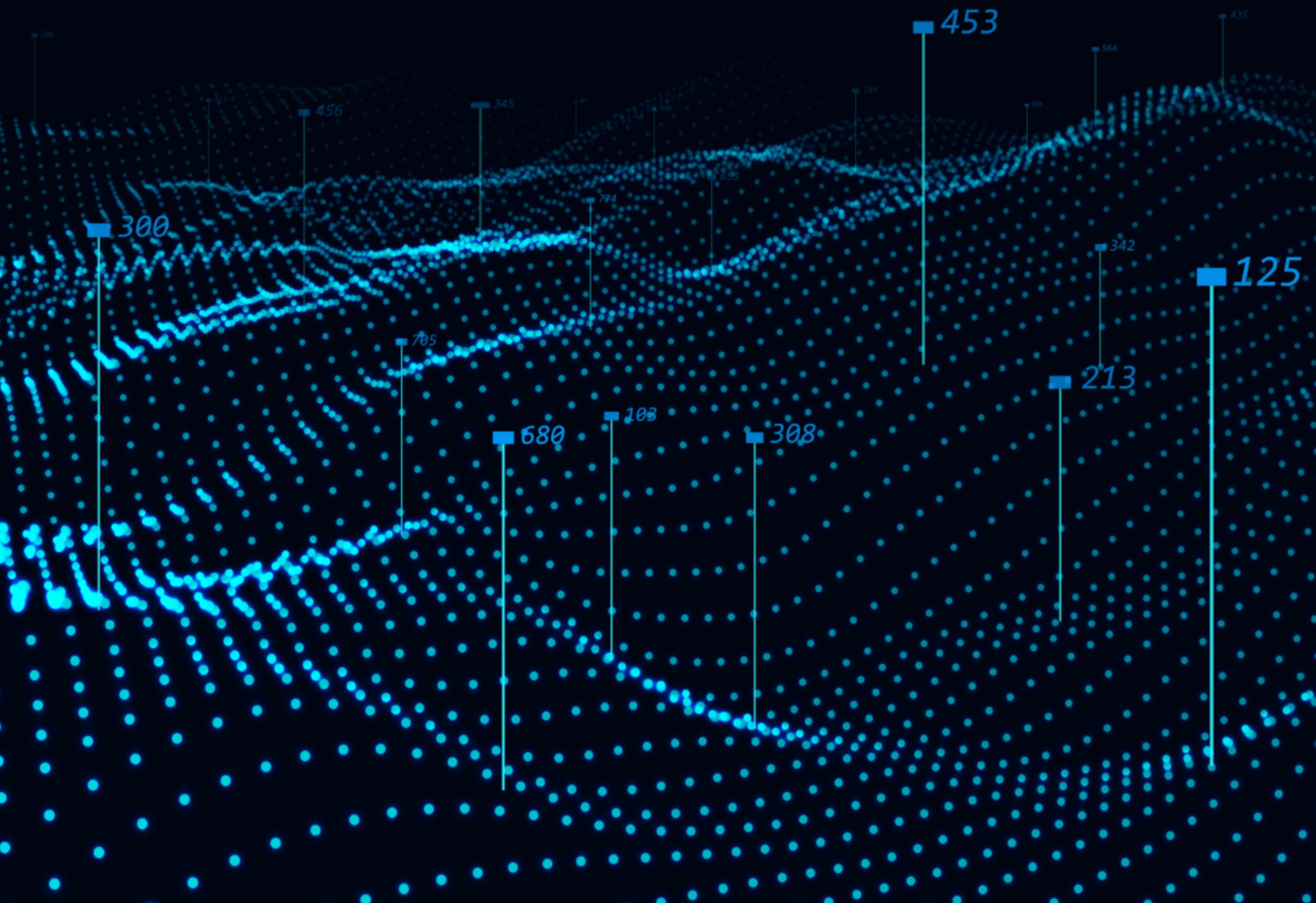
Transforming PV O&M with Advanced Analytics

A SunSniffer White Paper



Why we need to rethink PV plant O&M completely new

The PV industry is in the midst of a digital transformation.

Photovoltaic can be disruptive as we know.

But existing O&M and monitoring strategies did not keep pace with the vast decline of CAPEX[1]. While PV pricing dropped by more than 70% over the last 10 years[2], O&M and monitoring concepts still consist to a high degree of **non-automated work**. Analyzing GB of data with Excel is flying to the moon with a logarithm book and a ruler. Reduction of O&M costs and increase of yield are the key subjects on almost all solar conferences about O&M and asset owners.

This **mismatch** needs to be addressed – but how? Might it be time for a new technology?

In addition, a growing number of studies reveal the impact of power reducing issues – which is getting more and more relevant: Failures and degradations are often higher than expected; some defects do not expose themselves in lab or testing conditions; existing technologies are not able to detect issues during operation. These uncertainties represent **unpredictable risks**. Against the background of declining prices and still high O&M costs – with tools so inadequate – this calls for a change.

[1] https://www.nrel.gov/docs/fy15osti/64898.pdf

[2] https://www.seia.org/solar-industry-research-data

The growing downside of business-as-usual...

THESE ARE THE FACTS:

1. Degradation

A) Usual losses = higher than expected

Fraunhofer ISE found out that during the first few years of operation minor losses often are not recognized and have only small impact[3]. But they **cumulate**. Fraunhofer examined 44 plants in Germany, all almost 10 years old.

Almost all plants which have been inspected for this report are affected by a creeping power loss of 0.7%/year.

After 5 years a yearly degradation loss of 0.7% higher than calculated already grows to 3.5% – which reflects a total profit loss of more than 80,000€ at the end of the fifth year of a 10 MW plant*.

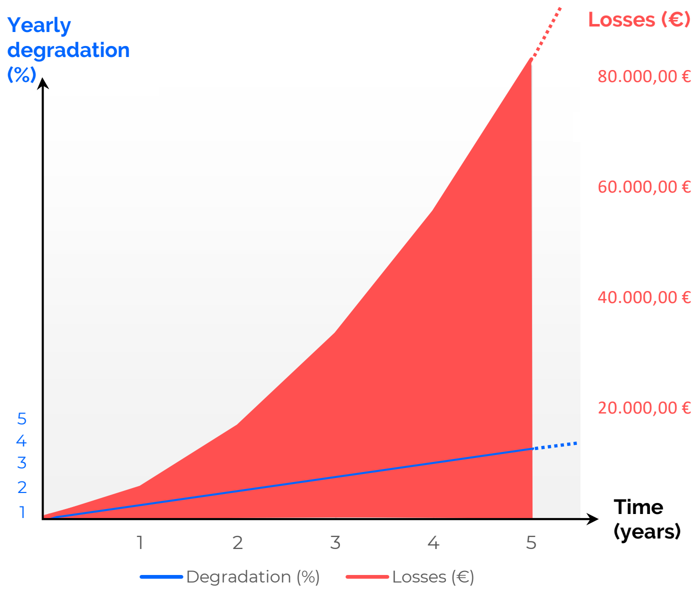


Figure 1: ***Creeping degradation of 0.7% are adding to more than 80.000€ after 5 years, as losses are accumulating and from year to year the maximum possible production amount decreases.***

The report noted that these losses are recoverable and **could be prevented**. How can those degradations be detected outside of scientists' extensive studies? Could digitalization of the modules help?

[3] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/conference-paper/36-eupvsec-2019/Kiefer_5BO75.pdf

B) More irradiation - but eaten up by degradation

In that same study, Fraunhofer stated that sun irradiance increased in the period of examination by 1.1%. Isn't that good news? Yes – and no, due to the before mentioned degradation. Yield increase is simply **eaten up by heat and degradation**, resulting in 0.3% yield increase only – if at all.

How can be seen and distinguished between degradation losses and increased irradiation? Wouldn't a **precise and current STC value** of each module show exactly what it COULD produce under that irradiation, and what it loses due to degradation?

C) "Every second module = eligible for warranty replacement"

Arizona State University (ASU) revealed in a study that **hot climates can increase degradation** to more than 1%[4]. The Photovoltaic Reliability Laboratory of ASU in 2014 evaluated 4 plants with 6,656 modules, using all available methods (pls. see figure 1). Plants were 4 to 16 years old.

Shouldn't it be possible to **see the exact degradation**? Shouldn't a technology provide exact this information, so that high losses can be avoided – and warranty, where justified, claimed?

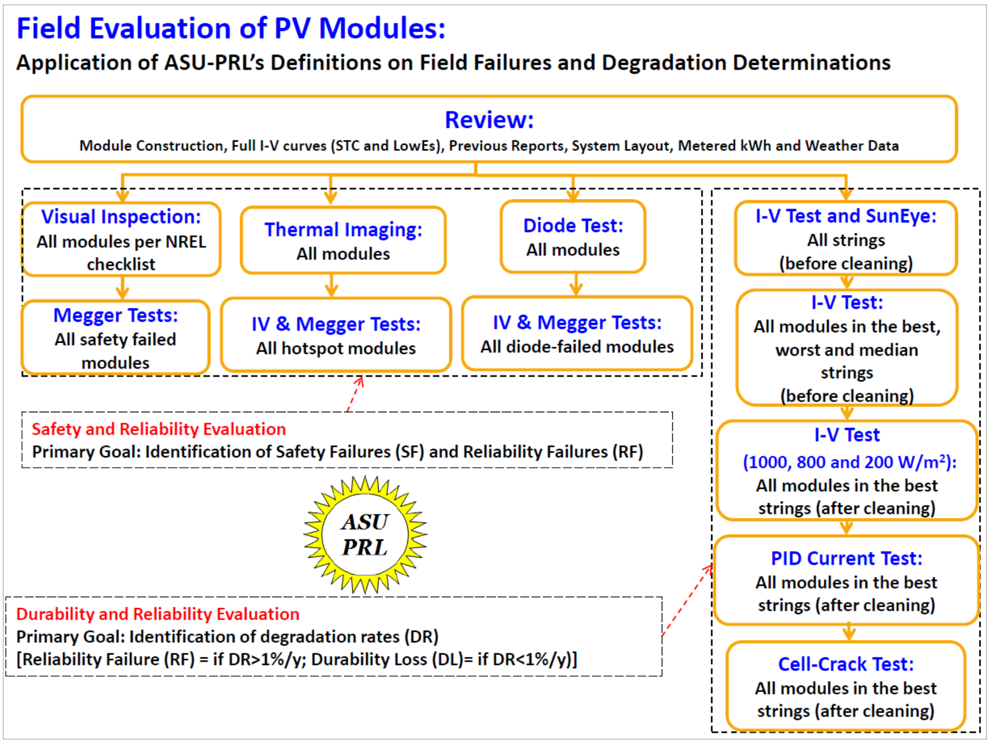


Figure 2: Methods used by ASU-PRL to examinate 4 plants in Arizona, U.S.A. (see note: [4]).

[4] https://www.nrel.gov/pv/assets/pdfs/2014_pvmrw_04_tamizhmani.pdf

2. Soiling = totally uneven

Royal DSM found out that soiling is very unevenly distributed within a plant[5]. Soiling grade diversification can vary by 8% or even more. Thus, relying on only one or just a few irradiation sensors throughout the plant – spot measurements – is not sufficient. Depending on location, soiling can be the driving reason for power losses, and it **cannot be measured accurately**! The study from ASU revealed one of their tested plants under a standard O&M regime had soiling losses of 6.9%*...

A fixed schedule for cleaning is much more ineffective than condition-based cleaning. AND it can affect the modules' surface negatively over time.

So how can the soiling grade be measured reliably for most **cost-efficient scheduling**? Wouldn't a technology with precise constant measurements of the soiled modules be the right tool? Wouldn't we need to check cleaning results?

**** Example: 10 MW plant***

- *Feed-in tariff: 0.08€/kWp*
- *Target yield/year: 1,000 kWh/kWp*
- *Soiling losses (%) within 1 year: 6.9%*
- *Soiling losses (€) within **1** year: **55,200€***
- *Soiling losses (€) after **5** years: **276,000€***

(when cleaned once a year)

3. Measurement uncertainty = unexpectedly high

TÜV Rheinland in 2015 checked measurement uncertainties of conventional inspection devices in lab and in the field[6]. What they found out was that uncertainty in lab or indoors is from 1.8% up to 5.0%. And in the field? It's 6.0 to 7.0%! That means that the devices are simply blind for any failures below 6% in the field – 6% losses are **virtually priced-in**.

Those figures apply for 2015, and measurement uncertainties might have been decreased by now. But still:

Do we really have to rely on inaccurate measurements, just because we are not aware of alternatives? Is there really no technology out there which IS **as accurate as needed**? A digitalizing technology for example?

DSM BRIGHT SCIENCE. BRIGHTER LIVING.

TÜVRheinland® Genau. Richtig.

[5] https://www.sunsniffer.de/images/downloads/DSM-SunSniffer_Report-Modeling-of-Soiling-with-SunSniffer.pdf

[6] https://www.sunsniffer.de/knowledge/TUEV-Modules.pdf

4. Inspection cost per module = 50% of module price!

And what are the inspection costs for such inaccurate methods? Usually they start at 20€ per module for in-field measurements. If better instruments are used, like in scientific labs, costs per module can easily reach 50€ and more per module. But only then accuracy is good enough to actually be of use, only then actionability is provided. Of course, this is **highly uneconomical** and not viable for commercial plant owners and managers.

This is even more true when inspection costs per module are compared to module costs. These deteriorated in the last decade, being at 60-70€/module (60 cell module) right now…

So, wouldn't it make more sense to simply swap a defective module with a certain power loss, instead of first having to examin it in the field? Sure – but how can it be found, without high costs and inaccuracy risk?! Not to mention the potential paper trail in order to safeguard the feed-in tariff.

Wouldn't it be highly useful to have a technology which **automatedly** examines each and every module in the field, during operation, and identifies faulty ones online? And **notifying** the manager immediately when the production falls below a certain **threshold** – like the warranty level? This way the money saved on research could be spend on better modules!

5. Claiming warranty = an awkward hassle

The study from ASU revealed that in Arizona 49-76% (!) of modules in those 4 plants perform less than they should and qualify for exchange on manufacturer costs as warranty cases. ASU performed **intensive testing** and analysis on those plants.

This is certainly not usual effort in commercial plants, because it requires huge amounts of work and time from professionals and thus is very expensive or just not available. Even if in colder climates the value might be lower, it still is a serious issue…

But how can those invisible warranty cases be detected without expensive installers and certified institutes' efforts? Shouldn't digitalized modules help, with precise measurements of their own health status and degradation?

And HOW can a plant owner successfully CLAIM warranty anyway? Regulations from module manufacturers need to be observed, and claiming warranty is always producing costs.

So how can warranty be claimed successfully and without producing further costs? Wouldn't it be ideal to have multiple measurements over time, which are **objective and transparent**?

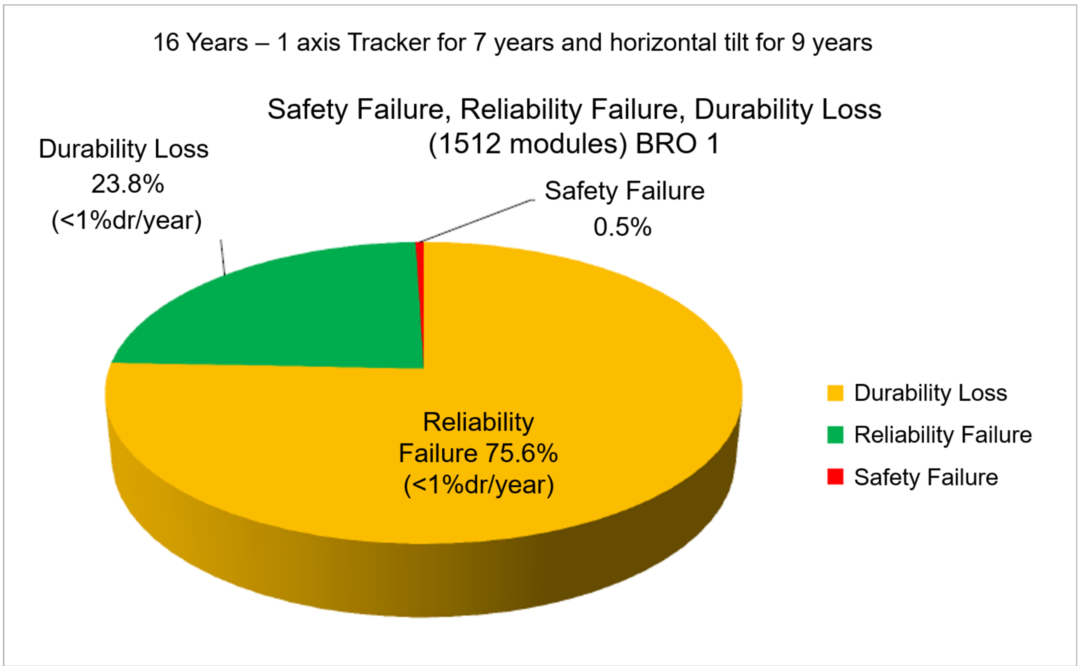


Figure 3: Study from Arizona State University, revealing the very high rate of 75.6% of reliability failures in the tested plant (see note: [4])

6. Some errors = invisible in the lab

Helmholtz institute conducted a study with module precise measurements combined with IR and EL imaging[7]. This study showed that spot measurements are not enough.

IR, EL and local flasher tests are spot measurements, therefore they only show a snapshot. Issues with volatile, aberrant, or condition-depending behavior cannot be detected with these methods. Same is true for demounted modules, being cut-off from field conditions and brought to a lab, being exposed to specific lab conditions which not necessarily reflect field conditions. **Temperature of a module in operation is much higher than in a lab**, so temperature-sensitive issues will just not show.

Conventional wisdom regarding cell cracks has always been that they are not significantly affecting power production. A latest study from German Helmholtz institute proved the opposite: losses can amount to 25% – AND they are invisible in flasher tests in a lab!

So: what kind of technology is needed to **detect those power reducing cell cracks**? How WERE those losses detected in THIS study?

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

[7] https://www.sunsniffer.de/images/downloads/Helmholtz_Analysis_of_digitized_PV-modulesystem_data_2019_with_introduction.pdf

An expensive and inefficient status quo...

SO WHAT IS NEEDED?

The facts above show that existing O&M methods are outdated, work intensive and not sufficient. The inspection tools are not precise enough or are simply not able to detect issues. In addition, usual monitoring is only at inverter or string level – but never at the source, at the power production point: at **module** level. Yet it is not possible to draw conclusions from summations: how can we know which module is broken and needs to be exchanged from the meter reading?! String monitoring at least reduces the supicious to maybe 20 possible modules. Still action on-site is needed to finally find the broken one.

So, what is needed? We need a new method! And how could that methods look like? Could maybe **module digitalization** help?

Yes, it can: module digitalization with AI provides actionability – it **transforms mere data into meaningful data**.

Actionability means putting modules automatically in **performance classes**, and knowing at your desk,

→ which modules needs to be **changed**

→ which modules are **warranty cases**

→ which modules are **soiled how much**

→ how much does a specific exchange action **cost**, and how much yield is **lost** during inactivity

→ when is the **next cleaning** action recommended, and according to specific plant experience: what **cleaning intervals** are appropriate

Actionability is created by profound commercial decision-help based on technical and automated expertise.

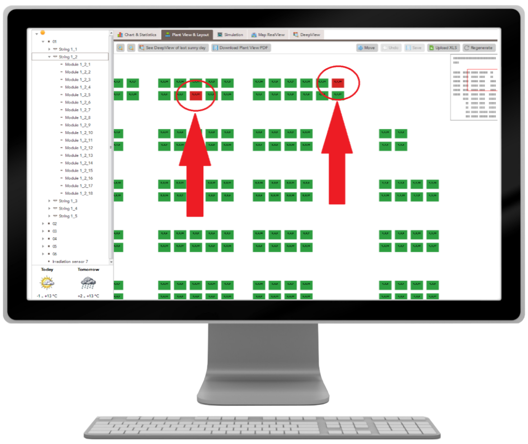


Figure 4: Computer with clear information about two defective modules

Insights never seen before

SunSniffer® investigates these facts since 10 years. It is the technical wing of a Family Office with a PV plant investment portfolio. When operating those plants, issues arose which lead to the development of this technology. Digitalization of modules and analysis by artificial intelligence was the solution. Only with **digitalized modules** their current health status is actually seen – precisely and in real-time. This is the prerequisite for actionability: being ABLE to take appropriate steps to mitigate or even solve power reducing issues – without even visiting the plant.

With digitalized modules, **O&M is completely changed**:

- Expensive and time-consuming on-site inspections are reduced dramatically, because defective modules or modules with justified warranty claims are **visible at the push of a button**.
- Modules are grouped into loss **classes**: modules to be exchanged, soiled modules according to their soiling grade, etc. This way **decisions can be made easily** when the yield fluctuates, because it is known exactly what is wrong where and which module needs what kind of treatment.
- Cleaning activities are reduced to necessary minimum, because cleaning can now be **scheduled according to the actual soiling condition**, and thus is cost/output-optimized.

Such **automation accelerates and simplifies** O&M greatly. At least 50% of field work can be dropped: extremely limited error detection activity is needed any more – no drone flights, whether as routine maintenance, or for an acute intervention; no manual measurements in the field. **Service on-site is reduced to absolute minimum**, but the benefits are far from being minimal. Automated module monitoring provides insights like – or even more detailed – scientific evaluations, but low-price.

Module measurement is a necessity – not our words, but the words of scientists. SunSniffer® evolved within the last 10 years. Long time field experience proved reliability. In a study the Bavarian Center for Applied Energy Research (ZAE Bayern) compared the SunSniffer® technology with drone flights, coming to the conclusion that SunSniffer® always knows power losses, even if it is below 1%[8].

ZAE BAYERN

[8] https://www.sunsniffer.de/images/downloads/SiliconPV_2017_Review_Final.pdf

Insights never seen before

SunSniffer® pays for itself!
Check yourself, with our O&M calculation

A sustainable technology needs to have its own ROI. For our own plants we did not accept mere cost producing devices. Our ambitions are **backflow** of invested capital, **increase** of yield, **reduction** of risks, and **improvement** of O&M.

We put together a small sample calculation with which anyone can calculate the own plant with SunSniffer®, on the basis of some variable assumptions.

In this example we assume a 10MW plant facing the typical issues mentioned above, like degradation and soiling.

What has to be kept in mind is that some unhealed issues not only reduce the power production by itself over one year, but that they accumulate and grow...

Only degradation loss of 0.7% for example would lead to 5,600€ loss in the first year. But this will bank to more than 80,000€ after 5 years!

To this, soiling losses must be added, and production losses and outages due to unexpected failures...

O&M costs can vary between 15€ and 4€ per kWp/year. How can O&M be high quality AND profitable?

With digitalized modules and automation! O&M costs can be reduced to 4€/kWp or even lower with the highest possible quality: Service staff on-site only need to accomplish what the analysis has told them, so no extra time in the field necessary.

SunSniffer® produces ist own ROI, being at 600% according to the – conservative – assumtions in this example.

Contact us for further information, and for the calculation of your own plant:
info@sunsniffer.de.

SunSniffer has its own ROI - it pays for itself:

Example:

Plant size:	**10 MW**	Losses per year:	
CAPEX:	**6.5 m €**	- Degradation:	**0.7 %**
Module size:	**300 Wp**	- Soiling:	**6.9 %**
Feed-in/PPA tariff:	**0.08 €/kWp**		
Lifetime:	**25 years**	Cleaning frequency:	**1/year**

SunSniffer costs:		SunSniffer savings:	
- CAPEX:	**1.50 cent €/Wp**	- O&M savings:	**1 €/kWp**
- Setup:	**6,965 €**	- Degradation healed:	**50%**
- Yearly WebPortal:	**0.45 €/kWp**	- Soiling healed:	**70% - cleaning**

Increase of efficiency in % of revenue:	**8.2 %**
Losses healed and savings per year Ø:	**66,000 €**
SunSniffer CAPEX+OPEX from revenue:	**1.3 %**
SunSniffer ROI:	**608.6%**
SunSniffer break-even:	**less than a year**

CONCLUSION

External issues like dust, shades or hail are always afflicting solar modules, and **internal issues** like degradation, chalking, PID, LID, LeTID, etc. are a constant risk. Those issues reduce power production, and the losses can cumulate fast and high – without even being noticed. Climate change is adding to this: especially in moderate European climate we see higher irradiance, but more frequent and extreme weather events, too. The number of studies which examine modules is constantly growing, revealing that **power reducing issues are surprisingly a much bigger problem than anticipated** throughout the last decades. Now taking the whole system into focus, it is seen that issues are not isolated to the individual components, but can correlate and influence each other.

Methods are far more precise than they used to be, and issues are detected now which simply COULD not be seen earlier. But still: even the best lab equipment has to mainly rely on **snapshots** and **test conditions** – and thus cannot see problems which arise in operation. The current measurement infrastructure is geared towards on/off errors. Even with the help of AI advancements: **what is not measured, cannot be seen**.

And what needs to be measured? In PV, it is the **module**: as the power producing unit it is the most critical part of a plant. But it is not monitored so far at all.

Current practices and existing methods of PV O&M **need innovation**. With PV industry still growing at a vast pace, constantly developing new materials, it is just not affordable to work with outdated and inaccurate methods. This is all the more true as the costs of those examination methods are in no relation to the costs of a module any more.

Digitalization leads the way here, as in many other industries. The key is **data**. We need more data, and we need to analyze it intelligently. Analyzing module data results in **actionable outcomes** with clear answers for profound decision making. It is shining light into a black box.

With digitalized modules and analysis by artificial intelligence, **automation** and **predictive maintenance** are easy at hand. Asset manager now face trailblazing decisions: keeping pace, or being left behind.

What's next?

Convince yourself in your own free trial!

Module-precise measurement technology with **artificial intelligence analysis** speaks for itself. Now what is next to be done? Contact us for **equipping a test plant**.

It is evident that the sooner the better: The earlier a plant is equipped with module precise technology, the less yield is lost. Ideally a plant is installed with modules already containing the sensor. Then even installation mistakes, like incorrect cabling, are detected instantly.

Existing installations can benefit, too, the sensor is easily retrofitted – just plug it to a module. The data can be integrated into existing portals.

How does it help me?

In the Webportal all information is presented user-friendly and in a most-possible intuitive way. Not only **KPIs** are shown, but comprehensive **decision support** and **clear instructions**, too: how many and which modules are out of warranty? How much would exchange cost now, compared to the losses if no action is taken? When will it be feasible to clean the modules? Etc.

SunSniffer® translates pure information into most valuable actionability.

Overview: SunSniffer® system and data transmission

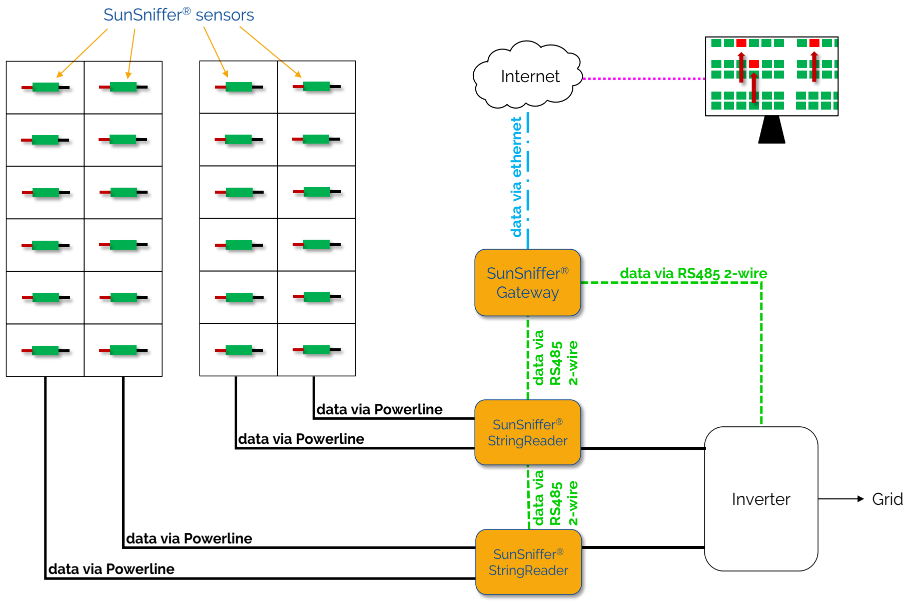
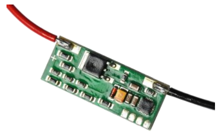


Figure 5: Overview of data transmissions in of the SunSniffer® system

SunSniffer® components

SunSniffer® consists of a **module measurement** device, plus string **measurement** device, plus **data collector** device which transmitts the data over internet to the **WebPortal** – or any other portal, if wished.



SunSniffer® sensor

The module measurement device is a small low-cost sensor which sits **in the junction box already**. Ask your module manufacturer for junction boxes with SunSniffer®, or choose modules with SunSniffer® integrated.

Junction box with SunSniffer® sensor

If an existing plant shall be **retrofitted**, this is easily done with the SunSniffer® Retrofit Box.

SunSniffer® Retrofit box with sensor

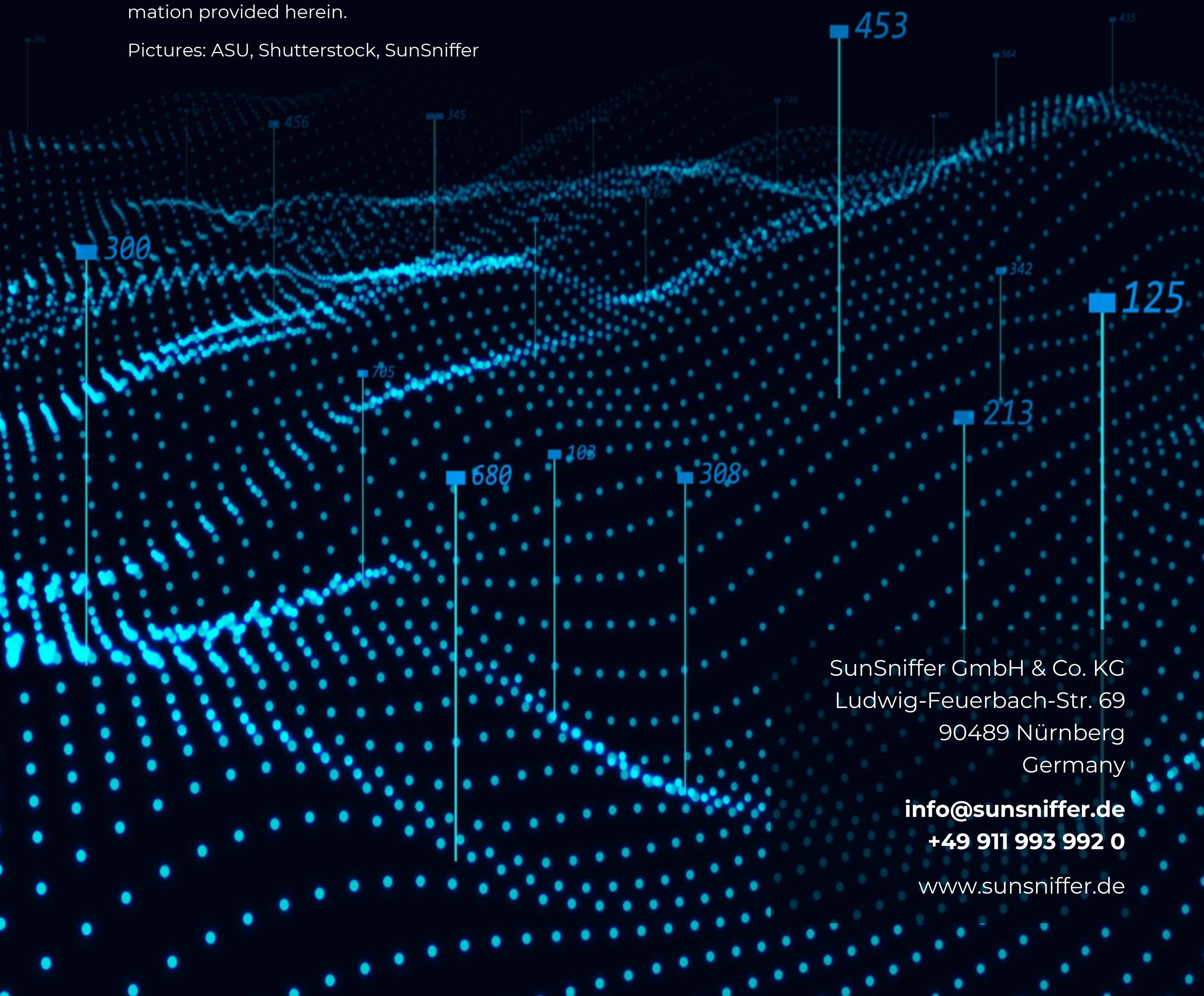
Either sensor in junction box or sensor in Retrofit box sends its data over the **Powerline** to the SunSniffer® StringReader (PLC, Powerline Communication).

SunSniffer® StringReader

StringReaders send their data to the SunSniffer® Gateway, which forwards **all collected data plus read-out inverter data** (if wished) **and other sensor data** (like irradiation sensors; if applicable) over internet to the SunSniffer® WebPortal.

SunSniffer® Gateway

Transforming
PV O&M
with
Advanced Analytics



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