Small components. Big impact.

Cabling of PV installations – Key factors for a successful long-time reliability

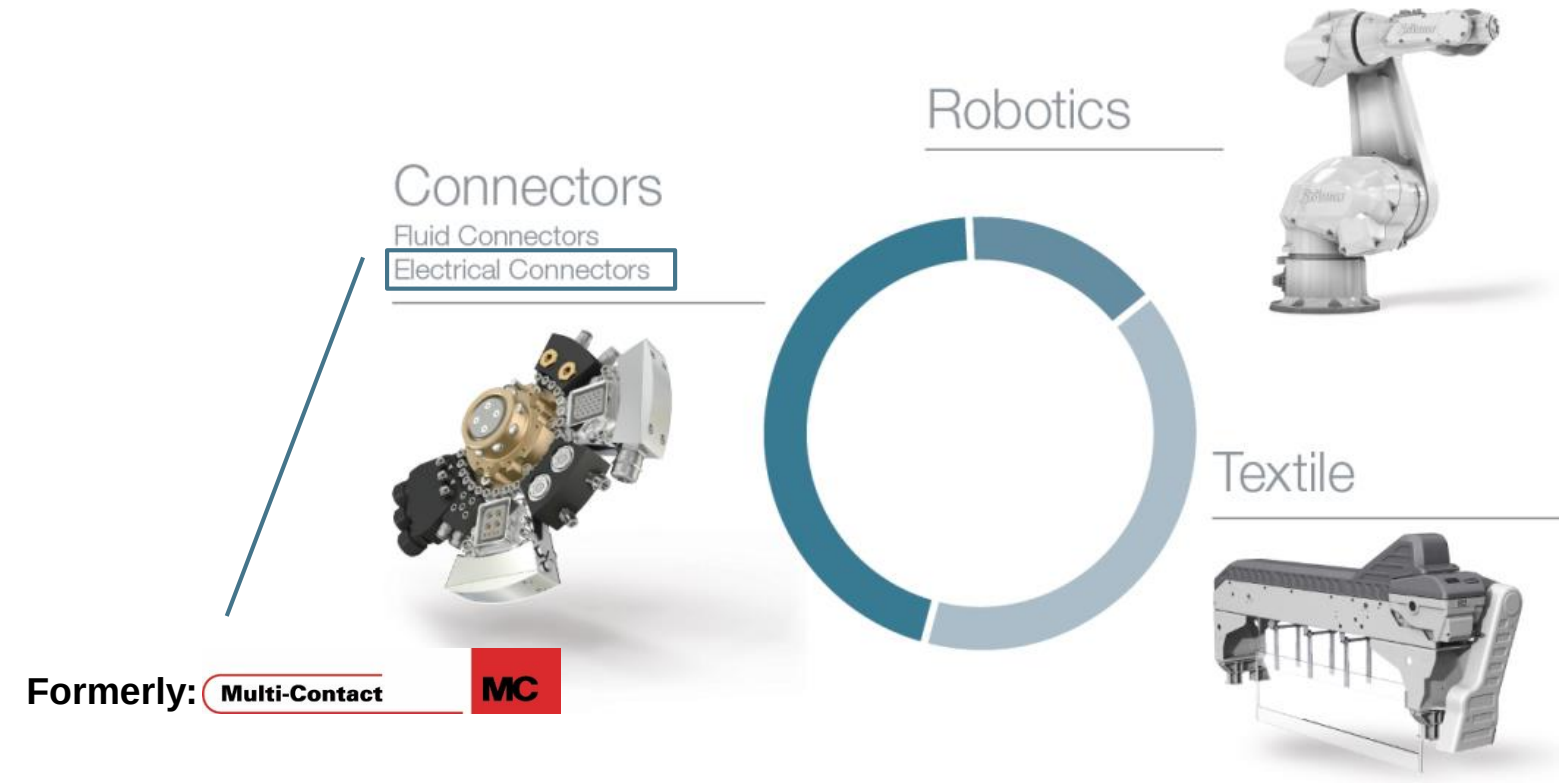
PV Magazine Insight on Quality– @ All Energy Australia

Stäubli Group – three activities, four divisions

> 125 years experience

> 5500 employees in 29 countries

> 300 GW PV connected

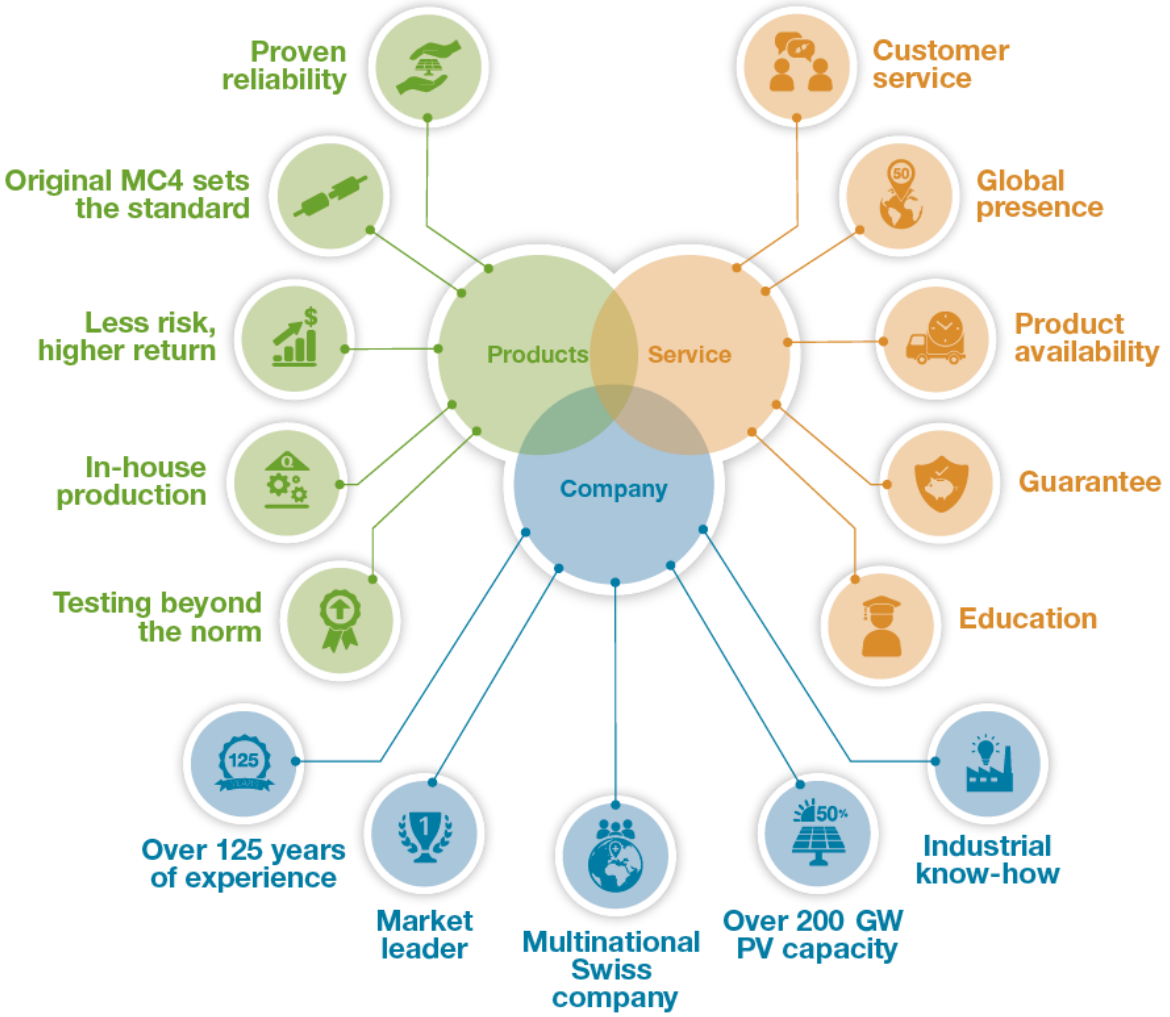


Your bankable partner – More than “just” a product

Products

Company

Service



Cabling of PV systems – You can't manage the unknown

Lack of knowledge about eBoS components (cabling/ connectors) …

- Component → technology, norms, materials, production processes
- Installation → norms, tools, assembly instructions

… and their relevance for the long-term success of a PV system

- Technical issues and their root cause
- Consequences/ risk on safety, efficiency (LCOE), profitability (ROI)

Resulting in eBoS components failures

Higher costs and losses

(Credit: Walmart lawsuit)

Failures and their financial impact

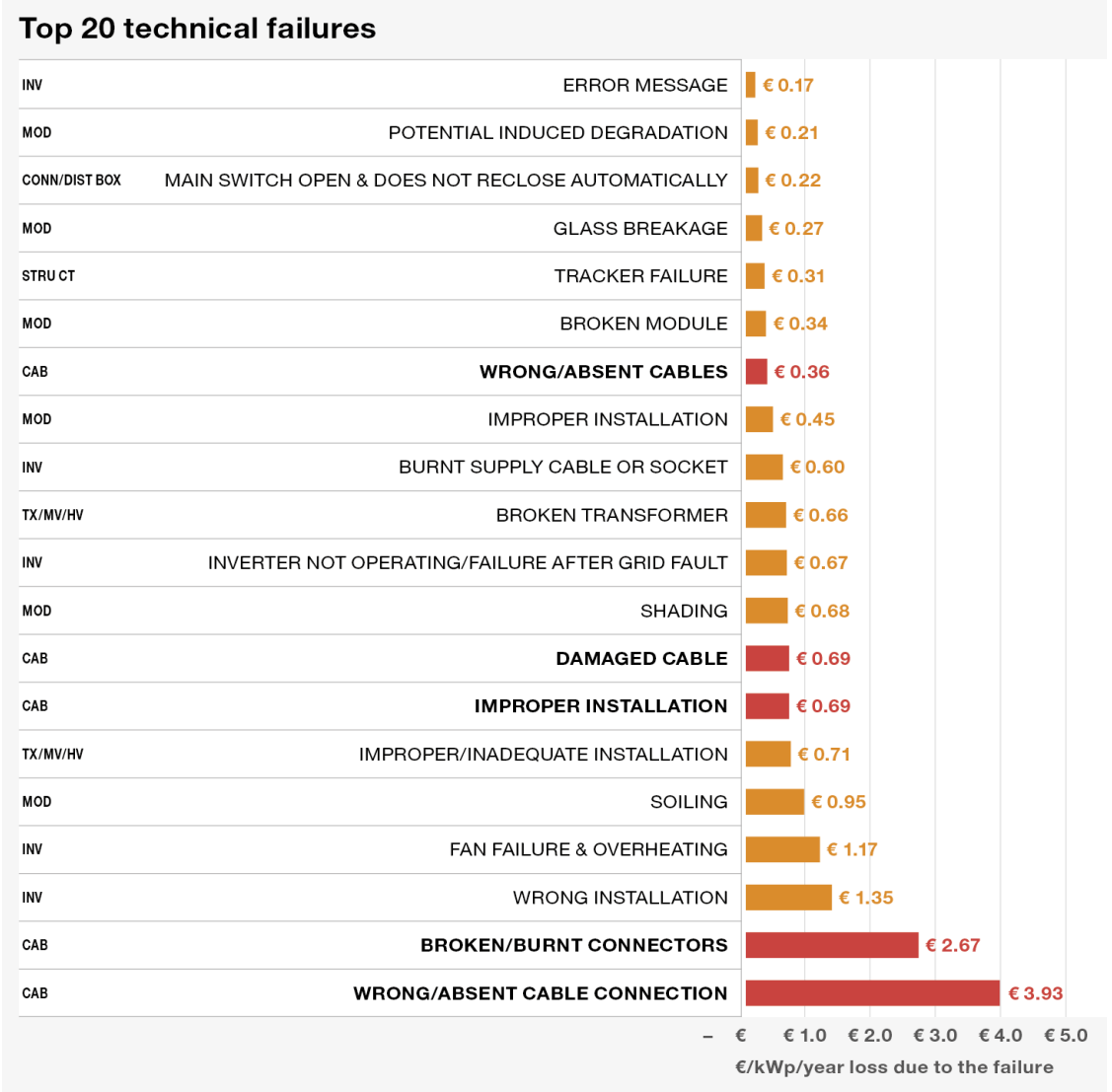
Solar Bankability project by European Commission's Horizon 2020

Common practice for professional risk assessment to reduce risks for investments in PV projects

- CPN (cost priority number) = cost-based failure mode and effects analysis (FMEA)
- Method was applied to database of >1 million documented failure claims (empirical and statistical)
- Technical failures/risks and their economic impact due downtime and/or power loss & repair/substitution costs
- Indication of the economic risk (in average) of a specific technical risk

Cable & connector with huge financial impact
→ Euro/ kWp/ year loss due to the failure

Risk mitigation measures with objective to minimize the LCOE by optimizing the balance between CAPEX & OPEX



*www.solarbankability.org

Failures in PV systems – You can’t manage the unknown

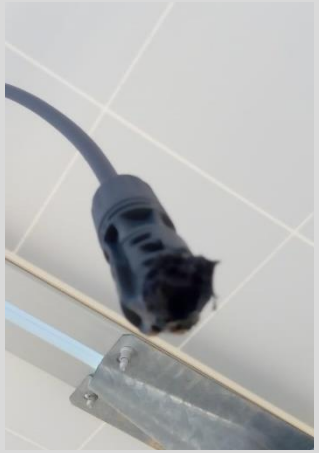
(Credit: Walmart lawsuit)

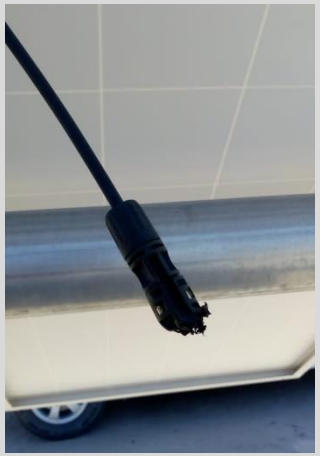
After reviewing the damage caused by fires, Walmart said in some instances it appeared Tesla personnel made cable connections using connectors that were not compatible.

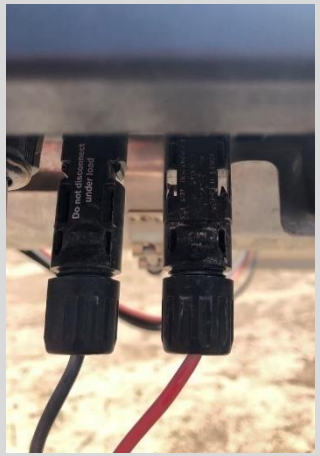
Walmart said its investigations "quickly discovered that Tesla routinely deployed individuals to inspect the solar systems who lacked basic solar training and knowledge."

Failures in PV systems – Case study

Site location: LATAM
Size: **>** 500 MW
Inspection: **<** 6 months after site completion







Failure pattern

- Broken/ burned connectors (several per week)
- Low-voltage at inverter caused by connectors

Consequences

- Performance loss (downtimes)
- Extra service/ repair cost
- Connector insurance claim to module maker and warranty claim to EPC for un-proper installation
- “Hand-over” to O&M company postponed

Solution

- Replacing failed connectors → change of complete system cabling?

Financial impact

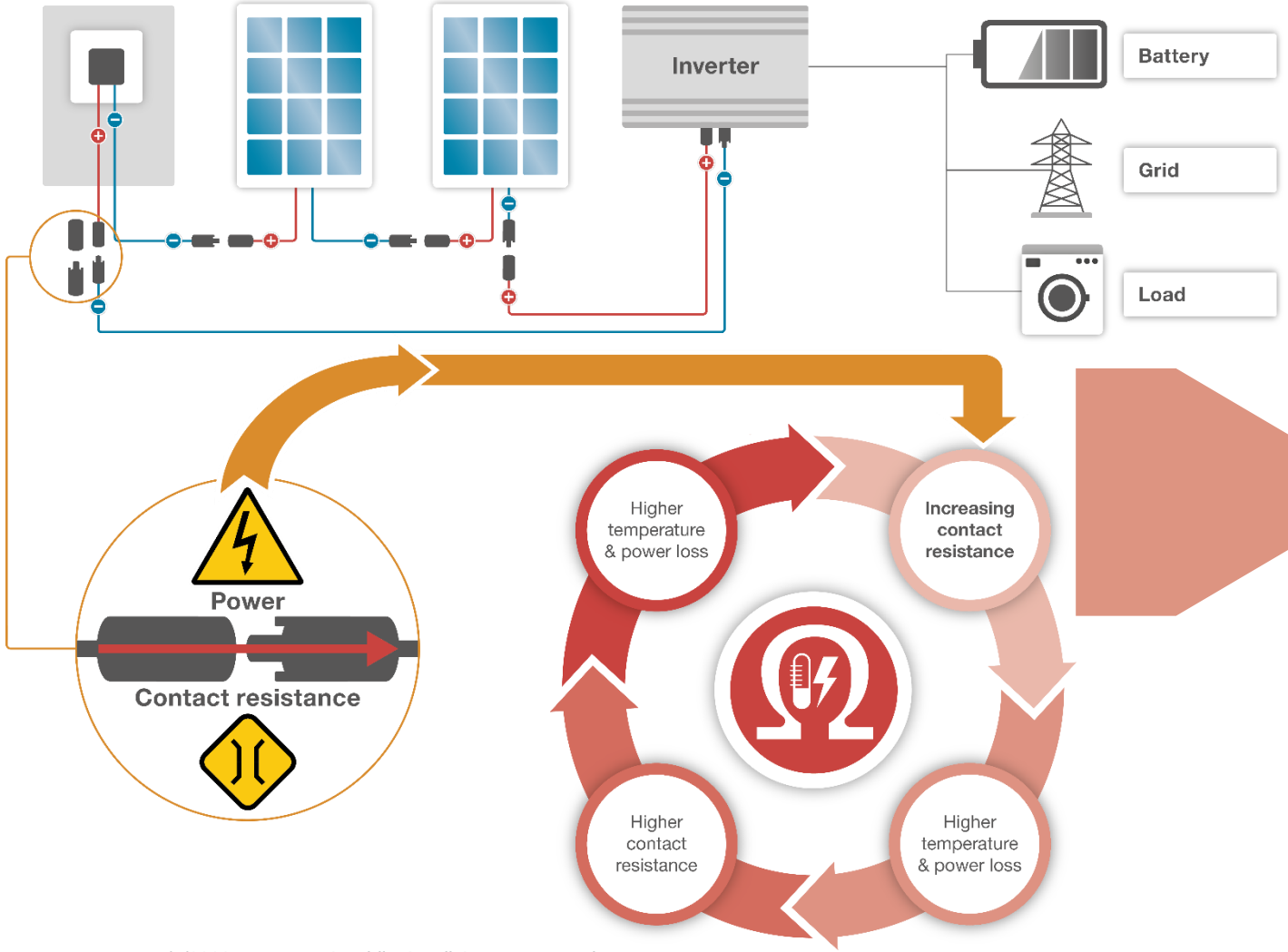
- No string level monitoring, irradiance sensor not functioning
- **Downtimes/ service & repair cost?**

Failures in PV systems – Connector failure due to cross-connection

100MW system - 3.112 panels affected so far

- No physical damage, but high temperature
- Mechanical damage, but electrically conducting with high temperature
- String failure due to completely broken connection mechanically and electrically

Why connectors (eBoS) can have this big impact

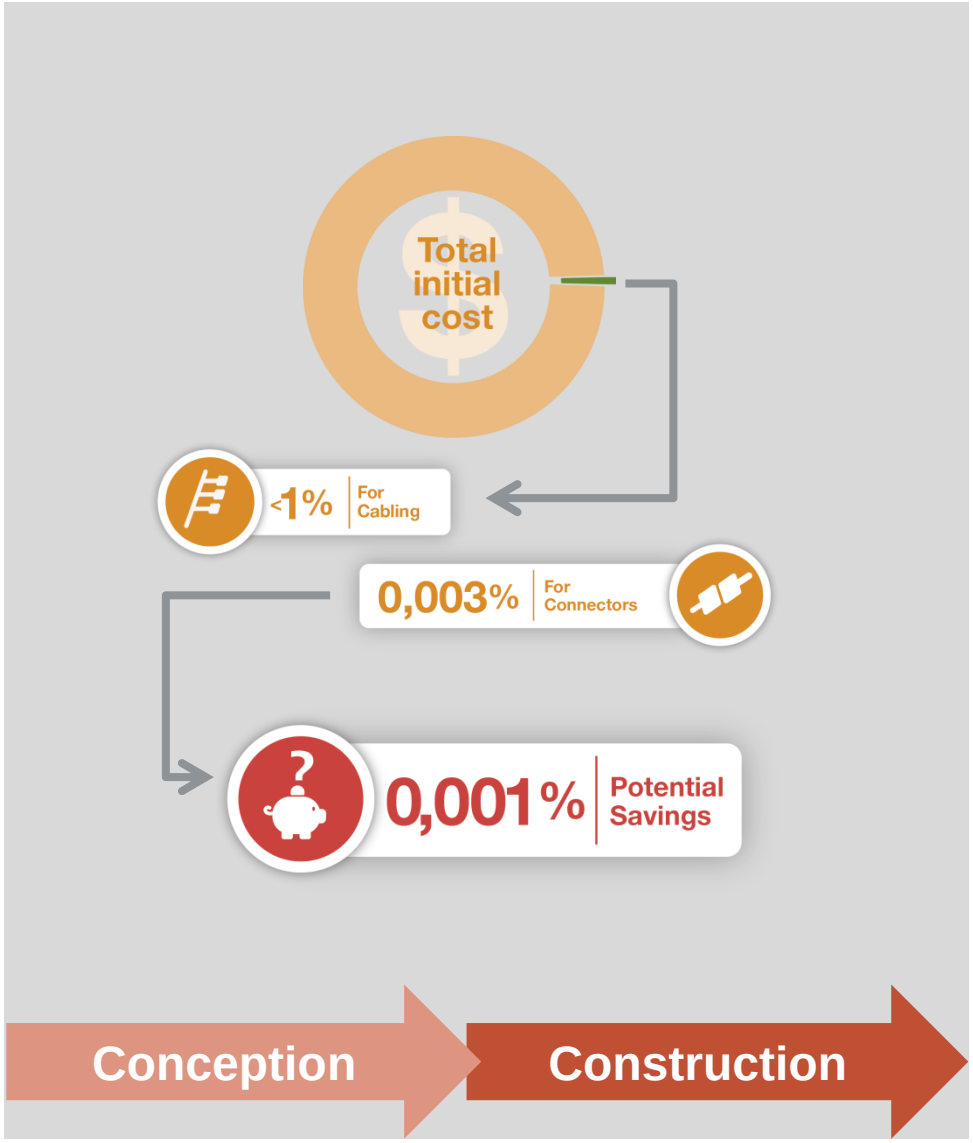


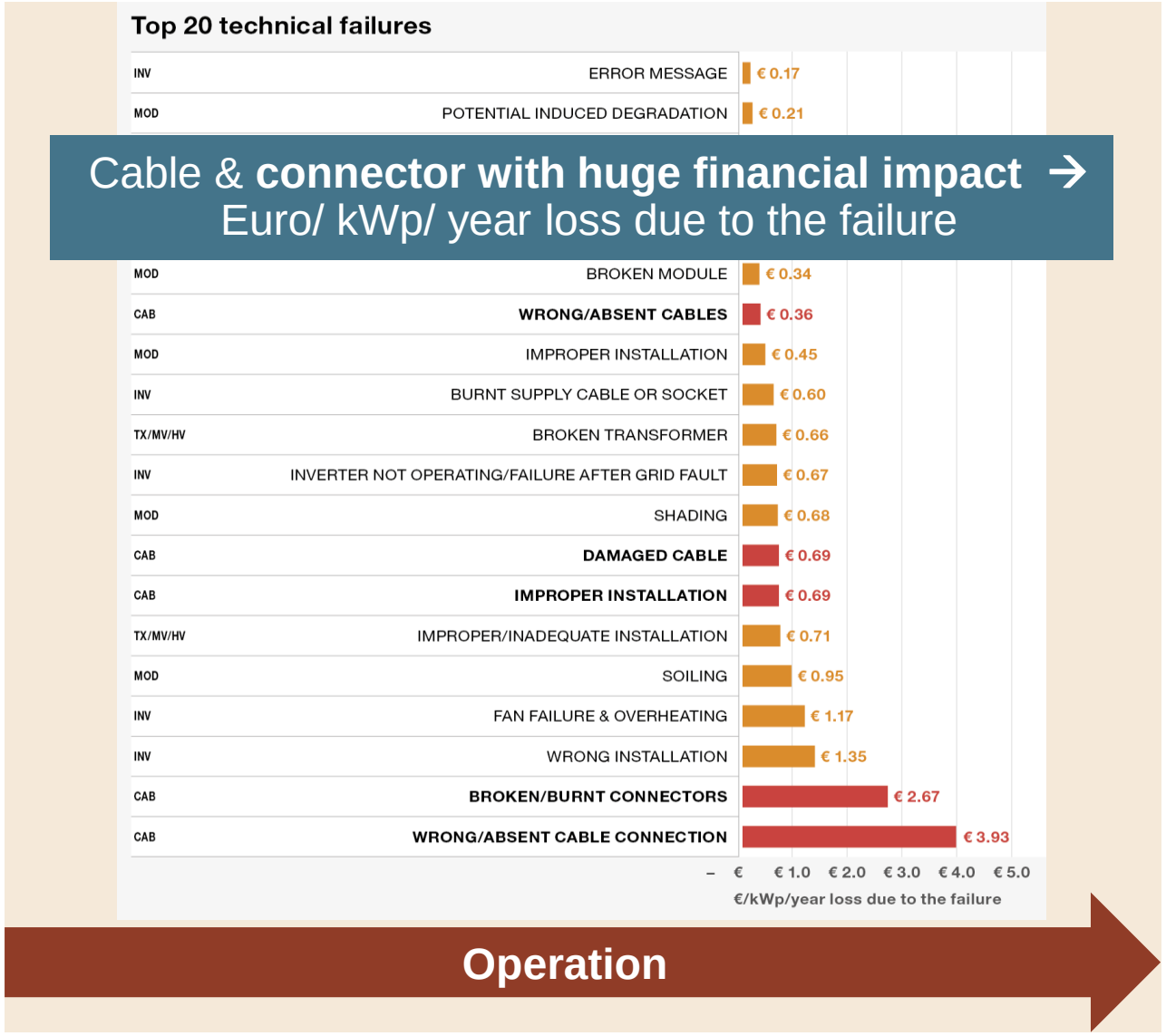
Constant low contact resistance

=

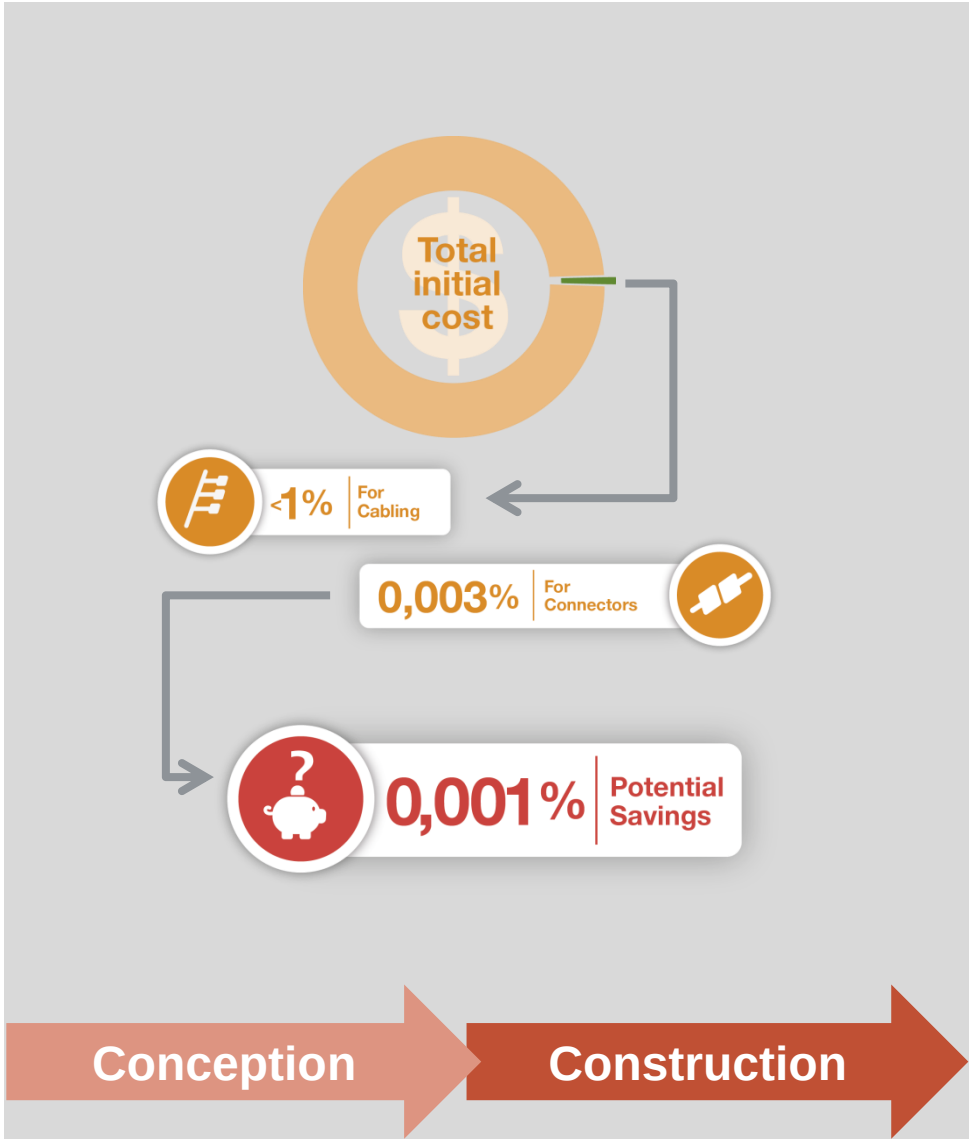
Long-term reliability and efficiency

Small components. Big impact.

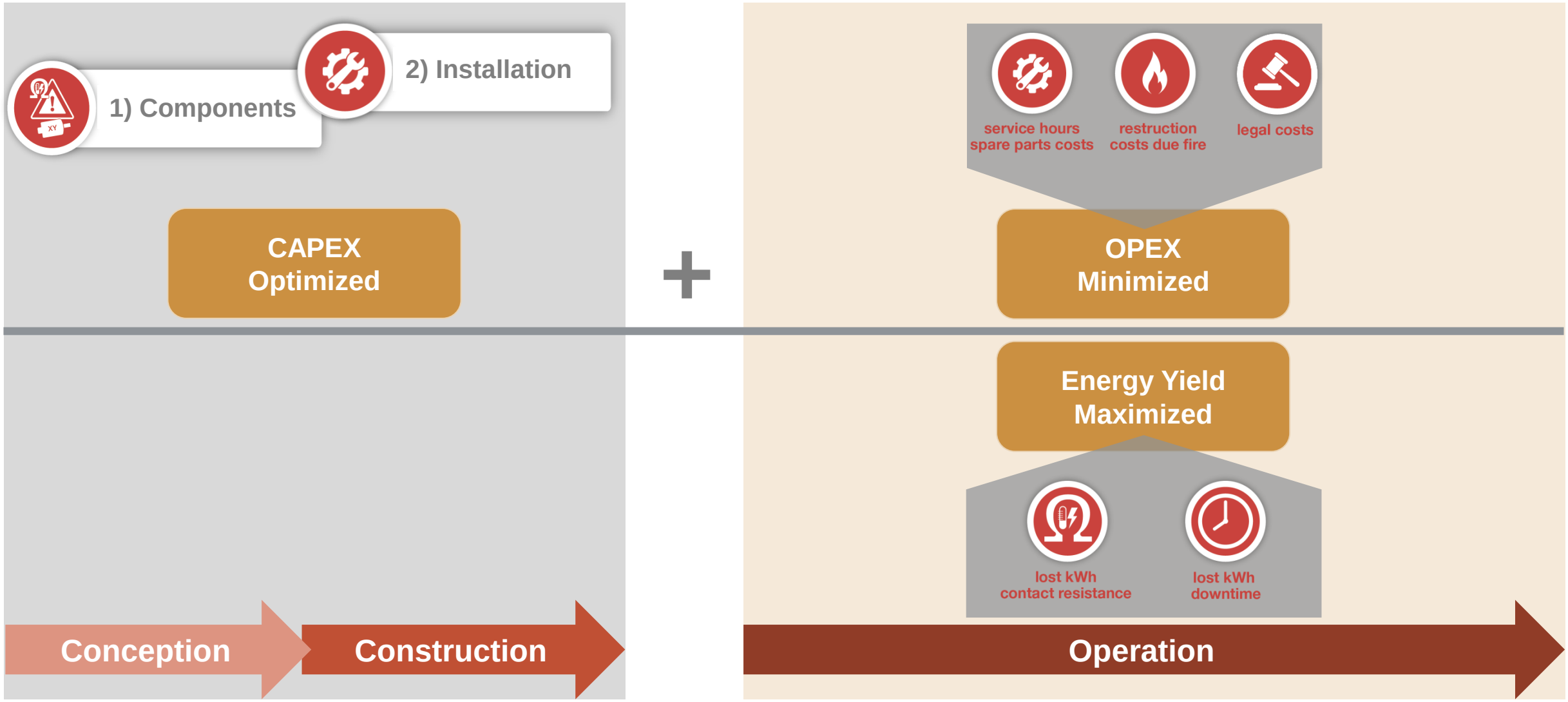




Small components. Big impact.

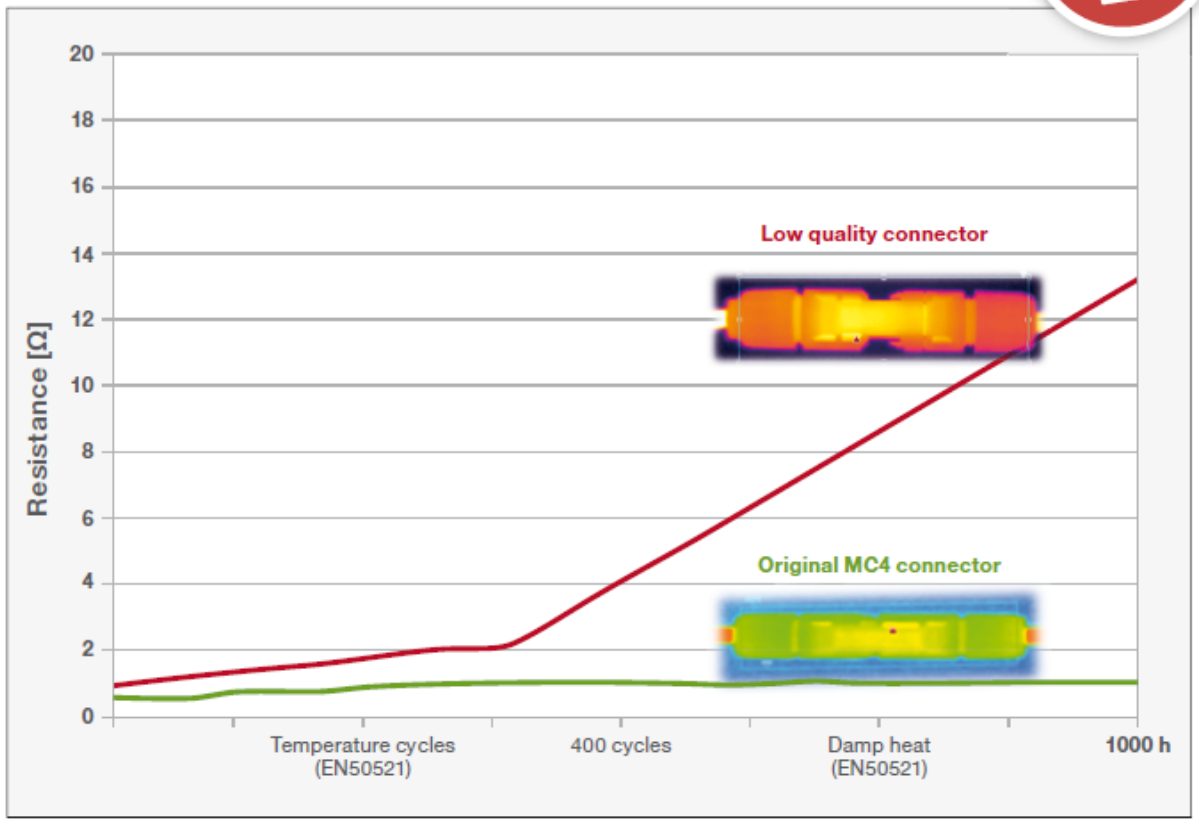


Leverage on LCOE (Levelized Cost of Energy)



1) Component Quality – Contact Resistance

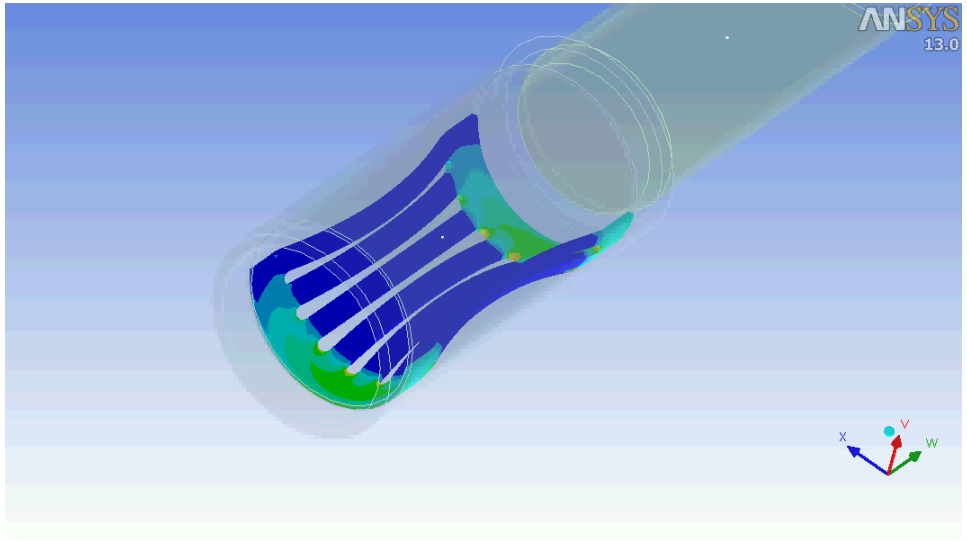
Initial Measurements and after TCT/DHT



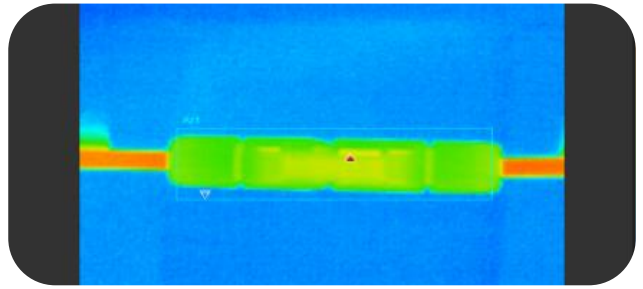
Consequences

- 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

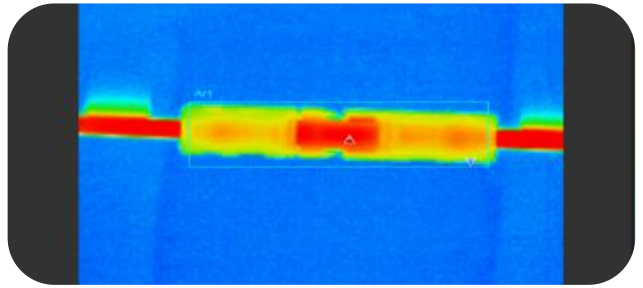
1) Component Quality – Stäubli Technology: MULTILAM



MC4 (MULTILAM Technology)



Competitor Product (no MUTLILAM)

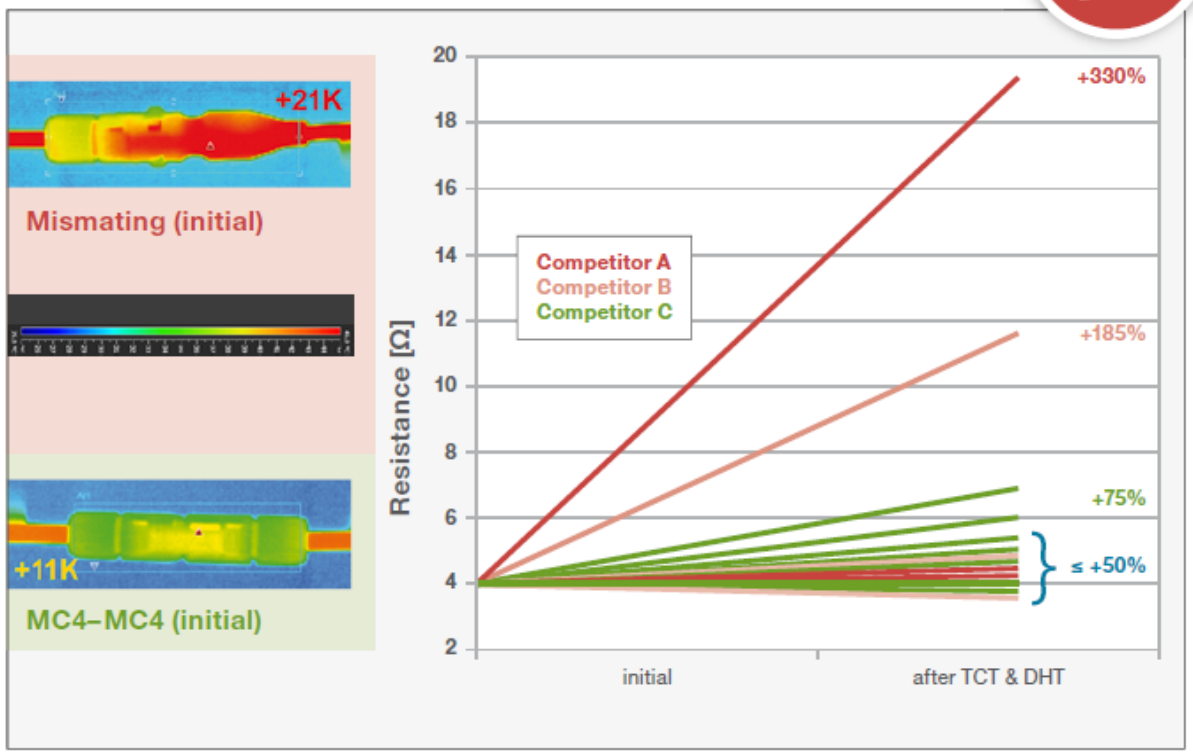


Scale
T_{Min} = 25°C
T_{Max} = 45°C

Measurements acc. to IEC60512-5-1

2) Installation – Cross-Connection

Initial Measurements and after TCT/DHT



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2) Installation – Cross-Connection: Normative References

Global Installation Norm: IEC 62548 – PV Arrays

9.3.9 Plugs, sockets and connectors

Plugs and socket connectors mated together in a PV system shall be of the same type from the same manufacturer. I.e. a **plug from one manufacturer and a socket from another manufacturer or vice versa shall not be used to make a connection.**

UL Standard 6703 – PV Connectors

Conditions of acceptance

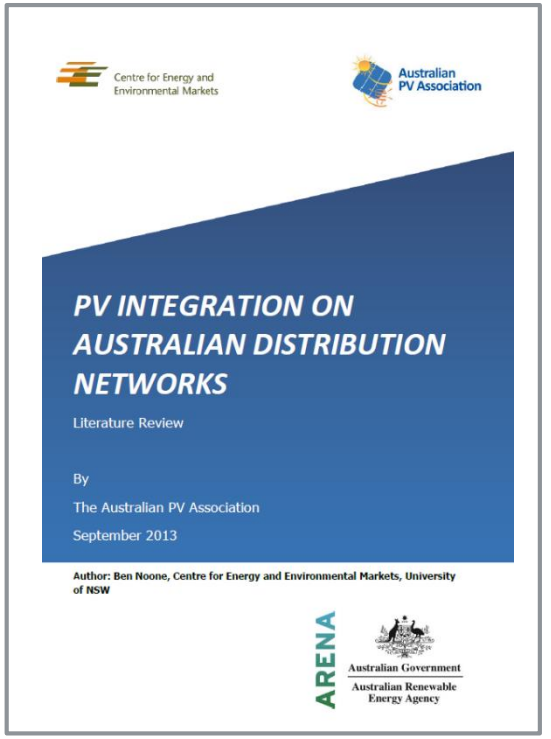
"…have been investigated as acceptable for assembly in the field by qualified electricians with factory provided tooling.

"These devices have only been assessed for UL Recognition with specific types of **mated connectors within their product family.**

They have not been assessed to operate with any other similar devices from any other manufacturer."

National Guidelines

- Australia, France, Brazil & Turkey



Financial and safety risk

Laboratory testing:
Connections 5 years after commissioning

Insulation Resistance

R > 400 MΩ

Original x Original Ø	1660,00 MΩ
Cross-Connection Ø	0,06 MΩ

Contact Resistance

R Ø 530 µΩ

Original x Original Ø	532 µΩ
Cross-Connection Ø	6841 µΩ

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
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Summery – Set the foundation right at the very early stages

Impact on LCOE → Optimized CAPEX +

Conception

- **System design, specifications, contracts** → LCOE balance
- **Components** → performance, processes, partner, track record, reputation, bankability, factory audit
- **Partners** → quality approach, educated technical staff (sub-contractors)

Construction

- **Pre-assembled** (factory)
- **Installation norm** → cross-connection, tools, crimping
- **Assembly instructions**
- **Cable-management**
- Construction **supervision** (coordination)

Minimized OPEX / Higher Energy Yield

Operation

- **Monitoring**
- (Preventive) **Inspection** visual/ thermal
- **Laboratory Testing**
- **Local support**/ expertise
- Spare part management