Supporting the Development of the European PV Industry and Markets through Enhanced Quality

White Paper prepared by SOLARUNITED

SOLARUNITED
GLOBAL SOLAR BUSINESS & TECHNOLOGY ASSOCIATION

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Disclaimer

"The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727272"

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WHAT IS THE PLATFORM?

The European Technology & Innovation Platform for Photovoltaics' (ETIP PV) mission is in line with the Energy Union and the SET Plan priorities focusing on "Renewable technologies at the heart of the new energy system" and for Europe to become "No. 1 in renewables". ETIP PV gathers all the relevant stakeholders within the PV sector, coordinating cooperative discussions with member states (MS), associated countries (AC), and the European Commission services. Its main role is to provide consensus-based strategic advice on all issues relevant to progressing research and innovation (R&I).

The ETIP PV is a continuation of the European PV Technology Platform (EU PVTP) under the new SET Plan governance. It is the recognised interlocutor for the European Commission (EC), MS and AC regarding the PV sector's specific Research and Innovation (R&I) needs.

ETIP PV envisions arranging representatives of the interested MS and AC, and forging working relationships among national/regional platforms to ensure synergies between EU and national and regional activities.

SCOPE OF WORK

ETIP PV provides advice on photovoltaic solar energy policy. It is an independent body recognised by the EC and the SET Plan Steering Group as representative of the photovoltaic sector. Its recommendations may cover but not limited to:

- R&I
- Market development, including competitiveness
- Education
- Industrial policy

The focus of ETIP photovoltaic's activities is on opportunities and challenges facing the European PV sector. Our recommendations are made with a view to improving the competitiveness of the European PV industry, both the upstream segments (including feedstock supply, equipment manufacturing, cell and module production) and the downstream ones (including technical solutions for grid integration, market solutions for grid integration, and installation).

CHAIRMEN'S MESSAGE

The decline of PV component and system prices in combination with favorable financing conditions leads to new ultra-low bids in PV Power Purchasing Agreement (PPA) tenders almost every month. Only three years ago reaching 6 USDcents per kWh was a pipe dream; PPAs below 3 cents is now reality in several sunbelt countries around the globe. Also in Europe, the price of PV electricity has decreased significantly in recent years and could decline to less than 4 EURcents per kWh in the coming years (ref: ETIP-PV competitiveness report, May 2017).

Competitive PV installations require from investors a high level of confidence in plants' abilities to reach the expected yield during their lifetimes. This is a common metric to gauge the performance of PV systems. Achieving these performances, as promised, is a cornerstone of PV competitiveness: it reduces the perceived risks from an investor's point of view, and therefore the cost of capital by reducing the risk premium. A reduced cost of capital is a key factor in reducing the cost of PV-generated electricity, which is a key driver for large-scale deployment and therefore for our industry.

This White Paper focuses on ETIP-PV activities regarding quality, reliability and performance, as supported by PV stakeholders, including materials and equipment providers, cell and module manufacturers, and research labs. Our partner Solar United and its members have long emphasized the need for a better understanding of quality PV installations in order to correctly identify benchmark providers of components and improve the manufacturing processes and materials. So far, many failures and degradations in the field are not yet understood with sufficient depth to allow the upstream (i.e., manufacturing) part of the PV industry to identify if and how processes and materials could be improved to mitigate or even prevent these problems from occurring. Industry maturity will require many initiatives to link the upstream and downstream parts of the PV value chain in a quest for total quality and guaranteed performance over time.

Fortunately, quality may prove not to be a major issue for the majority of today's solar installations, maintaining and even enhancing quality and lifetime while drastically further reducing cost are major challenges. It is a prerequisite for truly large-scale (multi-terawatt) deployment and to make a major impact on the transition of the global energy system and market. It's therefore crucial to ensure all the elements are in place to build a competitive and thriving PV industry.

Marko Topič
Wim Sinke
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1. Quality as a Maturity Indicator for the PV Industry

The PV sector has evolved extremely fast in the last decade and in 2016 crossed the 100 billion EUR turnover threshold. In a context of this fast market development, components are improving constantly, while operators are implementing more efficient processes and PV system prices are dropping dramatically.

Considering such a dynamic context, the question of the quality of the PV installations becomes central now that the industry faces reduced margins and global competition. The only way to achieve a sustainable development of PV technology in this environment must be to focus on quality products and procedures.

Quality: "*The ability of a PV installation to achieve and maintain over its prespecified useful life time the performances expected by the relevant stakeholders.***"**

PV plants are operating on a well-known base of success. Electricity production depends on the PV system's characteristics (i.e., its solar irradiation and ambient conditions). Usual degradation of performance over time is expected and therefore the production of electricity during the lifetime of a plant typically ranges between historical boundaries. Quality is borne out with respect to these boundaries within given probabilities. Poor installation procedures, or inadequate components can result in lower production, or a faster than expected degradation of performance.

To tackle these challenges, the quest for quality needs to be a priority, starting with the early development stages of PV plants, including their engineering and construction commissioning phases, through to completion, as well as long-term operations and maintenance. Current installations hold an advantage in knowing their existing track record, encompassing adjustments along the way to improve quality processes at different phases of a PV plant.

Quality means excellence.

All stakeholders involved in PV plant design and installation need to collaborate and engage for a sustainable long-term selection of products and systems. A short-term approach to building PV plants extremely fast could easily lead to poor quality. Not paying attention to details, rushing to meet deadlines for attractive incentives, or buying cheap components to reduce dramatically the Cost of Goods Sold (COGS) almost always leads to quality decrease and poor performances.

The PV sector must continue to reflect on the lessons learned from past experiences and take advantage of already made mistakes and system failures to build more robust and sustainable PV plants.

Systems performance generally has improved during recent years, mainly thanks to better processes focused on quality with these considerations:

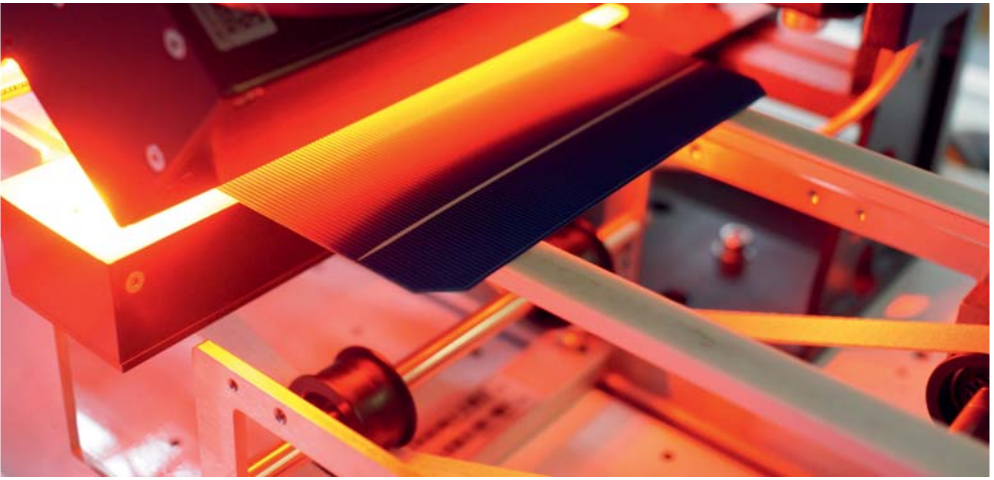
- **During the site selection phase:** Selection of an appropriate site is key to ensure a high-quality asset for the future. Sites with high slopes, bad soil conditions, environmental issues or complex interconnection solutions, are a few examples of what developers should avoid to ensure project optimization.
- **During the design phase:** A high-quality engineering project requires the selection of a reliable solar resource database, correct energy simulation, a good layout, and adequate electrical and mechanical dimensioning. These are a few examples of how the engineering team's work impacts system, its long-term performance, and cost of energy (LCOE).
- **During the procurement phase:** Material selection and high quality procurement are also key factors for the construction and operation of a PV plant. A proper request for proposal process, and a detailed review of technical and commercial offers from the procurement teams will make a direct impact on how smooth the construction phase runs. In many cases, differences in approved budgets at the end of the construction are originated at material selection and procurement phase.

- **During the permit phase:** Government permits stipulating high-quality standards are also key for solar companies involved in the development, construction and operation of the plant. How the project is designed and submitted to local authorities can avoid performance issues in the future.

- **During the construction phase:** For obvious reasons, construction is probably one of the most critical phases to ensure a high-quality PV plant, so for that reason, quality processes on civil works, mechanical works, electrical works, logistics, health and safety, waste management and environmental/social monitoring are absolutely necessary. Construction contractors without high-quality standards most likely will lead to failures. For example, foundations not properly installed in soil can affect the stability of the metallic structure and the PV modules. Also, electrical cables connected without adhering to different electrical standards and codes, can cause electrical materials' degradation if not worse (e.g., start a fire).

- **During the commissioning and hand-over phases:** Third-party commissioning teams involved between the construction and operational phases are accountable to ensure that the equipment is properly installed. Quality processes during commissioning are already well established in the industry.

- **During the lifetime of the PV plant:** Operation and Maintenance (O&M) teams receive a built PV plant. Problems that originate during construction will eventually become evident. Hence, it behooves operation teams to properly monitor and maintain a solid maintenance structure that reacts fast to sudden failures, and makes repairs on the fly. Failure to do so will impact negatively energy production, thus revenues. Simple tactics like creating cogent operation and maintenance manuals and processes that are regularly reviewed in detail by quality teams will no doubt enhance productivity. Today, many O&M responsible companies typically complain about the lack of standardized procedures to collect data from the field (operating plants), identify failures and defects, monitor whether a PV plant installation is performing according to the business plan, and track main component performances (modules, trackers, inverters, etc…).

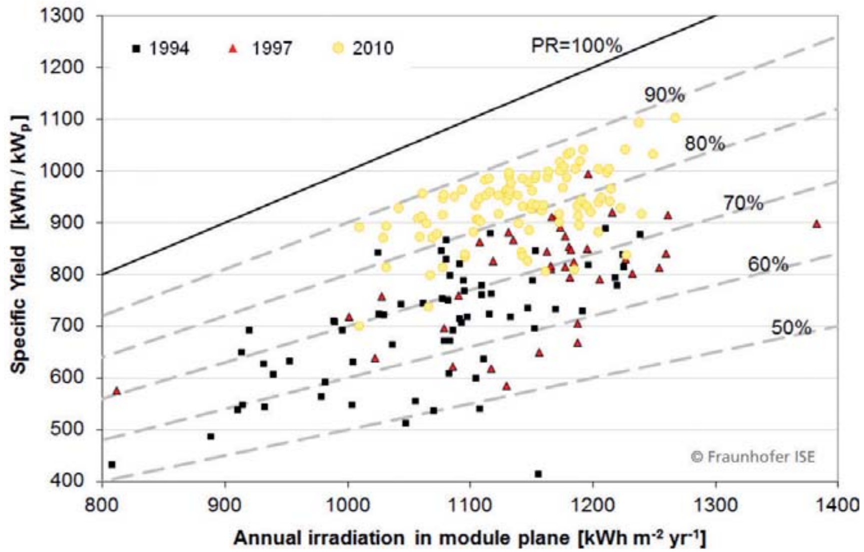


by courtesy of Vitronic, Wiesbaden.

2. Assessing the Real Situation of Quality and Performances in today's PV Industry

Assessing the actual quality level of PV installations is a complex task. Multiple initiatives and research projects have been published in recent years, with diverse results and interesting conclusions. Ideally, additional studies and a careful survey of existing and new installations in Europe should be undertaken. The resulting data should lead to an improved understanding of quality requirements.

Several case studies that serve as a microcosm of what is actually going in the field identified interesting aspects of performances and reliability. Their findings only hint at the evolution of the quality of PV installations at large.



W. van Sark, N. Holger Reich, B. Müller, C. Reise, K. Kiefer and A. Armbruster, Review of PV performance ratio development, Fraunhofer ISE, 2012

Assessing Quality through the Performance Ratio?

To assess the quality of PV systems, various key indicators can be used. For instance, one can mention the yield of the system, or the percentage of failure of its components. The performance ratio (PR) that is based on the yield is a commonly employed metric, as well as one of the most comprehensive. Today, most systems installed in Europe have a typical PR ranging from 80% to 90%. Some high-end PV systems could even top at ~95% in best cases and locations. Overall, systems have improved from the 50% to 75% ratios witnessed in the 1980s and the 70-80% in the 1990s. It is also worth noting that the variance of PR between systems has been greatly diminished in the past decade, as the figure on the previous page shows, proving that the industry has a better understanding of its fundamentals (see IEA PVPS Task 13 publications for more information [1bis])

Degradation rates

Degradation rate of PV modules can also indicate quality of a system by providing information on one of its key element. Nowadays, reported degradation rates range from approximately 0.36%/year for mono-cSi PV modules to 0.96%/year for CIGS ones. [2] It proves that PV modules can normally maintain their performances at an attractive level in the long term.

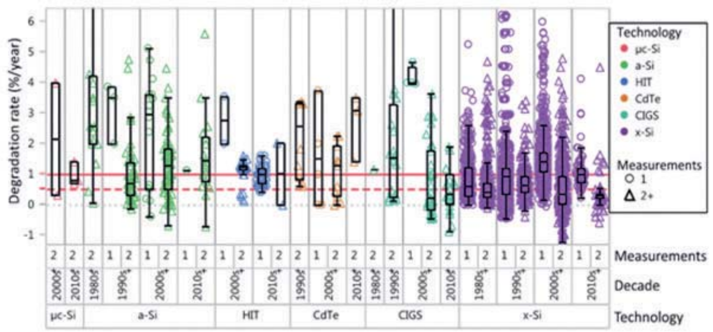
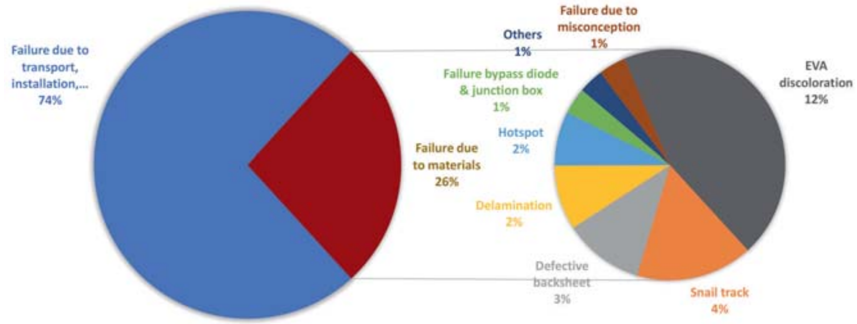


Figure 4. All degradation rates partitioned and colored by technology and decade of installation. Studies using one measurement are indicated by an open circle, and studies with two or more measurements are indicated by an open triangle. As a guide to the eye, 1%/year and 0.5%/year are indicated by a solid and dashed horizontal line, respectively.

D. C. Jordan et al., Progress in Photovolt., 2016

Nonetheless, as indicative as PR and degradation rates can be, they have their limitations. Indeed, the degradation rate is an average, theoretical figure, whereas the PR fails at showing the possible causes of a deficient performance. For these reasons, it is crucial to investigate the failures that can appear when operating a system. These technical failures can potentially concern all components of the PV system. Despite their scarcity, on average less than 1% on the first 5 years of deployment for modules, as studies and field data demonstrated, it is crucial to analyse them. [3] [4] Indeed, by substantially decreasing performances, these failures can deeply harm the profitability of investing in a PV system.



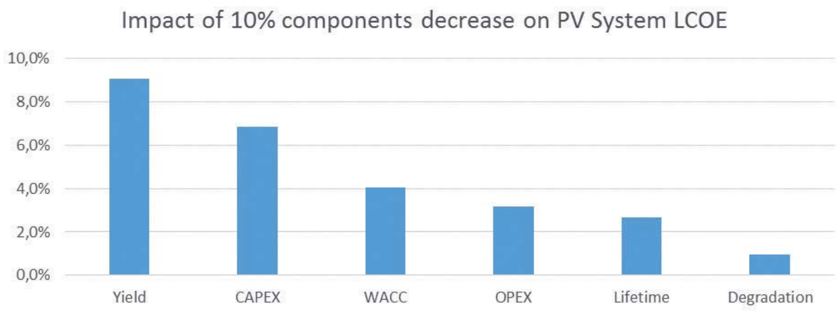
Data from D. Moser, M. Del Buono, W. Bresciani, E. Veronese, U. Jahn, M. Herz, E. Janknecht, E. Ndrio, K. de Brabandere and M. Richter, Technical risks in PV projects, SolarBankability Project, 2015. Analysis by the Becquerel Institute.

It is important to differentiate failures resulting from flaws occuring at the manufacturing stage from those resulting of errors at the stage of transport or installation, among others. As the figure 2 displays, in the case of PV modules, most failures are caused by inappropriate installation or transport conditions. [4] However, still more than a quarter of total failures are caused, partly or fully, by design and/or conception problems. Hence, these are the responsibility of industry parties along the value chain. They have a huge role to play by improving the quality of their products, but also by educating other players further downstream, such as transporters or installers.

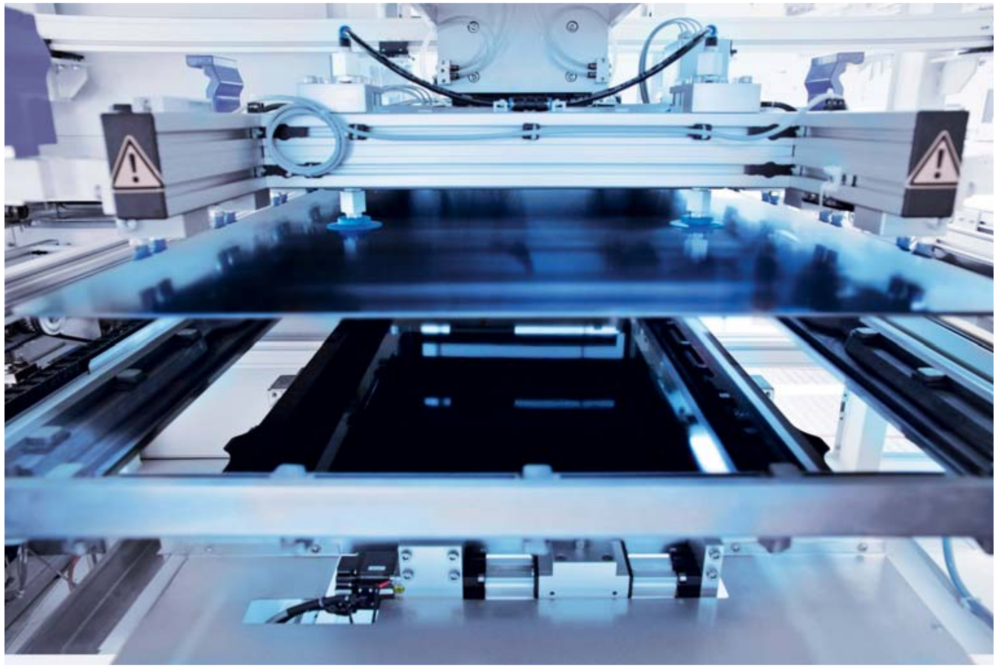
2. ASSESSING THE REAL SITUATION OF QUALITY AND PERFORMANCES IN TODAY'S PV INDUSTRY

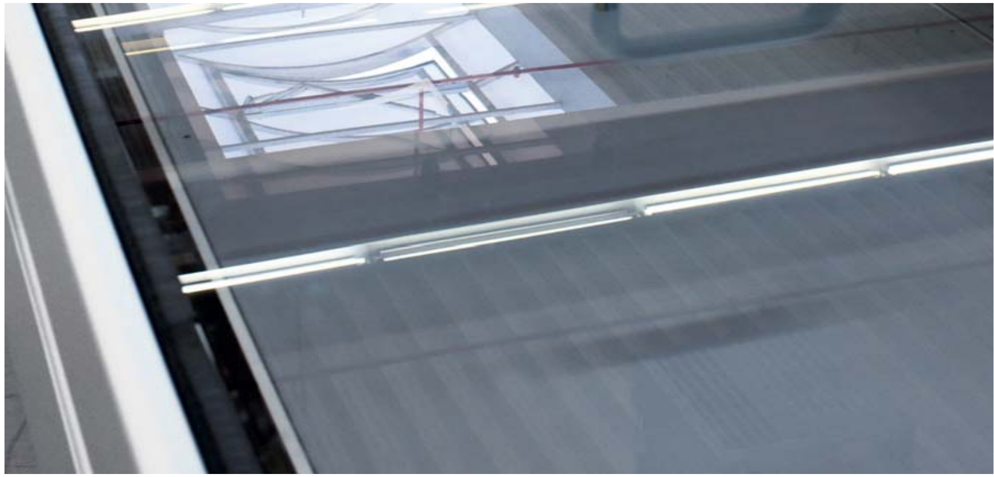
Different studies assessed the economic impact of such failures as well as the costs of mitigating them. The Solar Bankability project evaluated the cost-benefit of preventive and corrective mitigation measures on a metric called Cost Priority Number (CPN), which gives an indication of the economic impact of failures on a PV plant. The costs of taking preventive mitigation measures in terms of component testing to avoid PV modules failure ranged between €0.05 to €0.5 per kWp/year. [5] This amount can be considered as negligible in regard with its potential benefits quantifiable in a CPN reduction of around € 20 kWp/year in a scenario where components are substituted, reducing losses that would have otherwise led to downtime of several €/kWp/year.

It might slightly increase the CAPEX, but would certainly reduce the OPEX with a greater impact, hence reducing the LCOE of the system, from 1% up to 5% according to their simulations. [6] These conclusions are confirmed by another study, published by KIC InnoEnergy, which believes that in the case of thin-film modules, mitigating degradations could contribute by up to 4.5% in reducing LCOE in the next decade. [7] The CHEETAH joint-project financed by the EC's Horizon 2020 initiative also investigated the question. It demonstrated through sensitivity analysis that among all variables, the yield (which is directly linked to the PR) was the highest influencer of the LCOE, substantially in front of other variables such as CAPEX, OPEX or the WACC. [8]



CHEETAH Project, D5.5 Impact of quality and reliability on PV competitiveness, 2016.





3. SYSTEM QUALITY AND COMPONENTS QUALITY

3. System Quality and Components Quality

We have enough knowledge to make some sound observations: Top quality components will make the difference between a high-quality PV plant and a low-quality PV plant, with its correspondent impact on failures and PV plant revenues.

Performance Ratio is impacted by the energy output of the PV plant, which is directly dependent on the single performance of every component installed. Consider these factors:

- Modules: There are a large number of modules manufactured today with different prices and different **warranties** too. A high-quality module will perform better in the long term and the PV plant operator will verify it on the module's annual degradation, hot-spot creation, or mechanical failures like broken glasses or frame defects, amongst others.
- Inverters: Quality inverters can also be distinguished thanks to its performance on how much electricity is lost during the DC to AC conversion, how easily the inverter adapts the electricity factors to the grid needs, or how it can maximize the module's operating conditions. These components have evolved significantly during the past 5 years, incidentally, mainly thanks to companies focused on quality. Yet, the reliability and expected lifetime of inverters requires more attention.
- Structures (trackers or fixed tilted): The mechanical part of the PV plant is also an example of how a quality process can be implemented in manufacturing a better product. The algorithm trackers follow the sun; their motor quality and ratio of failures are key factors making the difference between the panoply of models. Definitively, it's something that will affect the PV plant operation and its long-term revenues.
- Other components, such as cables, monitoring system, and electrical transformers, are critical for PV plant performance. A quality check is requested during manufacturing and installing phases.

The PV plant performance is highly linked to each component's own quality.

4. Supporting the European PV Industry Through Quality

Today, the solar PV market highly depends on quality standards.

Reducing the LCOE by two main factors – cost reduction and energy – will increase yields in the following ways:

- **Reducing costs:** Quality standards are present in how component manufacturers apply processes to ensure top performing components, while reducing the cost of manufacturing. Employing the most efficient manufacturing techniques is a priority , but can only be achieved if one implements such high-quality processes throughout production. We have seen prices decrease dramatically for nearly all of the all the main components of a solar plant in recent years.

  Costs are also reduced in the field during the construction phase by applying lean techniques on organizations. For example, a timing optimization for mechanical and electrical mounting is not only feasible, it also dramatically reduces labor costs.

  Also,operating expenses (OPEX) are being optimized today by better organization of the maintenance teams, among other measures, such as utilizing better technology in cleaning systems and optimizing water usage. O&M teams normally work together at the same facility where the can monitor several PV plants located nearby, and react faster if needed. Solar's high deployment in recent years ushered in a quality mentality at the better organizations, which are certainly better for it Another potential benefit is reducing labor costs.

- **Increasing the energy yield:** Main components improvements are also responsible, for an energy yield increase.

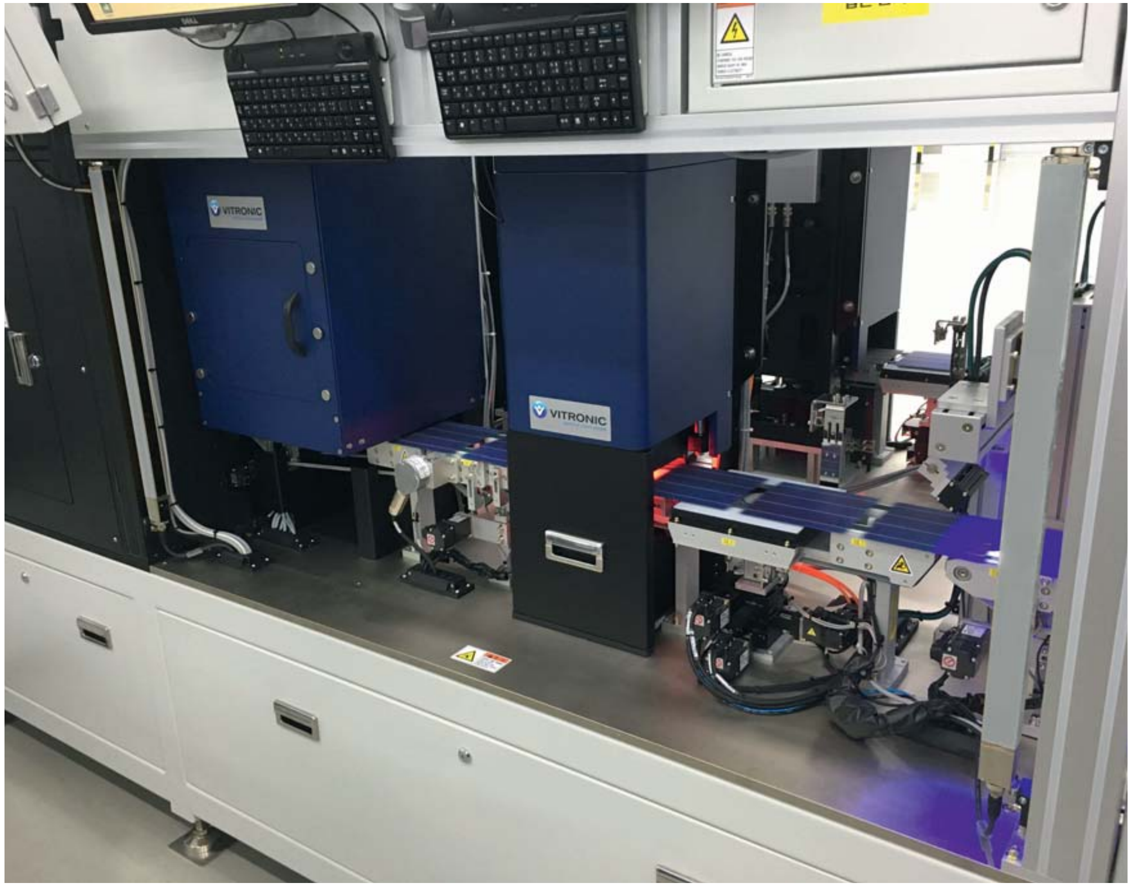
  Lowering electrical losses in PV modules' technical parameters depend on improving the materials used in its manufacture, as well as improving inverter performance – thanks to proper hardware and software functioning. Improving how trackers can maximize solar irradiation received by modules is an example of how the industry is doing its best to optimize the LCOE through the quality of manufacturing processes. Of course, the R&D factor linked with high-quality standards are key when one tracks the evolution of PV module efficiency.

  The energy yield is also optimized in the field, thanks to stellar operations and maintenance teams who as a matter of practice regularly reduce the occurrence of failures.

Ecolabeling and quality

Apart from the solar industry being more and more competitive, quality is also needed from an environmental point of view. By doing so, more PV plants will be able to come online annually.

Ecolabels are now rightfully applied to even works in progress to acknowledge environmentally friendly manufacturing processes, building processes, waste management, materials in PV components, recycling schemes or environmental monitoring, among others.



by courtesy of Vitronic, Wiesbaden.

CONCLUSIONS

Conclusions

Thanks to the large number of operating PV plants in many different countries, there's now enough of a track record to make a deep and complete analysis about systems, technologies and components performance and reliability.

The industry needs to take advantage of lessons learned in the field, which could contribute to increase quality on the upstream part of the PV industry, from module manufacturers to engineering and construction companies, asset managers or industry associations.

There is a clear need for many companies in the industry to benefit from Big Data available pertaining to PV component performance, as well as at all the different phases of the value chain of a solar plant.

The European PV industry has a key role to play. It has a head start with world-class equipment manufacturers and research labs, companies active along the entire PV value chain from polysilicon to crystalline silicon wafers, cells and modules, thin-film, inverters, trackers, and all other components. European EPC companies are among the world's best. Sound O&M maintains and enhances more than 100 GW generated from PV systems installed on the continent.

By focusing on quality at all levels the position of the European PV Industry will be strengthened, resulting in new jobs and a long-term sustainable future for all interested parties, including society at large.

One must also consider the bigger issue at stake from an overall global perspective. Can the industry afford bad publicity if system failures are reported in the press, and investors lose confidence? Let's put solar's best foot forward, and not see it suffer needlessly by reputation damage because of anecdotal quality issues that could lead to nation states to consider other renewal energy options, such as wind and water.

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August 2017