Multi-Contact

MC

STÄUBLI

Cabling of PV Installations – Small components. Big impact.

Stäubli Electrical Connectors – your bankable partner

The big picture – Attention to the smallest detail always shows the biggest returns

The demand for safe, clean reliable renewable power is growing at an ever increasing rate. Today 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. In the face of increasing cost-consciousness within all industrial sectors, the downward pressure on costs as well as on BOS components (balance of system) is becoming more and more crucial. Due to this, profitability has been lagging, so companies try to optimize CAPEX costs mainly and safe money on the components – often already during the phase of design. But the real keys to improvement are both better capital and operational efficiency. Determining factor when it comes to favorable conditions for investment loans and credits is the profitability of a project during the operation period on the basis of reliable partners, components and an adequate operation and maintenance.

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 of building a project, but also operating and maintenance expenses over time. It is used to compare the cost of solar energy to other sources and determines the long term profitability of a power plant.

Figure 1: Composition of LCOE.

[CAPEX, short hand for 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 or operational expenditure applies to expenditure on an ongoing, day-to-day basis in order to run a business or system]

The concept of bankability – Minimizing your Risk, Maximizing your Return.

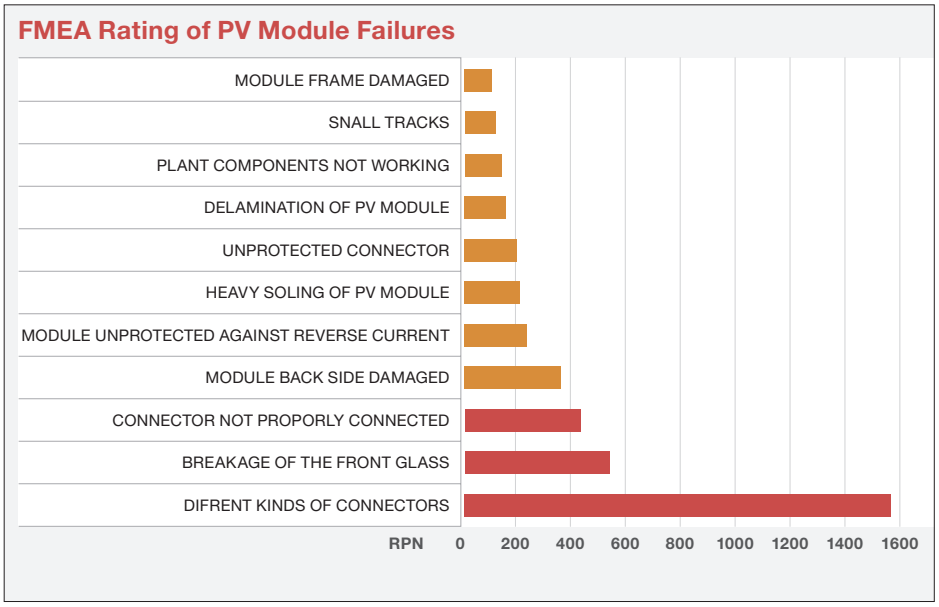


Figure 2: FMEA Rating of PV Module Failures by TÜV Rheinland.

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.

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. **Careful selection of bankable products and components to be built into the system** is also a core topic, as these have considerable impact on the bankability and the economic success of a PV asset.

The guiding principle for bankability is to minimize risk while to maximize 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, in order to reduce the cost, can cause **unexpected loss of production or potential safety issue during the lifecycle of a PV system**.

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.

In a first attempt, the project presents **a cost-based Failure Modes and Effects Analysis (FMEA)** to be implemented into the PV sector and tries to define a methodology for the estimation of economic losses due to planning failures, system downtime and substitution/repair of components.

In Solar Bankability, the role of the FMEA was to focus on the most important failure risks with respect to their **impact on electrical and financial performance**. An example of FMEA rating of PV module failures is given in the diagram above.

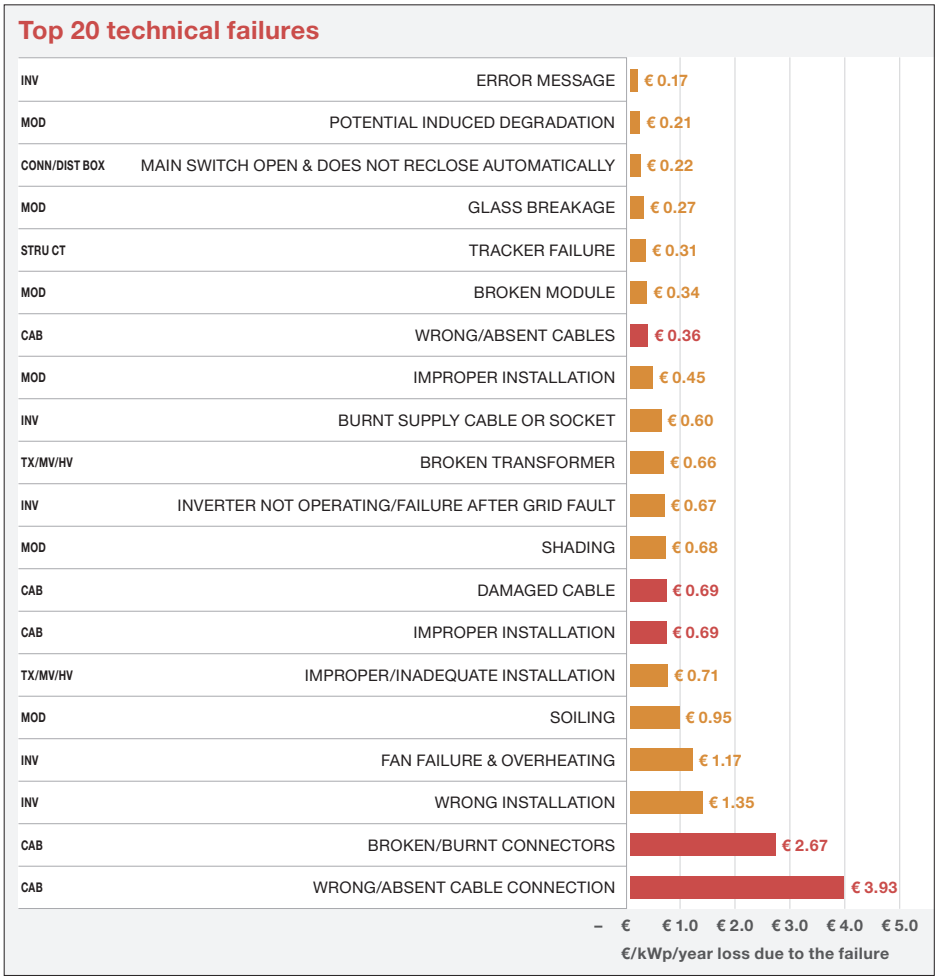


Figure 3: Calculation of the economic impact: Solar Bankability is a project funded by the European Commission's Horizon 2020 program www.solarbankability.org

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.

In order to provide a framework for the calculation of the economic impact, a cost-based approach has been taken into consideration. The special coefficient called the CPN (cost priority number) 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 in order to prioritize the risks by the means of the CPN ranking and the associated economic impact. The failure data are based on owner-provided failure tickets and detected failures during on-site inspections. Several parameters were considered (e.g. PV plant type, costs due to downtime/fixing, number of reports of failures, plants affected by a specific failure, etc.).

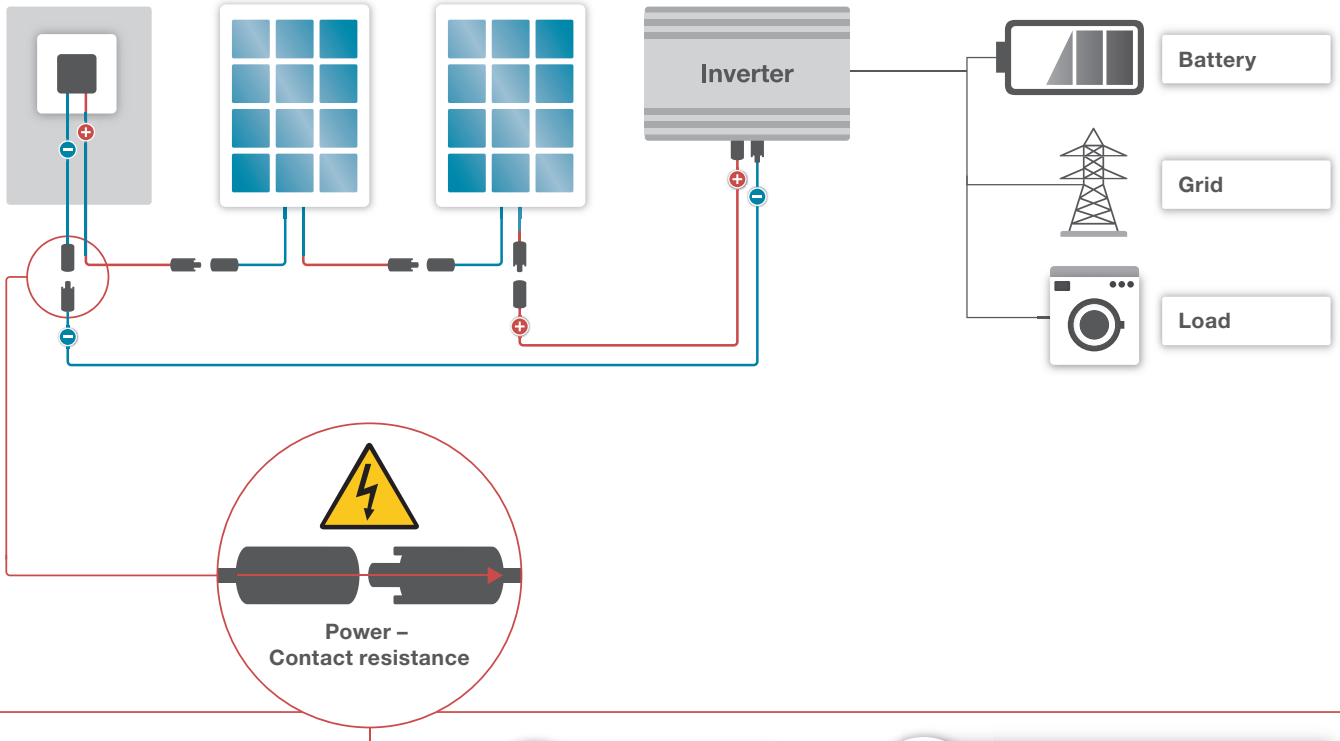
The economic impact of a specific failure can be split into two categories:

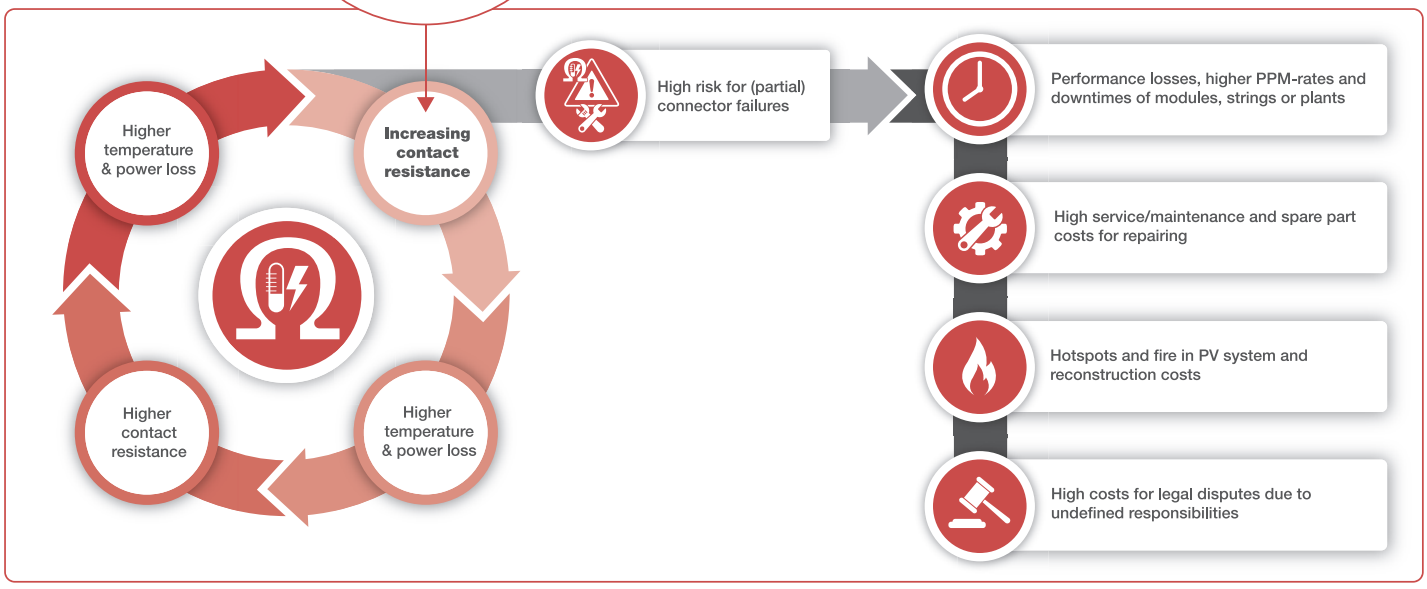
- Economic impact due to downtime and/or power loss (kWh to Euros)
- Economic impact due to repair/substitution costs (Euros)

Why do connectors have such a big impact?

The bankability of a PV project is at risk when several risk factors endanger the operation of the PV plant including up to damages to it. As seen the cabling can play a major role in this context. The cabling transmits the power from the modules to the inverter or the consumption. The key to efficient operation and safe power transmission is, without a doubt, constantly low contact resistance of the most crucial components – the connectors.

Vice versa an increasing contact resistance can lead to a massive and ultimately decisive influence on the risks and the efficiency of a PV project.





Why saving at the wrong place and increasing risks?

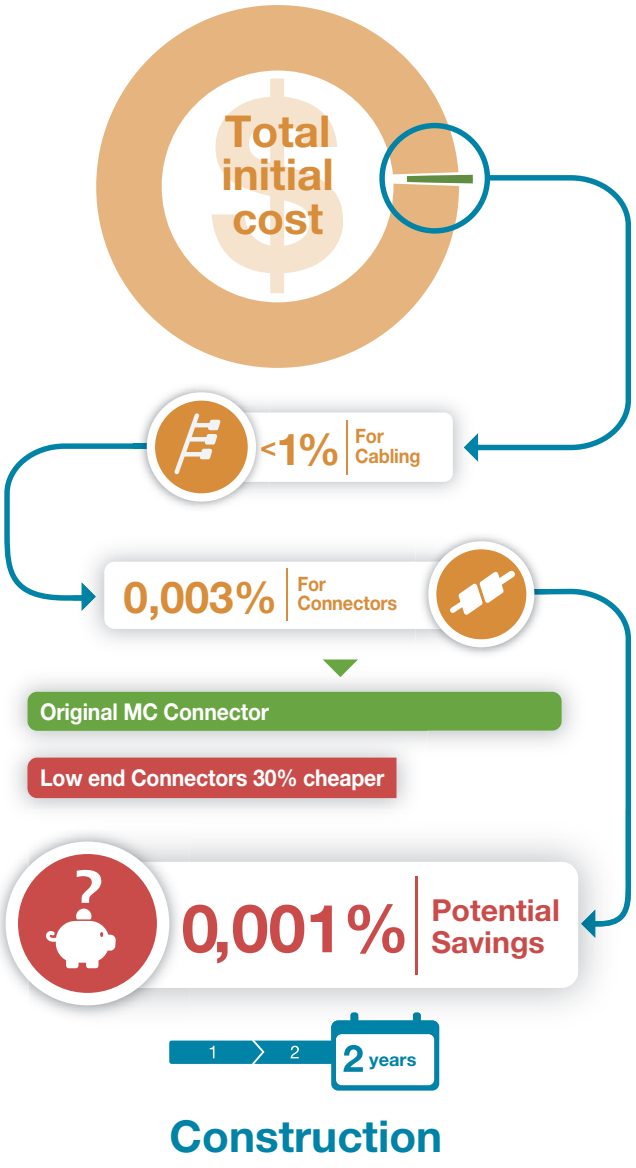
During the project planning phase of a PV system, the main focus is on the initial costs and largely on the two highest-cost items: the solar modules and the power inverters. Connectors as crucial part of the cabling are often put aside even though their **careful selection and impact on the bankability of every photovoltaic project are substantial**.

They have to secure safe and reliable transmission of the power being produced. 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)

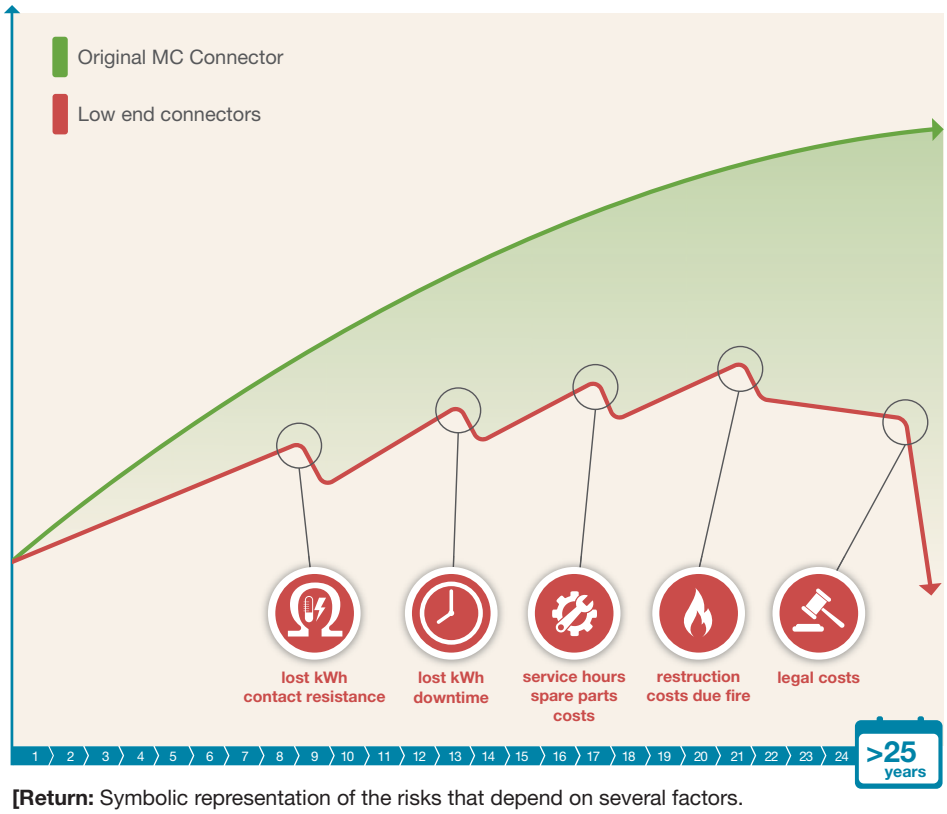
The components for cabling (connectors, junction boxes, cables) play only a minor role in the calculation as they amount to less than 1% of the total initial costs (CAPEX), for connectors an even tinier percentage (approx. 0.003%). Thus, choosing low-end connectors that are about 30% cheaper in price compared to Stäubli connectors might signify an absolutely minor cost differential: That means a potential saving of no more than 0.001% 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 minor 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.



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

OPERATION (OPEX)



[Return: Symbolic representation of the risks that depend on several factors. They might as well occur simultaneously]

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.

Wrong connector selection can lead to higher operating and maintenance expenses (OPEX) and lower energy yield over time (>25 years).

Result: Lower efficiency of the PV system and a negative impact on the Return on investment and the LCOE.

Project Bankability – Sources of risk

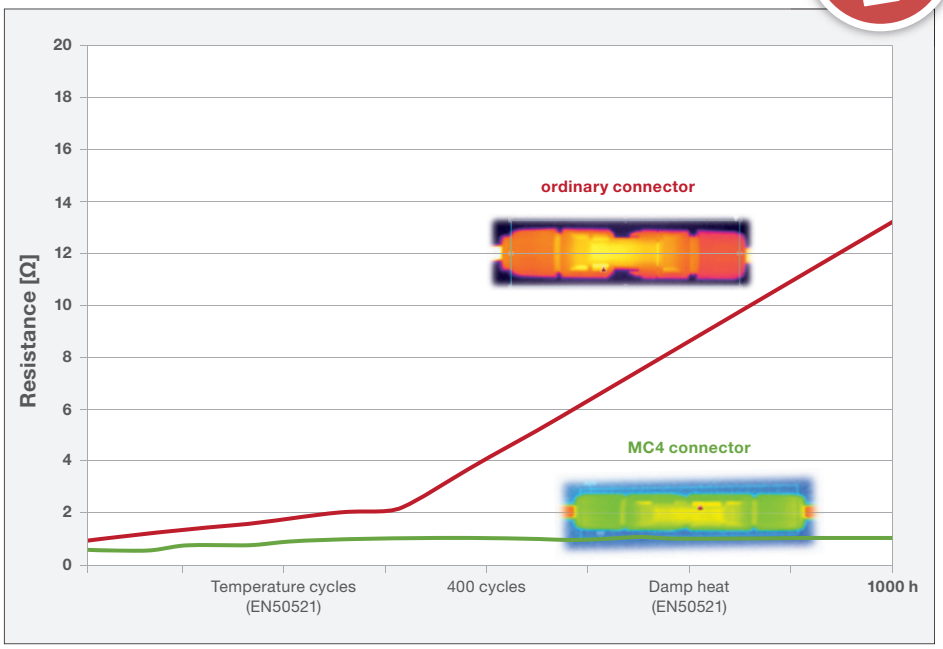
There are three main risk sources, which can lead to the mentioned consequences. Not only selection of quality components but also the correct handling is hereby relevant.

1. Quality vs. Low-end Product

2. Cross-Connection

3. Defective Installation/Crimping

1. CHOOSING LOW-QUALITY CONNECTORS OVER QUALITY CONNECTORS



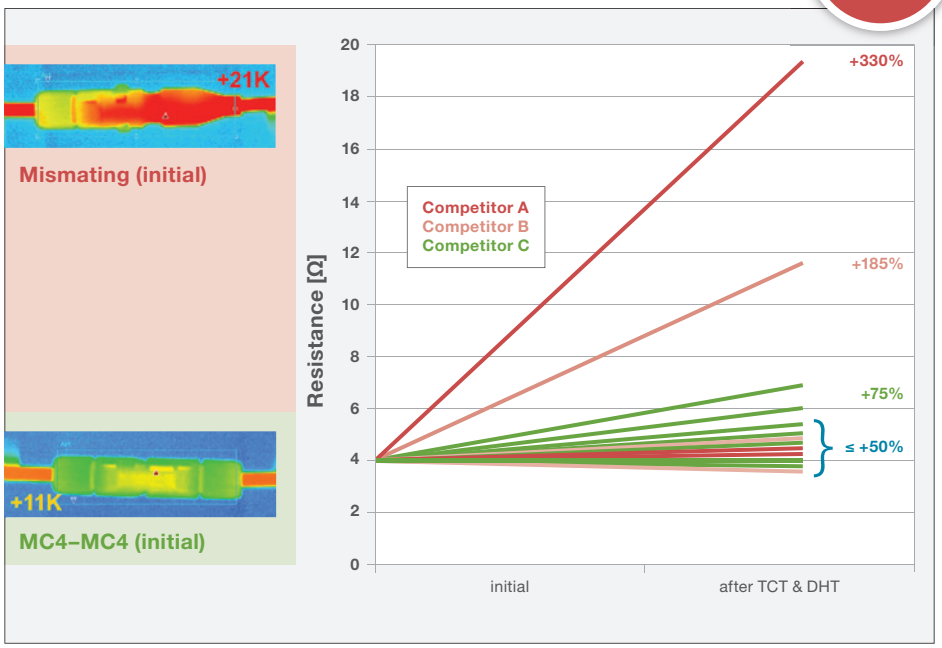
The original MC4 connector is almost totally stable in terms of temperature: there is no heat accumulation thanks to the tried and tested MULTILAM technology. The use of Low-end connectors, however, is very risky as the strongly increasing contact-resistance curve illustrates.

Consequences:

- Performance losses, higher PPM-rates and downtimes of modules, strings or plants
- High service/maintenance and spare part costs for repairing
- Hotsopots and fire in PV system and reconstrucion costs
- High costs for legal disputes due to undefined liabilities

With Stäubli original 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 features 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.

2. AVOID CROSS-CONNECTIONS



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

Original MC4 vs. ordinary connectors: Higher temperature and extremely increasing contact-resistance-curve for the competitor products after a TCT (Temperature Cycle) & DHT (Damp Heat) testing.

Always pay attention to use Stäubli components during the whole installation process. By mismating or cross-connecting, you easily entail **technical as well as legal risks** due to:

- Deficient technology and product material.
- Different production process – capacity and quality standards.
- **All tolerance zones** have to be aligned ensuring tightness as well as sufficient high contact forces even in case of mating extreme tolerances.
- The **chemical compatibility** of all raw materials (including production and auxiliary materials) have to be ensured.
- All changes of the **production process** have to be investigated with respect to possible interactions.
- Certification and Standards are given for one product from one manufacturer; those are not manufacturer-independent.

Different norms and regulations, which declares very clearly there is no compatibility between two different connectors. No certification according to EN50521, IEC62548 or TÜV:

- No warranty/guarantee.
- Question of guilt: Who is responsible/ liable?
- Submitting a case to the court always involves high costs and bother over a long period.

Consequences:

- Performance losses, higher PPM-rates and downtimes of modules, strings or plants
- High service/maintenance and spare part costs for repairing
- Hotsopots and fire in PV system and reconstrucion costs
- High costs for legal disputes due to undefined liabilities

3. DO CORRECT INSTALLATION AND CRIMPING

Simple crimp tool

Certified crimp tool

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, often due to false crimping. 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-fulfilment of the norm criteria.
- Unstable contact resistance.
- No gas-tightness.

The problems/risks mentioned above might also occur due to a defective installation.

Consequences:

- Performance losses, higher PPM-rates and downtimes of modules, strings or plants
- High service/maintenance and spare part costs for repairing
- Hotsopots and fire in PV system and reconstrucion costs
- High costs for legal disputes due to undefined liabilities

In brief – Low saving potential but high impact on ROI

Small components, low costs, low saving potential

0,003% For Connectors

Original MC Connector

Low end Connectors 30% cheaper

0,001% Potential Savings

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

vs.

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 – making compromises with quality usually is accompanied with high losses and risks that could be avoided. Yet, there are several factors influencing LCOE and return on investment.

Always pay attention to the fact that there are multiple deciding factors when it comes to safe connection. Important decisions have to be made before as well as during the installation process.

1. Quality vs. Low-end Product

X

2. Cross-Connection

X

3. Defective Installation/Crimping

X

Multiplying factors

- Plant design/technology (module, inverter).
- Connector(s) affected (module, string, inverter).
- Downtime per connector
- Price/feed in tariff per kWh
- Hourly rate service rate
- Number/price of connectors
- …

lost kWh contact resistance

lost kWh downtime

service hours spare parts costs

restruction costs due fire

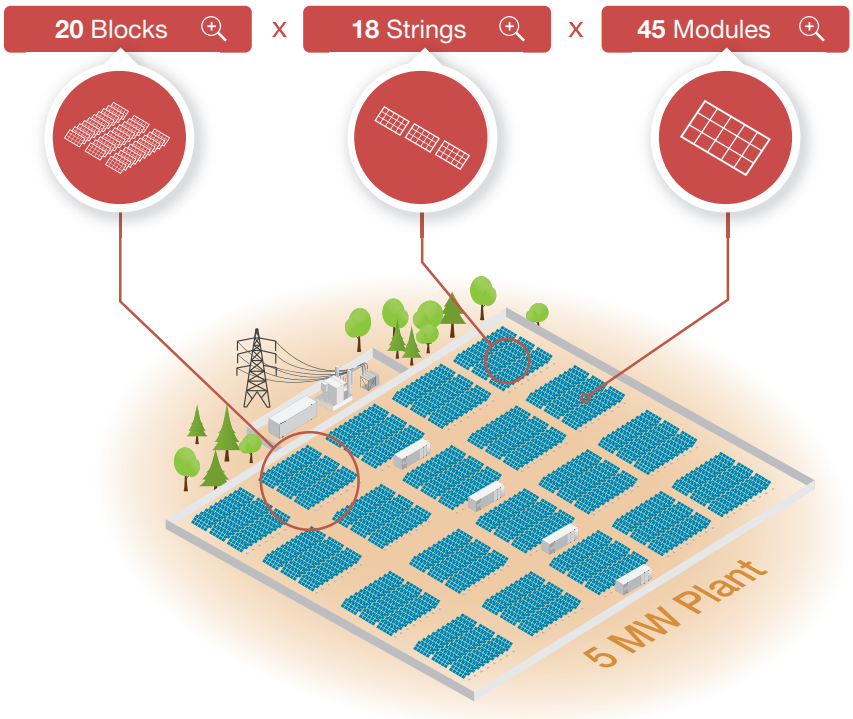
legal costs

Practical example – 5MW PV ground-mounted plant

A common 5 MW plant consists of 20 blocks containing 18 strings with 45 modules each. This makes all in all about 32’000 connectors on modules plus approx. 3’000 for field assembly/installation. This makes in total approx. 35’000 connectors – 35’000 small details to influence LCOE as well as ROI positively. In the case of downtime, defect connectors disable current flow and inevitably stop the energy feed-in. However, the failure of only one single connector can also entail the outage of an entire string.

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.

An average **5’000 kW x € 8.34 = € 41’700 per year loss due to cabling/connector failure**.



[Depending on: Detailed planning, project dimension & design, construction, location, components, etc.]

35’000
Connectors

35’000
Details to influence **your** ROI positively

1. Choose original MC Connector
2. No cross-connection
3. Correct installation

Minimize risk, maximize return

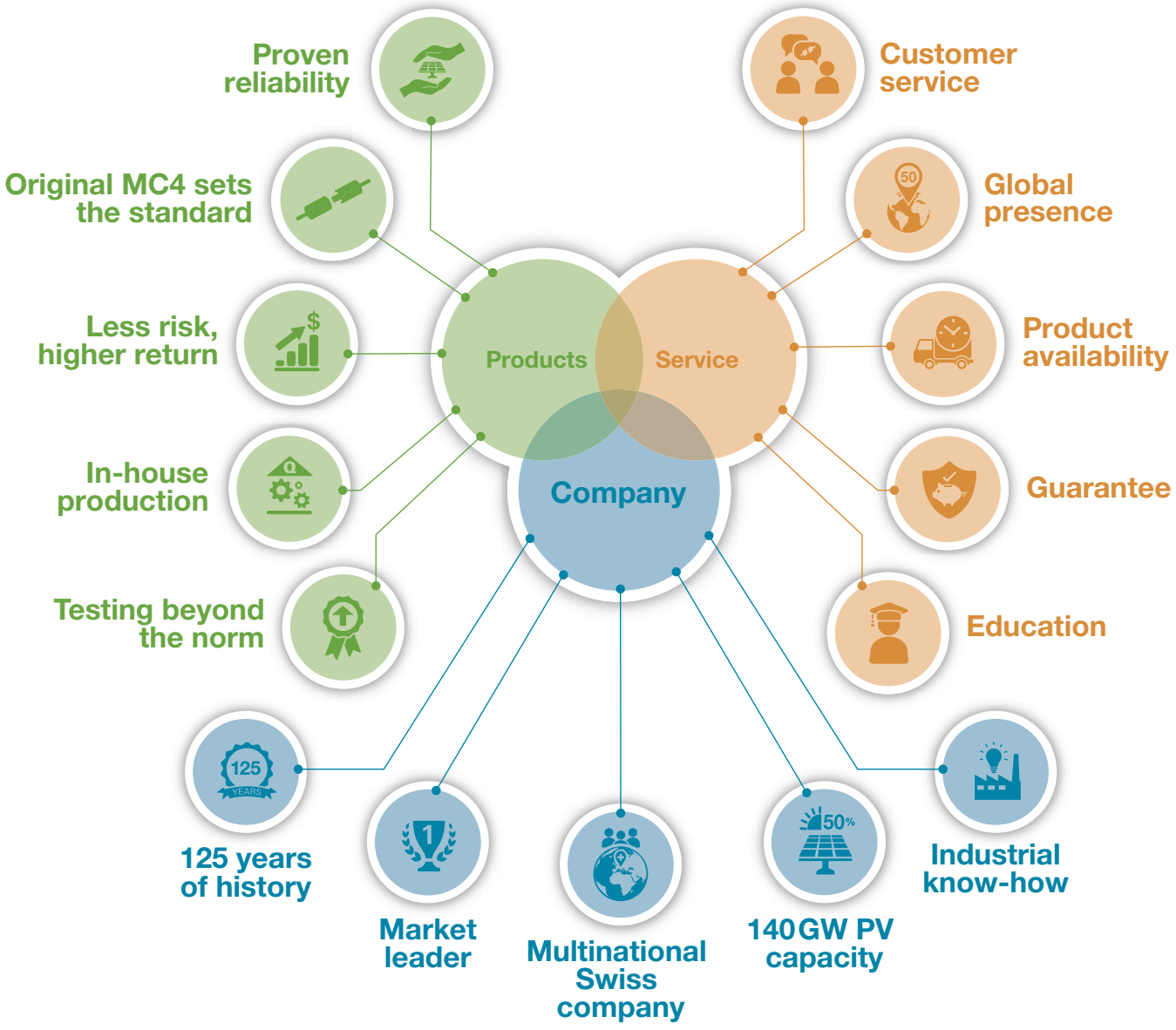
Why Stäubli is the bankable partner for PV Cabling

After all, bankability is not only a term used to describing the degree of financial risk, but also a **matter of trust**.

The attention Stäubli pays to every detail is what creates trust and makes us a bankable partner and supplier of reliable components that keep your PV installation up and running efficiently and safely. By choosing Stäubli, you benefit from profound expertise, extensive support and long-life connectors that help you to obtain a low LCOE.
There are several reasons that make Stäubli Electrical Connectors your ideal partner.

With us, you are entering into a long-term partnership built on reliability, dynamism and exceptional quality in both products and services. Stäubli Electrical Connectors – is more than "just" a product.

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?



Company – Our attention to detail builds trust. And trust builds best results.

125 years of experience

Stäubli Electrical Connectors (formerly Multi-Contact) is part of the Stäubli Group, a **technology leader and pioneer** in the fields of electrical and fluid connectors, robotics and textile machinery since its foundation in 1892. Together with the company formerly known as Multi-Contact, which was founded in 1962, we have nearly **55 years of practical experience** producing reliable electrical connectors for photovoltaics and other industries. A **passion for quality and innovation**, inherited from long industrial experience, is our fundamental driving force.

Global market leader

We have been the **pioneer** and market leader for electrical connectors in photovoltaics for **more than 20 years**. Our position on the global market is the result of our **continuous efforts to meet and exceed our customers' demands**. We never compromise when it comes to quality, long-term reliability or our partners' success.

Multinational Swiss company

A **workforce of nearly 5,000** employees worldwide enables us to maintain a strong global network. However, we are still **rooted in Switzerland** and look back on a great history and remarkable heritage. Typical values such as **quality, reliability and trust are held in high esteem** and are at the basis of our customers' success as well as our own.

150 GW PV capacity

Entering 2017, we have more than 150 GW of installed photovoltaic capacity, amounting to **50% of the global cumulative PV capacity**, that had been successfully connected using our Stäubli photovoltaic connectors. This figure **demonstrates the reliability and highest quality** of our products. They guarantee **proper operation over their whole lifetime** (>25 years) and have a positive impact on the bankability of photovoltaic projects.

Industrial know-how

Our industrial expertise can help you. We are a forward-looking company on a constant quest for the next great innovation that will **help our customers to work more productively, efficiently and sustainably**. We cover the whole process from idea to end product, offering standard products as well as customized solutions to meet individual customer requirements.

Product – We don't just make quality. We live it.

Proven reliability

More than **1 billion photovoltaic connectors** in the Stäubli MC4 connector family have been successfully connected worldwide over the **past 20 years in the harshest environments**. We are the only supplier to have this remarkable track record. The reliability of Stäubli products is unmatched.

Original MC4 sets the standard

The first industrial photovoltaic connector (MC3) was introduced by Stäubli in 1996 followed by the **original MC4** in 2004 setting the **industry standard** ever since. The exclusive **MULTILAM advanced contact technology** raised the bar in terms of consistent quality and **outstanding reliability**.

Less risk, higher return

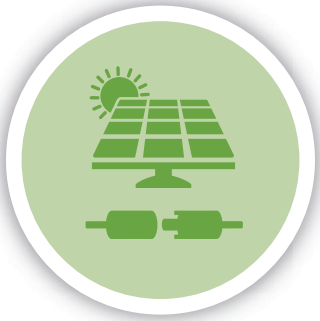
Photovoltaic connectors may be **small components, but they have a big impact** and directly **influence the bankability/LCOE** of a PV plant. The use of reliable, long-lasting Stäubli photovoltaic connectors guarantees **low service cost, low power losses** and reduced downtime due to their low contact resistance, as well their **elimination of risks for hotspots and fire**.

In-house production

Instead of outsourcing, we set a high value on the **local production** of our components in Switzerland and Germany, as well as on the **assembly in our factories** in Germany, the USA and China. Furthermore, we are able to offer and arrange **customer audits**. Our combined technical expertise as well as our control of production and supply processes enables us to **guarantee quality in terms of functionality, safety and material characteristics**.

Testing beyond the norm

We pride ourselves in **meeting all the requirements of the global market** and are a certified manufacturer. Complying with international standards is fundamental for us. Stäubli sets an even higher value on **field data, testing by customers and long-term in-house testing:** our clients' success stories are what motivate us.



Service - We stand by your side as your partner – in every part of the world.

Education

Thorough education is our utmost concern as it is at the basis of engineering and manufacturing high quality products. We strongly support **continuous knowledge acquisition and staff training**. Furthermore, we try to improve our customers' education by means of key industry conferences, workshops and webinars.

Guarantee

We attach great importance to ensuring our components are of the highest quality and reliability. Our products are therefore subjected to t**horough durability and quality testing** before delivery. Furthermore, we learn continuously from **field experience**.

Product availability

Many components are kept in our product range on **a long-term basis**. This enables us to deliver parts even after long periods of time, which is especially important for the **retrofitting of existing PV plants**. We do our best to guarantee **short delivery times and logistics support** for our customers.

Global presence

We are a multinational group with a presence in **25 countries and agents in 50 countries** on five continents. Our strong **global network** enables us to provide close contact with customers through **local support**, as for example through our sales and service subsidiaries. Our qualified **team of experts and sales reps in the field** provide comprehensive global support.

Customer service

Customer service is high on our list of priorities. We therefore provide **expert advice and the best possible support** to help our clients with their concerns – however challenging they may be. We do our best to **help you with all your requirements** regarding products, projects and services.

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■ Stäubli Units ○ Agents

Global presence of the Stäubli Group

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