

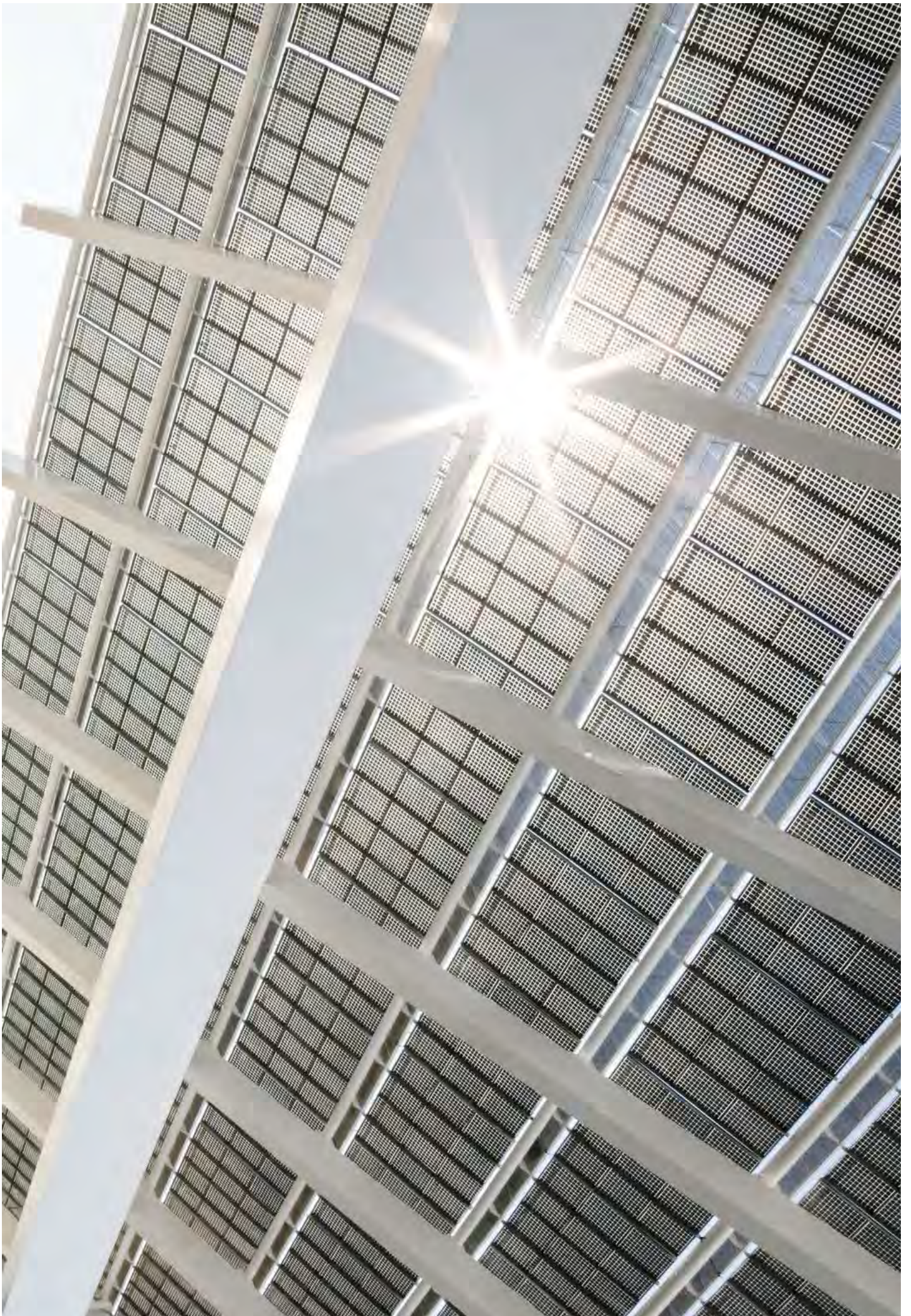
FAST MOVING TECHNOLOGY

STÄUBLI

Small components. Big impact.

Solarline | Connectors for renewable energy





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.

Minimizing CAPEX

In view 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 save money on the components – often already during the phase of design.

Securing profitability

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.

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 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.

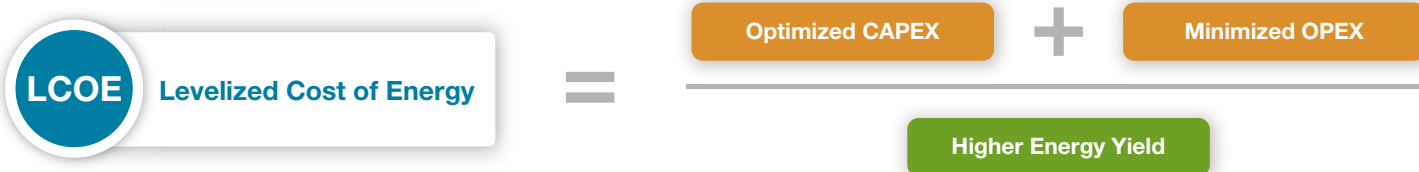


Figure 1: Composition of LCOE.

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.



www.staubli-alternative-energies.com

THE CONCEPT OF BANKABILITY

Minimizing risk, maximizing return

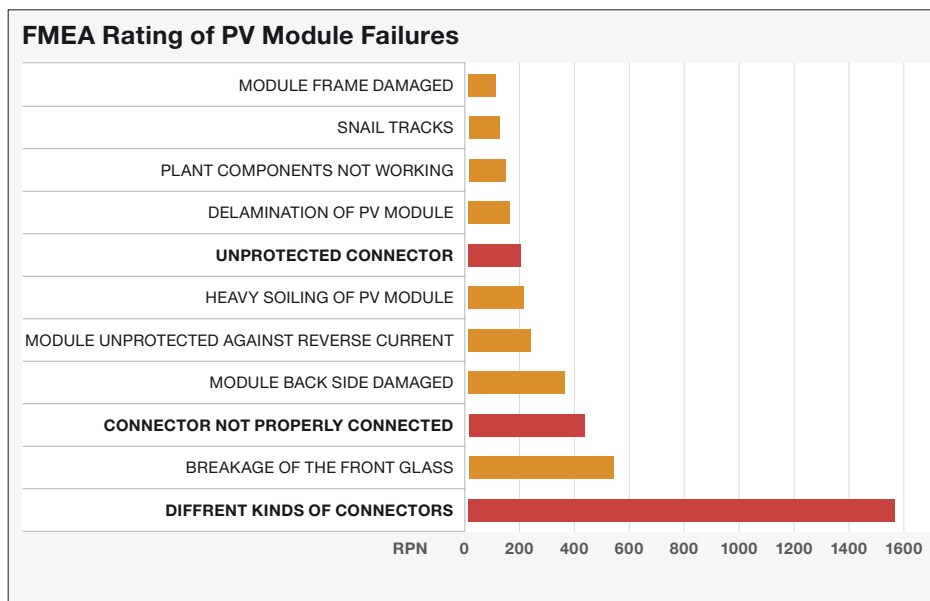


Figure 2: FMEA Rating of PV Module Failures by TÜV Rheinland.

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 ($RPN = S \times O \times D$). The higher the RPN, the higher the risk and substantial consequences on the PV plant and its profitability.

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. That 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 the project-due-diligence to rate from risk-perspective the reliability of the project-cash-flow.

The stakeholders go through review process and have to be rated as bankable in order to improve chances of a positive financial decision as well as to manage and mitigate risk.

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. 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 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, 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 tries to define 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.

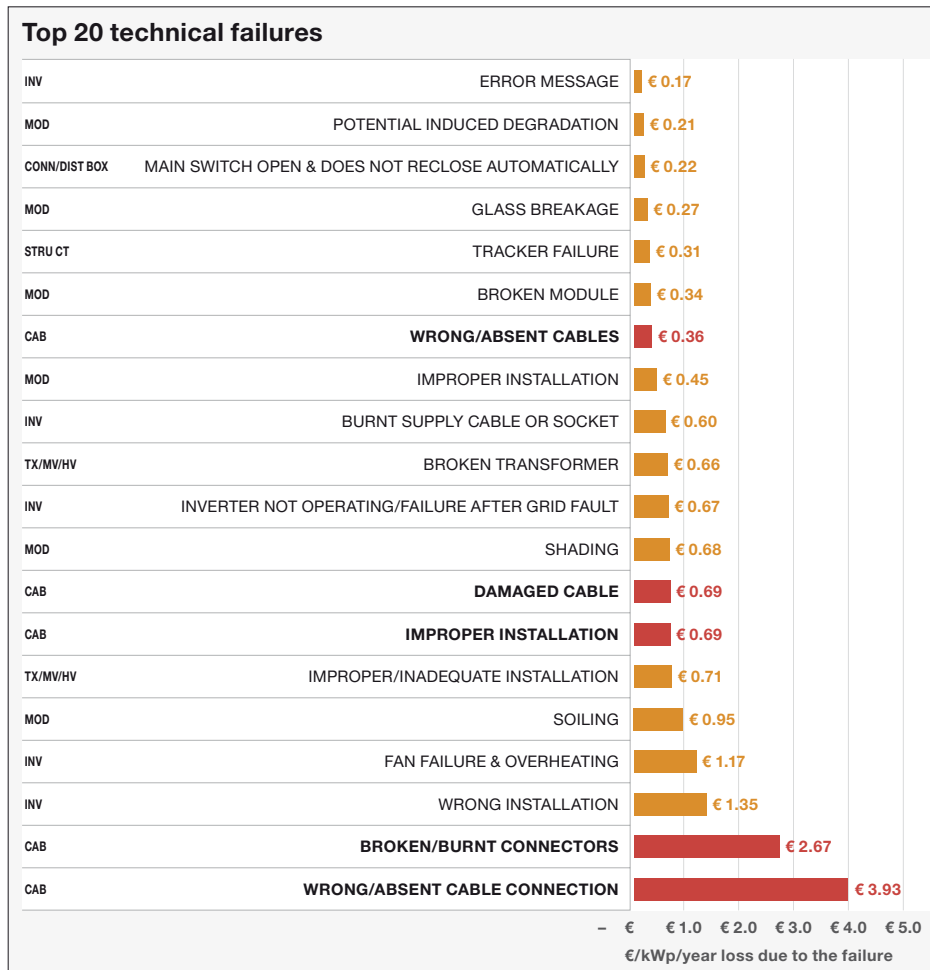


Figure 3: Calculation of the economic impact: Solar Bankability is a project funded by the European Commission's Horizon 2020 program (www.solarbankability.org).

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.

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 in order 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)



CONTACT RESISTANCE

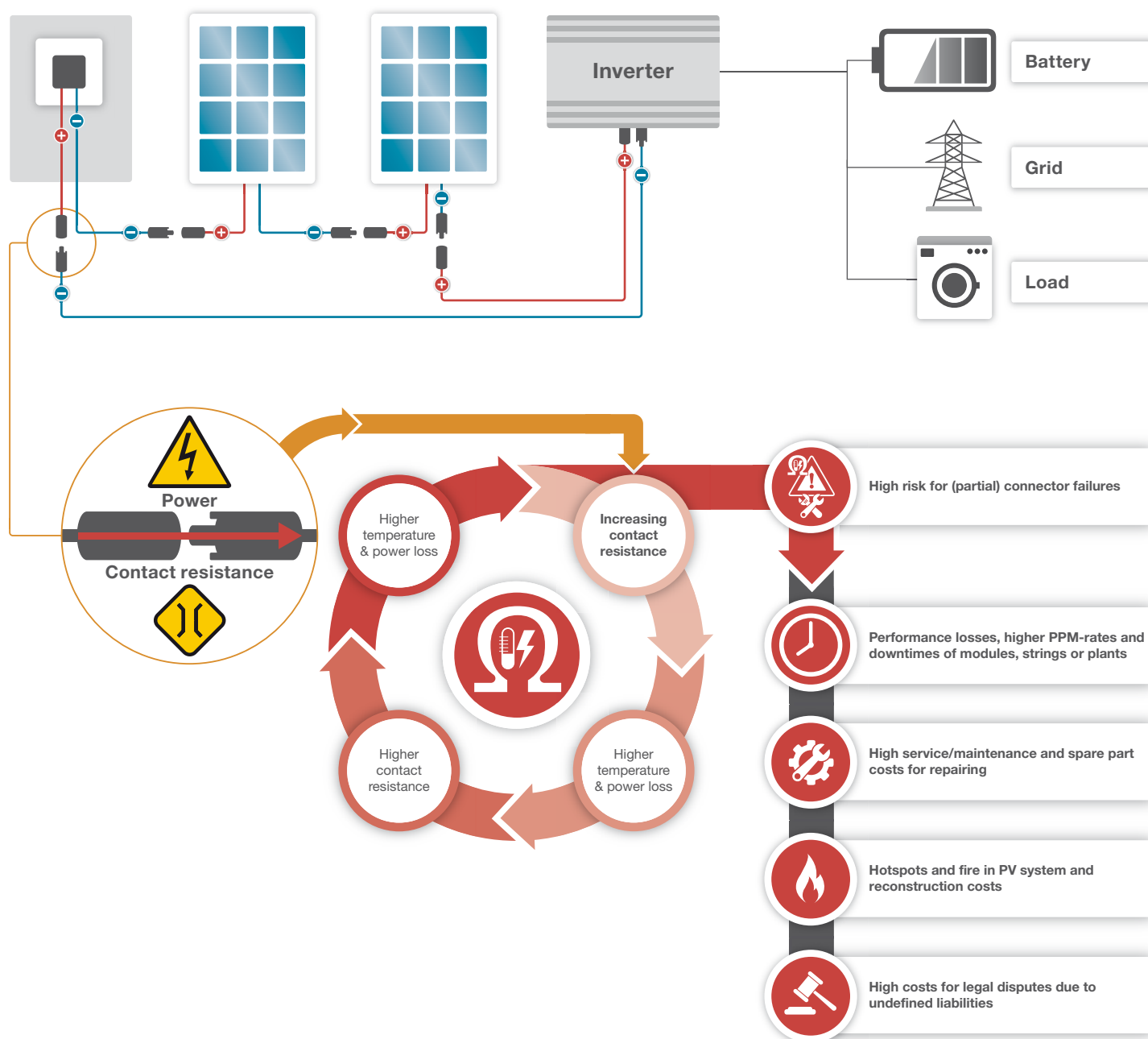
Why do connectors have such a big impact?

The bankability of a PV project is at risk when several risk factors endanger the operation of the 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 below illustrates.



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. 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.

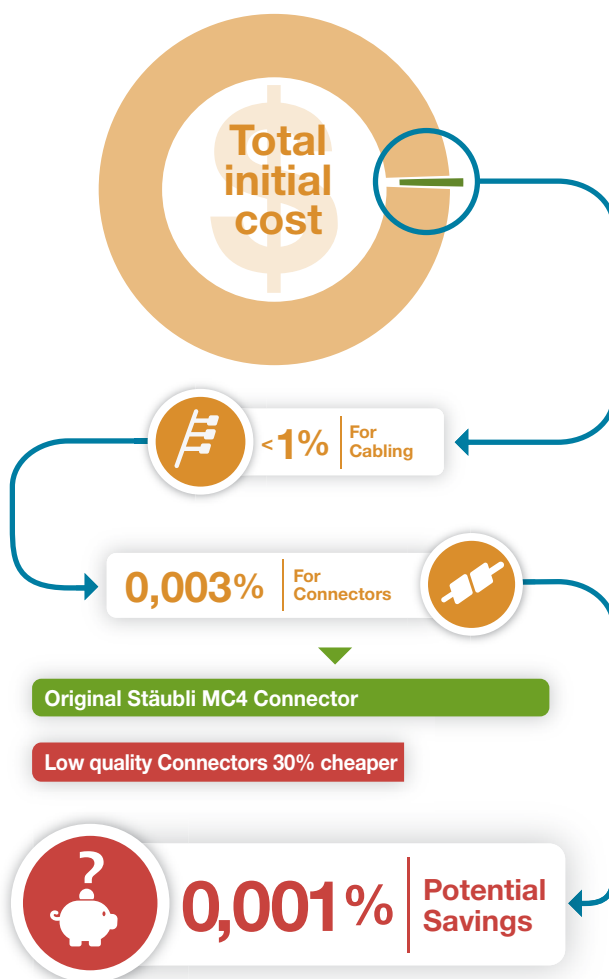


Figure 4: Investment: Costs are depending on correct and detailed planning, project dimension and design, construction, location etc.

Operation (OPEX)

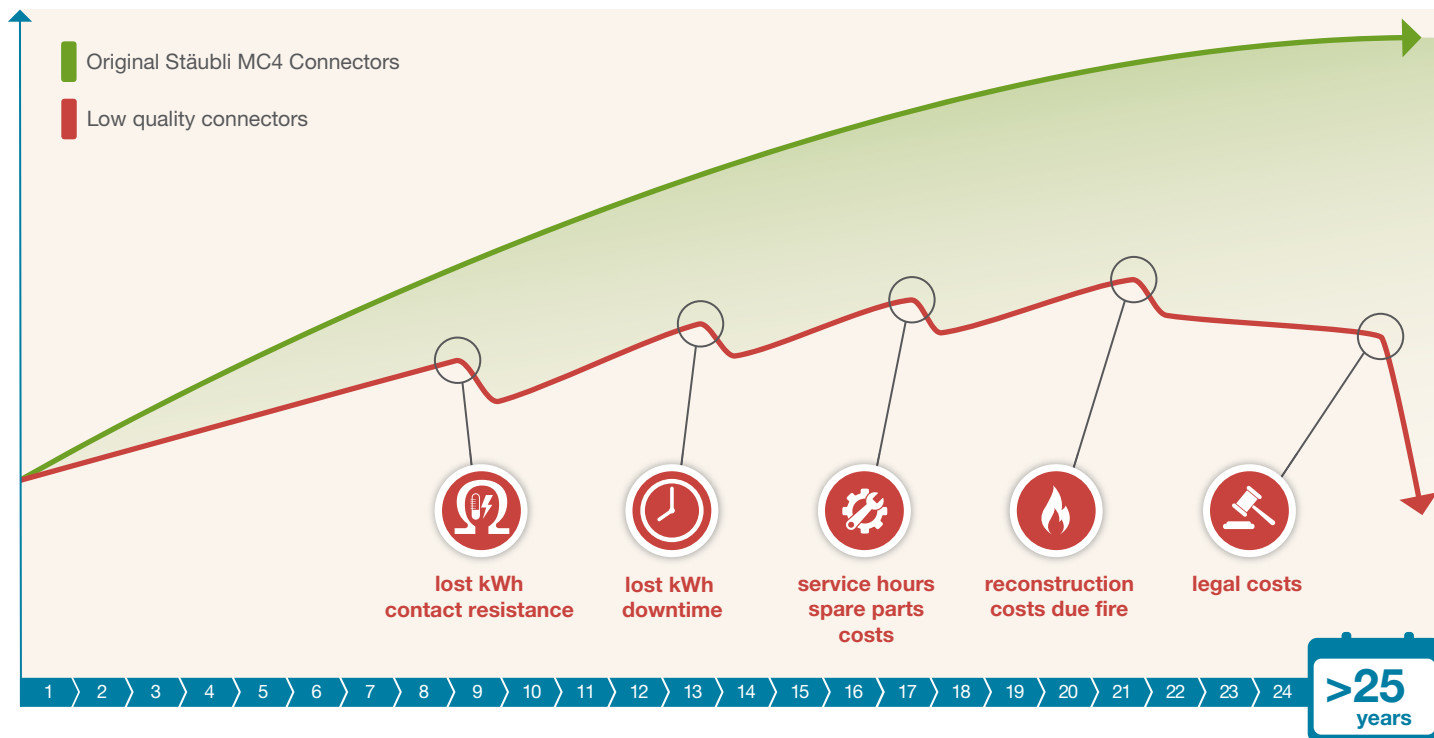


Figure 5: Symbolic representation of the risks that depend on several factors. They might as well occur simultaneously.

Safe operation in the long run

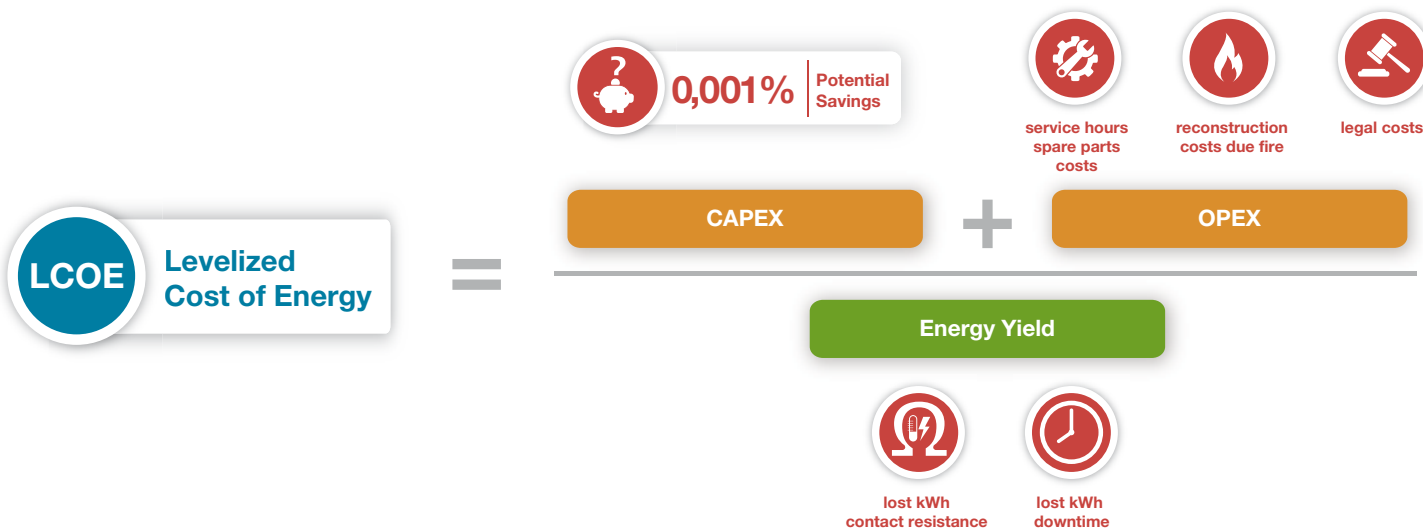
During the project planning phase, it is also absolutely important to take into consideration that the plant engineering is designed for an operational phase often exceeding 25 years. That means that all the components should provide longevity as well as

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.



PROJECT BANKABILITY

3 sources of risk

Not only the selection of quality components, but also their correct handling are 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

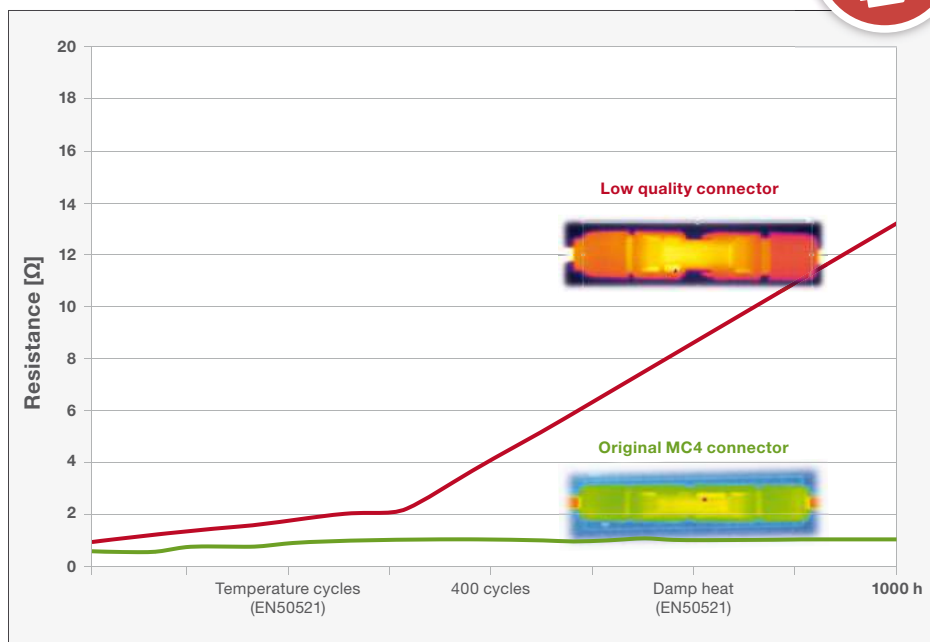


Figure 6: Diagram of increasing contact resistance and temperature due to low quality.

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:



High risk for (partial) connector failures



Performance losses, higher PPM-rates and downtimes of modules, strings or plants



High service/maintenance and spare part costs for repairing



Hotspots and fire in PV system and reconstruction costs



High costs for legal disputes due to undefined liabilities

2. Avoiding cross-connections

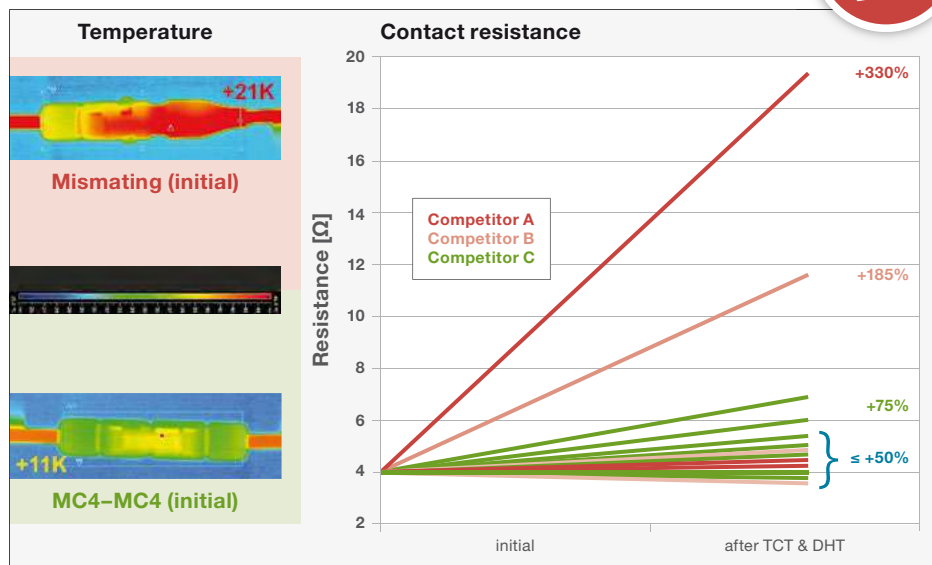


Figure 7: Diagram of increasing temperature and contact resistance due to cross-mating.

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.



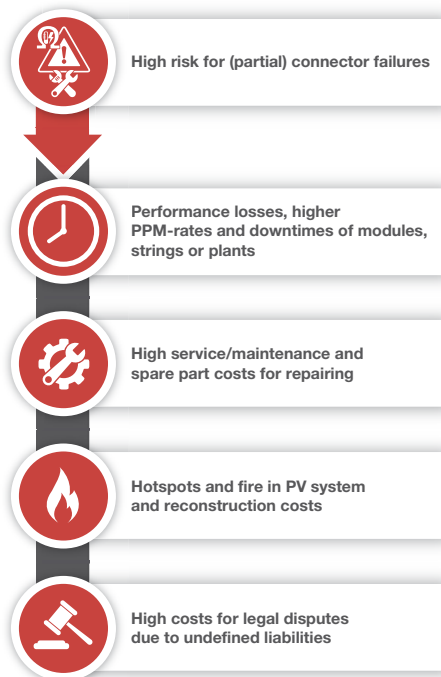
By mismatching or cross-connecting, you easily entail technical as well as legal risks. Therefore, it is important to always use Stäubli components during the whole installation process (from module to inverter).

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 norms (UL1703 and IEC62548 installation norm) and regulations, which disallow cross-mating of two different brands and studies/field data which prove very clearly there is no compatibility between two different connectors. Furthermore, the certification for the EN50521 product norm will be 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.

Consequences:



3. Correct installation and crimping

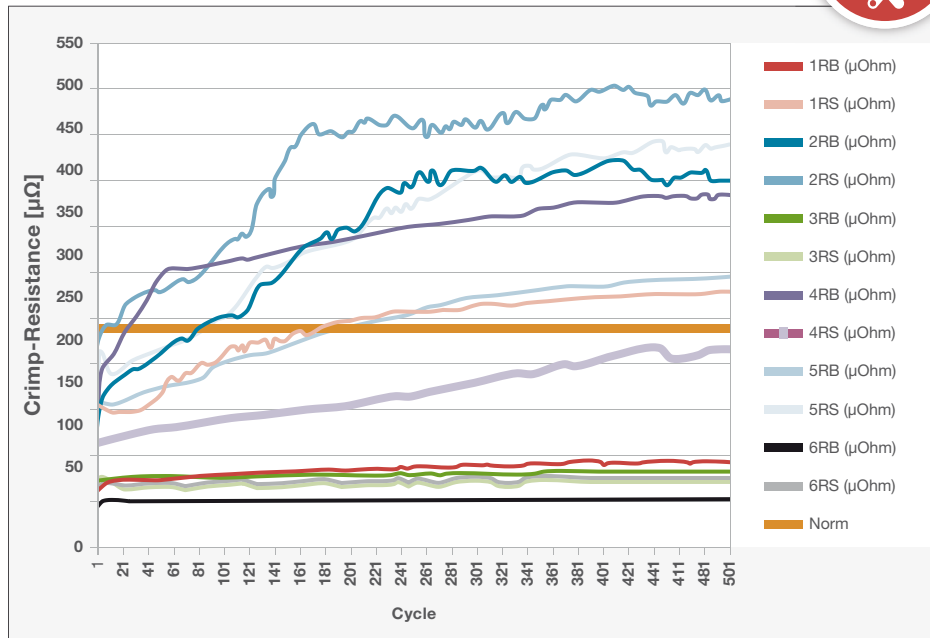


Figure 8: Diagram of crimp resistance forces.

Another risk for the neat functioning and profitability of a PV plant might result from defective installation. This often results from false crimping. Therefore, 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:

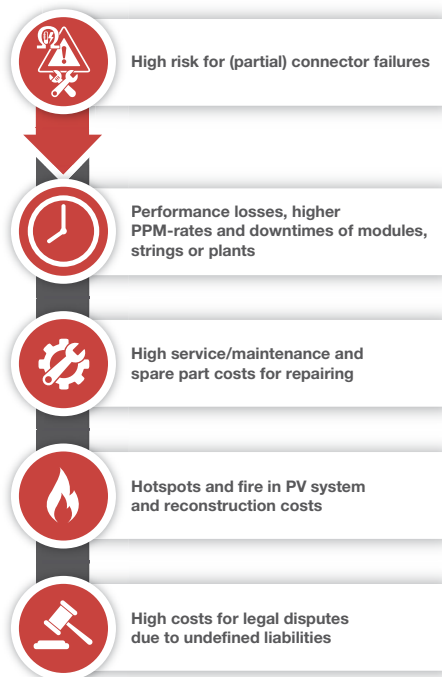
- Non-fulfillment of the norm criteria
- Unstable contact resistance
- No gas-tightness

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



Rolling-in of crimp area is not uniform

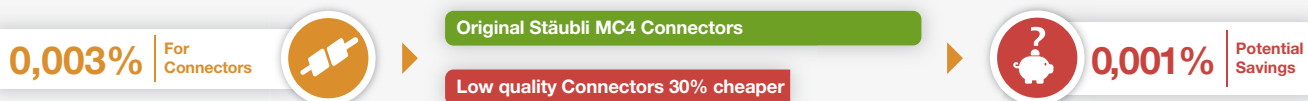
Consequences:



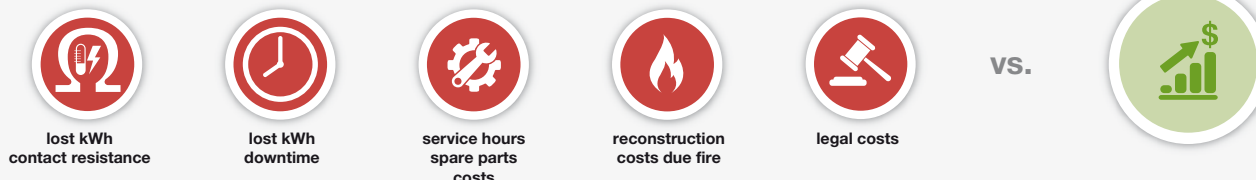
IN BRIEF

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



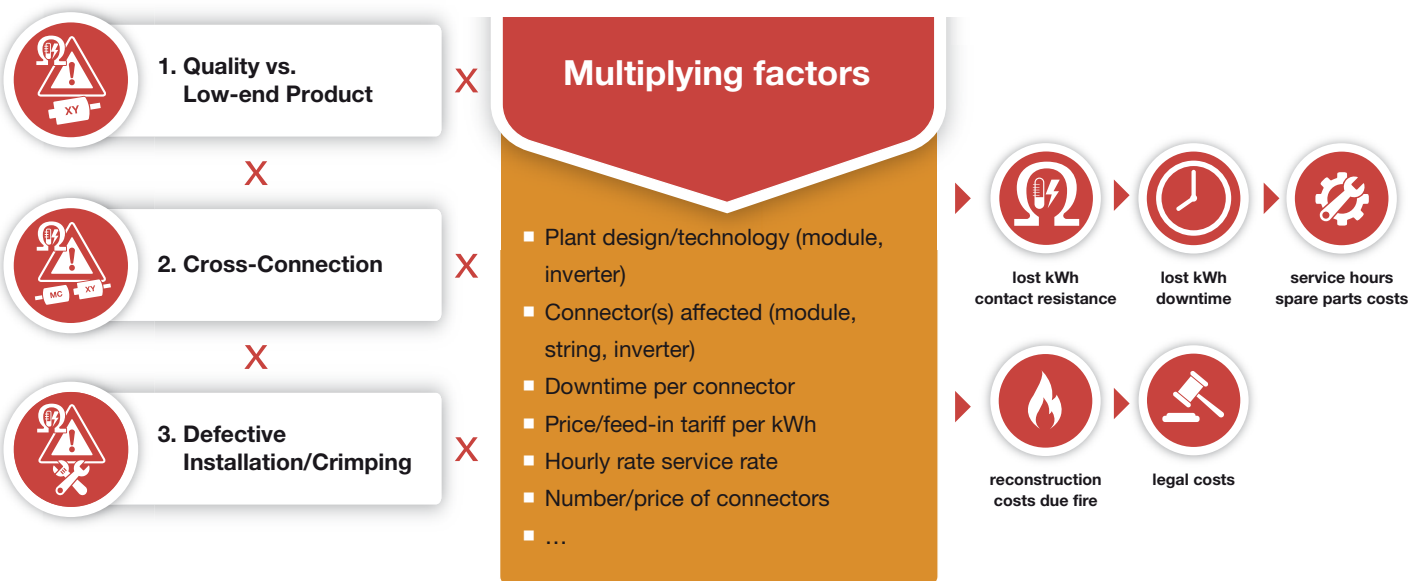
Connectors may be small components, but their influence on the efficiency and bankability of a PV project is undeniable. Saving money on connectors means saving at the wrong place as making compromises with quality usually is accompanied

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

5 MW PV ground-mounted plant

In this example the 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. In total, there are approx. 35'000 connectors representing 35'000 small details to influence LCOE as well as ROI positively. In the case of downtime, defective connectors disable current flow.

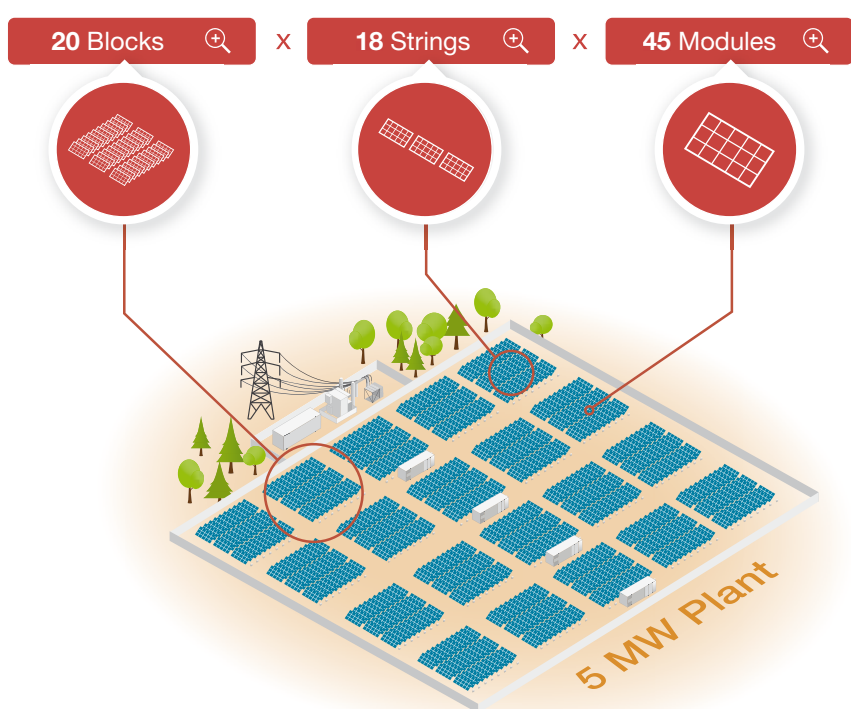
However, the failure of only one single connector can also entail the outage of an entire string.

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 5'000 kW plant, we calculated on the basis of the FMEA/CPN rating by Solar Bankability Project, as seen previously. That would be 5'000 x € 8.34 = € 41'700 per year loss resulting from cabling/connector failures solely.



35'000 Connectors

35'000
Details to influence
your ROI positively

- 1 Choose original Stäubli MC4 Connector
- 2 No cross-connection
- 3 Correct installation



**Minimize risk,
maximize return**

Figure 9: Numbers can differ depending on detailed planning, project dimension and design, construction, location, components etc.

CORPORATE BANKABILITY

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.

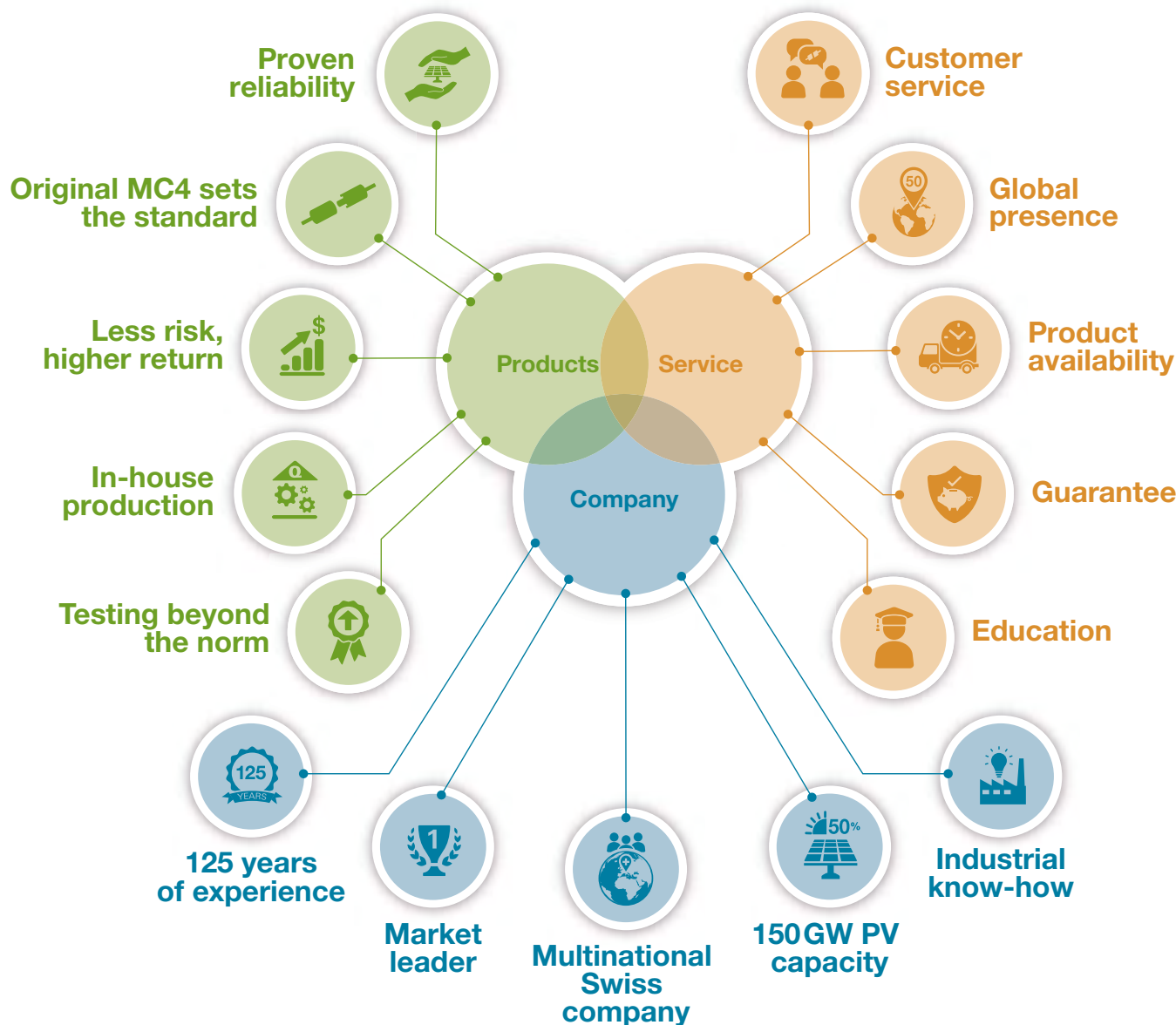
The attention Stäubli pays to every detail is what creates trust and makes us a bankable partner and supplier of reliable components that keep your PV installation up and running efficiently and safely. By choosing Stäubli,

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.





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 4'500 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.



PRODUCTS

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 2002 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.



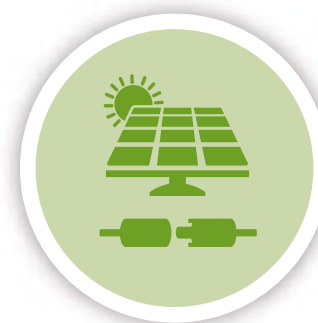
In-house production

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 thorough 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 29 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.







■ Staubli Units ○ Agents

Global presence of the Staubli Group

www.staubli.com