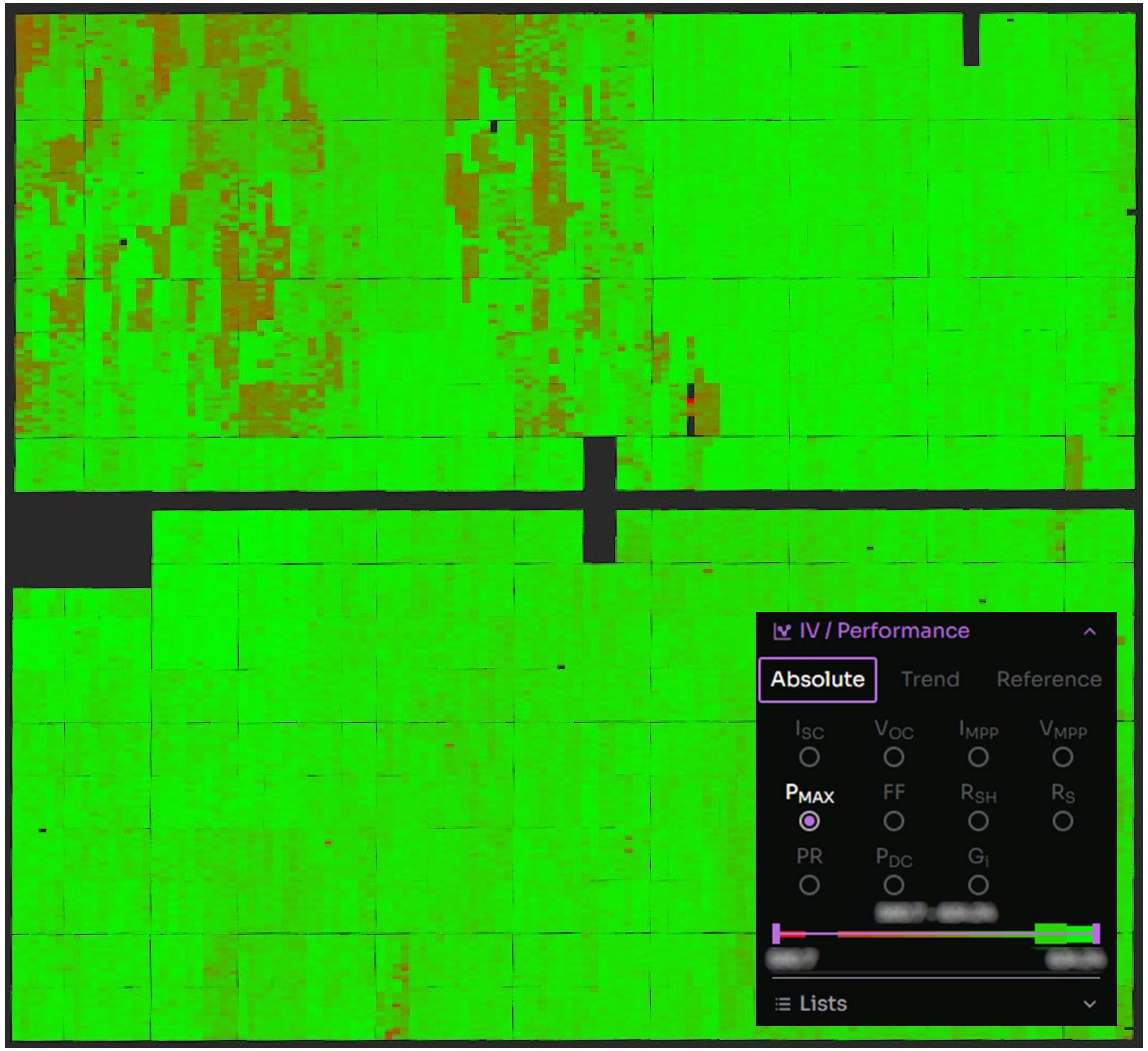
- Once measured, then the P_{max} of the 30,000 modules in the field can be calculated with reference to the 20 modules lab results

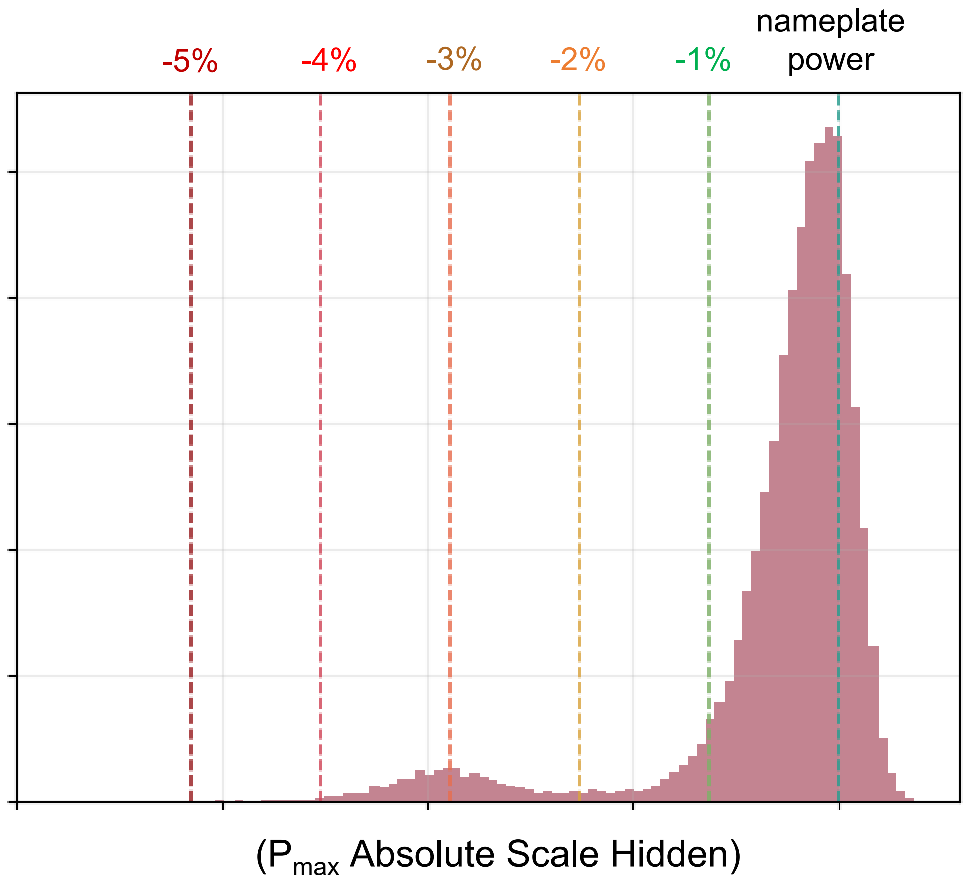


Circuit Model to infer module I-V characteristics from EL Image



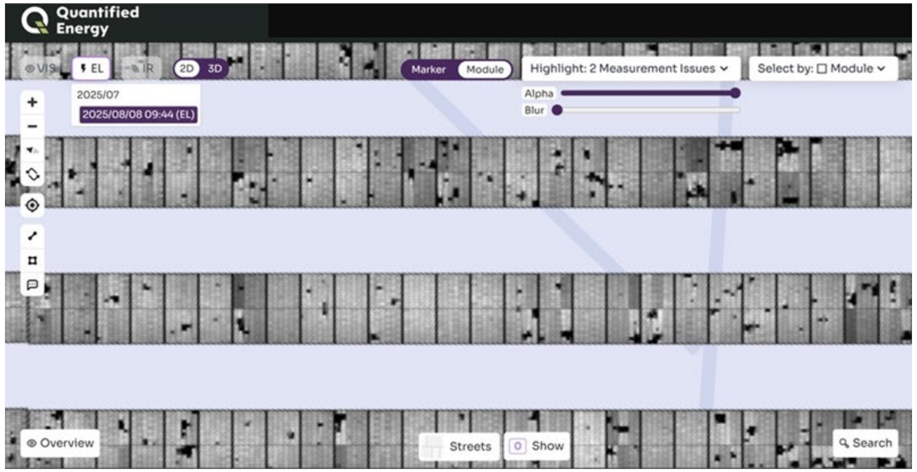
Resultant Heat Map of the Module P_{max} (stabilized) and power loss





Key Takeaways

- ❑ Drone EL is now a practical inspection tool for utility-scale PV assets (upcoming IEC 62446-4).
- ❑ Map and record any locations exhibiting degraded system performance or signs of damage to support subsequent investigation.
- ❑ UVID-related patterns can be detected systematically in the field and confirmed in the lab.
- ❑ Quantitative EL Analysis converts EL patterns into quantified power-loss estimates, calibrated against lab IV measurements at STC
- ❑ With module ID mapping, FAT and SAT data can be linked, enabling spatial patterns observed in the field to be traced back to possible batch-related issues



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UVID: Risks, detection, and impact on solar projects

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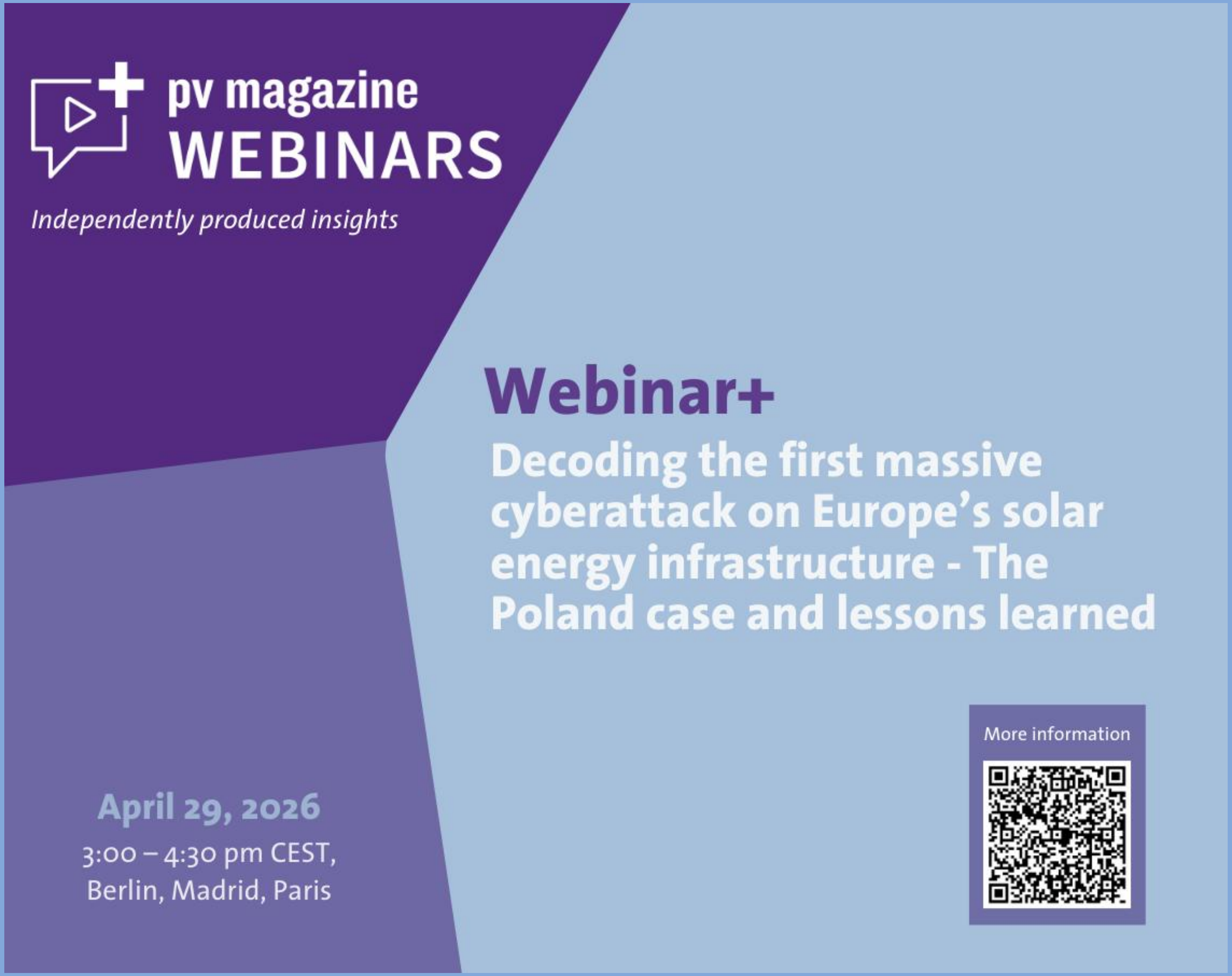
We will also examine the weaknesses and vulnerabilities that allowed the hackers to cause harm and discuss why the generation was not directly manipulated.



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