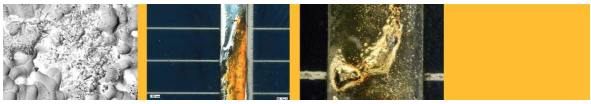
SOPHIA
PV RELIABILITY WORKSHOP



15th SOPHIA PV-Module Reliability Workshop

Summary of the "Experts Discussion Round"

Topics:

- *Reliability/certification of lightweight modules. Moderator: Ingrid Hädrich, (ISE)*
- *Reasonable lifetime to aim for: 15 or 50 years? Moderator: Karl-Anders Weiß, (ISE)*
- *Future of field inspection. Moderator: Sergiu Spataru, (DTU)*

Discussion rounds with the attending experts are an established format at the SOPHIA PV-Module reliability workshops to evaluate e g the relevance of upcoming topics or emerging technological developments or failure modes. At the 2025-edition of the workshop which took place at the DTU campus in Risø, Denmark on April 29th-30th 2025 three topics have been discussed. The content and outcoming of the discussion-groups are briefly summarized below.

Topic 1: Reliability/certification of lightweight modules. Moderator: Ingrid Hädrich, (ISE)

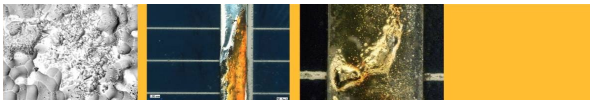
Main advantages of lightweight PV modules are reduced thickness and weight, higher customizability, and associated improved integration opportunities. However, they also come with some challenges: Module damage during transportation is more likely than for standard PV modules, and there are significant concerns about the long-term reliability and durability, exacerbated by a lack of reliable data. While some modules have been operating for ~15 years, the high volatility in choice of bill-of-materials makes finding representative data difficult. Producers may be aware of reliability issues, but rarely share them.

Most critical weak points of lightweight PV modules are reliability under damp heat, humidity freeze, and UV exposure testing, with edge sealing playing an important role. Mechanical impact can damage the front encapsulation, leading to worse behavior under damp heat. On an application level, the backside adhesive (when glued to a surface) or the mounting and clamping components (when mechanically affixed) play an important role for product reliability.

Organizer
Fraunhofer ISE, Dr. Karl-Anders Weiß,
Dr. Ingrid Hädrich
Host
DTU, Peter Behrensdorff Poulsen

For questions please contact
maren.verena.Jehle@ise.Fraunhofer.de

DTU Fraunhofer ISE



From a standardized testing viewpoint, there is no clear definition for lightweight PV modules, and customer reliability expectations may not be the same for all products. Not all standardized tests are applicable to all applications, with rigid norms reducing innovation opportunities and/or leading to an omission of standardized (re-)testing. As there are significant differences between lightweight PV modules and products, the testing should be informed by the environmental conditions of intended use.

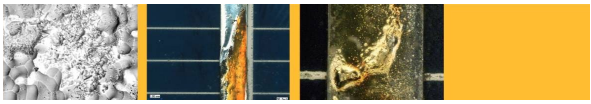
Topic 2: Reasonable lifetime to aim for: 15 or 50 years? Moderator: Karl-Anders Weiß, (ISE)

The participants in the discussion explored what "reliability" truly means in the context of varying applications, such as utility-scale, building-integrated (BIPV), and Agri-PV, emphasizing that optimal lifetimes may differ accordingly. The rapid pace of technological advancement — delivering three to four times more power per installation area in just 15 years — challenges the logic of ultra-long-lasting modules, especially considering that older technologies become less competitive over time due to rapid improvements in materials and performance. Questions were raised about whether it is more sustainable to focus on shorter lifetimes with strong recycling practices, or to push for longer durability to reduce environmental impact. Lifetime definitions (e.g., -20% power loss) and future end-of-life scenarios remain uncertain, and the economic argument through Levelized Cost of Energy (LCOE) was a recurring theme.

The group also raised concerns over the PV industry's current reliability practices, including inadequate quality control, insufficient outdoor testing, and the lack of robust monitoring systems. Issues like inconsistent materials from suppliers, poorly documented field failures, and design choices not optimized for real-world applications highlight the need for improved reliability methodology and value chain integration. Participants stressed the importance of application-specific designs, especially for emerging markets or climates, and noted that transport and installation are often primary failure sources. A critical take-home message was that recycling infrastructure must be significantly improved before committing to short-lifetime (e.g., 15-year) modules as the norm, to ensure environmental and economic sustainability. There was also consensus on avoiding overengineering for unrealistic use cases, instead focusing on optimizing bill of materials (BOM), standardizing module sizes, and ensuring alignment with recycling capabilities and lifecycle strategies.

Topic 3: Future of field inspection. Moderator: Sergiu Spataru, (DTU)

The discussion explored how imaging-based inspection methods such as infrared thermography (IRT), electroluminescence (EL), photoluminescence (PL), and ultraviolet fluorescence (UVF) are likely to grow in importance across utility-scale, residential, and floating PV applications. In the near future, plant commissioning and module delivery may become key drivers for imaging, especially to quantify (later)



power loss and support warranty claims during installation. In operational systems, inspections will be more reactive, i.e. triggered by severe weather events or unknown underperformance. However, the high cost of replacing modules limits replacement campaigns after 10 years, making inspections more critical for diagnosis and liability assignment. Participants noted that profitability in residential inspection remains a challenge, as full module replacement is often more economical than inspection. Affordable, easy-to-use handheld tools are needed, especially for small-scale operators. Integrating inspections into performance ratio (PR) assessments and contracts could add value, provided responsibility and liability (e.g., between manufacturers and O&M operators) are clearly defined.

Full automation of inspections still faces significant barriers, especially for faults like isolation failures, bypass diode issues, or cracks in connectors. The lack of standardization in inverters, which limits capabilities like reverse current bias or controlled modulation, was identified as a major bottleneck. Visual inspection is still critical for detecting physical issues such as glass breakage and backsheet damage, and advancements in robotics and automation are necessary to supplement or eventually replace manual checks. Future opportunities for AI-based inspection were discussed, including its potential for estimating power loss and detecting PID or mechanical damage – especially if manufacturers release open-source tools (mentioned at the talk given by Lukas Koester at the workshop on Tuesday 29th April 2025). Technological bottlenecks such as the high cost of InGaAs and SWIR cameras, and the need for string level forward bias or operational point control for EL and PL respectively, must be addressed to enable broader drone or robot-based high-throughput imaging process. Overall, cross-industry collaboration and proactive responsibility from manufacturers will be essential to standardize, automate, and integrate inspection practices into the long-term reliability of PV systems.