FAST MOVING TECHNOLOGY

Small Components. Big Impact.

Solarline | Connectors for renewable energy

EN

STÄUBLI

THE BIG PICTURE

Attention to the smallest detail pays off for safe returns

The demand for safe, clean, and reliable renewable power is growing at an ever increasing rate. Today photovoltaic (PV) technology is not only ecologically, but also economically a sensible alternative for power generation.

A large scale PV power plant has to be competitive against conventional energy sources as well as other PV projects. With the elimination of government subsidies for this kind of energy generation in many regions and markets, the focus has now shifted to the plant's overall efficiency.

Minimizing CAPEX

In view of increasing cost-consciousness within all industrial sectors, the pressure on the cost of eBOS components is becoming increasingly important. As a result, profitability decreases, so companies try to optimize CAPEX costs and save money on components – often already in design phase.

Securing profitability

However, the real keys to improvement are both better capital and operational efficiency. When it comes to favorable conditions for investment loans and credits, the determining factor is the profitability of a project during the operation period. And here, the dependability of the partners, the components, as well as reliable operation and maintenance play an important role.

Decisive factor for your ROI

When it comes to the profitability and the return on investment of a PV project, a low LCOE (Levelized Cost of Energy) is the deciding factor. This crucial metric, expressed in cents per kilowatt hour (kWh), takes in account not only the capital cost (CAPEX) of building a project, but also operating and maintenance expenses (OPEX) over time. It is used to compare the cost of solar energy to other energy sources and determines the long term profitability of a power plant.

Leverage on LCOE (Levelized Cost of Energy)

Figure 1: Composition of LCOE.

CAPEX: capital expenditure, is an expenditure which results in the acquisition of permanent asset intended to be permanently used in the business for the purpose of earning revenue; OPEX: applies to expenditure on an ongoing, day-to-day basis in order to run a business or system.

Minimizing risk, maximizing return

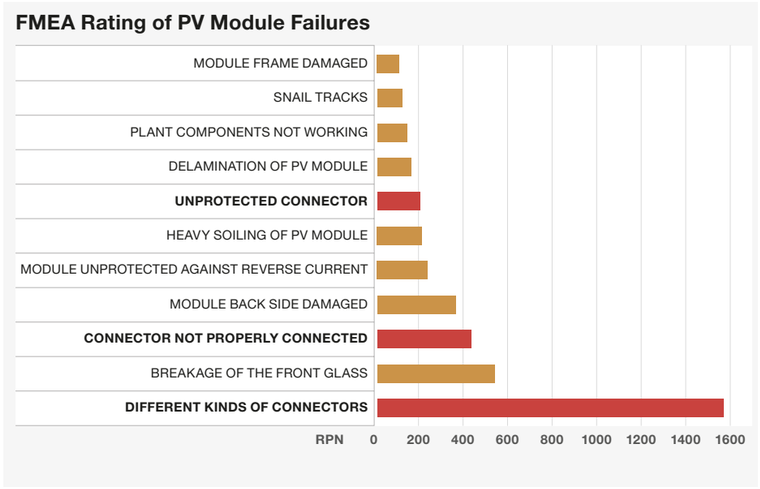


Figure 2: FMEA Rating of PV Module Failures by TÜV Rheinland.

Prioritization of various risks, belonging to a certain phase and component, according to their **Risk Priority Number (RPN)**. In the FMEA, each identified risk is evaluated for severity (S), occurrence (O) and detectability (D) and rated on a scale from 1 to 10 for each parameter. The RPN is obtained by multiplying those three factors and their given numbers (RPN = S x O x D). The higher the RPN, the higher the risk and substantial consequences on the PV plant and its profitability.

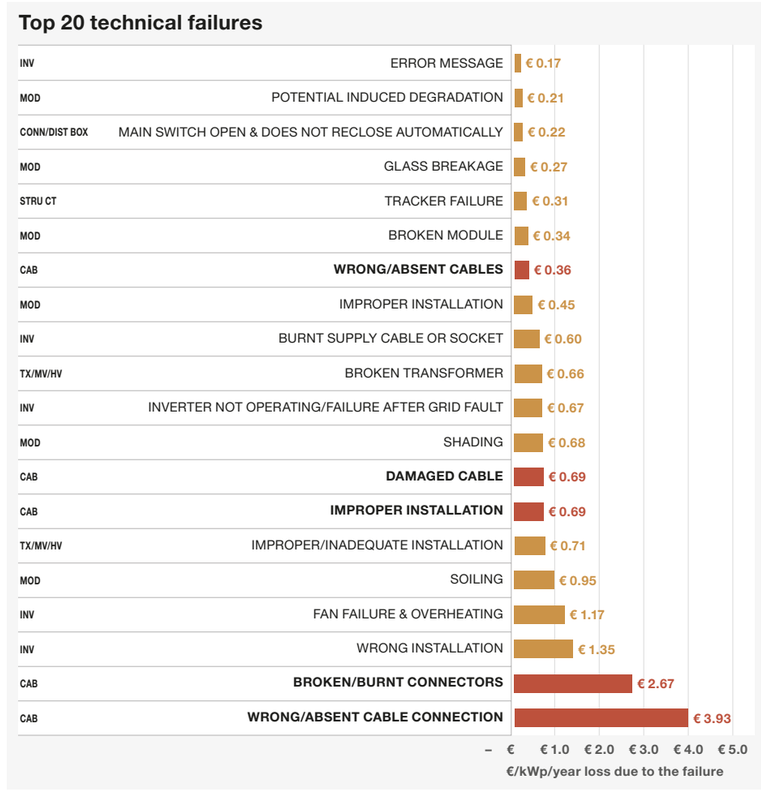
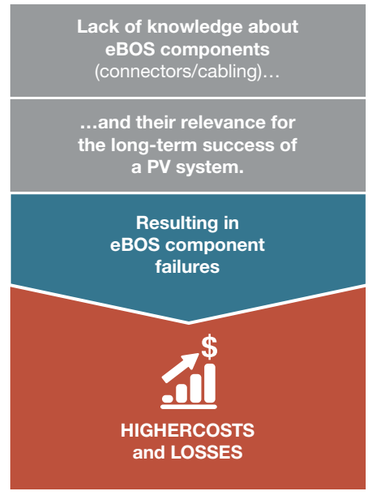


Figure 3: Calculation of the economic impact: Solar Bankability is a project funded by the European Commission's Horizon 2020 program (www.solarbankability.org).

Failures on cabling/connectors are among highest risk potentials according to the list of the top 20 technical failures during operation and have the biggest financial impact.



Generally speaking, in the solar industry, bankability is a term used to describe the degree of financial risk. The degree of bankability of any project, solution, technology or supplier will affect the availability and cost of capital.

Developers and investors have to assess the investment risk: qualitative evaluation on technical and legal aspects. This also involves a quantitative economic evaluation with the focus on the balance between Total Initial Costs, Total Operating Costs and Levelized Cost of Energy.
The assessment is clustered in main dimensions of project-due-diligence to assess the reliability of the project cash flow from a risk perspective.
The stakeholders go through a review process and have to be rated bankable in order to improve the chances of a positive financing decision and manage risk mitigation.

The careful selection of bankable products and components to be built into the system has a considerable impact on the bankability and the economic success of a PV asset. In order to ensure a competitive LCOE and the long-term success of a PV system, but also the necessary financing, the appropriate, bankable project partners must be chosen.

The key to long-term efficiency

The guiding principle for bankability is to minimize risk while maximizing the return. This can only be achieved through secured efficiency in the long term on the basis of high-quality components. Wrong choices in planning, due to lack of knowledge or low-quality components, can cause unexpected loss of production or potential safety issue during the lifecycle of a PV system.

Solar Bankability Project

The EU-funded Solar Bankability Project aims to establish a common practice for professional risk assessment on the basis of existing studies and collected statistical data of failures in PV plants. Its risk analysis tends to assess the economic impact of technical risks and how this can influence various business models and the LCOE.

Failure Modes and Effects Analysis

In a first attempt, the project presents a cost-based Failure Modes and Effects Analysis (FMEA) to be implemented into the PV sector. It presents a methodology for the estimation of economic losses due to planning failures, system downtime and substitution/repair of components with respect to their impact on electrical and financial performance.

Prioritizing risk

To provide a framework for the calculation of the economic impact, a special coefficient called CPN (cost priority number) has been introduced. It corresponds to RPN (risk priority number) in the classic FMEA and is part of a cost-based approach that has been applied to the collected failure data. This allows to prioritize the risks and their economic impact by means of the CPN ranking.

Collected failure data

The failure data are based on owner-provided failure tickets and detected failures during on-site inspections. Several parameters were considered (e.g. plant type, costs due to downtime/fixing, plants affected by a specific failure etc.).
The economic impact of a specific failure can be split into two categories:

- Economic impact due to downtime and/or power loss (kWh to Euros)
- Economic impact due to repair/substitution costs (Euros)

STÄUBLI

CONTACT RESISTANCE

Why do connectors have such a big impact?

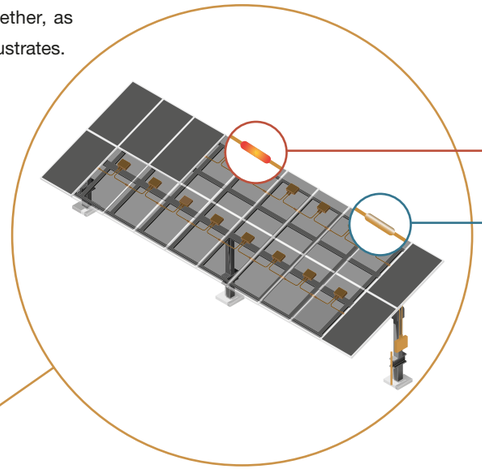
The bankability of a PV project is at peril when several risk factors endanger the operation of the plant, including up to damages to it.

As seen, the cabling can play a major role in this context as it has to ensure stable transmission of the generated power from the modules to the inverter or the consumption.

The key factor for sustainability

The key to efficient operation and safe energy feed-in is, without a doubt, longterm reliability as well as constantly low contact resistance of the most crucial components, the connectors.

Vice versa an increasing contact resistance, e.g. due to deficient material characteristics, can lead to a massive and ultimately decisive influence on the risks and the efficiency of a PV project. It is important to note that risk factors are closely linked together, as the infographic on the right side illustrates.



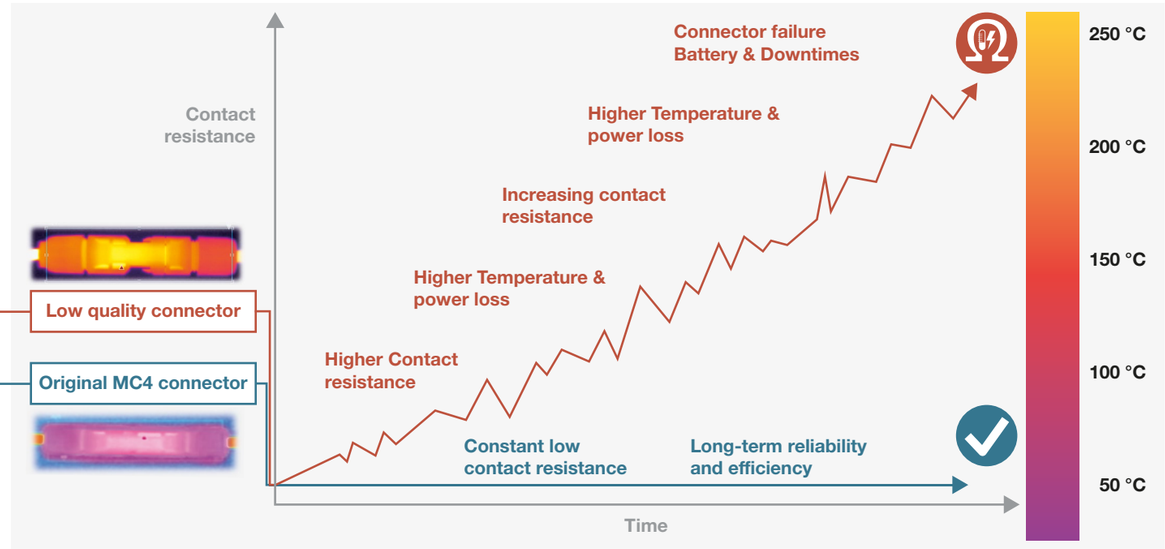
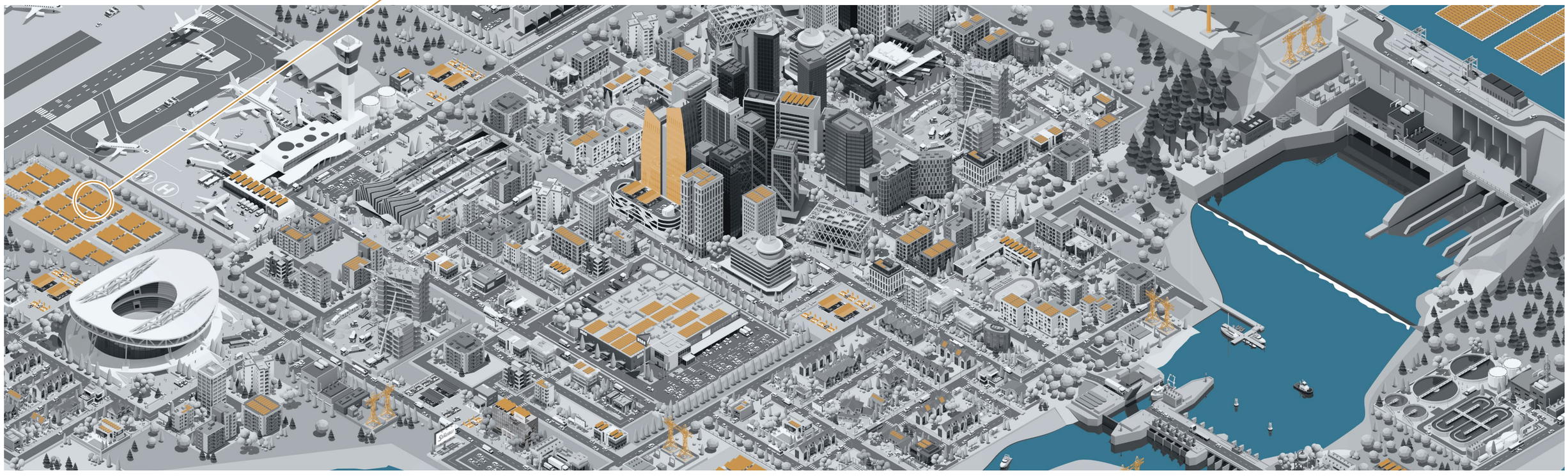


Figure 4: Increasing contact resistance and temperature over time of a Low quality connector vs. Original MC4 connector.



SMALL COMPONENTS. BIG IMPACT.

Why saving at the wrong place and increasing risks?

Both careful selection of connectors and their impact on the bankability of every photovoltaic project are substantial.

During the project planning phase of a PV system, the main focus is on the initial costs and largely on the two highest-cost items: the solar modules and the power inverters. Connectors as crucial part of the cabling are often put aside.

Yet, they have to secure safe and reliable transmission of the power being produced over the long-term. Without constant connection or due to failure, there is no assured feed-in and, as consequence, reduced profitability as well as less return.

Investment (CAPEX)

In the caluclation the components for cabling (connectors, junction boxes, cables) play only a minor role as they amount to less than 2% of the total initial costs (CAPEX), and for connectors an even tinier percentage (approx. 0.2 %). Thus, choosing low-end connectors that are about 30 % cheaper in price compared to Stäubli connectors might signify an absolutely minor cost differential: that means a potential saving of no more than 0.07 % of the initial costs. Regardless those minuscule potential savings, PV project developers sometimes try to save costs by selecting low-end product solutions in order to optimize CAPEX.

The compromise with quality however involves many risks, endangers the return on investment and can quickly turn those short-term savings into substantial losses. These apparently small components can have a massive and ultimately decisive influence on the risks and on the return on investment respectively the LCOE of the PV project.

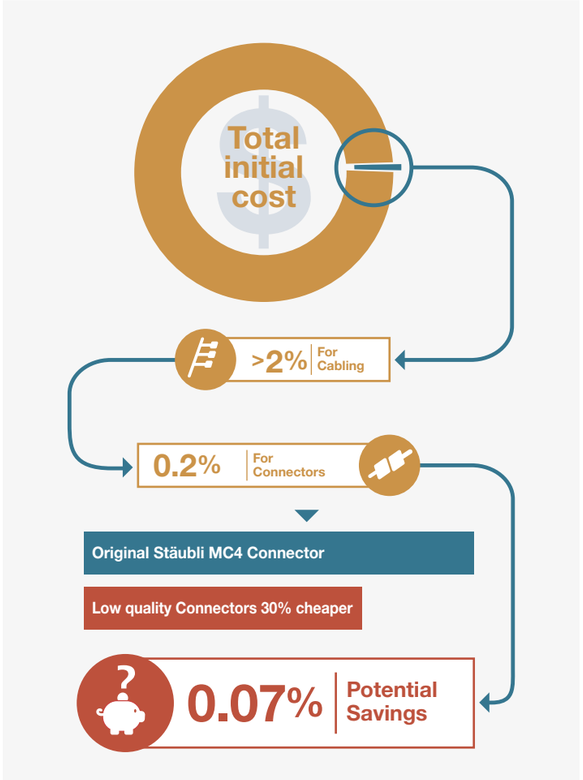


Figure 5: Investment: Costs are depending on correct and detailed planning, project dimension and design, construction, location etc.

Operation (OPEX)

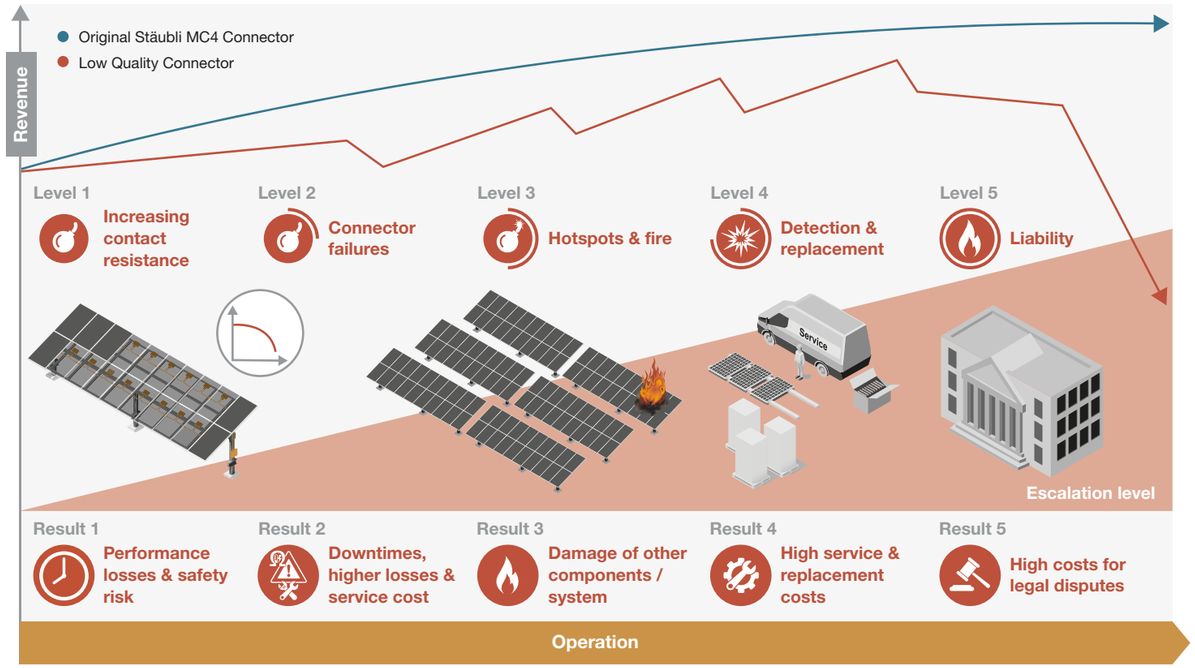


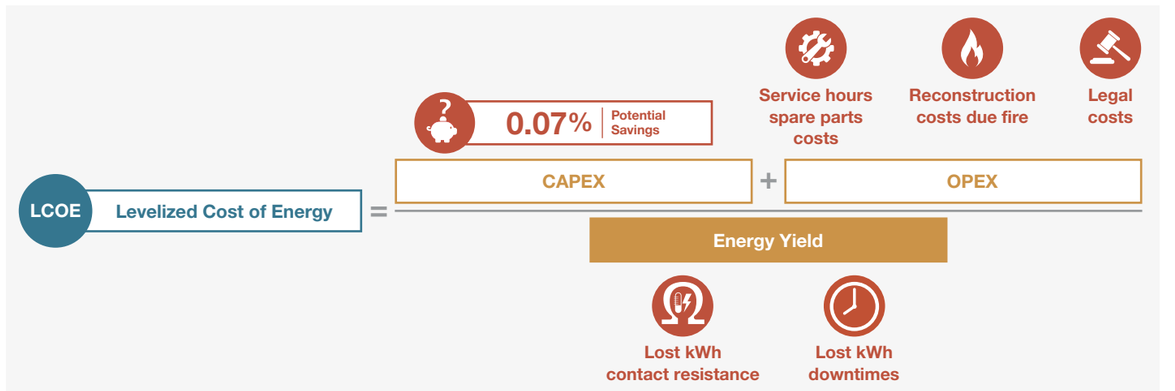
Figure 6: Symbolic representation of the risks that depend on several factors. They might as well occur simultaneously.

Safe operation in the long run

During the project planning phase, it is also absolutely important to take into consideration that the plant engineering is designed for an operational phase often exceeding 25 years. That means that all the components should provide longevity as well as outstanding technical characteristics in order to ensure stable efficiency.

Serious consequences

Wrong connector selection can lead to higher operating and maintenance expenses (OPEX) as well as lower energy yield over time (>25 years). From this follows a lower efficiency of the PV system and a negative impact on both the return on investment and the LCOE. Therefore, thinking further in terms of long-term operation is absolutely substantial.



Three sources of risk

Not only the selection of quality components, but also their correct handling is crucial for the plant's profitability. There are three main risk sources, which can lead to the mentioned consequences and put the neat functioning at risk:

1. Quality vs. Low-end Product
2. Cross-Connection
3. Defective Installation/Crimping

1. Choosing low-quality connectors over quality connectors

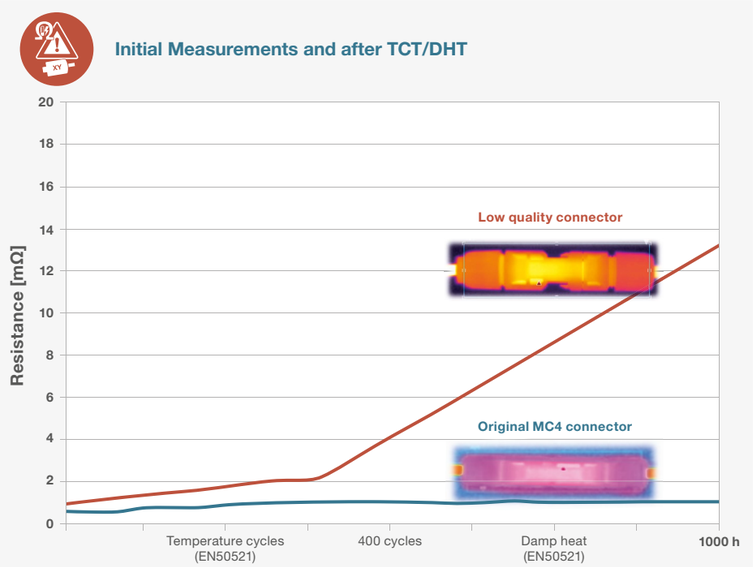


Figure 7: Diagram of increasing contact resistance and temperature due to low quality.

With Original Stäubli MC4 connectors you benefit from over 20 years of experience in the photovoltaics industry as well as the outstanding technical characteristics of the innovative MULTILAM advanced contact technology. Thanks to their constant spring pressure and patented design, MULTILAM feature multiple contact points to improve connection and energy transfer, resulting in a constantly low contact resistance. This ensures safe and long-life operation and reduces downtime and service cost significantly. Furthermore, risks for power loss and hotspots or fire that will lead to enormous reconstruction costs are reduced to a minimum.

The Original Stäubli MC4 connector is almost totally stable in terms of temperature: there is no heat accumulation thanks to the tried and tested MULTILAM technology. The use of Low quality connectors, however, is very risky as the strongly increasing contact resistance curve illustrates.

Consequences

- Performance losses & safety risk
- Downtimes, higher losses & service cost
- Damage of other components/system
- High service & replacement costs
- High costs for legal disputes

2. Cross-connections

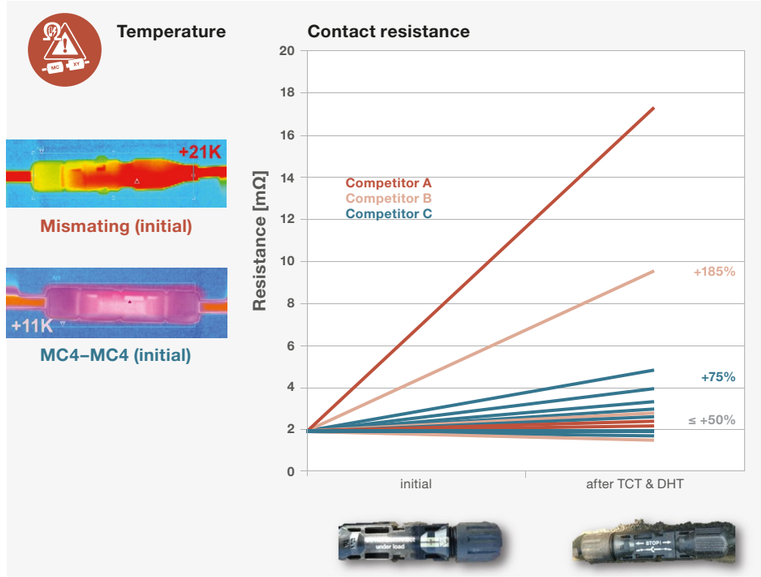


Figure 8: Diagram of increasing temperature and contact resistance due to cross-mating.

By mismating or cross-connecting, you easily entail technical as well as legal risks. It is important to always use connectors with plugs and sockets of the same brand for the installation process from module through to inverter.

Factors that are causing incompatibility:

- Deficient technology and product material
- Differences in production process and quality standards
- **No aligned tolerance zones** to ensure tightness as well as sufficiently high contact forces
- No **chemical compatibility** of all raw materials (including production and auxiliary materials)
- Changes of the **production process** without respecting possible interactions
- Disrespect for the fact that certification and standards are given for one product from one manufacturer; those are not manufacturer-independent

There are different standards (UL1703 and IEC62548 installation standard) and regulations, which disallow cross-mating of connectors of different brands. Also studies based on field data prove very clearly, that there is no compatibility between connectors of different manufacturers. Furthermore, the certification for the EN50521 product standard will terminated by cross-mating. Always keep in mind that submitting a case to the court, e.g. in the event of a fire involves high costs and bother over a long period.

The problems/risks that were mentioned before might also occur due to cross-connection. There are several manufacturers that claim to produce “Stäubli compatible” components. Doing cross-connection, however, is not permitted under any circumstances and may lead to severe damages.

Mating Original MC4 components vs. MC4 with different connector brands: Higher temperature and extremely increasing contact resistance for the competitor products after a TCT (Temperature Cycle) and DHT (Damp Heat) testing.

Consequences

- Performance losses & safety risk
- Downtimes, higher losses & service cost
- Damage of other components/system
- High service & replacement costs
- High costs for legal disputes

3. Incorrect installation and crimping

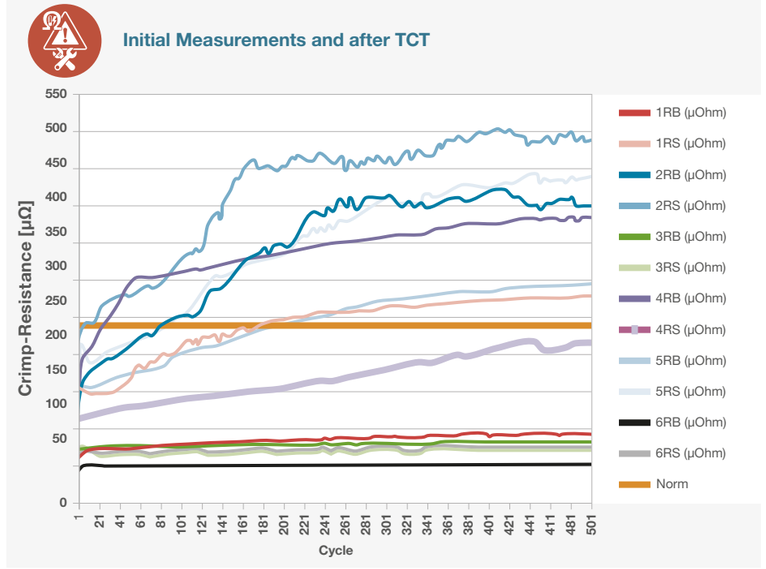
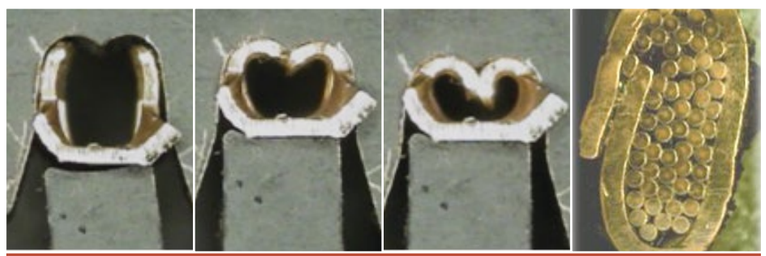


Figure 9: Diagram of crimp resistance forces.



Rolling-in of crimp area is not uniform

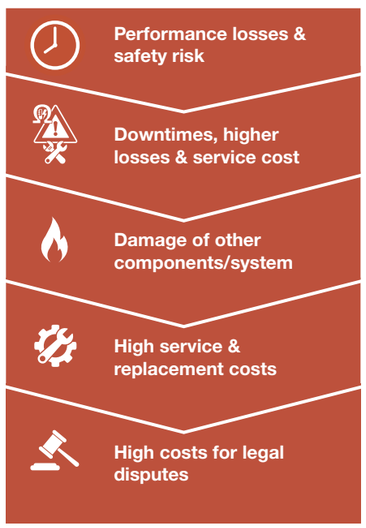
Another risk for the neat functioning and profitability of a PV plant might result from defective installation. This often derives from false crimping.
We highly recommend to always make sure to use certified crimping tools in order to ensure correct and safe installation.

False crimping and too low crimp forces might lead to:

- Non-fulfillment of the standard criteria
- Unstable contact resistance
- No gas-tightness

The problems and risks mentioned previously might also occur due to a defective installation.

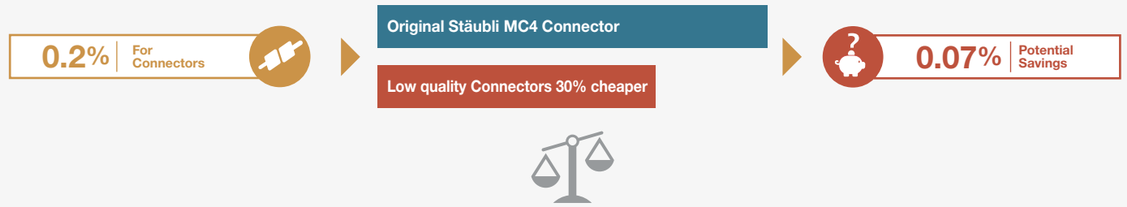
Consequences



IN BRIEF

Low saving potential but high impact on ROI

Small components, low costs, low saving potential



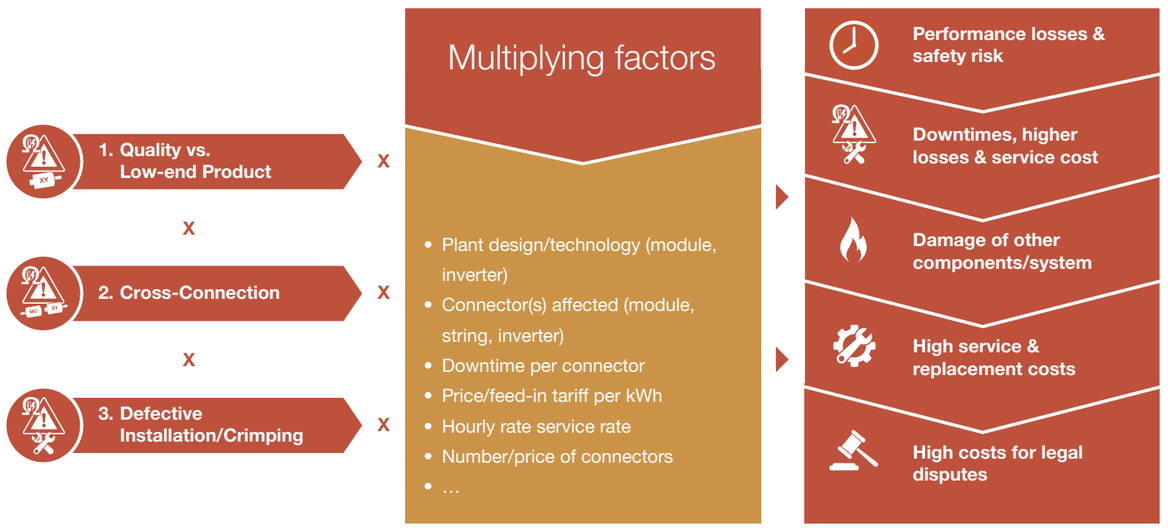
High risk potential and impact on the ROI of the PV plant

Connectors may be small components, but their influence on the efficiency and bankability of a PV project is undeniable.

Saving money on connectors means saving at the wrong place as making compromises with quality usually is accompanied with high losses and risks that could be avoided.

Aggravating factors

Always pay attention to the fact that there are multiplying factors both closely linked and crucial, when it comes to safe connection. So why try to save a tiny percentage on initial costs when it massively increases the risk potential and therefore also endangers the long-term return on investment?



PRACTICAL EXAMPLE

50 MW PV ground-mounted plant

In this example the 50 MW plant consists of 200 blocks containing 16 strings with 28 modules each.

In the sum this makes all in all about 180’000 connectors on modules plus approx. 18’000 for field assembly/installation. In total, there are approx. 198’000 connectors representing 198’000 small details to influence LCOE as well as ROI positively. In the case of downtime, defective connectors disable current flow.

However, the failure of only one single connector can also entail the outage of an entire string.

High potential losses

It is important to keep in mind that all of the sources of risk and problems mentioned are likely to occur not only once but several times in a row. Defective components and improper installation may lead to many lost kWh, high service and maintenance costs and even total breakdown/destruction.

To illustrate how much losses you may have to register annually on an average 50’000 kW plant, we calculated on the basis of the FMEA/CPN rating by Solar Bankability Project, as seen previously. Failures in connectors and cabling alone would result in considerable losses each year.

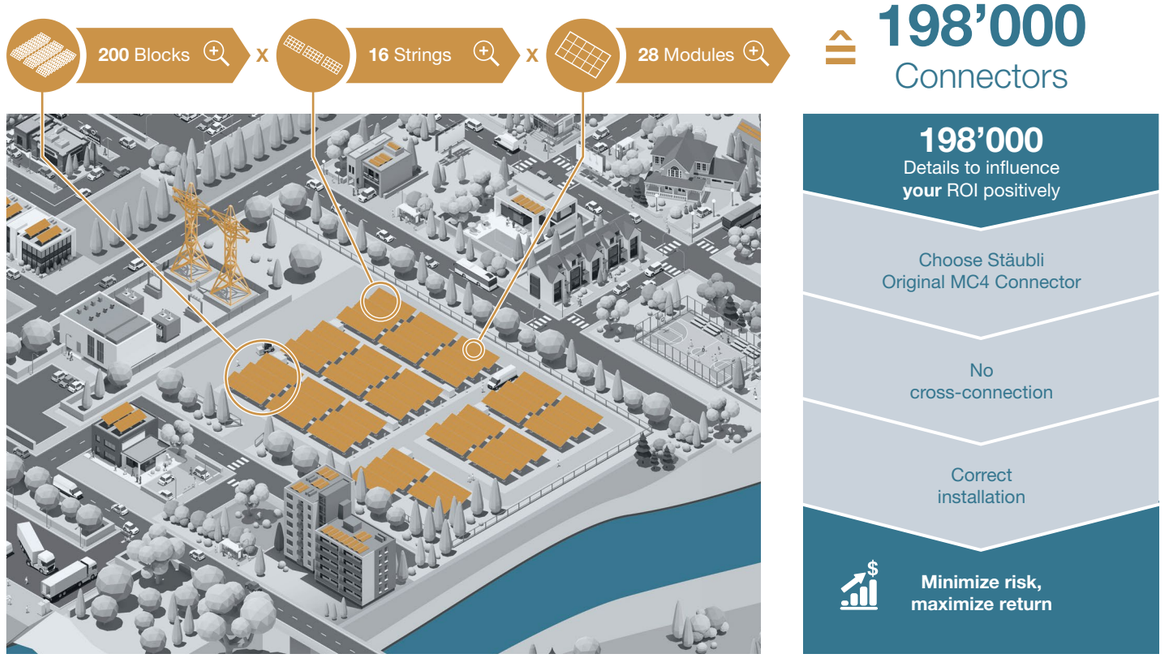


Figure 10: Numbers can differ depending on detailed planning, project dimension and design, construction, location, components etc.

EBOS PRODUCT & SERVICE OFFERING

Set the foundation right at the very early stages

Stäubli has continually set the benchmark for PV connectors in the solar industry. In 1996 beginning with the launch of the Original MC3 and then the Original MC4 PV connector in 2002. Globally, over 5 billion Stäubli connectors have been installed in solar power plants – and our growth continues thanks to our partners who recognize that quality pays off both short term and in the long run.

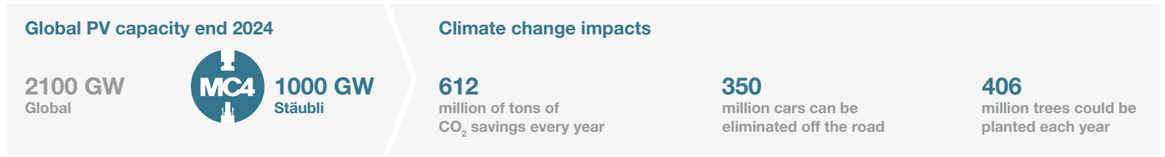


Figure 11: Connecting 1000 GW PV capacity is the equivalent to planting 406 million trees or reducing 612 million metric tons of CO_2 every year.

The fast-paced dynamics of the solar industry have introduced intense competition that makes having an experienced partner by your side an undeniable advantage. When envisioning and designing new PV power plant projects, it is necessary to consider all the details and rely on industry-leading expertise. We understand the key elements necessary for your PV power plant project to succeed today and thrive for years to come. Beyond our comprehensive portfolio of high-quality eBOS components, we can also add value to your business with our expert service. Our global team of highly skilled technicians can help train your staff and support operations to ensure everything runs safely and smoothly. We care about the details and your plant’s performance – our service experts are committed to quality and will find the best solution to mitigate risk and secure higher yields from your PV systems.

eBOS Product Solution & Service Offering

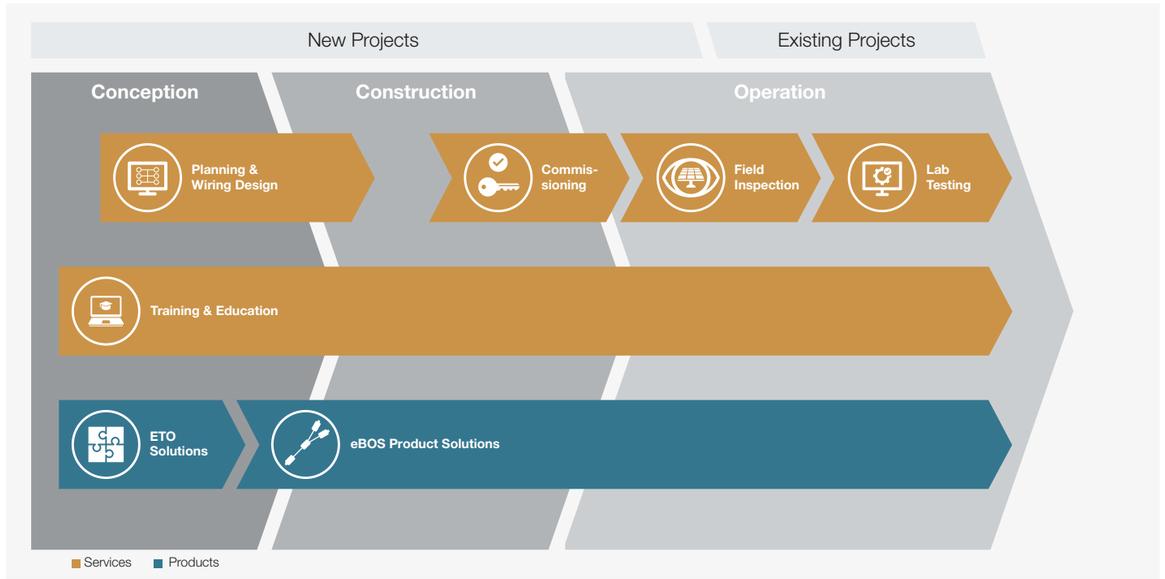


Figure 12: Stäubli’s comprehensive Product and Service Solution portfolio.

PV Sol Bankability 11014310-en I 05.2024

● Stäubli Units ○ Representatives/Agents

Global presence of the Stäubli Group

www.staubli.com

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