Power Plant Supply Chain Services

Mitigate sourcing risks.
With TÜV Rheinland.

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TÜVRheinland®
Precisely Right.

Power Plant Supply Chain Services

From supplier selection to final installation, PV power plant & BESS supply chain experts from TÜV Rheinland provide comprehensive support in completing successful and sustainable projects.

Every solar project is unique, and so is our service. To meet and exceed expectations, we adjust to your individual needs with market trends. Whether you are a developer, investor, EPC contractor, lender, owner or operator, our tailored services will ensure that you are comfortable with all sourcing decisions.

For over 40 years, TÜV Rheinland has provided solutions for the solar industry – testing, verifying, certifying, inspecting and auditing. At every step along the way, we have continued to learn, improve and refine our processes. We also apply solutions to BESS business, ensuring a deeper and more comprehensive protection of customer rights and interests.

With decades of experience in supply chain services for PV & BESS projects of different capacities, we are committed to aligning our services with a sustainable development framework. Our global network of laboratories is designed to address emerging challenges, accompanied by a team of specialists dedicated to supporting and advising our clients. This positions us uniquely to navigate the complexities and diverse interests within PV & BESS supply chains, empowering you to overcome any challenges your PV & BESS project may encounter.

OUR EXPERTISE. YOUR BENEFITS.

- Ensuring alignment with sustainable development goals by tailoring services to meet project-specific needs.
- Promoting transparency in the context of ESG principles by using objective information to determine final suppliers.
- Boosting confidence among investors, lenders, and insurers by demonstrating commitment to quality and sustainability.
- Upholding project quality standards and reducing the risk of faulty products on-site.
- Providing essential support precisely when and where needed by navigating the complexities of the PV industry with our world-class experts and local laboratories.

Comprehensive Service Portfolio Along the PV Power Plant Supply Chain.

For PV module, battery energy storage system, inverter, mounting structure, and other equipment.

Our audits and inspections of production lines identify potential weaknesses and risks, ensuring safe and qualified final products.

Moreover, we test PV modules and other components in our accredited laboratories for durability, verifying that BOS components (such as mounting structures and inverters) match specifications and perform as expected. This helps improve quality, performance and compatibility by reducing the risk of serious defects and critical safety issues.

The result of this systematic quality assurance is not only the development of a technically safe and efficient PV power plant, but also bankability: investors and lenders can feel confident that your project is accounting for and addressing inevitable risks.

	Development	Pre-production	Production	Post-production
TÜV Rheinland expert team	▪ Supplier quality evaluation and ranking ▪ Supplier supply chain traceability verification and ranking ▪ ESG capability assessment ▪ Technical advisory			
At factory	▪ Factory audits	▪ Capability assessment ▪ Pre-production inspection	▪ DuPro factory inspection ▪ Inline quality assurance	▪ Pre-shipment factory inspection ▪ Packing/loading inspection
In TÜV Rheinland's laboratory	▪ Module benchmarking	▪ Reliability tests ▪ Reference module creation	▪ Fast verification sample tests	▪ Final random sample tests
On construction site				▪ Pre-installation testing ▪ Post-shipment tests with mobile solar lab (only in Europe) ▪ Post-shipment inspection (quality control and conformity) ▪ On-site inspections (claim assessment, Failure analysis)

Development Stage

In today's diverse product market, TÜV Rheinland assists clients in accurately identifying the best supplier match through technical expertise before project initiation, ensuring the smooth success of your project.

Supplier Quality Evaluation and Ranking

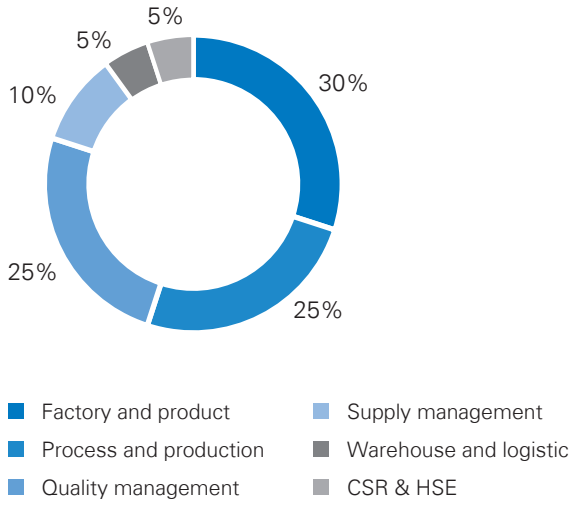
Based on extensive industry experience, we provide clients with the most comprehensive pre-supplier assessment services. For traditional quality and technical assessments, we have introduced 6 major assessment dimensions and over 20 assessment criteria. Additionally, tailored to different equipment and specific situations, this extends to over 200 detailed audit items.

6 indexes **20+** criteria **200+** sub-criteria

INDEX	CRITERIA
Factory and Product Qualification	▪ Factory capacity and management system certification (ISO 9001/14001/45001and system documents) ▪ Product certifications (Test reports and CDF)
Quality Management System	▪ Supplier evaluation ▪ Organizational structure and staff training ▪ Customer communication and complaint handling ▪ Procedure document and record control ▪ Output power control procedure ▪ Equipment calibration and management ▪ Plan and periodic verification for quality control testing ▪ Faulty product management ▪ Environmental conditions and premises management
Incoming Material Management	▪ Incoming warehouse management ▪ Incoming quality control
Production and Process Control	▪ Production process design, development and change management ▪ Critical process control requirements
Inline and Final Product Quality Tests	▪ Power measurement ▪ Electroluminescence test ▪ Insulation, withstand voltage and grounding continuity test ▪ In-house laboratory (optional)
Packaging, Storage and Shipping Management	▪ General requirements ▪ Packaging requirements ▪ Warehouse storage tidiness and EHS situation ▪ Handling and loading requirements ▪ Marking and traceability management

With our factory audit mechanism, a scoring system is ultimately established for clients' review. Under a standardized evaluation criterion, it allows for a clear and straightforward comparison of potential suppliers, facilitating the identification of top-quality suppliers.

Evaluation Weight



Evaluation Dimensions

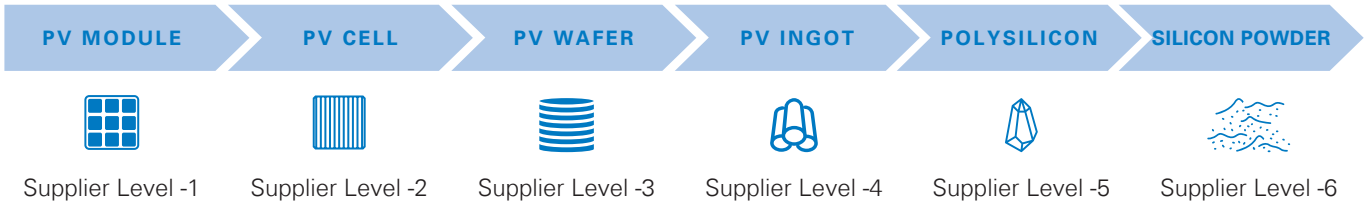
- **COMPLETENESS**
- **EFFECTIVENESS/CONSISTENCY**
- **ONSITE MANAGEMENT – RISK INDICATION**

EVALUATION RESULT	SCORE RANGE
Excellent (Category A)	90 ≤ Score
Moderate (Category B)	80 ≤ Score < 90
Need improvement (Category C)	75 ≤ Score < 80
Need improvement (Category D)	Score < 75

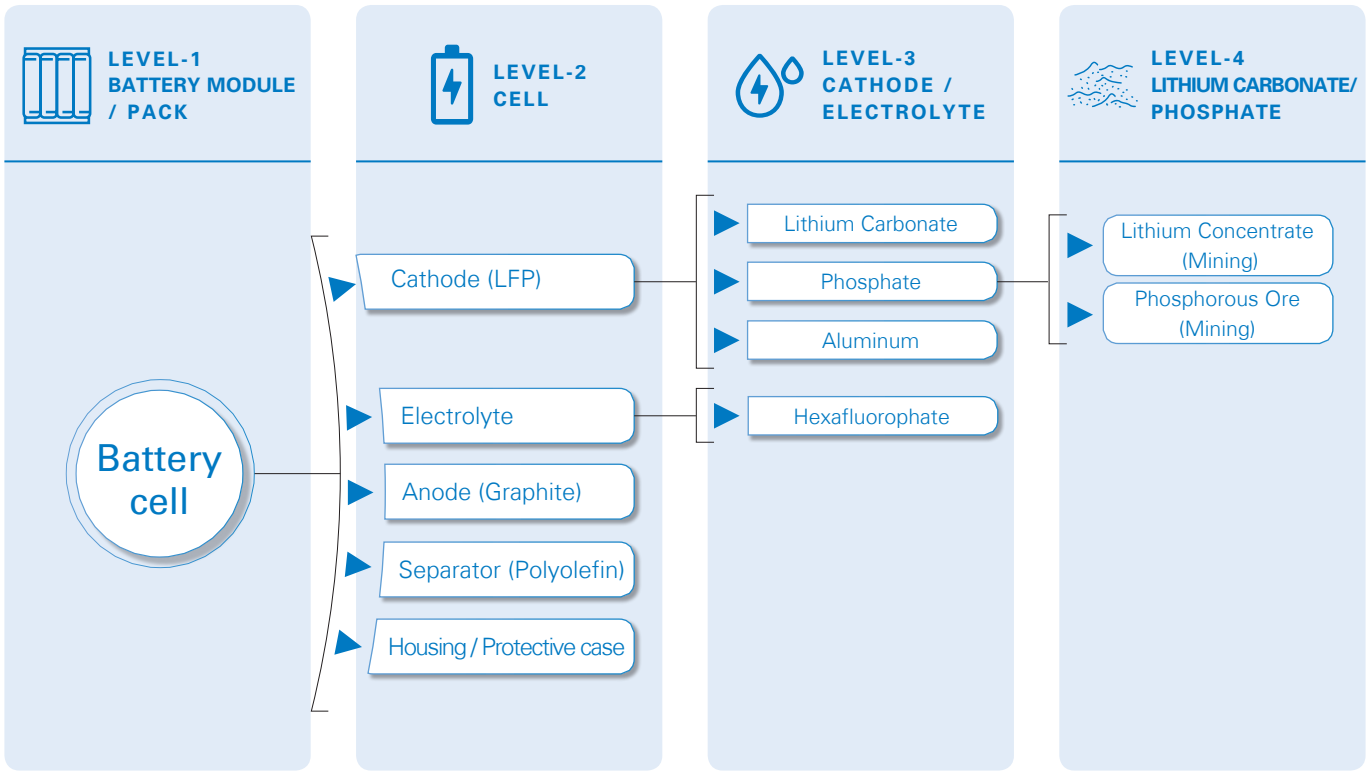
Supplier Supply Chain Traceability Verification and Ranking

In the escalating demand for sustainability in the market, the requirement for suppliers to trace their materials during production throughout the whole supply chain is becoming increasingly explicit. Leveraging various industry operational models and management systems, TÜV Rheinland have developed our own assessment criteria to assist clients in a clearer analysis of suppliers and their respective traceability capabilities.

PV Supply Chain



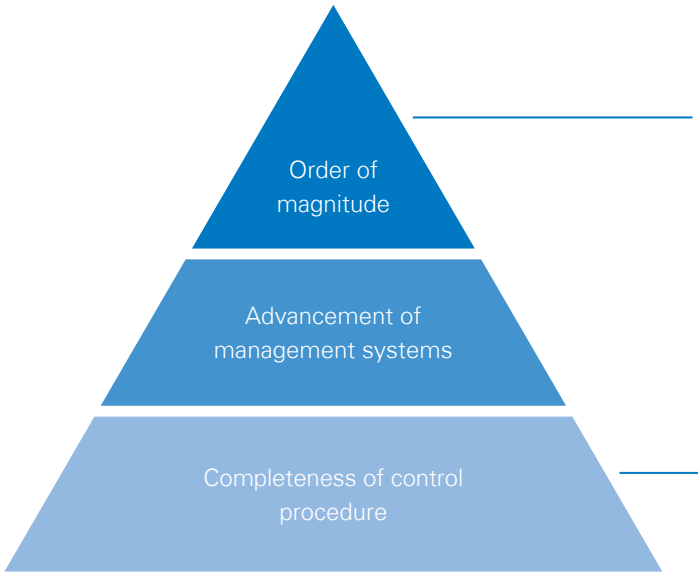
Energy Storage Supply Chain



Traceability Scoring and Rating System

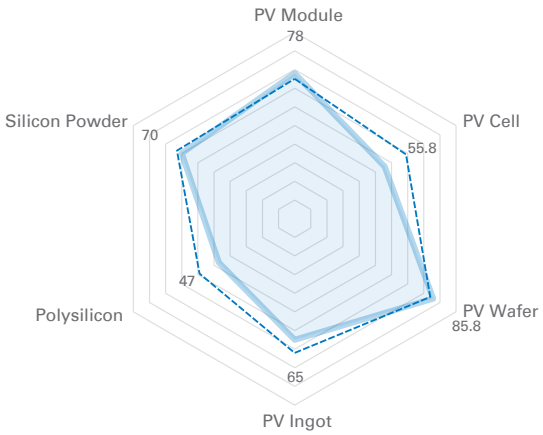
To meet customer demands and market conditions, TÜV Rheinland has established a comprehensive scoring system. Through scoring, ratings, and capability charts as different types of evaluation results, clients can understand and assess suppliers' traceability capabilities from different dimensions, helping them choose the most suitable supplier.

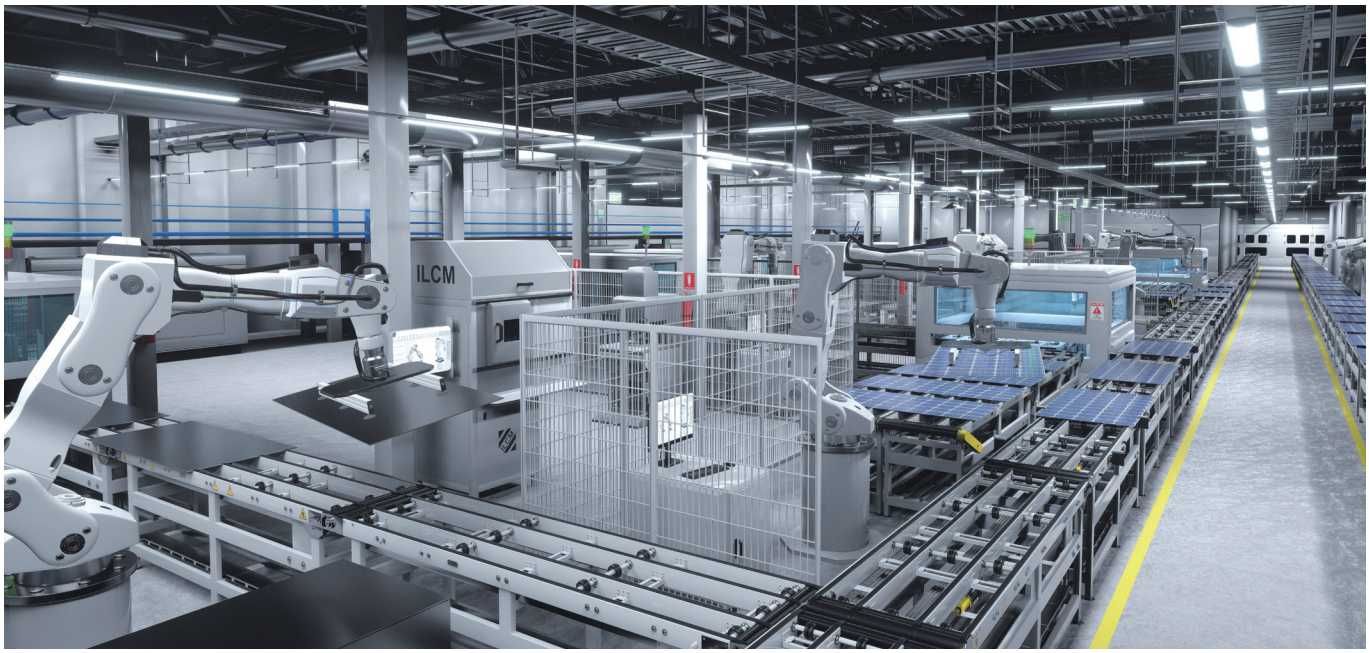
The reason TÜV Rheinland has a highly recognized rating platform is primarily based on the following logic: first, a supplier should have a well-established material management capability and process, which forms the foundation. Building upon this foundation, if the supplier possesses a management system, a digital platform, it will further enhance their managerial capabilities. As the traceability magnitude become increasingly refined, it demonstrates the excellent control capability the supplier has over materials.



RATING

AA	Outstanding	≥80 score
A	Common level	≥65 score
B	Need Improvement	≥55 score
C	Only meet basic requirements	< 55
F	Material information untraceable	0 score, critical item fails





ESG Capability Assessment

The concept of ESG has been gradually introduced into the industry and has attracted much attention from buyers and suppliers. TÜV Rheinland has interpreted and disassembled the complete ESG content in light of buyers' needs and the current development of the industry, and initially formulated and continuously improved the ESG audit contents to meet the needs of the industry.

01 Environmental Impact

02 Health and Safety

03 Labor Practices

04 Governance and Ethics

Question Answering

- Self-declaration as the main form
- Basic information is confirmed by QA form
- Rapid basic assessment
- Relatively simple report

Evidence Verification

- Detailed on-stie confirmation of disclosures
- The report contains evidence and records of verification
- Detailed assessment

On-site Investigation

- Inspect on-site to experience workstyle
- Close contact with factor's employees
- Gaining insights into the actual factory conditions through observing details

RATING

AA	Outstanding	Topics rating of 100 - 96%
A	Acceptable	Topics rating of 95 - 81%
B	Need Improvement	Topics rating of 80 - 60%
C	Unacceptable	Topics rating of 59 - 40%
CC	Critical	Topics rating of 39 - 0%

During Project Inspections

TÜV Rheinland is committed to providing comprehensive support for your project. Prior to the official commencement of production, we conduct a thorough **pre-production inspection** at the factory to ensure readiness and alignment with project requirements. Our team of professional supervisors **oversees the entire production process**, from material input to production and storage, ensuring comprehensive quality control coverage.

During the production phase, we implement necessary sampling inspections, with a particular focus on critical processes and sample testing of semi-finished/final products to ensure compliance with high standards. Upon completion of the finished product, we conduct meticulous quality **pre-shipment inspections** based on strict sampling ratios to ensure that the products fully meet customer expectations.

To safeguard the **logistics process**, we meticulously control the packing, packaging, logistics information, and packing process of samples, ensuring that everything is in order before shipping. Upon arrival at the destination, we promptly conduct **arrival inspections** to detect potential damages caused by logistics, ensuring that you receive the products in perfect condition. In the final stage, we offer **installation inspection** services to ensure that everything meets expectations post-project completion.

A notable highlight is our **independent laboratory testing** service, which sets us apart. This service is seamlessly integrated into the entire service cycle mentioned above, providing an added layer of assurance and quality verification for your project. Choosing TÜV Rheinland guarantees you professional support throughout, ensuring a smooth project delivery and meeting your high-quality standards.

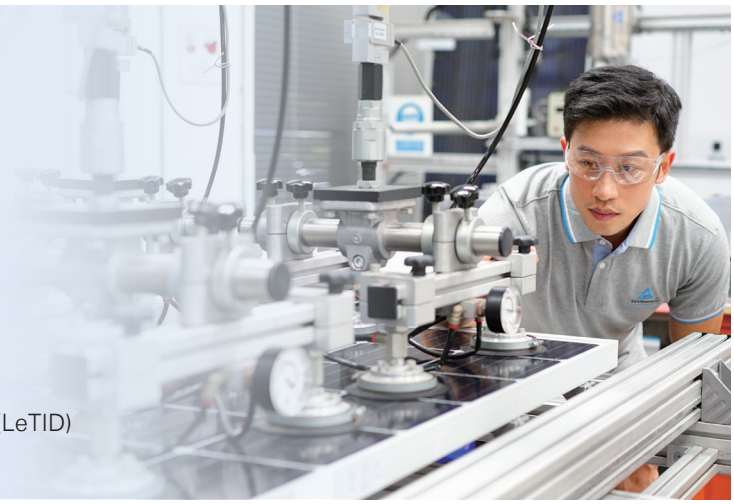
Independent Laboratory Tests

Independent tests can be performed in our accredited (ISO 17025) laboratories: Cologne (Germany), Pleasanton (USA), Bangalore (India), Milan (Italy) and Shanghai/Taicang (China Mainland). All tests are performed under IEC standards, if applicable, and customised test sequences are offered.

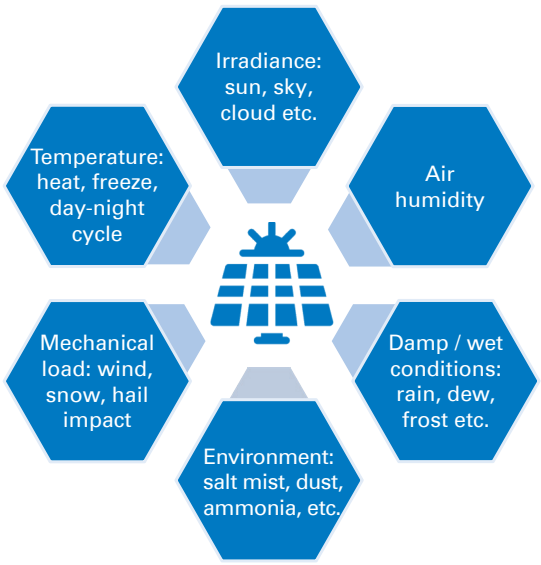
PV Module Laboratory Tests

FAST VERIFICATION TESTS

- Visual inspection
- Power determination
- Electroluminescence (EL) test
- Safety tests
- Performance at different irradiance/temperature
- EVA gel content & peel-off tests
- Thermographic testing
- Static mechanical load
- Dynamic mechanical load
- Potential induced degradation (PID)
- Light induced degradation (LID)
- Light and elevated Temperature Induced Degradation (LeTID)
- Bifaciality (φ) coefficient verification



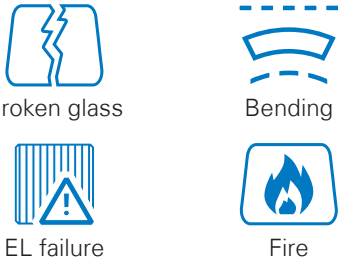
RELIABILITY TESTS AND EXTENDED RELIABILITY TESTS



- Damp heat test (DH)
- UVID test
- Thermal cycling test (TC)
- Humidity freeze test (HF)
- Impulse voltage test
- Hail impact
- Bypass diode thermal test
- Hot-spot endurance test
- Outdoor exposure test
- Salt mist
- Ammonia corrosion test

EXTENDED RELIABILITY TESTS FOR NEW TREND

New technology tends include double-glasses designs, HJT/TOPcon modules, large size modules have been gaining more market share recently. Solar systems using new technology module reach higher yields, while facing more challenges for the long-term burnt module reliability. The higher string current may lead to an increased risk of broken glasses of bifacial modules, PID/LID influence, Bending failure, hot spot issue, etc. Therefore, TÜV Rheinland recommend tests with higher currents to account for conditions in the field as in 2PfG 2556/06.18.



UVID

Modern cell architectures with UV-transmitting encapsulants are more vulnerable to UVID. Experimental results showed significant **degradation of 1% to 25%** which varies from different cell technologies. TÜV Rheinland brought forward **2 PfG 2944/07.23** to provide solutions to investigate this degradation mode.

Test procedure and pass criteria

2 samples

- Visual inspection
- EL imaging
- Initial stabilization
- Performance at STC
- Insulation test
- Wet leakage test
- UVID (front side) 120 kWh/m^2
  - Characterization tests*
- UVID (back side) 60 kWh/m^2
- Final stabilization
- Characterization tests

Characterization tests

- Visual inspection
- EL imaging
- Performance at STC
- Insulation test
- Wet leakage test

*No requirement on performance

Sample requirement:
- Minimum two samples required

Test conditions:
- Testing to Module Front: 120 kWh/m^2
- Testing to Module Back 60 kWh/m^2

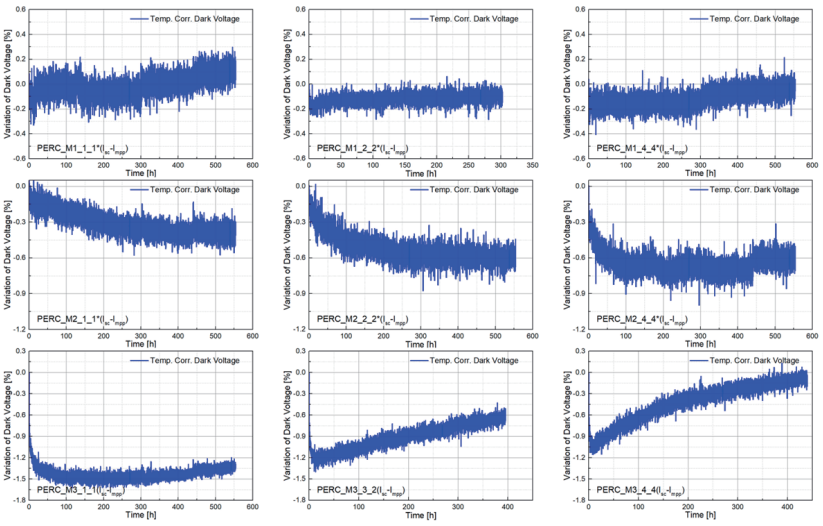
Pass criteria:
- No visual evidence of a major defect
- Insulation resistance and leakage current meet requirements of IEC 61215-2
- Power drop less than 3% in the end of test sequence

LIGHT AND ELEVATED TEMPERATURE INDUCED DEGRADATION (LETID) TEST

PERc module's power output may be affected negatively by light and elevated temperature induced degradation (LeTID).

n-type technologies such as PERT, TOPCon may be also susceptible to LETID, but the magnitude of degradation would be lesser.

TÜV Rheinland's 2 PfG 2689/04.19 test method shortens the test lead time and simplifies the test procedure while the severity of the test condition and quality of the final results is not compromised.

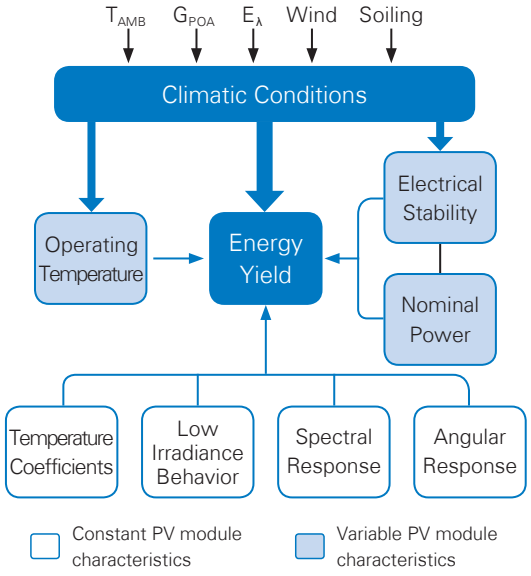


Current Injection: I_{SC}-I_{MPP} | $2*(I_{SC}$-$I_{MPP})$ (2 PfG condition) | $4*(I_{SC}$-$I_{MPP})$

PAN FILE DATA PACK CREATION AND VERIFICATION

The PAN File characterizes the performance of the PV module in PVsyst. With the base PAN file which only includes parameters taken from the data sheet, performance and energy yield is simulated with high uncertainty.

TÜV Rheinland maintains state-of-the-art equipment and is a leading provider for accurate power rating and testing of commercial PV modules. The critical parameters such as IAM, GTE, series resistance, spectral response, temperature coefficient etc. which are used in PAN files will be extracted from precise measurements in accordance with IEC 60891, IEC 60904 and IEC 61853 series of standards.



PV Mounting Structure and Tracker

PV mounting/tracker systems are becoming more and more important to the design, production, installation and maintenance of PV systems. Since solar power projects vary by regional legal requirements and site-specific conditions, each design must be considered individually.

As well as adhering to local laws and regulations, project planners increasingly need to be familiar with international requirements for their projects.

TÜV Rheinland is providing tailor-made inspection and testing services to support clients in quality assessment for PV mounting systems and solar trackers.

PRODUCT SCOPE

- Ground-mounted (fixed-tilt) racking systems
- Sloped-roof racking systems (inclouding roof-integrated)
- Flat roof racking systems (including ballasted)
- Solar trackers (single/dual axis)
- Custom systems (e.g. floating systems)

TAILOR-MADE TESTING SERVICES FOR MOUNTING/TRACKER SYSTEMS

- Tensile strength and compression test
- Mechanical load test
- Environment test
- Salt mist and corrosive atmosphere test
- Wind tunnel test, etc.

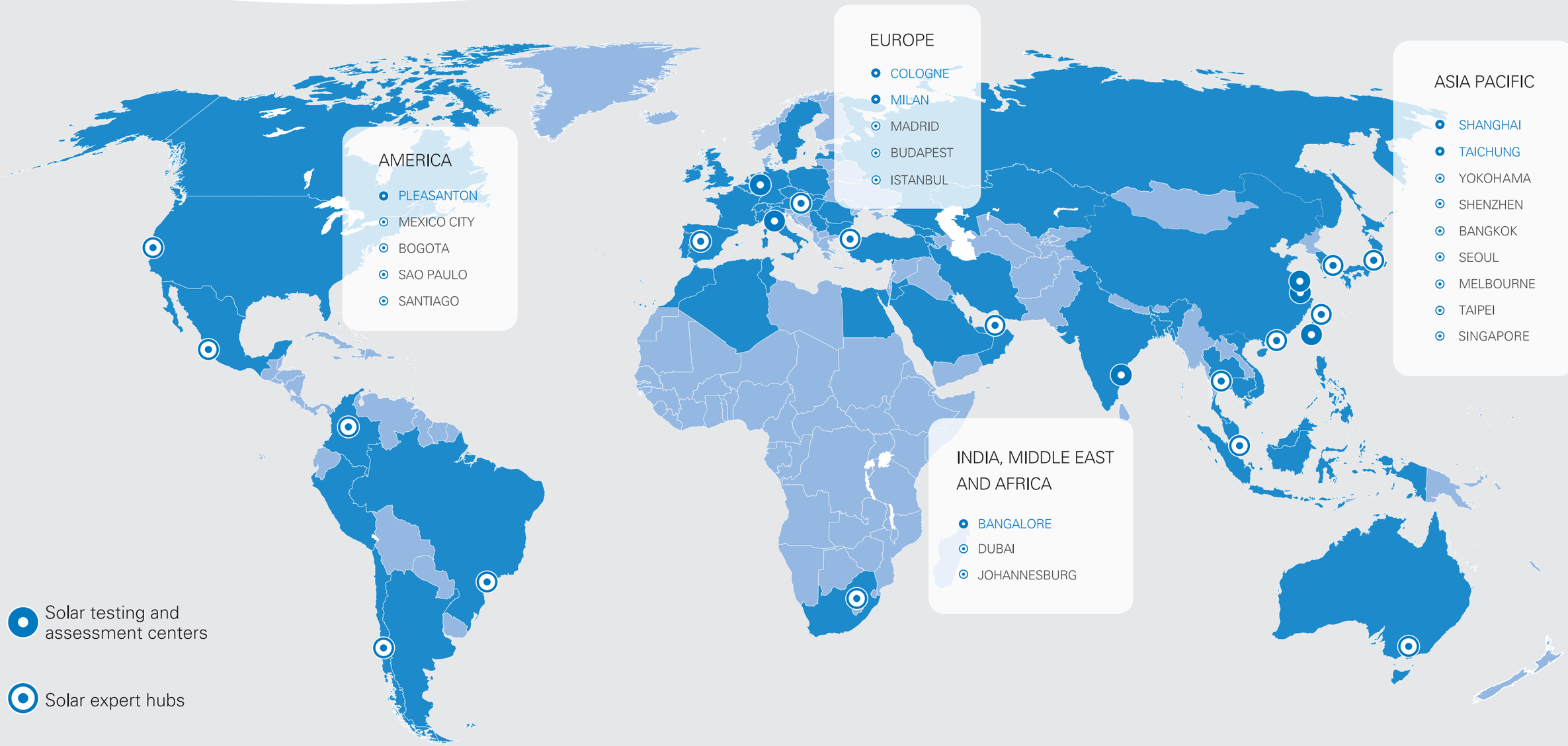
Global Network, Local Services.

Our testing centers with multiple accreditations consist of state-of-the-art equipment and sophisticated engineering teams. Additionally, a number of outdoor measurement sites under various conditions, including dry & hot, tropical and moderate climates, ensure a wide range of assessments on the performance of PV modules. As the premier third party testing and certification institution for the PV industry, over 300 experts of TÜV Rheinland worldwide can rapidly respond to the local needs of manufacturers, retailers and investors, offering value beyond expectations. The combination of various disciplines makes us a trustworthy partner, able to advise you and play an active role in helping you achieve success.

300+ experts

40+ years of experience

No.1 in PV products testing and certification



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