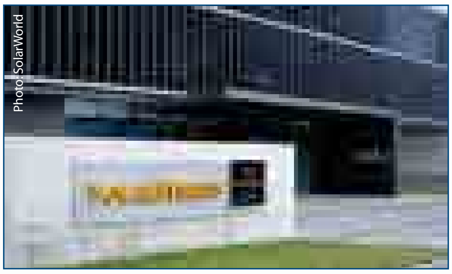
06 | 2017 | 78538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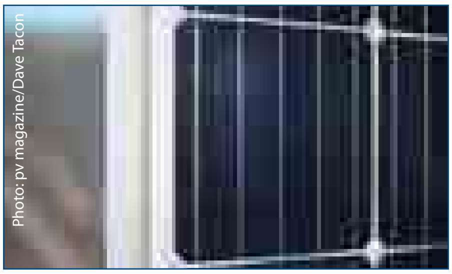
Markets & Trends

SolarWorld insolvency: A round-up of industry reaction to the German firm's insolvency filing. *Pages 5, 46*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Industry & Suppliers

Fixing the LID: How the UNSW is advancing the fight against LID in multi PERC cells. *Page 92*


Photo: Tesvolt

Storage & Smart Grids

C&I storage: Battery suppliers are increasingly creating systems and services for the C&I sector. *Page 110*

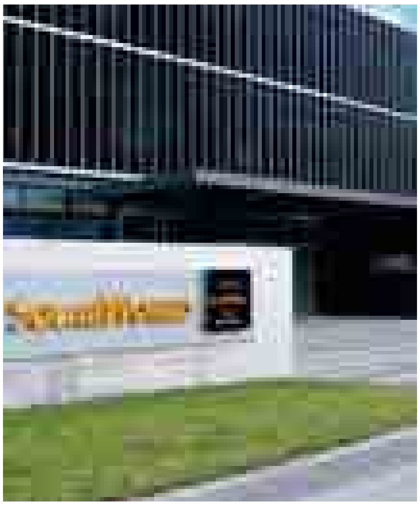
pv magazine

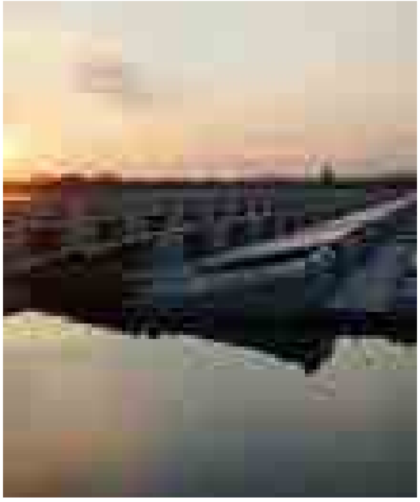
PHOTOVOLTAIC MARKETS & TECHNOLOGY


Photo montage: Martin Markstein

10 Array Changing Technologies

Three leading technologies go through as award finalists, as we sharpen the focus on the innovations changing the arrays of tomorrow. *Pages 52–61*





Contents 06/2017

Markets & Trends

Markets & Trends

Applications & Installations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Of the over 16 GW of projects for which CEA has provided quality assurance services, around 9 GW included factory audits. CEA brings the results of these audits together with other metrics in its benchmarking program.

Quantifying Risk: CEA introduces benchmarking

Quality assurance: Having been involved in assuring quality with over 16 GW of PV installations, Clean Energy Associates is putting its experience to good use. Its new Supplier Benchmarking Program brings together its proprietary data set with an analytical methodology, delivering a tool to judge PV module suppliers' ability to deliver on promises of durability and reliability. Director of Technology and Quality George Touloupas sets out the program.

The PV industry's exponential growth has happened so fast that some important questions regarding module quality remain unanswered. As the PV module is the single most important energy and revenue-generating component, its long-term performance is key to the financial success of a PV project. A crucial metric is the maximum annual degradation, which directly plugs into the financial model, and is guaranteed by the manufacturers via the provision of limited warranties.

At the same time, and since PV modules have a long history of field installations, organizations such as NREL have conducted studies on degradation and produced interesting statistics. The key takeaway is that PV technology is robust and reliable, and deserves the confidence of investors and planners.

However, there are some important caveats that provide nuance to the top line conclusion:

A backsheet scratch has far more serious risk potential than a frame scratch. In CEA's scoring system, the backsheet defect will get a higher risk score than the frame defect, to reflect this difference.

1. Most installations – over 75% globally – have only come about in the last five years.
2. The geographical spread of installations in harsher climates is a recent development.
3. The cost reduction curve is exceptionally hard to forecast, with steep drops every other year, driven by trade wars, regulatory uncertainties, and supply-demand cycles. New technologies, materials, and processes simply don't have enough time to gain a substantial track record before fully scaling up into mass production.
4. The push to drive down costs in production and maintain the – typically thin or even negative – margins is putting continuous pressure on production lines to keep running at ever higher utilization rates.
5. The suppliers' limited warranties have well-known shortcomings.

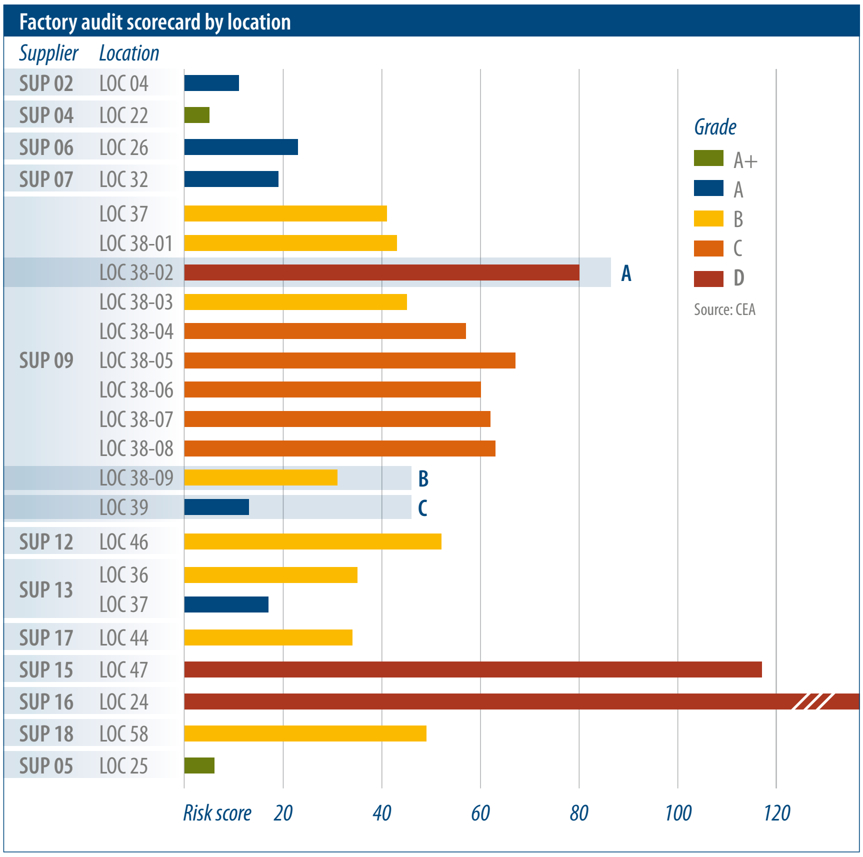
Behind the benchmark

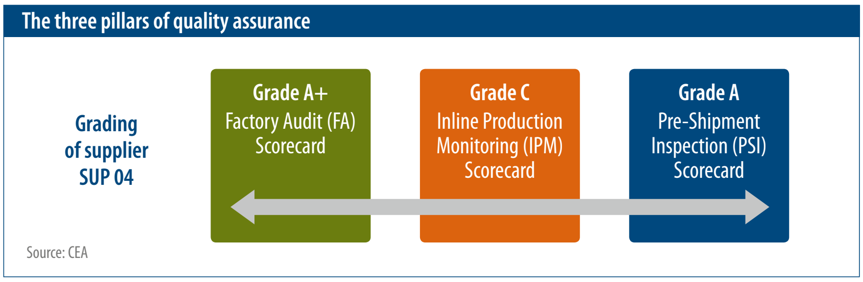
Given these factors, CEA has brought together its data, based on its experience in providing third-party quality assurance oversight, including on-site PV factory inspections, to produce a Supplier Benchmarking Program. Of the over 16 GW of quality assurance programs CEA has been involved in, over 9 GW included providing on-site factory oversight.

The Supplier Benchmarking Program ensures that high quality data taken during every project can be assessed regarding their risk potential and aggregated over manufacturing locations. It then provides a benchmarking tool to judge the ability of PV module suppliers to produce high quality products consistently over time. Every finding and every product defect is recorded during quality assurance oversight. The findings and defects are additionally assessed and given a numerical score according to their potential to create a significant risk of failure of the PV module in the field.

The scoring approach is partially informed by the 'failure mode, effects, and criticality analysis' (FMECA) methodology, which was pioneered within the automotive industry. More specifically, for the Pre-Shipment Inspection (PSI), the risk priority number (RPN) scoring method is applied on the defects found and characterized using CEA's internal list of more than 50 defect types. According to the methodology described in the IEC 60812-1 standard, the RPN number is the product of three scores: RPN = severity × occurrence × detectability, where each of the factors is assigned a value from 1 – 10, according to their

Graphics: pv magazine/Harald Schütt





risk potential. Every defect in CEA's list of defects found during PSI has been characterized and given a respective value. As a result, after each project, the sum of all risk scores of all the defects, normalized for project size, gives a very good view of its standing compared to other projects. In order to risk-score the Factory Audit findings, a different approach is taken. All the findings are classified into three categories: minor, major, and critical. The classification of the findings into these categories follows CEA's internal guidelines. The risk score of a major finding is X times the risk score of a minor finding, and the risk score of a critical finding is X times the risk score of a major finding. The rationale behind this exponential increase in the risk score, is that, according to CEA's guidelines, a finding that is classified as major has a much higher risk potential than a minor one, and a critical finding, which is a very rare event, has a much higher risk than a major finding.

Similarly, during Inline Production Monitoring, which is applied during the whole production period of a project, all findings are recorded and classified, according to the same risk categories. Similar score weighting multipliers are introduced, and the persistence of findings over time, as well the detection of an excessive number of findings is given extra weight. CEA believes that, besides the severity of the findings per se, a supplier's inability to speedily mitigate findings and/or keep the number of findings low, has a negative influence on the quality of the project, and should therefore be given a higher risk score. The total sum score is normalized over the duration of the project, so that different projects can be compared.

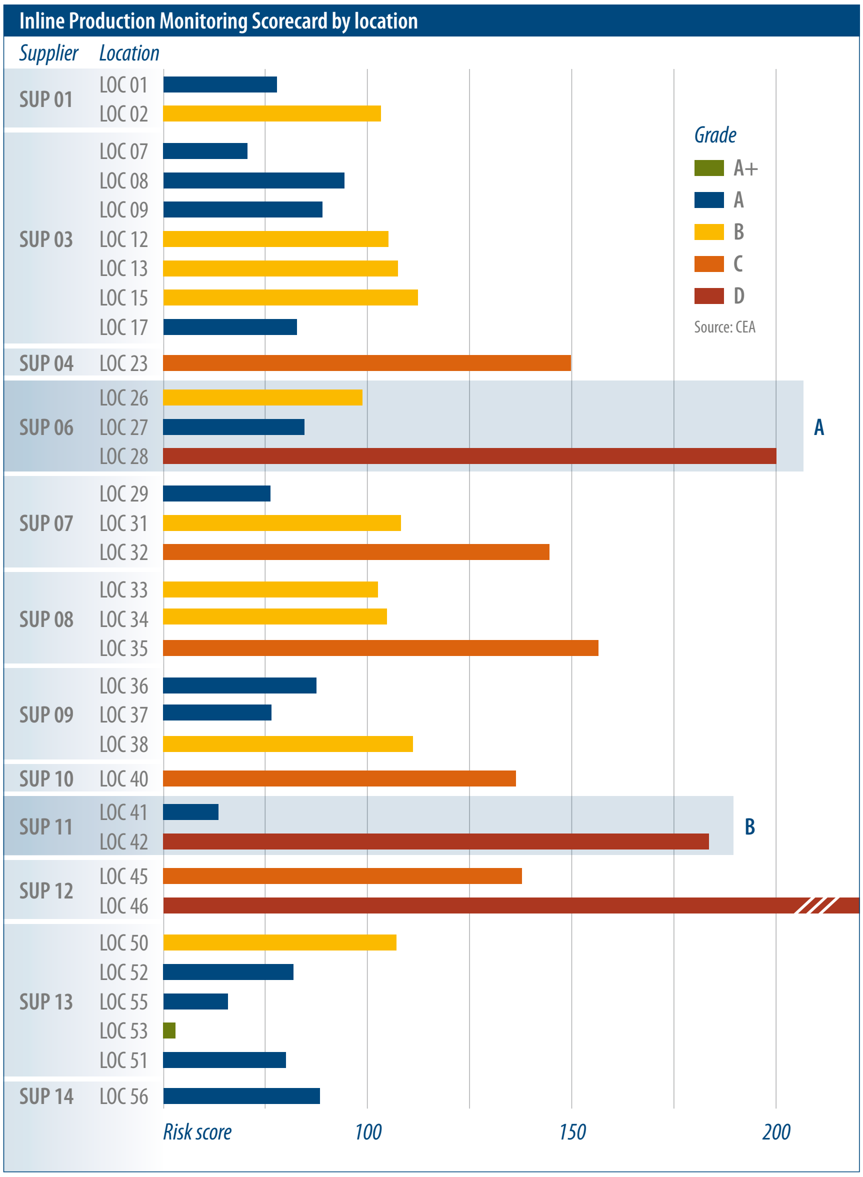
It should be stressed that, although the absolute values of the scoring system are arbitrary, they are assigned according to objective rules and guidelines, as the ultimate goal is to be able to compare suppliers and locations against benchmarks. Applying the above methodology and analysis over several gigawatts of quality assurance data points, taken from many projects, produced at different supplier locations over time, provides the following benchmarking grading system.

The grading ranges were produced by charting all scores, reviewing the results, and fine-tuning the ranges to reflect accurately CEA's perception of the comparative quality level of all locations. Location grades are derived by averaging over projects manufactured at the same location, and supplier grades can be derived by averaging over location grades.

By looking at various charts, and maintaining the anonymity of suppliers and the locations, some interesting observations can be made. The Factory Audit scores are shown for a number of mostly tier-1 supplier locations (above left).

The most striking feature is the great variability. This applies even for vari-

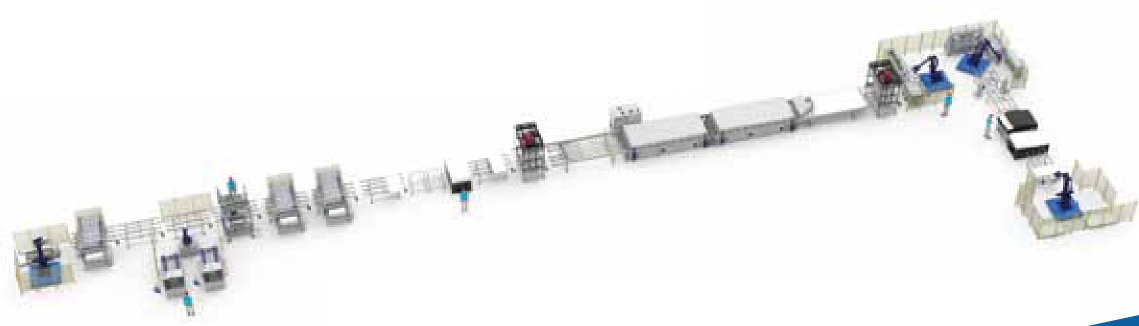
CEA applies three quality assurance activities in supplier facilities during production	
Factory Audit (FA)	A team of engineers audits a factory location using a 1,000+ point checklist. Every finding is recorded and classified according to risk potential.
Inline Production Monitoring (IPM)	A team of engineers continuously monitors all stations of a factory location during the production of an order, using a 260+ point checklist.
Pre-Shipment Inspection (PSI)	A team of engineers performs visual, EL, and IV inspections to a sampled lot of finished modules, according to a list of vetted quality criteria. Every finding is recorded and classified according to its risk potential.



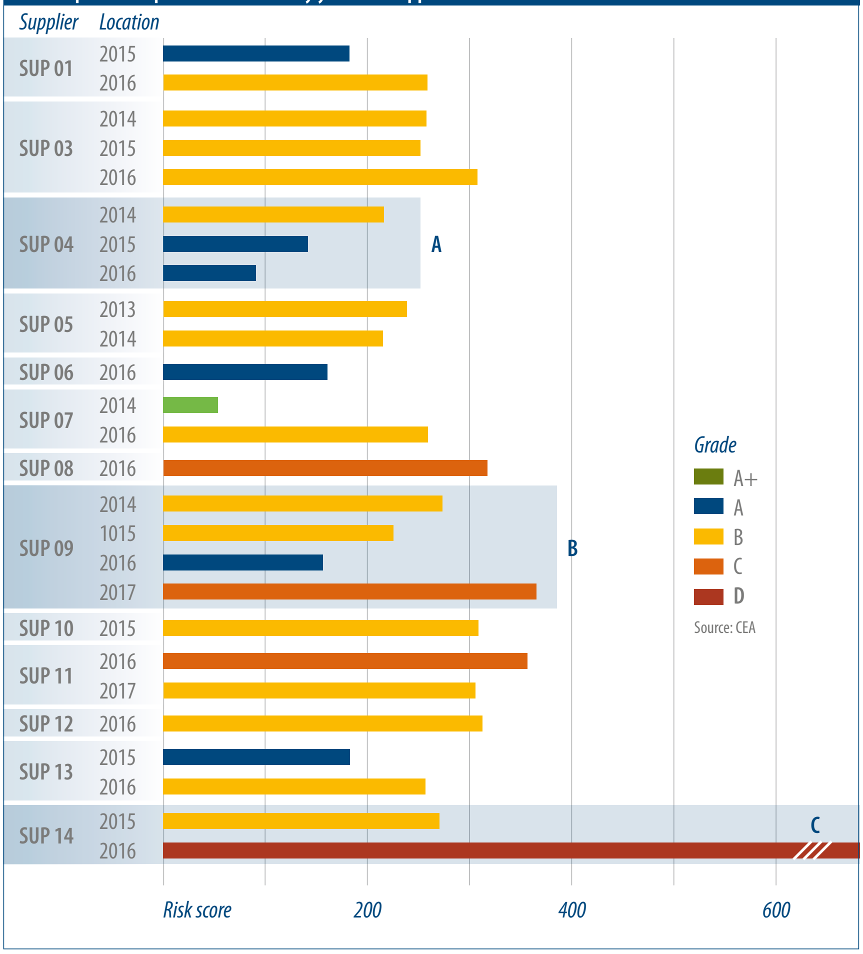
ous locations of the same supplier. Supplier 09 (SUP 09), was audited in various locations, and we can also see individual scores for workshops 1–9 of Location 38 (LOC 38). In the chart, we can see that Supplier 09 has an A grade in location 39 ('C'), which is, interestingly enough, an overseas OEM location not owned by the supplier. Even in the same location 38, grades can vary widely, with workshop 38-02 ('A') having an alarming D grade, but workshop 38-09 having an average B grade ('B'). Location 47 is a BNEF tier-1 supplier, but the D grade, accompanied by a very high score, means that serious improvements should be applied before beginning production.

The second chart to the left highlights once again the wide variation in the risk potential of different manufacturing locations, even if they belong to the same supplier. Supplier 06's location grades range from a good A to a high risk D grade ('A'). It's interesting to note that location 28 does not have the high degree of automation of the other two locations. For supplier 11 ('B'), there is a dramatic difference in grading. Location 41, an OEM location, has a good A score, but location 42, despite being the supplier's own location, has a very risky D grade.

The third chart (p. 82) shows grades and scores of various suppliers as they evolve over time. Supplier 04 ('A') shows a yearly improvement trend as it managed to move from a B grade to an A grade



Pre-shipment inspection scorecard by year and supplier



Source: CEA

within three years, which is a very positive trend, consistent with industry goals. On the other hand, supplier 09 ('B'), showed an improvement from a B grade to an A grade from 2014 to 2016, but then plunged to a C grade in 2017. Supplier 09 is experiencing very high demand in Q1 and this creates a lot of pressure on the production lines. However, since this grade is based on Q1 projects, it will be interesting to monitor the supplier's progress over the course of 2017. Supplier 14 had an average B grade in 2015, but jumped to a very high risk score and a D grade in 2016. This supplier was plagued by financial issues in 2016, and this seriously – and visibly – affected its ability to produce high quality PV modules.

The three different facets of CEA's quality assurance oversight complement each other, as they focus on different areas of risk. A Factory Audit is a snapshot, and is therefore not fully representative of the ability of a supplier to produce good quality modules. A good FA score is a great starting point, but problems may arise in production. Such production problems will reflect in a bad IPM score. However, the same project may have a good PSI score, because the supplier redirects the lower grade modules to other clients and doesn't submit them for PSI. The progress of supplier 04 over all three pillars of Quality Assurance points to just such a story (chart p. 80).

Until the PV industry matures, tools that quantify risk, such as CEA's Supplier Benchmarking Program, can be valuable guides for investors and financiers in navigating a very complex supply chain landscape. ◆ George Touloupas

Grade	Description	Risk analysis	Factory Audit (FA) range	Inline Production Monitoring (IPM) score range	Pre-shipment (PSI) score range
A+	World class location/ supplier	Very low quality risk	0 – 10	16	79
A	Good location/ supplier	Low quality risk	11 – 31	17 – 59	80 – 196
B	Average location/supplier	Average quality risk	32 – 54	60 – 104	197 – 314
C	Basic location/ supplier	Increased quality risk	55 – 77	105 – 150	315 – 432
D	Risky location/ supplier	Very high quality risk	> 77	> 150	> 432

ABOUT THE AUTHOR

George Touloupas is the Director of Technology and Quality at the solar PV quality assurance, supply chain management, and engineering services firm Clean Energy Associates (*www.cleanenergyassociates.com*). At CEA he leads projects centered on developing CEA's internal quality standards, researching new production technologies, and developing new services. Touloupas has an extensive background in PV manufacturing, as well as downstream experience, working prior to joining CEA as the Chief Operating & Technical Officer at Philadelphia Solar in Jordan and Technical & Operations Director at Recom among other roles.