SOLAR INVESTORS GUIDE

SIG 2/2026

O&M for solar parks

Reduce operating and maintenance costs

photo: EMC-direct

pV Europe
solar technology and applications


photo: Mildred Klaus

Safeguarding investment against future costs

As a rule, one to three percent of the total investment should be allocated to operation and maintenance expenses over a 20-year period. Solar parks are therefore considered low-maintenance assets, with O&M costs significantly lower than those of fossil fuel or nuclear power plants.

Maintenance costs are largely driven by the extensive area covered by module fields. A solar park with a capacity of 300 MW and grid connection will require 250 to 300 hectares of land. There are hundreds of thousands of solar modules, kilometres of cabling and millions of small components such as DC connectors, cable ties and clamps. Cost optimisation therefore focuses on minimising component variety and using durable, long-lasting components. In a solar park, components are exposed to weather and solar radiation for many years. Over time, this exposure affects both plastics and metals.

To operate plants proactively, monitoring and advanced analysis tools are essential. Thermal imaging drones scan module fields to detect faulty modules. Electroluminescence analysis is used to identify damaged cells after a hailstorm. Sample tests on the ground can be employed to examine the backsheet films of solar modules.

These examples illustrate a broader principle. Operation and maintenance requirements must be integrated from the earliest planning and installation phases. Ultimately, long-term asset value is shaped long before the first kilowatt is generated, and the more systematically this is done, the more effectively the investment is safeguarded against avoidable follow-up costs and long-term depreciation.

We wish you an informative and insightful read.

Heiko Schwarzburger
editor-in-chief
PV Europe & photovoltaik

PREVIEW SIG3/2026

Innovations for mounting

Our next SIG deals with the installation of large solar farms. Prefabrication of the cable harnesses and logistics on the construction site are crucial levers for reducing costs. It will be published on **9 June 2026**.


photo: Jens Distelberg

E-PAPER SOLAR INVESTORS GUIDE

C&I storage systems

Energy costs matter. They shape competitiveness, whether a company is trading internationally or serving the local market. And with fossil and nuclear prices heading in only one direction, renewable energy from sun and wind is looking less like an alternative and more like the smart money.

Solar PV is particularly attractive, affordable to plan and install, and adaptable to whatever space a business has available, be it rooftops, facades or underused land. Pair it with a capable commercial storage system and energy bills can come down considerably.

Payback periods typically range from three to eight years, depending on how many revenue streams the storage taps into. A single unit can run several at once (the multi-use approach) and this is where the real value lies. Most C&I storage systems today maximise use of rooftop solar, shave peak loads, snap up cheap grid power when it's available, smooth frequency fluctuations and keep the lights on when the grid falters. In short, they earn their keep.

Control is digital, with AI managing complexity behind the scenes. Better still, these systems can grow and adapt alongside the business in capacity, output and functionality, future-proofing the investment.

▶ *https://www.pveurope.eu/sig-2026-1-ci-storage-systems*

photo: Heiko Schwarzburger

The contacts in this box for bypass diodes are destroyed.

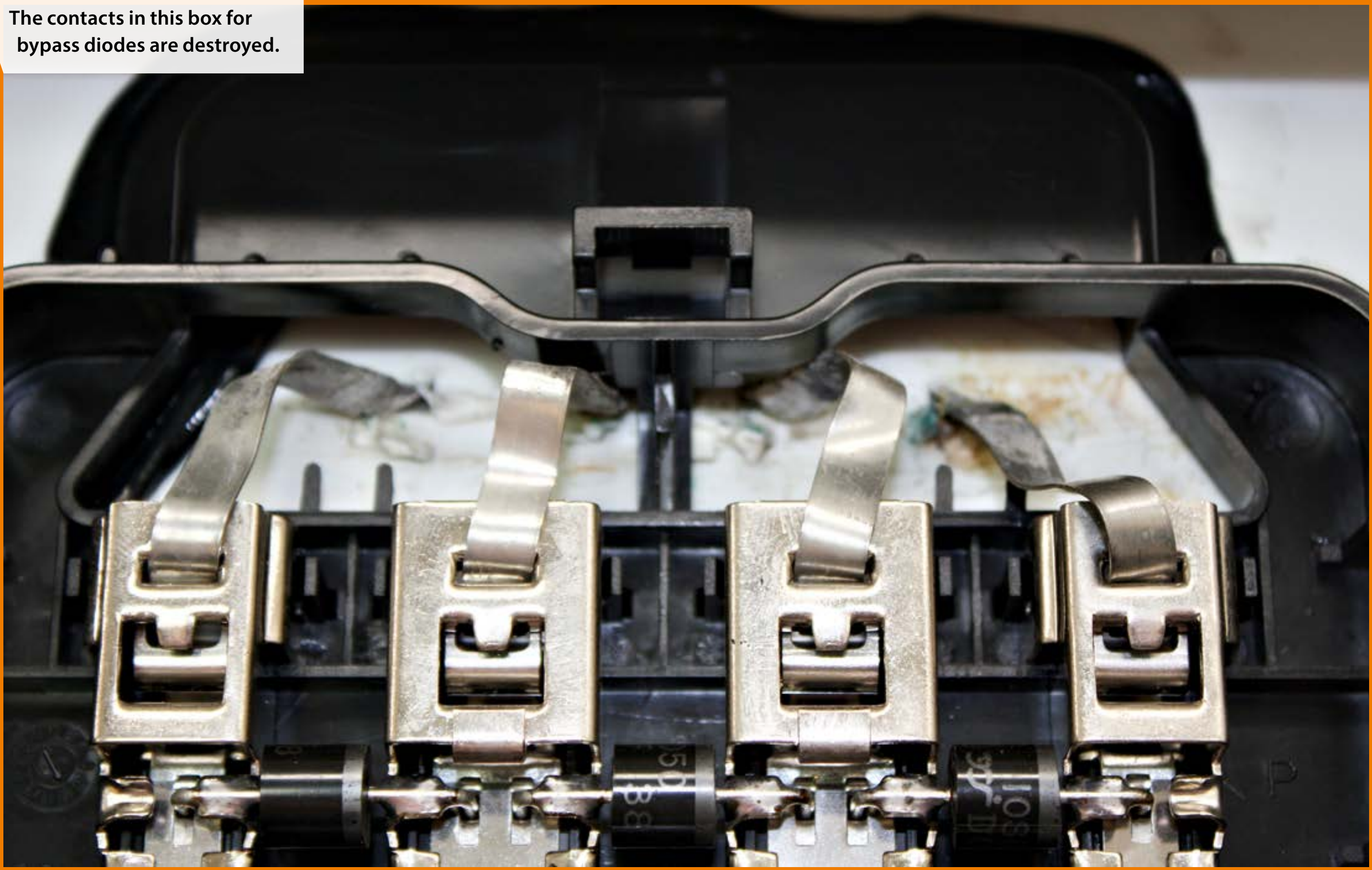


photo: Heiko Schwarzburger

Professional maintenance protects investments

Operation and maintenance ■ As with any technical system, solar parks require regular inspections, checks and occasional repairs. The foundation of effective operation and maintenance is continuous monitoring in the control room and the professional interpretation of operating data.

by Heiko Schwarzburger

After a quarter of a century of rapid expansion and technical learning, the solar industry has gained considerable experience as it turns to the next phase of development. In the process, the idea of maintenance-free installations has proven to be a myth, one that has resulted in avoidable and at times substantial losses for many operators.

Today, the sector has moved beyond its early years. Professionally planned and installed solar parks typically budget one to three percent of total investment for operation and maintenance. Construction does not mark the end of the business case. Rather, it marks the point at which long-term performance begins. A solar park is expected to deliver electricity reliably for decades and to serve its customers over the long term.

Lessons learned, not without cost

Experience has brought its share of technical setbacks, some of which have carried a high price. First-generation thin-film modules, for example, proved less reliable than anticipated. The semiconductor material showed instability and output declined sharply after only a few years. A substantial share of early installations had to be replaced, in some cases stretching both plant operators and module manufacturers or importers to their financial limits.

Operators in Italy and Spain continue to address a widespread serial defect affecting back-sheet films. Between 2010 and 2012, intense cost pressure saw some manufacturers replace EVA film with polyamide. A decade later, it

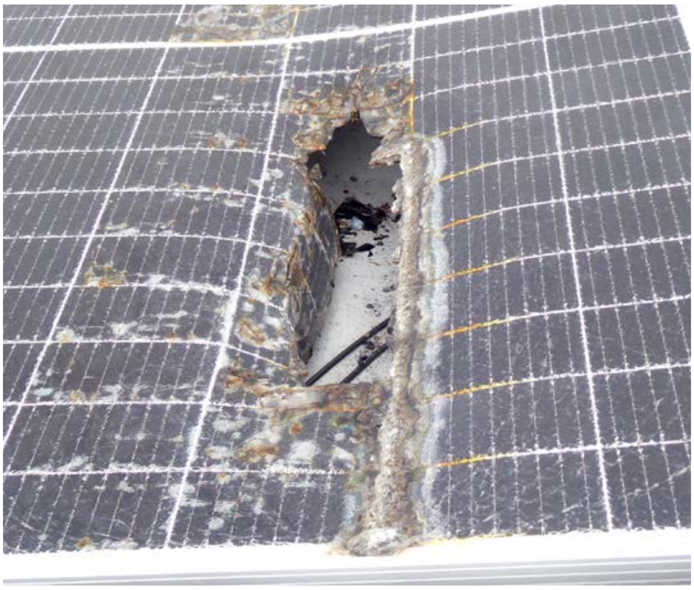


photo: Lutz Erbe

The back sheet material in this module was obviously a bad choice.

became evident that polyamide embrittles and cracks under prolonged UV exposure, a process known as chalking.

Chalking of backsheet films

The implications of this are significant. Water vapour can penetrate the laminate and cell interconnections begin to corrode. Many solar parks now operate at system voltages of 1,500 V DC and are typically equipped with transformerless inverters. If rear insulation is compromised, contact with a damaged backsheet during operation can present a serious safety risk.

In practice, embrittled backsheets first appeared as insulation faults reported by inverters. Downtime increased because inverters failed to connect in the morning. Only after sunlight had evaporated surface moisture did affected systems resume feeding electricity into the grid.

A problem that develops over time

In many cases, degradation progressed gradually. The issue intensified over the years before becoming visible. Cracks formed in encapsulation films and, in severe cases, entire cell strings detached from modules. The phenomenon was first observed in southern Europe, where higher solar radiation and stronger UV exposure accelerated material ageing.

FLIR

New equipment for system testing


photo: Flir

Flir, based in Frankfurt am Main, offers specialised testing equipment for the installation and maintenance of solar modules in solar parks, on commercial rooftops and residential buildings. The tools allow operators to monitor the performance and safety of PV systems, including in larger solar power plants. The product range includes:

FLIR CM78-PV clamp meter: This device was designed for electrical inspections in commercial and industrial applications. It supports DC measurements up to 1,500 kVA at a rated voltage of 1,500 V under CAT III conditions and can process either DC or AC currents of up to 1,000 A via the clamp. The meter includes functions such as inrush current measurement, variable frequency drive operation (VFD mode), true RMS measurement (TRMS) and a low-impedance mode (LoZ) to handle demanding electrical testing and measurement tasks.

The integrated non-contact infrared thermometer and laser pointer assist with fault detection in switchboards, cables and motors. The system supports diagnostic work through contact measurements or by capturing intermittent faults using the data logging function. The CM78-PV also supports wireless connection to Flir's Meterlink app, allowing technicians to capture and share measurement data quickly in the field.


photo: Flir

PV78 irradiance meter: This compact instrument was developed for surveying solar sites, installing solar modules and maintaining photovoltaic systems. It enables rapid measurements of solar irradiance from zero to 1,400 W per square metre (according to IEC 62446-1). Users can measure temperature by placing the instrument directly on the panel or by connecting an external probe for continuous measurements. The device also includes a compass to determine orientation and a tilt function to verify the angle of roofs or panels. The large, high-contrast LCD display remains easy to read even in direct sunlight.

PV48 solar module tester and I-V tracer:

This instrument was developed to assess the performance and efficiency of solar modules. It quickly measures critical parameters such as maximum power, voltage, current, open-circuit voltage (Voc), short-circuit current (Isc) and ambient temperature. With its I-V curve tracing function, the device provides intuitive visual analysis for modules of up to 800 W per panel. The tester includes an integrated lithium-ion battery and a large high-contrast LCD display.

Solar technicians can use the device to document performance degradation in solar modules. Output declines naturally as modules age. The PV48 tester allows operators to verify whether degradation remains within expected limits. Such documentation can save considerable time and effort in the event of warranty claims.

Solar troubleshooting kits:

Flir has also introduced two troubleshooting kits for photovoltaic systems. These provide a complete approach to testing and verifying solar modules.

The **Solar-PV-KIT-1** troubleshooting kit for solar modules includes the CM78-PV clamp meter rated to 1,500 V DC, a flexible universal current clamp (up to 3,000 A), the PV78 irradiance meter and measurement leads.

The **Profi-PV-KIT-2** consists of the CM78-PV clamp meter (up to 1,500 V DC), the flexible universal current clamp (up to 3,000 A), the PV78 irradiance meter, the PV48 module tester and a Flir thermal imaging camera.

▶ ***https://www.flir.com/en-gb/home/***

These issues would have been detected much earlier with continuous monitoring of operating data. Insulation faults at inverter level would have been detectable, because operating data ultimately reflects the physical condition of the system. Ultimately, every fault and delay accumulates in reduced energy yields and therefore in lower revenues. Professional monitoring by trained personnel is therefore central to preserving asset value. Operation and maintenance, when approached systematically, protect the long-term return on investment.

photo: M. Diehl

You can see the cells from the back of the module. The sheet is degenerating very fast and will break soon.

photo: BASF-SE/Hans-Juergen Doelger

The new test device from Trinamix makes it easy to check the back sheets in the solar field.

Modern technology and AI as support

Operations teams are increasingly supported by advanced digital tools. Artificial intelligence and comparative algorithms analyse performance data automatically, identify emerging patterns and help localise faults, thereby reducing the cost and duration of maintenance interventions.

Thermography and electroluminescence are two established methods for detecting module defects. Drones survey extensive solar fields, systematically scanning thousands of modules, identifying irregularities and documenting findings. Regular cleaning also plays a role, particularly where agricultural operations or metal processing facilities are located nearby.

Alongside routine inspections, targeted assessments after heavy rainfall, hail or significant snowfall are all essential. After winter in particular, careful checks ensure that the solar park is technically prepared for the high-yield months ahead.

▶ ***https://www.pveurope.eu/maintenance***

SOLAR INVESTORS GUIDE PODCAST

Cybersecurity – Villains come via the Internet

photo: M. Diehl

Cybersecurity is a burning issue for inverters and solar storage systems. Uri Sadot is Cybersecurity Program Director at SolarEdge and Chairman of Digitalization at the European industry association SolarPower Europe. In this talk, he explains risks and incidents and analyzes gaps in the security of systems and installations. He says: Those who take precautions avoid criminal access. Those who wait risk significant damage – from economic losses to system failure and grid disruptions. Duration of the podcast: 1:09 hours

▶ ***https://www.pveurope.eu/podcast***

SOLAR INVESTORS GUIDE E-PAPER

Minimising risks of solar projects

Investing in solar parks, expansive rooftop systems and cutting-edge battery storage demands patience and a truly long-term perspective. Such projects are typically designed to operate for twenty years or more, making it crucial to safeguard them against a broad spectrum of risks over their entire lifespan – a priority that remains all too often underestimated. This issue of our Solar Investors Guide centres on the topic of risk. Our aim is not to cause concern, but to raise awareness and offer practical, actionable guidance for managing these challenges with professionalism. We pay particular attention to technical aspects and the exceptional quality of the components used. TÜV Rheinland's inspection engineers work worldwide, assessing and securing solar parks. Time and again, they find that durability and high quality are not given enough consideration when selecting solar modules, inverters and storage batteries.

This oversight can have costly, long-term consequences. As the saying goes, buy cheap, buy twice. We also share advice on protecting your investment from unauthorised access – whether from thieves targeting valuable metal components such as cables or inverters, or from criminals seeking to access operational data and plant controls via the internet. Robust cybersecurity is becoming ever more important and is now required by both grid operators and authorities. The surge in cyberattacks over the past three years underscores just how critical this issue has become.

▶ ***https://www.pveurope.eu/solar-investors-guide-6-minimising-risks-0***

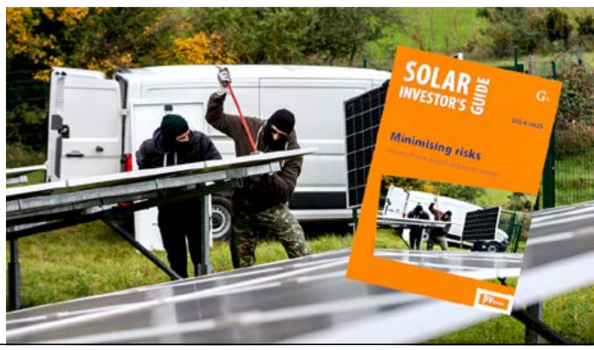


photo: BASF-SE/Hans-Juergen Doelger

Only identical connectors as MC-4 may be used.

Small parts, major impact on PV reliability

Installation ■ Connectors, clips, cables and other small installation components are frequently underestimated during photovoltaic system construction. Their size may appear insignificant, yet poor quality or incorrect installation can cause serious problems during operation. Maintenance effort and repair costs can increase considerably. **A practice report**

photo: www.patrick-kunz.com/Stäubli

DC connectors may be among the smallest components in a photovoltaic system, but they carry high voltages and currents and must function reliably for decades under demanding environmental conditions. Over the lifetime of a PV installation they are exposed to rain, heat, frost and strong temperature fluctuations.

Two elements determine the durability of a connector: the plastic housing and the metal contact element. The housing consists of an insulating body with sealing nut and gasket. It isolates the contacts and exposed cable conductors and protects current-carrying parts from environmental influences. High-quality connectors use housings tested for thermal stability as well as resistance to mechanical stress such as bending and impact. They protect against weather and fire while maintaining the electrical conductivity required for reliable operation.

Importance of the contact element

The core of every DC connector is the metal contact element. In most designs a spring contact carries the current while the cable conductor is attached by crimping.

The quality of this contact determines the electrical resistance of the connection and therefore the heat generated during operation. High-quality contacts maintain stable resistance over many years, ensuring reliable current transmission within the module field. Manufacturers verify this stability through extensive testing procedures.

Testing beyond standards

In addition to outdoor test installations, laboratory testing is used to simulate long-term operating conditions. Climate chambers and accelerated ageing tests reproduce environmental influences such as heat, moisture and UV radiation.

The manufacturer of the original MC4 connector, for example, conducts tests that go beyond the requirements of existing standards. Independent certification by TÜV Rheinland confirms the reliability of these components.

In practice, high-quality connectors pay off over the lifetime of a system. They contribute to improved system safety, reduced failure risk, lower maintenance requirements and stable energy yields.

Correct crimping is essential

The quality of connector assembly has a major influence on the safety, efficiency and service life of a photovoltaic system. Even small mistakes during crimping can have serious consequences.

Before crimping begins, installers must select compatible materials. Connectors, cables and tools must be properly matched. When selecting connectors, installers should consider:

- voltage rating
- current carrying capacity
- operating temperature
- conductor cross-section

Only after these parameters have been defined should the appropriate solar cable be selected.

Tools: quality instead of compromise

Installation tools must match both the cable cross-section and the connector type. Only approved stripping tools should be used. These adapt automatically to the conductor size and avoid damaging individual wire strands.

Certified crimping tools, ideally with a ratchet mechanism, ensure consistent compression force. Such tools open automatically once the required pressure has been reached.

Universal crimping pliers without manufacturer approval should not be used. Photovoltaic connectors require particularly high safety standards.

Combining different connector types risks serious damage to the solar installation.

Crimping the connections on plugs and modules is critical for the quality of the system.

photo: EMC-direct

Only bare conductor inside the sleeve

Before crimping, the cable insulation must be removed to the correct length. Depending on the connector type, this is typically between seven and ten millimetres.

During this step, installers must ensure that no individual strands are damaged or cut. Slightly twisting the exposed strands helps reveal potential damage. If stripping is incorrect, the cable end should be cut off and stripped again. Damaged conductors increase electrical resistance and may cause overheating or fire.

Control and execution of the crimp

The conductor must be inserted centrally and fully into the crimp sleeve. Only the bare conductor may be crimped – never the insulation.

During crimping the connector must be guided straight into the tool and the pliers pressed completely until they open automatically. A poorly positioned or angled crimp can lead to excessive heating and ultimately to contact failure or arcing.

Quality inspection

A properly executed crimp connection can be recognised by several characteristics. All strands must be evenly compressed, the crimp must be symmetrical and the surface smooth and shiny, indicating sufficient compression pressure.

There should be no loose wires or insulation residues within the crimp area. The contact area must also be clean and free from contamination or material defects.

A poorly crimped connector may appear harmless at first glance. In practice it can cause power losses, increased fire risk or failure of parts of the installation. Installers should therefore invest in certified tools, qualified personnel and high-quality components.

Tools for stripping and crimping

The operational reliability of a photovoltaic system depends heavily on the quality of electrical connections. What appears straightforward is often underestimated in practice.

Before connectors are crimped, the solar cables must be stripped. This can be done using manual or automatic stripping tools. Manual stripping pliers have the advantage that their blades are precisely matched to specific conductor cross-sections, allowing consistently high-quality results. Automatic stripping tools adjust to different conductor sizes and can therefore speed up installation.

Testing tools before use

Before selecting a tool, installers should test its handling and function. The range of reliable automatic stripping tools remains relatively limited, which is why many professionals rely on proven brand-name products.

EMC-DIRECT

Free white paper available for download

To raise awareness of high-quality standards in the installation and electrical integration of photovoltaic systems, specialist authors working with EMC-direct have prepared the white paper "Understanding – and avoiding – common causes of damage in photovoltaic systems". It is available for free download here:

▶ ***https://www.emc-direct.de/en/the-company/whitepaper/***

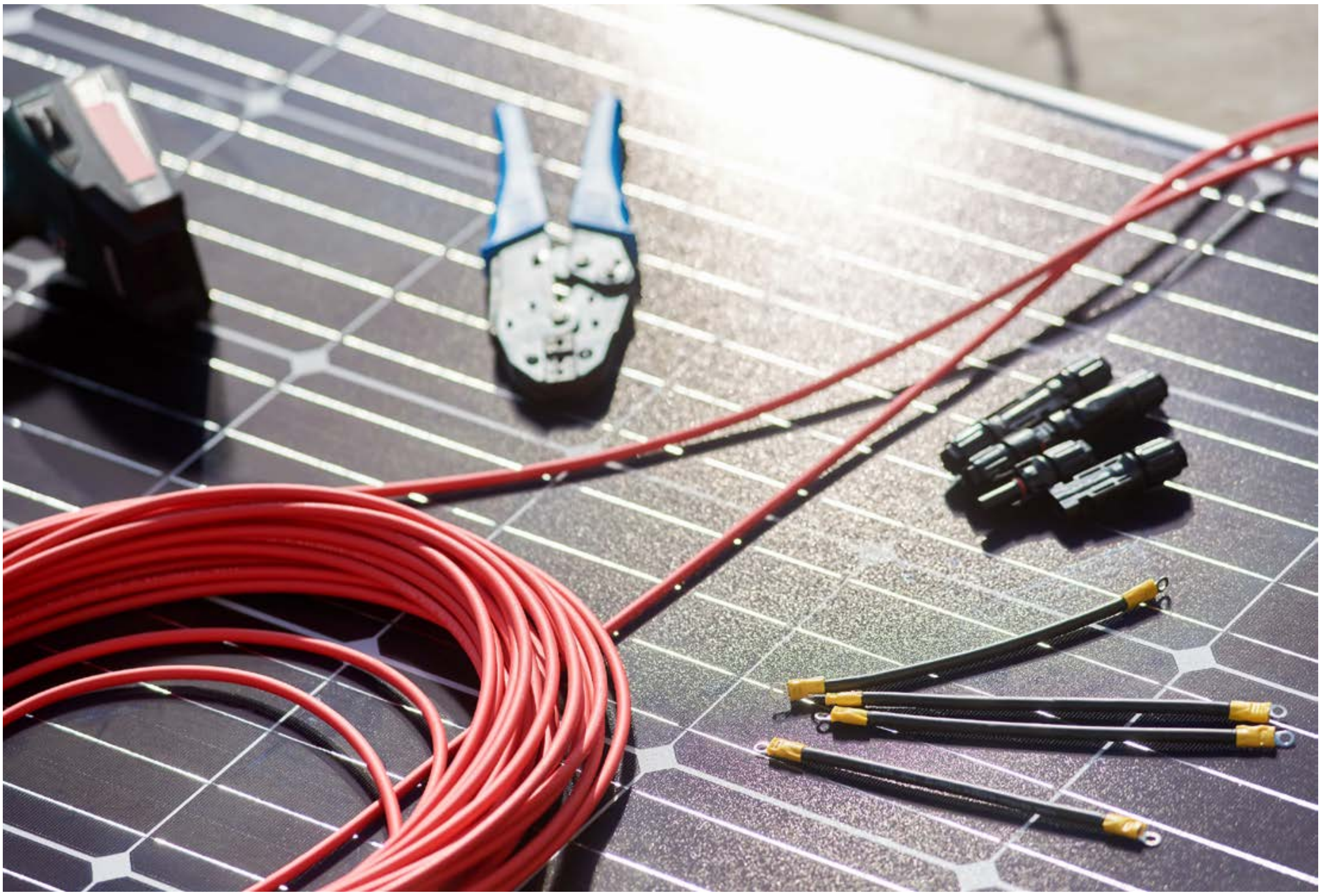


photo: Getty Images

Close-up view of different details and instruments for mounting and connecting solar photovoltaic system. Objects laying on blue solar panel. Alternative energy resources renewable ecologycal concept.

photo: EMC-direct

Pipes for solar cables made of black material are not necessarily suitable.

For crimping tools the selection is considerably larger. Differences in quality are not always obvious. The key component is the crimp die – the element that compresses the connector and forms the electrical connection.

Typical weaknesses

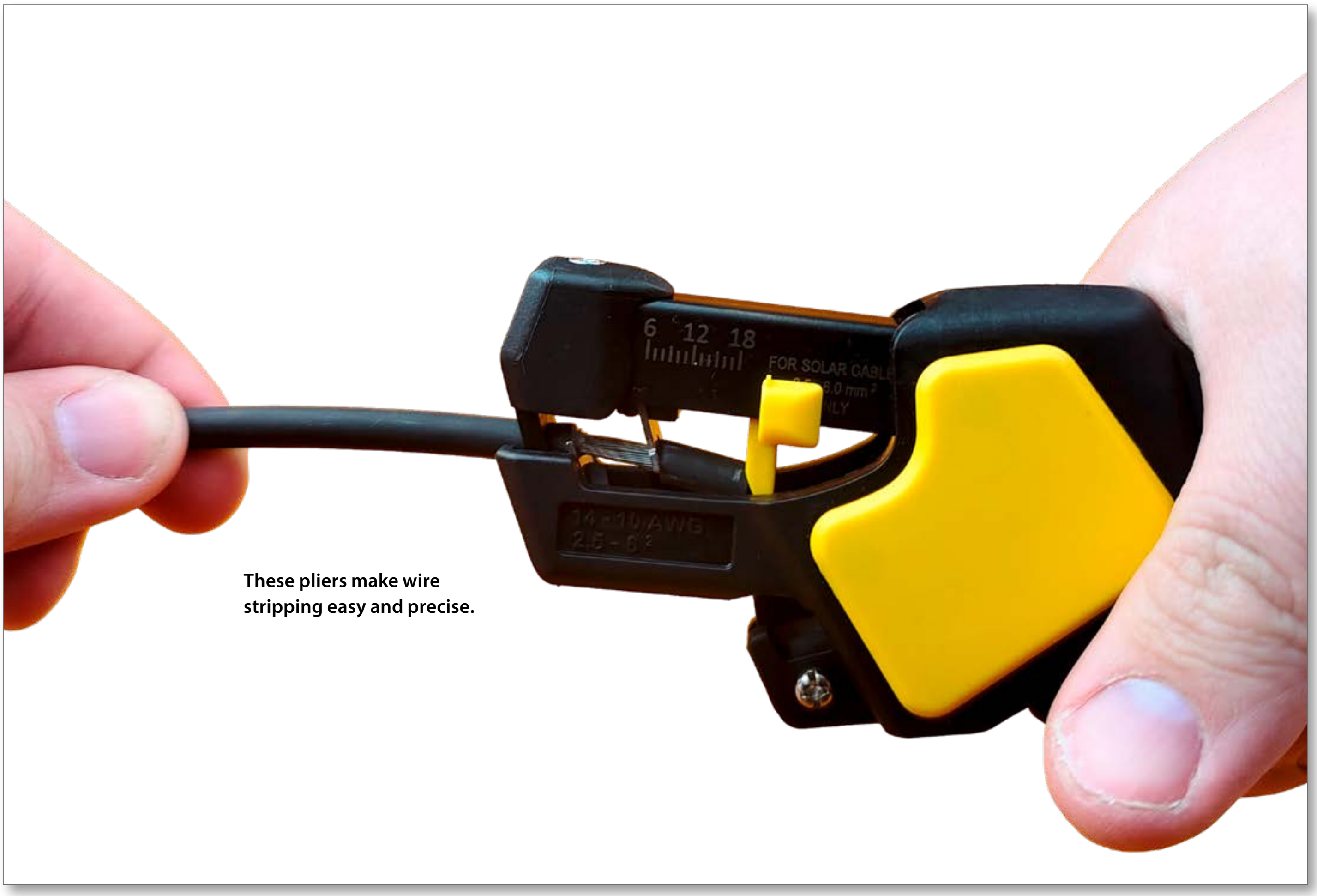
Ergonomics, handling and durability are often weak points in inexpensive crimping tools. Low-quality tools are frequently recognised by loose construction, weak springs and very low weight.

Poor tool quality can result in unreliable crimp connections and ultimately affect system reliability and economic performance. High-quality tools, by contrast, are robust and precisely manufactured, allowing consistent results.

The "rattle test"

Simple tests can help assess tool quality. One quick indicator is the so-called rattle test. High-quality tools show minimal play between components and produce no rattling noises when moved.

Another check concerns the ratchet mechanism. If the ratchet produces a cheap plastic



These pliers make wire stripping easy and precise.

photo: EMC-direct

sound, this may indicate thin materials and poor workmanship. Ergonomic handles without visible mould seams also suggest careful manufacturing and attention to user comfort.

Inspecting the crimp die

One of the most important indicators of tool quality is the crimp die itself. It should be precisely manufactured and polished at the contact surfaces.

Polished dies allow the connector material to deform evenly during compression. This prevents metal residues from sticking and ensures uniform shaping of the contact.

The result is a smooth, evenly rounded connection with a uniform shine. Irregular or dull surfaces may indicate inferior dies and insufficient compression quality.

Common crimping errors

Using unsuitable tools often leads to faulty crimp connections. The consequences can be serious: electrical resistance increases, the connection heats up under load and in extreme cases burning may occur.

Studies from the Solar Bankability project by Trust-PV show that incorrect installation and cabling are among the most common causes of faults in photovoltaic systems. Such problems can significantly reduce system performance and economic viability.

Awareness of quality during installation therefore pays off for installers and system operators alike.

Avoiding mixed connectors

Solar modules are usually delivered with one half of a connector pair already attached to the cable. During project planning it is therefore essential to ensure that connectors and sockets originate from the same manufacturer.

Combining connectors from different manufacturers – known as cross-mating – can lead to cracks, leakage and increased contact resistance inside the connector. In severe cases this may result in overheating, melting or fire. The damage is not always immediately visible. Failures may appear later during operation and lead to reduced output, string outages or shutdown of parts of the system.

IEC 62548 therefore specifies that connectors and sockets connected within a photovoltaic system must be of the same type and manufacturer. The updated module safety standard IEC 61730-1 also requires the connector type installed on the module to be indicated on the module label.

The product standard for PV connectors is IEC 62852. If connectors from different manufacturers are combined, the product certification no longer applies. Although some products are advertised as "MC4 compatible", MC4 is a protected trademark of Stäubli rather than a general industry standard.

Cable ties and environmental exposure

The selection of cable ties and protective conduits also influences the long-term reliability of photovoltaic installations. Environmental factors such as UV radiation, temperature fluctuations, humidity and salt exposure must be considered.

Standard black cable ties generally provide only around three years of UV resistance and are therefore unsuitable for photovoltaic installations.

Corrosion at the material contact between steel and aluminum.

For installations in Central Europe and Mediterranean regions, cable ties made from UV-stabilised polyamide 6.6 are recommended and can achieve service lives of around ten years.

In more demanding environments such as alpine or subtropical regions, cable ties made from polyamide 11 or stainless steel can last more than forty years. Installers should therefore always consult manufacturer data sheets and verify the stated UV resistance.

Preventing contact corrosion

When mounting clips or fastening elements on aluminium module frames, protection against contact corrosion must also be considered. Corrosion occurs when different metals are electrically connected in the presence of moisture.

For example, steel clips attached to aluminium frames may cause corrosion of the aluminium over time. Sharp edges can form and eventually damage cable insulation.

High-quality clips often feature protective coatings that prevent direct metal contact. Zinc-aluminium coatings are commonly used to reduce corrosion risk.

Cable protection conduits

Cable protection conduits are another factor influencing installation quality. When selecting conduits, installers should consider UV resistance, fire protection, mechanical strength and

water resistance. For above-ground installation, UV-resistant corrugated conduits made from polypropylene are widely used.
They are lightweight, flexible and can remain UV stable for up to twenty years. For underground cable routing in solar parks, rigid or flexible HDPE conduits are generally preferred.

UV stability of plastics

Colour alone does not guarantee UV resistance. The black colour of many conduits results from carbon black pigments, but only specific formulations provide effective protection against ultraviolet radiation.

If unsuitable conduits are installed on roofs or exposed mounting structures, they may become brittle within a short time. Cracks often appear first at bends or connection points. UV radiation gradually breaks down polymer structures, causing plastics to fade, harden and eventually fracture.

Correct cable sizing

Correct cable sizing is essential for efficient and safe system operation. If the conductor cross-section is too small, electrical resistance increases and cables may overheat during operation.

Solar cables carry direct current from modules to inverters, battery systems or grid connections. Along the cable length a voltage drop occurs, increasing with cable length and current.

To minimise these losses, the cable cross-section must be matched to the operating conditions. In practice cross-sections of four or six square millimetres are commonly used.

Durability lies in the details

Environmental influences affect every component of a photovoltaic installation. Sunlight, moisture, temperature fluctuations and chemical exposure act continuously over decades.

While planning often focuses on modules and inverters, fastening elements and cable management components frequently determine long-term reliability. In corrosive environments such as coastal regions, industrial sites or agricultural facilities, conventional plastics and galvanised metals may quickly reach their limits.

Improved resistance

Materials such as polyamide 12 and high-grade stainless steel provide significantly improved resistance to chemical and environmental influences. Careful selection of installation components therefore plays a decisive role in ensuring the long-term reliability and economic performance of photovoltaic systems.

Conclusion: The importance of so-called C-parts cannot be overstated. In large solar parks, they are installed hundreds of thousands or even millions of times.

If they fail, a problem arises that can escalate into a disaster over time. Therefore, careful and forward-thinking selection of components is essential. Otherwise, incalculable risks to the investment will follow.

THE AUTHORS

Thaddäus Nagy


photo: J. Gemke/EMC-direct

Managing director of EMC-direct. In recent years, Nagy and his team have supported the construction of several dozen ground-mounted solar plants across Europe. The products of the specialised supplier of cable protection and fastening technology, based in Dorsten near Gelsenkirchen, are used in large solar projects, including installations in Austria and Denmark.

Frank Mazur


photo: EMC-direct

Head of sales at EMC-direct and expert in cable management and cable protection for photovoltaic systems.

Arnd Diedrichs


photo: J. Gemke/EMC-direct

Head of product management and procurement at EMC-direct and specialist in the development and design of installation tools.

Jurij Gerdes

Field sales engineer for renewable energy at Stäubli Electrical Connectors.

SOLARGIK

Digital tool for solar park management

Solargik, a provider of agri-PV systems and all-terrain tracking solutions, has developed a new approach to operating solar parks. Its new tool, Sunnie, is an assistant platform that uses artificial intelligence (AI) to generate recommendations for operations managers based on live plant data.

This marks a step beyond conventional management systems, which typically rely on dashboards to display data at varying levels of detail. In previous systems, operators had to analyse the information themselves and determine the necessary responses.

This task is now handled by Sunnie's AI. According to Solargik CEO Gil Kroyzer, "With Sunnie, we've bridged the gap between data and decision-making. Sunnie does exactly that: it turns complexity into clarity, enabling operators to react in real time to real-world conditions."

To generate its recommendations, Sunnie draws on Solargik's SCADA platform, SOMA Pro. The platform records operating values from inverters, trackers and battery storage, along with sensor readings. These are combined with large language models (LLMs), enabling Sunnie to adapt continually to new inputs and site conditions.

▶ *https://www.solargik.com/*

SOLAREDGE

Mobile app for operations for residential and C&I solar installers

SolarEdge has launched SolarEdge Go, a mobile app that integrates essential tools for solar installers into a single platform. The app aims to streamline installation, commissioning, management, and servicing processes while introducing advanced remote management capabilities. By consolidating the functionalities of SolarEdge's existing SetApp and Mapper applications, SolarEdge Go reduces the need for on-site visits and enhances operational efficiency for installers.

The app offers advanced features for fleet and site management, including a real-time interactive map, access to inverter settings, and remote diagnostics such as error logs and configuration adjustments. Installers can easily manage multiple sites, monitor system uptime, and address alerts promptly to optimise performance. Site registration, equipment pairing, and permission adjustments for remote access are also simplified, enabling greater efficiency and flexibility.

SolarEdge Go supports seamless site installation and commissioning with features like rapid Power Optimizer pairing, grid setting adjustments, and post-commissioning upgrades.

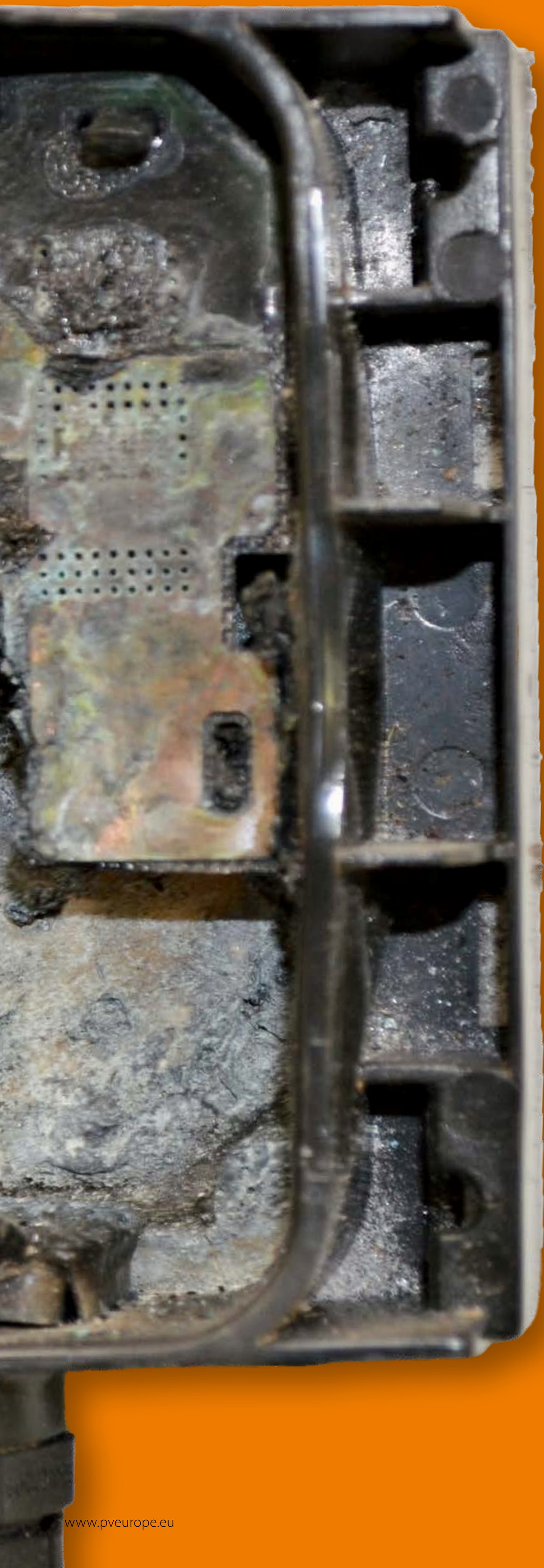
▶ *https://www.solaredge.com/en*

Burnt-out junction boxes are often due to manufacturing defects. Faulty wiring is frequently the cause.

Misbehaving modules – spotting faults, taking action

Troubleshooting ■ Numerous types of defects can compromise a solar panel's performance. Service professionals should be familiar with the most common faults, some of which are safety-relevant. A concise overview is available on the Secondsol blog.

by Sven Ullrich



Anyone experienced in maintaining a solar installation will recognise the scenario: the yield data for a string suddenly drops, a module shows unusual discolouration or a routine inspection reveals a deformed junction box.

Not every finding signals immediate danger, but some defects develop gradually over years and eventually cost money or, worse, compromise safety. For solar and roofing professionals, it is essential to spot typical module faults reliably, assess their relevance and know when repair is worthwhile or when replacement is the better option. An overview of common issues is available on the Secondsol blog below.

Finding faults

The tools for uncovering defects are diverse. Even a simple visual inspection often reveals obvious irregularities, yet many faults remain invisible until closely examined. Thermography, for example, makes temperature differences on the module surface visible. It reveals hotspots, defective bypass diodes and high-resistance connections.

Electroluminescence (EL) looks deep inside the module, down to the cell level. By energising the module, its cells emit light in the near-infrared range, enabling special cameras to expose low-level defects.

In EL images, intact cell areas appear bright while defective or inactive zones stay dark. This method reveals microcracks, interrupted solder joints and the characteristic patterns of potential-induced degradation. Curve measurements and monitoring data analysis also highlight performance deviations that may indicate module faults. Another diagnostic approach uses a laser to generate pulsed signals that installers can convert to audible feedback at the string end.

Potential-induced degradation

Potential-induced degradation (PID) is one of the more hard-to-detect fault types because it starts unseen and progresses slowly. It is common in systems with transformerless inverters, where the lack of galvanic isolation can allow a high potential to build up between the cells and earth.

SOLARPOWER EUROPE

Guidance on hybrid PV and EPC quality

Robust and transparent due diligence processes, so-called "health checks", conducted by technical advisers or independent engineers are essential to maintaining the integrity, financial viability, sustainability and long-term reliability of hybrid systems.

For the first time, SolarPower Europe's new Technical Due Diligence Guidelines provide stakeholders with a comprehensive framework for assessing the feasibility, bankability and performance of hybrid solar PV and battery storage projects throughout their lifecycle.

The latest revision of SolarPower Europe's Engineering, Procurement & Construction report sets out industry-aligned best practices, expanded chapters on risk management and health and safety, and additional guidance for delivering professional EPC services for hybrid solar PV and battery storage projects, from engineering and delivery to commissioning.

The third EPC edition further strengthens guidance on electrical safety, skills requirements, responsible procurement, audits and traceability, including environmental, social and governance (ESG) considerations, construction readiness and quality checkpoints.

▶ *https://www.solarpowereurope.org/*

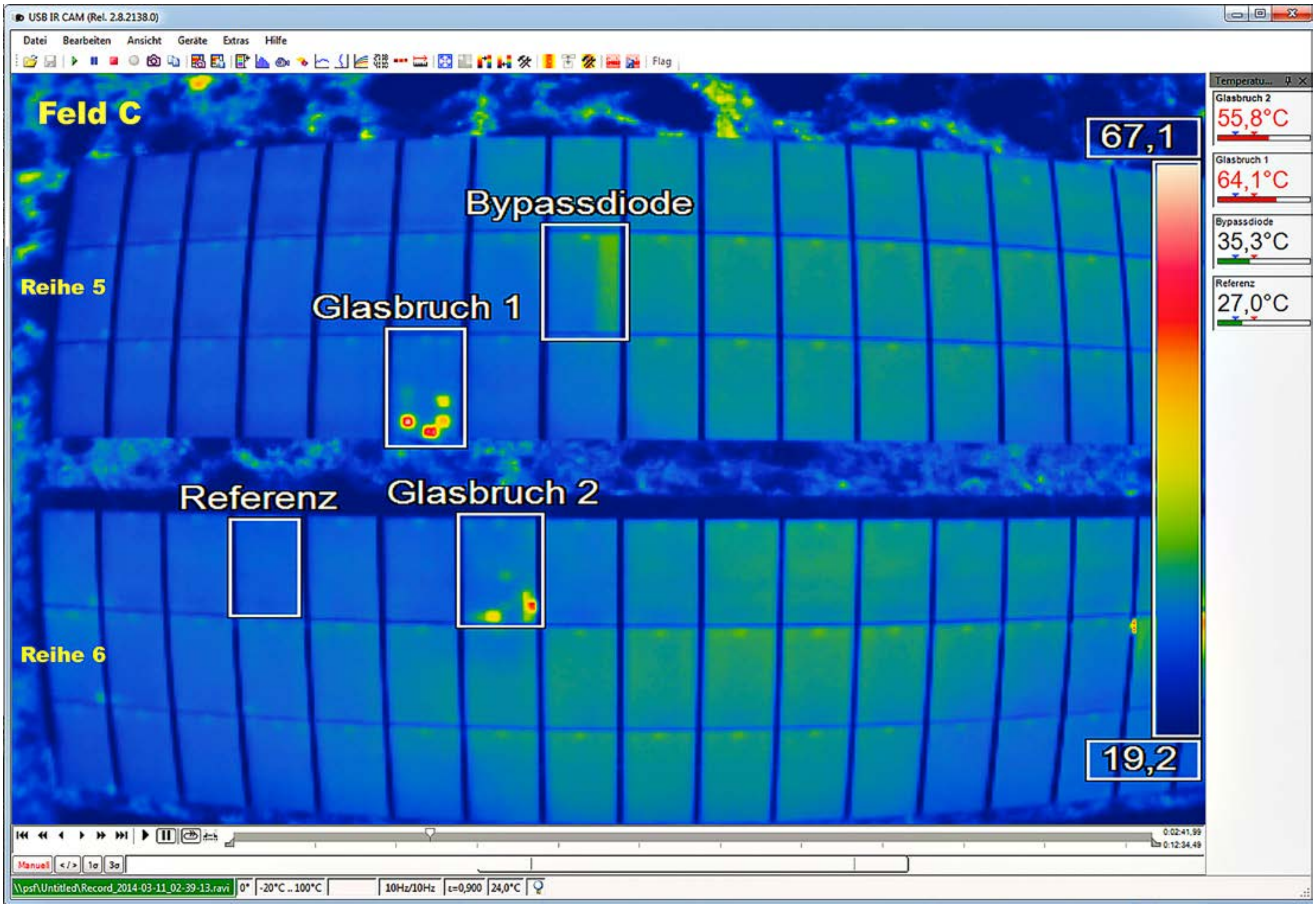


photo: Flying Eyes Germany

Thermography reveals different temperatures on the cell surface. This allows conclusions about defects.

Sodium ions migrate from the module glass through the silicon nitride layer into the cell, creating conductive pathways that lead to local short circuits. High humidity, heat, contaminants and diffuse light can accelerate the effect.

PID first shows up in monitoring data when individual strings gradually underperform neighbouring strings, despite shading and soiling having been ruled out. A visual inspection often shows nothing, but EL imaging reveals the typical pattern: darkened cells spreading from the negative terminal and module edges toward the positive terminal. Yield losses can be significant.

The good news for operators is that PID is reversible. Special PID boxes apply a high positive voltage to the modules at night, driving sodium ions back into the glass. In practice, recovery often becomes visible within weeks. Manufacturers increasingly use PID-resistant materials to minimise the risk, but it cannot be eliminated entirely.

Light-induced degradation

Light-induced degradation (LID) begins in the first hours of operation on monocrystalline modules. It is not damage in the conventional sense but a material effect: boron-oxygen complexes form in the silicon lattice and trap charge carriers, which are then lost to power production.

LID presents as a one-off drop in performance shortly after commissioning. Cells may appear darker, and EL imaging typically shows a chequerboard pattern. It does not progress further, and for most installations it poses no critical issue.

Modules using gallium-doped or n-type silicon are largely immune. Manufacturers account for expected LID in rated output figures, and it is generally neither a safety risk nor a maintenance concern.

Dangerous Hotspots

Hotspots occur when certain cells become overheated due to shading, soiling or defects, forcing current through inactive cells that then generate heat as an ohmic resistor. Thermography makes hotspots immediately apparent.

Hotspots are safety-relevant because they can damage materials or even trigger fires. Bypass diodes help by redirecting current around the affected string, though this reduces yield.

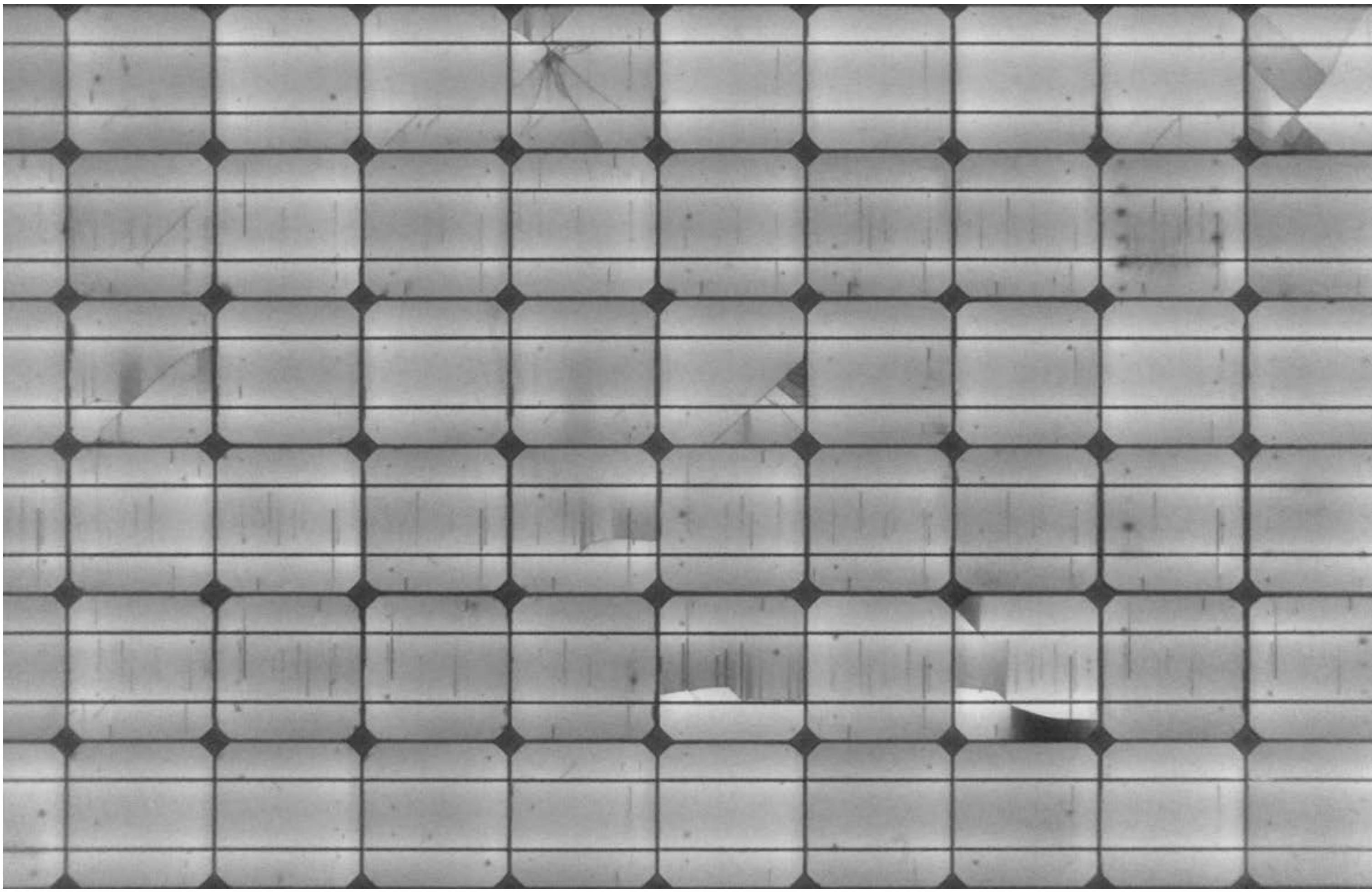
Regular cleaning and careful planning to avoid shading reduce hotspot risk. Module replacement is advisable only when material defects are the underlying cause.

Defective solder connections

In crystalline modules, cells are joined by tinned copper interconnects. Breaks in these connections are usually invisible to the naked eye. EL imaging reveals darkened cell areas; thermography localises overheated spots.

Manufacturing flaws, mechanical or thermal stress and corrosion are common causes. Corrosion, often due to moisture ingress, is visible as characteristic discolouration. Faulty solder joints raise resistance, cut yield and may themselves become hotspots. In extreme cases, they lead to arcing and fire risk, and repair is usually impractical.

photo: Aerial PV Inspection



Electroluminescence allows us to see deep into the module: Cell cracks are clearly visible. Dark areas no longer generate electricity.

Cracks in the backsheet

The backsheet protects cells from environmental stress. Cracks, breaks or deep scratches are serious and often visible in ground-mounted or steep roof installations, though they may only emerge on thermography in flat arrays.

Such damage can enable moisture to enter the module, leading to corrosion and insulation faults with potential touch voltage hazards. Repair offers only limited long-term reliability, and module replacement is usually safest.

Discolouration, brwoning and other film effects

Backsheet staining with yellowish or brownish patches often indicates overheated cells or inferior materials. Thermography helps reveal related faults. On the front, discolouration of the EVA encapsulant appears as darker zones and is caused by ageing of the polymer under UV, heat and oxygen.

Smaller areas of discolouration may be primarily cosmetic, but pronounced effects can accelerate degradation and reduce yield. Repair is not possible; significant performance loss typically warrants module replacement.

A particular form of EVA discolouration known as 'snail trails' appears as meandering lines under the front glass and signals microcracks. These often develop gradually and are not immediately safety-relevant, but they should be monitored. EL imaging helps determine whether replacement is justified.

NUISANCE BIRDS

Preventive measures for solar installations

The birds and other animals that take shelter under solar panels can quickly lead to noise, mess and serious system damage. How can this challenge be addressed without creating new issues elsewhere? Our expert Michael Mattstedt explains in part two on our feathered fiends.

Pigeons are not just an urban issue. "There are few unaffected locations in urban installations," says Mattstedt. "For these large birds, photovoltaic systems must seem too good to be true. The protection they offer makes them ideal nesting sites."

Mattstedt recommends comprehensive preventive measures at every installation. But there's a caveat: "If we secure one roof, we simply shift the problem to the next. We're making the animals homeless, but they'll find somewhere else to breed."

His suggestion: managed pigeon lofts with food, water, and expert oversight. This is all the more relevant given the risks of bird flu. In these safe spaces, the pigeons can breed without causing damage. Read the full report here:

▶ ***https://www.pveurope.eu/maintenance/nuisance-birds-preventive-measures-solar-installations***

photo: Velka Botička

PID can be cured with special devices.

Microcracks and cell breakage

Microcracks are widespread yet invisible without EL imaging; thermography may also reveal them through cooler areas. They arise from production, transport, installation or external impacts such as hail.

The crack pattern frequently reveals how the damage occurred. As long as electrical contact remains, yield may not suffer much, but if areas become electrically isolated, performance drops and hotspots can form. Modules with such cracks require continued monitoring.

Delamination

Cloudy, milky areas under the front glass indicate delamination: a loss of adhesion between glass, encapsulant and cells due to UV, heat and moisture. Yield declines as reflective losses increase, and moisture penetration may lead to insulation faults.

If the rear encapsulant loosens, the junction box can detach, increasing the likelihood of arc faults. Small delamination areas should be watched; expanding discolouration can become safety-relevant.

Broken glass

Cracks and fractures in module glass are usually visible but can be overlooked near clamps and frame transitions. Causes include installation errors, overloads from snow, wind or hail, and rough handling.

Broken glass is always safety-relevant: moisture entry, reduced insulation and yield loss are typical outcomes. Replacement is required; careful transport and correct mounting help prevent this damage.

Defective bypass diodes

Bypass diodes protect cell strings by routing current around shaded or defective sections. Faulty diodes may only show up in current-voltage measurements or thermography when sections warm noticeably. Under shading, hotspot and fire risks rise. Causes often include high-voltage damage from lightning with inadequate protection. In some cases diodes can be replaced, but full module replacement is often the more economical and safer option.

Defective junction boxes

The junction box, where electrical connections, diodes and external cables meet, is a common failure point. Loose, open or deformed boxes often show up in visual inspections; thermography reveals overheated regions.

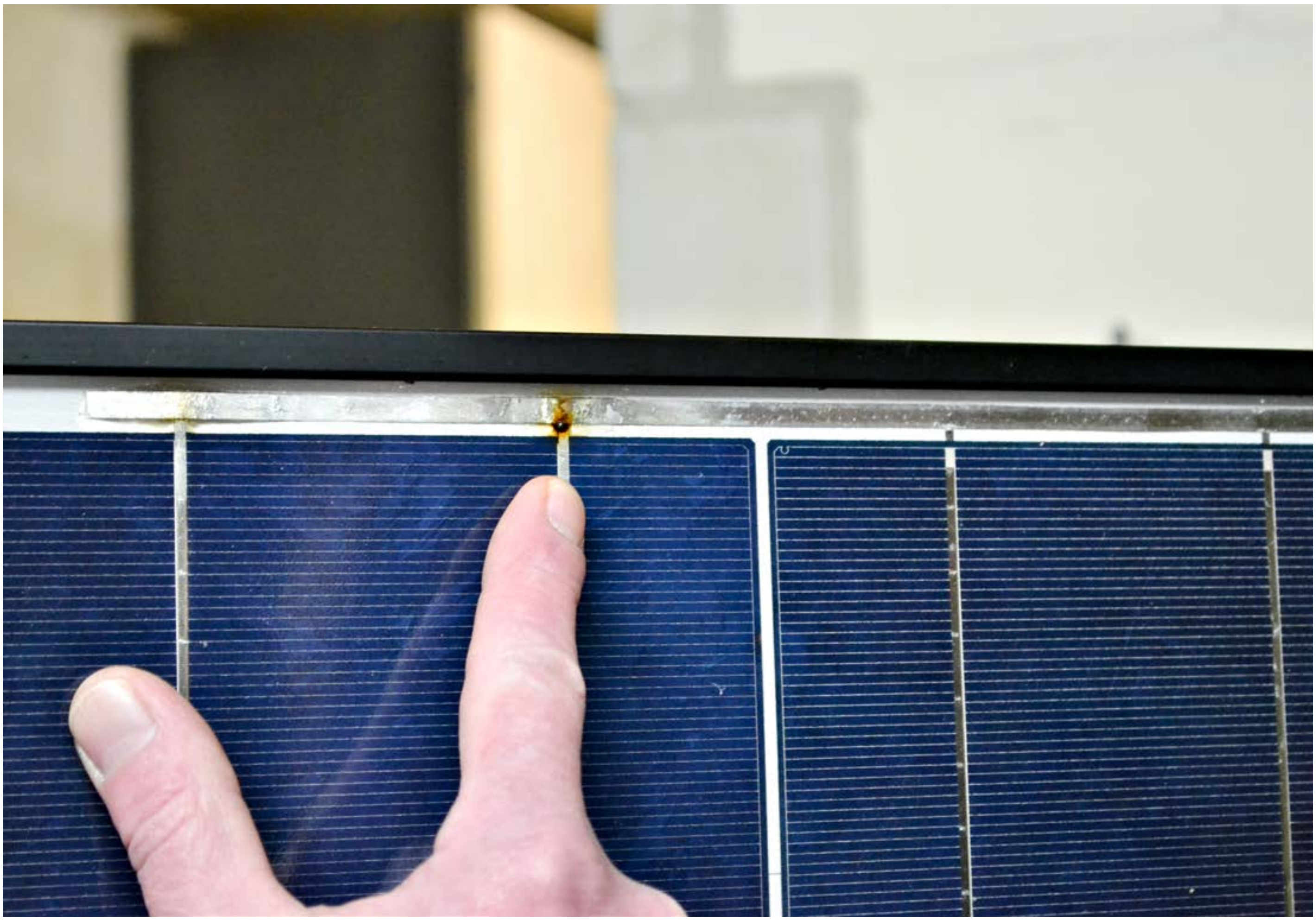
Causes range from manufacturing defects to moisture ingress and poor wiring. Consequences include yield loss, corrosion and arc risk. Regular visual and thermographic inspection can prevent serious follow-on damage; repair or replacement of the module is usually the safest course.

Matching replacements

Where replacement becomes necessary, the module should match the electrical parameters of the string and system, with visual consistency an added benefit. This overview provides a first insight into both visible and hidden defects that can affect solar modules. Further examples are published on the photovoltaik website and on the Secondsol blog, where inspected replacement modules are available via an online marketplace.

▶ *https://blog.secondsol.com/en/*

photo: Velka Botička



Corroded solder joints are an indication that moisture is penetrating the module.

photo: Velka Botička

Glass breakage due to hail: This module should be replaced.

Boosting older PV plants by up to 35 percent

Revamping ■ Replacing ageing modules in existing solar plants can significantly increase output while preserving legacy feed-in tariffs. A project in Germany illustrates both the potential and the technical challenges involved.

by Heiko Schwarzburger

photo: PV3

The project was preceded by a thorough assessment of the existing installation.

photo: PV3

The modules were lifted onto the roof using cranes.

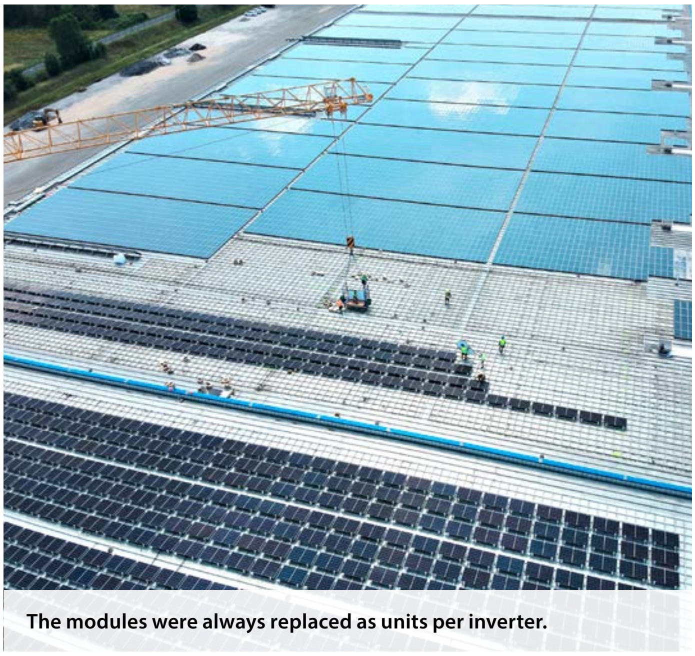


photo: PV3

The modules were always replaced as units per inverter.

Philippsburg is widely known in Germany as the former site of a nuclear power station that was long the focus of anti-nuclear protests. In late autumn 2025 its cooling towers were demolished and dismantling of the plant began.

Less well known is that Philippsburg is also home to what was once Germany's largest rooftop photovoltaic system. Built in 2010 on the roof of Goodyear Dunlop's European logistics centre, the installation delivers 7.4 MW of solar capacity. Rather than being dismantled, the plant has now been revamped.

Sixteen years ago, around 96,000 thin-film modules were installed on the 113,000-square-metre logistics hall roof. Over the years, the output of the thin-film modules declined significantly. Today, they have been replaced by around 16,000 high-efficiency silicon modules mounted at a ten-degree tilt facing south. The original modules had been installed parallel to the roof.

Despite the unchanged nominal capacity, the refurbished system now produces up to 35 percent more electricity. "When we built Germany's largest rooftop installation in 2010, the aim was to advance renewable energy," says Stephanie Lindner, Managing Director of PV Julist, which owns and operates the plant. "After more than a decade of operation, it was time to give the installation a technical upgrade and show what modernisation of existing PV assets can achieve."

What revamping means

Revamping refers to the technical modernisation of a photovoltaic installation without rebuilding the entire system. Ageing or defective components are replaced in order to increase yield, improve operational reliability and bring installations into line with current technical and regulatory requirements.

A key economic advantage is that many existing components can remain in service. Plants that still benefit from older, comparatively attractive feed-in tariffs under Germany's Renewable Energy Sources Act can retain those tarphoto: PV3

Halfway there: Some of the new modules are already installed.

iffs during revamping, provided the nominal capacity of the system does not increase. The result can be higher electricity generation, continued use of existing infrastructure and relatively short payback periods for the investment.

Partnership as a success factor

When the engineering firm PV3 was commissioned with the revamping project in Philippsburg at the end of 2024, it soon became apparent that the project would require close co-operation between several specialised partners.

PV3 took responsibility for overall project management. The original mounting system had been supplied by Schletter Group, which was again tasked with developing a structural concept for the conversion. The installation work itself, including dismantling and reinstalling modules, was carried out by GME Clean Power.

photo: PV3

The new modules are mounted at a ten-degree angle and face south.

Managing the economic challenge

Operators know that summer months typically generate the highest yields, and that ideally, construction work would avoid this period. In Philippsburg, however, the conversion had to take place during the peak production season. To minimise production losses, the ten inverters of the system were upgraded sequentially. The project team replaced all modules connected to one inverter before beginning work on the next.

At no point were more than two inverters disconnected from the grid simultaneously, limiting the loss of generation during the retrofit.

Upcycling rather than rebuilding

At the start of the project, existing components were reviewed for reuse, while the thin-film modules were removed. By contrast, the AC-side infrastructure – including combiner boxes, inverters and communication systems – remained in good condition and only needed to be adapted to the new module strings. The original roof-parallel mounting structure supplied by Schletter was also analysed and approved for continued use. The company developed a concept for tilting the modules ten degrees towards the south and supplied the additional mounting elements required.

The existing Solo profiles were reused throughout the installation. Only module supports and bearings were replaced.

“For a project of this size, reusing the profiles saves considerable time and cost,” explains Manuel Schwarzmaier, project manager at Schletter Group. “It also improves sustainability because only a small portion of the mounting components had to be replaced.”

A sensitive roof structure

The retrofit work began once planning and structural assessments were completed. One factor required particular attention: the load-bearing structure of the logistics hall roof, which could not be subjected to concentrated point loads.

To address this, the installation team from GME Clean Power developed a lifting concept using suspended loads. Two large cranes with 80-metre booms operated simultaneously on either side of the roof, removing old modules while new ones were delivered and installed directly. The complete module exchange was finished within 13 weeks.

“Revamping is not a plug-and-play exercise but a complex process that requires detailed technical and economic analysis,” says Tobias Söhnchen, project manager at PV3. “Only careful planning ensures that a project is both technically feasible and economically viable.”

Quality control before commissioning

After the installation work was completed, the system underwent extensive quality checks. Such inspections are sometimes neglected in retrofit projects, which can lead to performance losses or technical faults later in operation.

In Philippsburg, infrared drone inspections and electroluminescence measurements were used to identify thermal anomalies, disconnected substrings and cell cracks.

Finally, light and dark current-voltage curve measurements provided detailed information on module performance and electrical resistance within the strings. After minor adjustments, the system was approved by an officially appointed independent expert.

Upgrading existing assets

The revamping project, carried out on behalf of PV Julist, was completed in November 2025. It illustrates that modernising existing installations can often deliver greater benefits than replacing them entirely.

By upgrading modules and retaining functioning infrastructure, operators can extend the life of older PV plants and significantly increase electricity production. In many cases, revamping offers a cost-effective way to modernise solar assets while preserving established revenue streams.

▶ ***https://www.pveurope.eu/investors/projects***

photo: PV3

Success! The huge roof has been newly equipped with solar panels.

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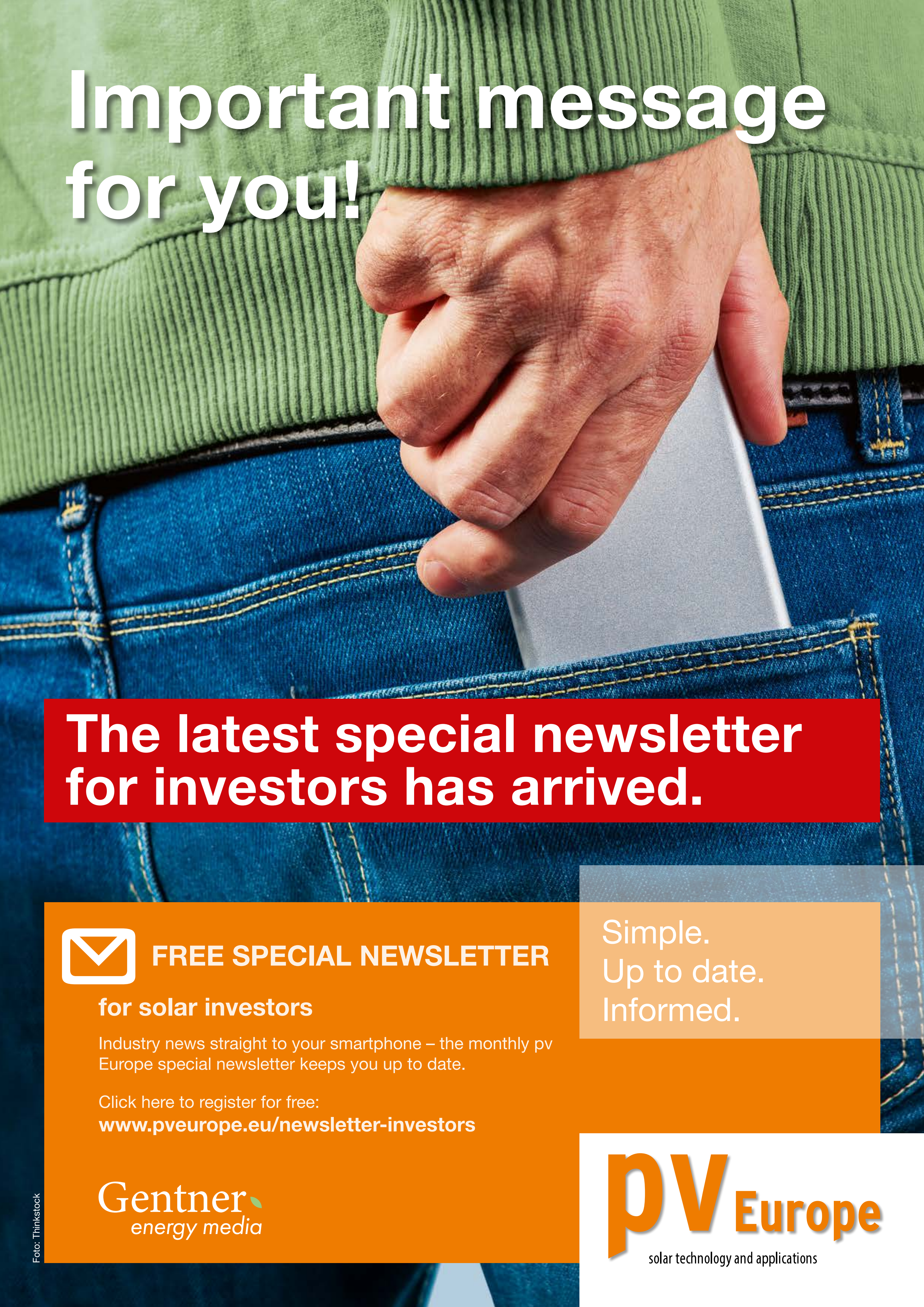
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