



The pv magazine/CEA/Gsola test program

The results so far: summary and observations

Author: George Touloupas, Director of Technology & Quality
Presenter: Paul Wormser, VP of Operations
Date: 26 September 2018
Event: pv magazine Quality Roundtable, SPI 2018
Version: v2

Company Snapshot

- CEA is a solar PV advisory firm that is able to provide unrivaled insight into the manufacturing process to ensure the success of solar energy projects worldwide

More than
60 Employees

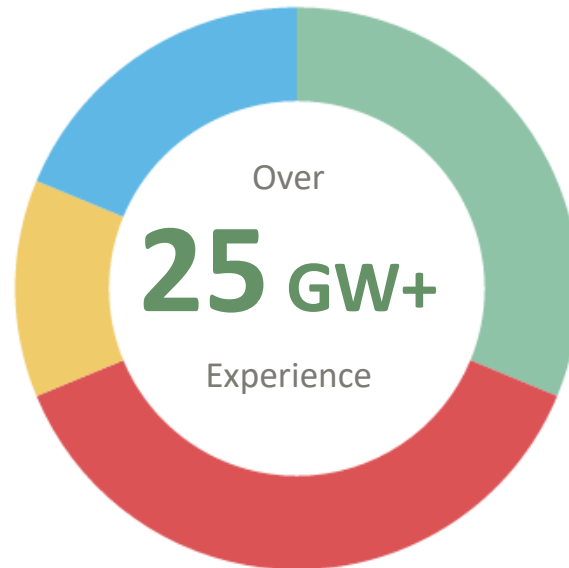
Over
35 Engineers

Over
10 Years history

A presence in
10 Countries

Technical Advisory

Engineering Services



Supply Chain Management

Quality Assurance

Client engagements in
40+ Countries



Audited over
140+
Solar Factories
Worldwide



Certified by

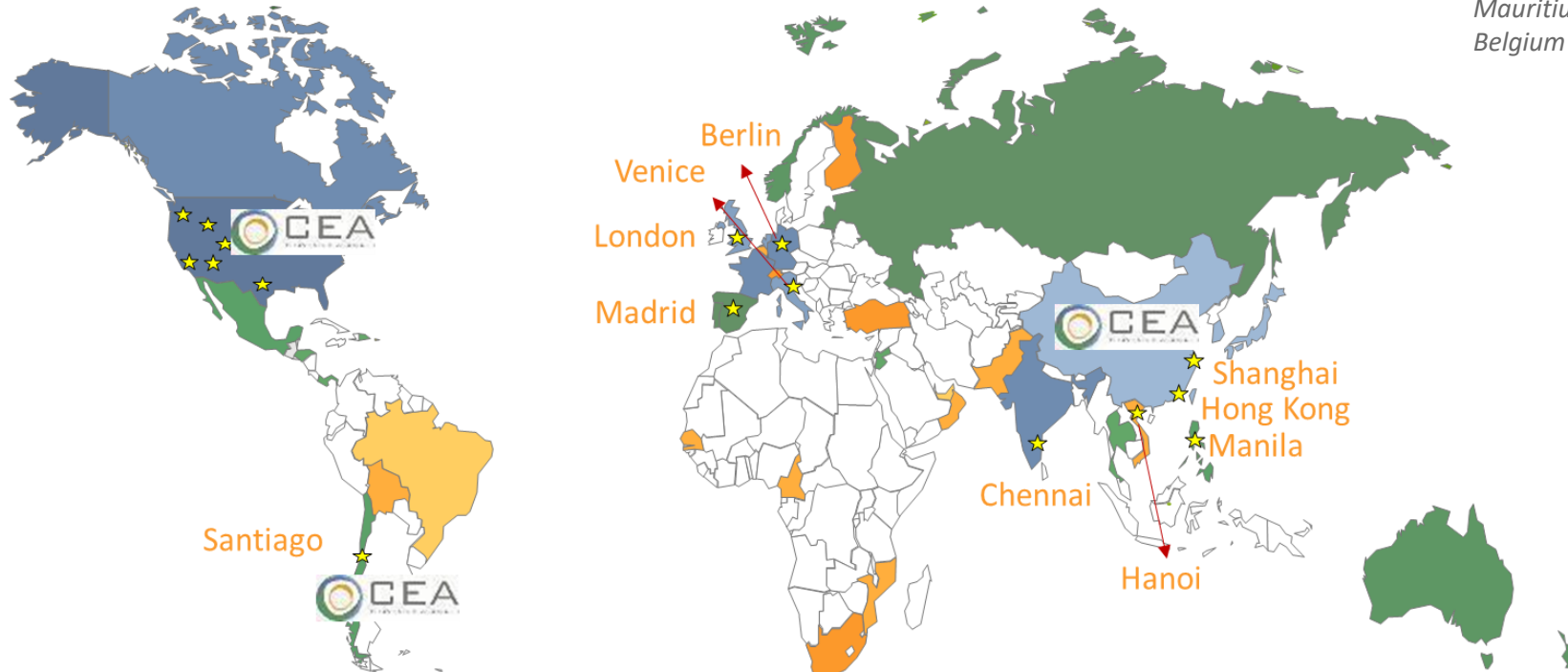
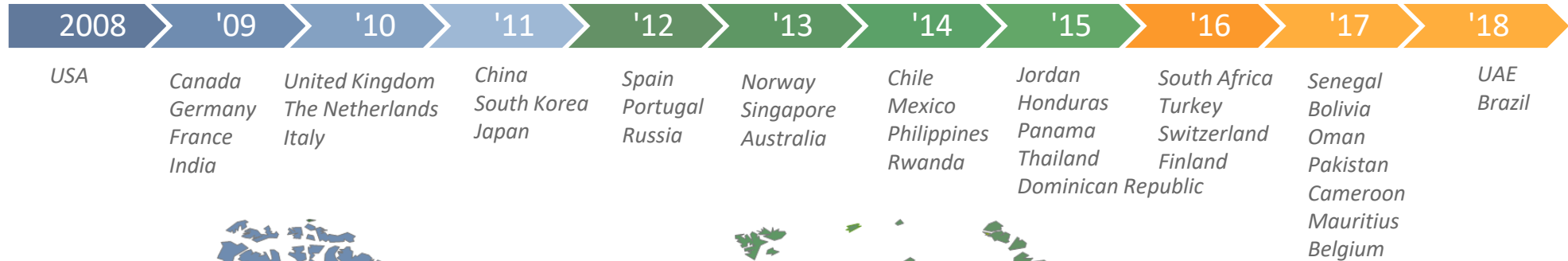


Proud member of



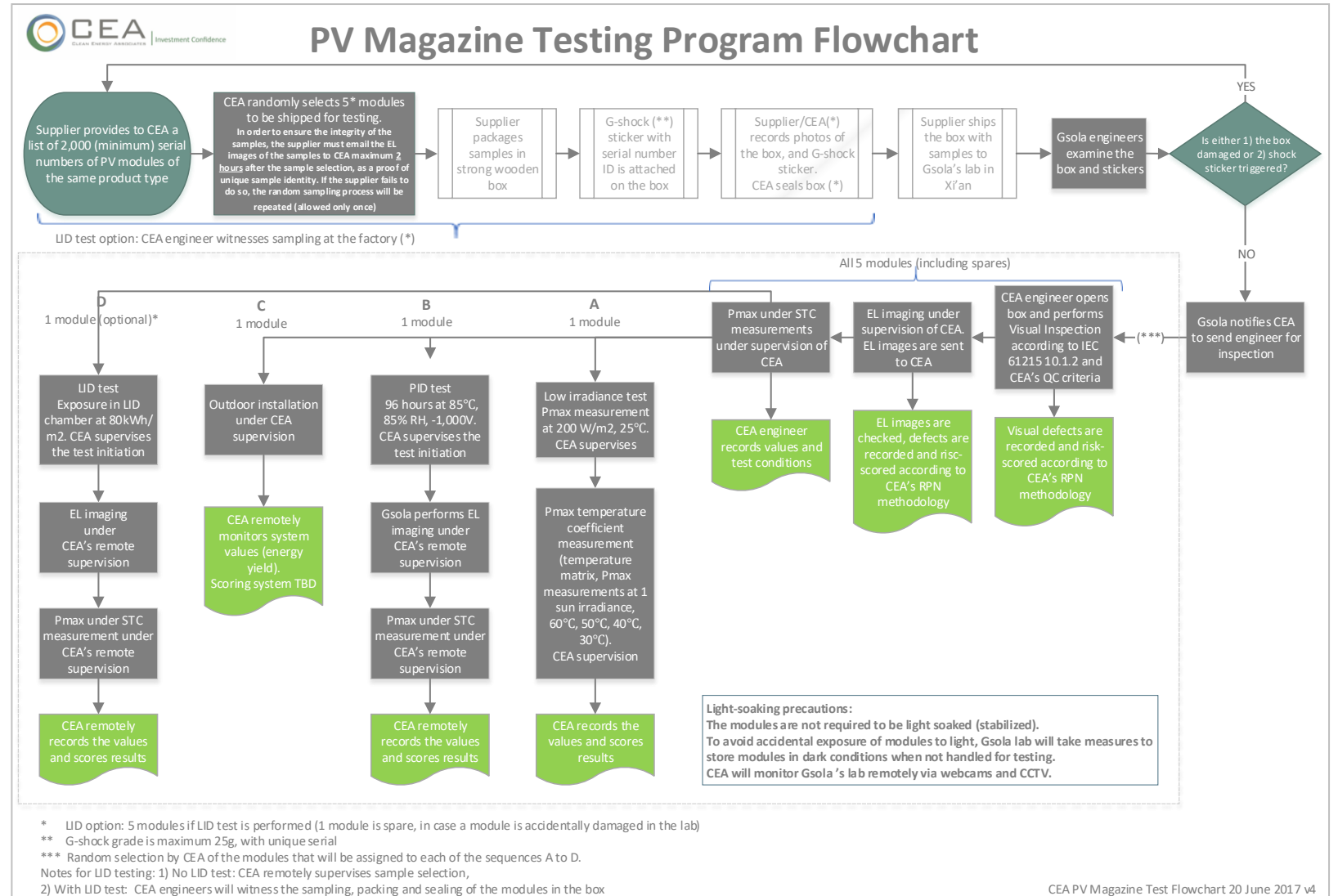
Global Footprint

- Since 2008, CEA has developed successful client engagements in 35+ countries and increased employee presence across 10 countries



A lighter approach to module testing

- The pv magazine test is not meant to replace certification or reliability testing.
- It has been designed to be executed in 1 week (apart from the outdoor performance test).
- At the same it must be relevant and useful to buyers and sellers.
- The test has been designed and is monitored and supervised by CEA.
- It takes place at Gsola's lab in Xi'an, China.



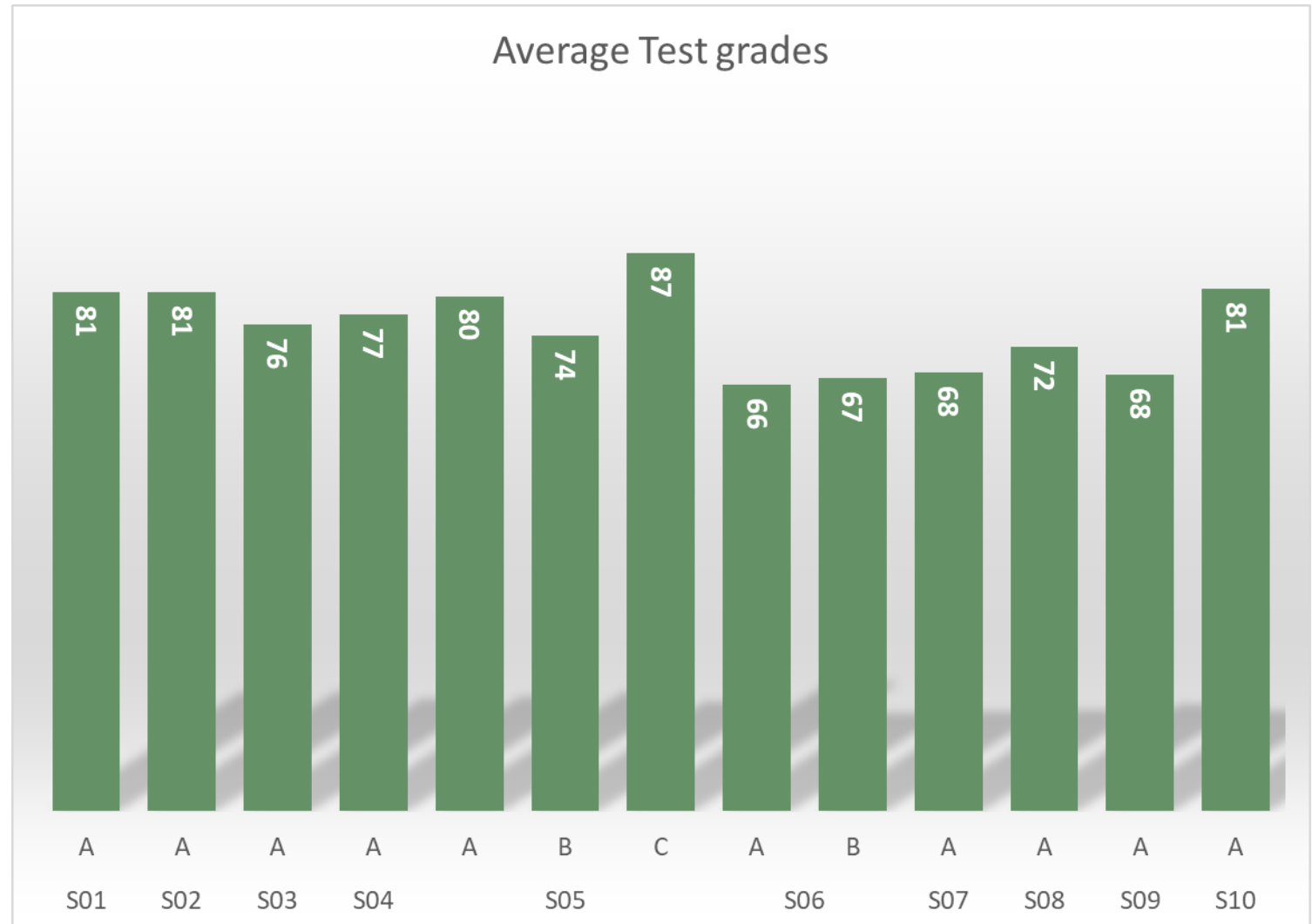
pv magazine test features

- **Benchmark testing**
Results are graded on a scale of 1-100
- **Product quality testing**
Visual inspection
EL inspection
- **Characterization testing**
Low Irradiance Loss
Power Temperature Coefficient
- **Reliability testing**
PID test
LID test (optional)
- **Energy Yield**
Outdoor energy yield performance

| # | Test | Weight in average grade |
|---|--------------------------------|--|
| 1 | Visual inspection | 10% |
| 2 | EL image inspection | 10% |
| 3 | Low irradiance efficiency loss | 25% |
| 4 | Pmax temperature coefficient | 25% |
| 5 | PID loss | 30% |
| 6 | LID loss (optional) | Graded separately, not part of average grade |
| 7 | Outdoor energy yield | Graded separately |

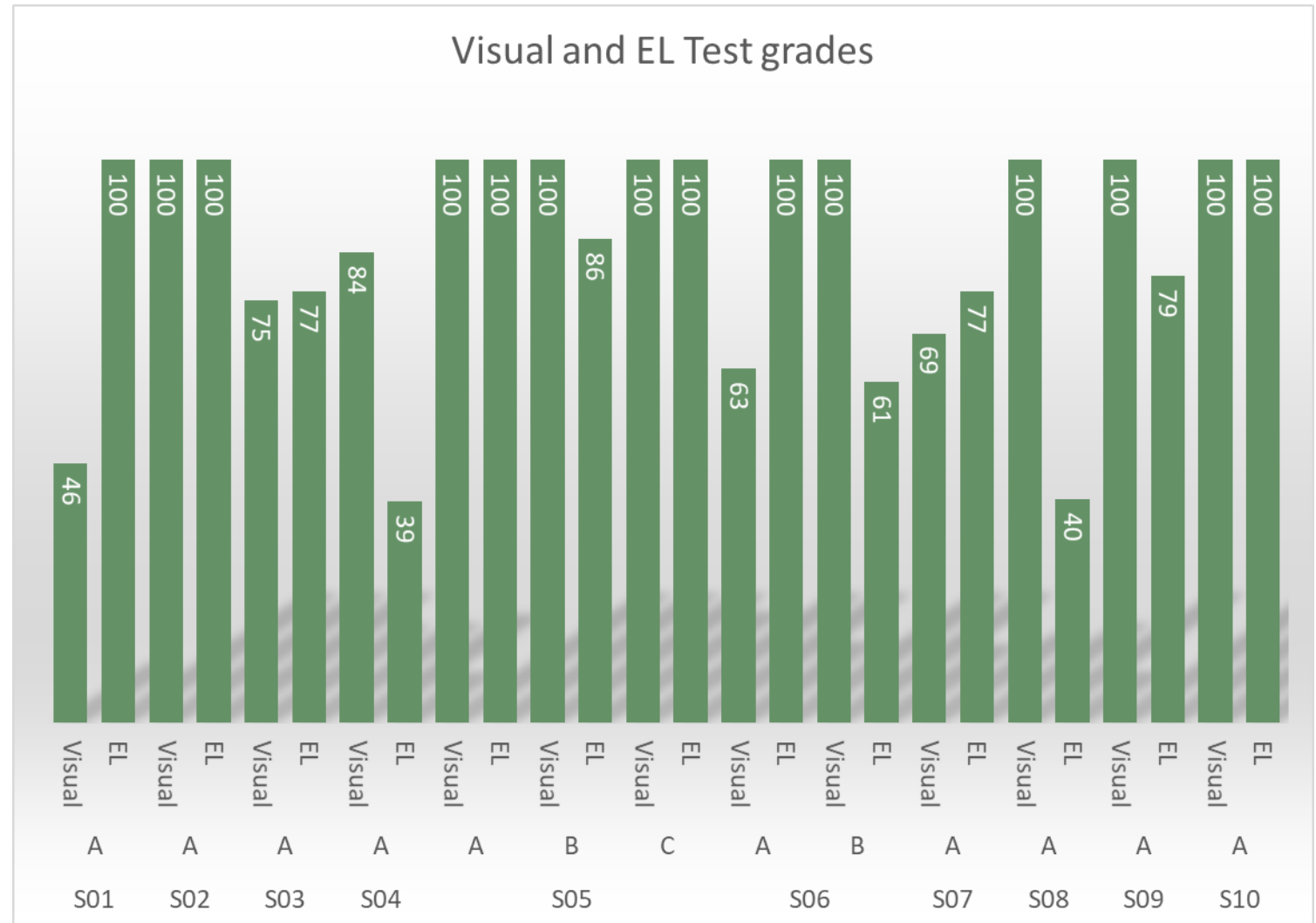
pv magazine test average grades

- 13 products from 10 manufacturers have been tested so far.
- Each test or inspection result is given a grade from 1-100.
- The grading system is detailed in the December 2017 issue of pv magazine.
- The average grade depicts the average performance of tests 1-5.
- LID, which is optional, and outdoor energy yield, will be benchmarked separately.



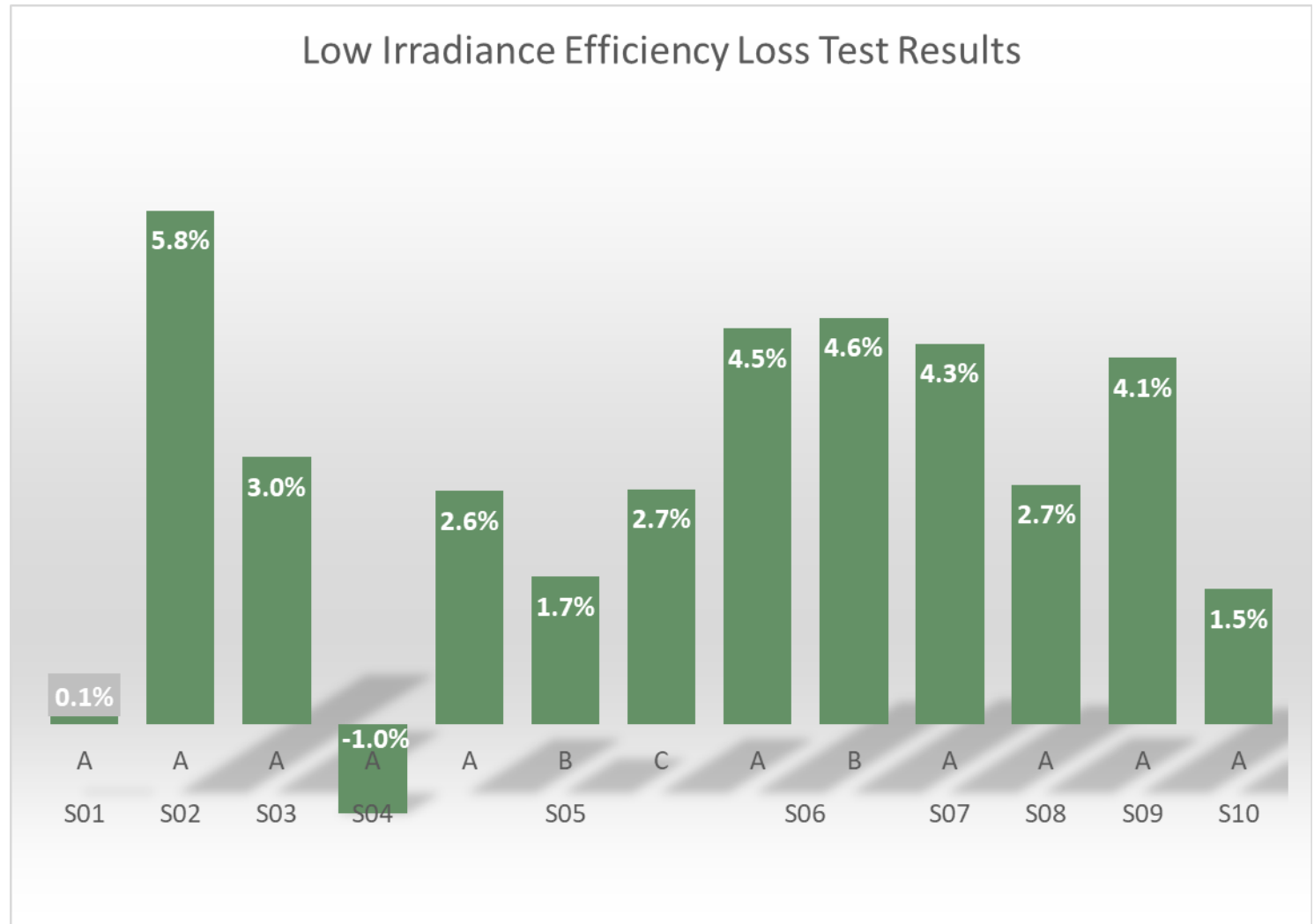
Visual and EL test grades

- Manufacturer S05, has submitted 3 products (A, B and C) for testing, and got very high grades in the total 6 visual and EL inspections: 5 times a perfect grade of 100 and 1 time a very high grade of 86.
- This shows a very good quality level in production, as there were very few defects.
- Random sampling from a large quantity ensures a level playing field for all manufacturers.



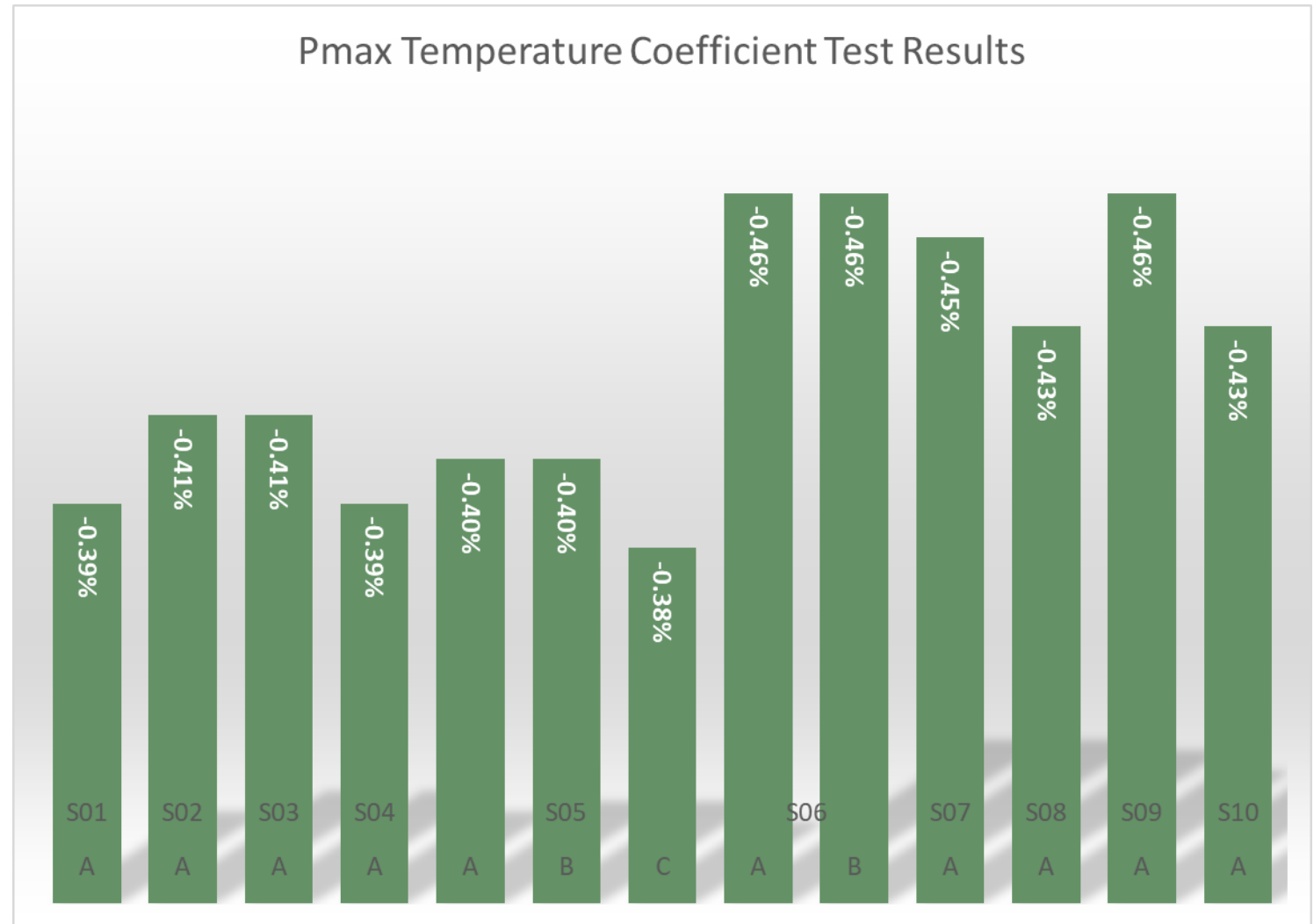
Low Irradiance Efficiency Loss

- The product of manufacturer S01 has almost zero loss, which is very beneficial for installations with low light conditions.
- Manufacturer S04 has a negative loss, which is effectively a gain, meaning that the module efficiency improves in low light
- Manufacturers S05 and S10 also have very low losses.
- This can be explained by the advanced cell architectures employed, that show better efficiency in low light than conventional cell types.



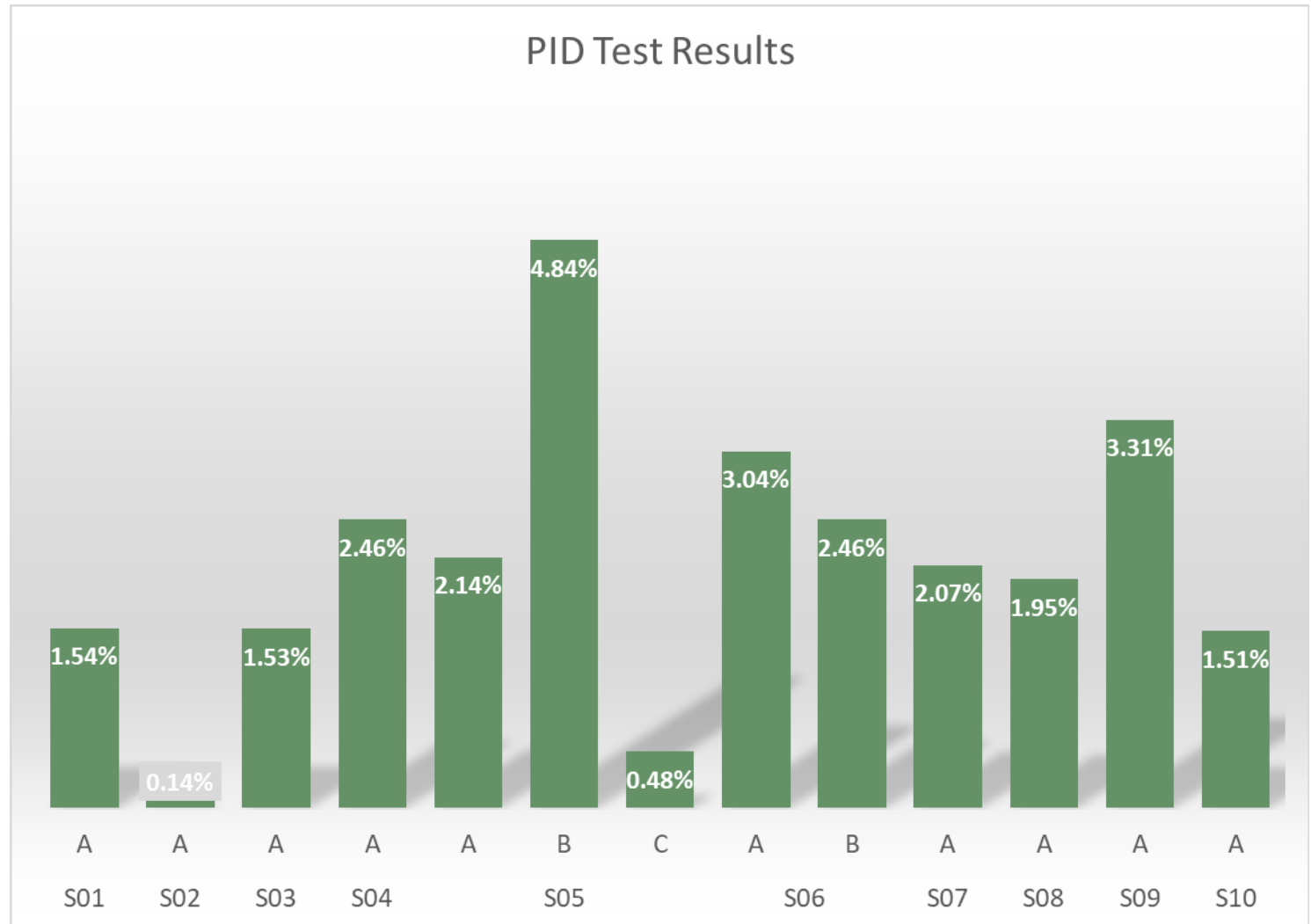
Pmax Temperature Coefficient

- We observed that advanced cell architectures exhibited better (lower absolute values) temperature coefficients, typically between $-0.40\%/^{\circ}\text{C}$ and $-0.38\%/^{\circ}\text{C}$.
- Conventional cells reached even as high as $-0.46\%/^{\circ}\text{C}$, which can be very detrimental to energy yield in hot climates.



PID loss

- Manufacturer S02 had almost 0% PID, and this is due to a very special cell architecture that is not prone to PID.
- Manufacturer S05 had mixed results, with one sample showing very high degradation and another one showing very low. The high result may be due to an unsuitable encapsulant but is also amplified by the fact that the cell was bifacial, as bifacial modules are more sensitive to PID than monofacial modules.
- Another interesting observation, not depicted in the charts, is that testing for PID at -1,500V has a non-proportional effect on PID, which we observed when testing the same product at -1,000V and -1,500V and found a tripling of the degradation.

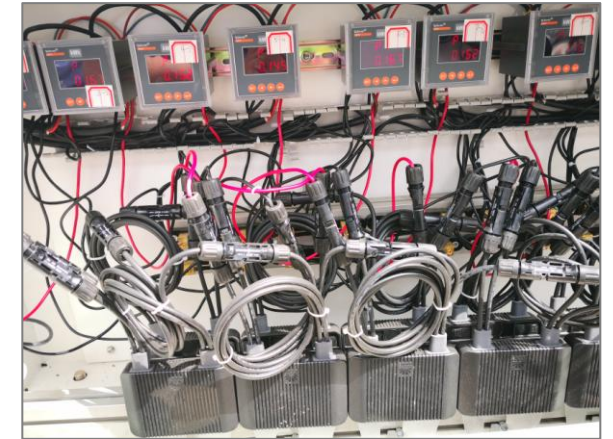


The outdoor test

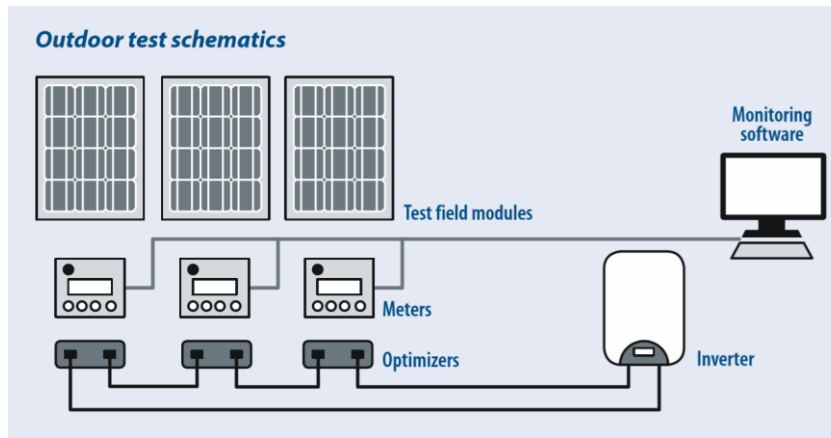
- As part of the pv magazine test program, Gsola has prepared an outdoor installation field in Xi'an, China, on the rooftop of a building that houses its manufacturing facilities and the test lab where the pv magazine tests are conducted.
- Xi'an has a temperate climate, with cold winters and mildly humid, hot summers.
- Each product will be installed in the test field for a 12-month period, and its energy yield (kWh/kWp) will be monitored and measured.
- Dedicated areas have been designed for the monitoring of bifacial modules
- The first results started coming in June 2018.



Gsola outdoor test field in Xi'an



Optimizers and high precision meters



Monitoring schematic

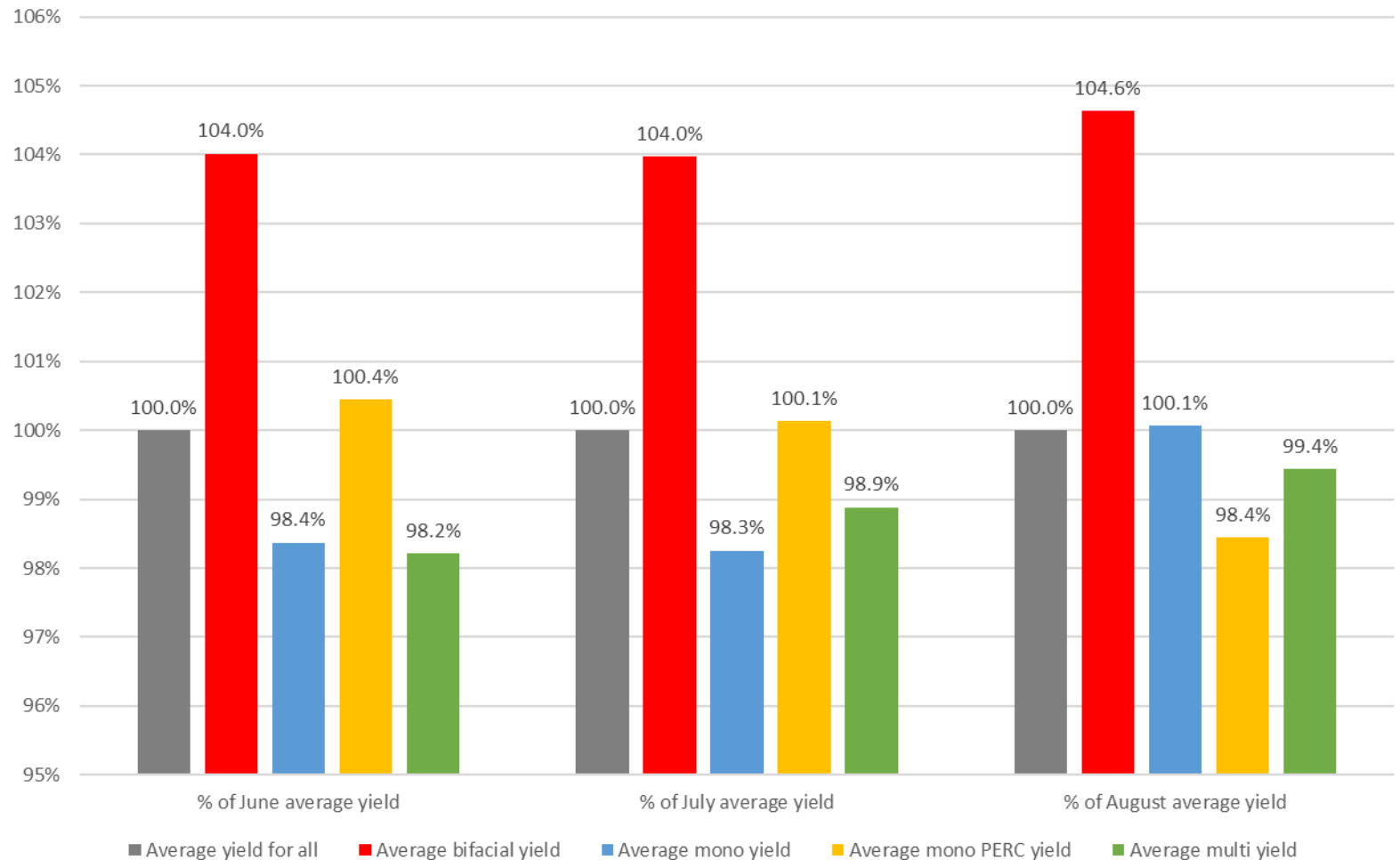


Weather station

The outdoor test: first results

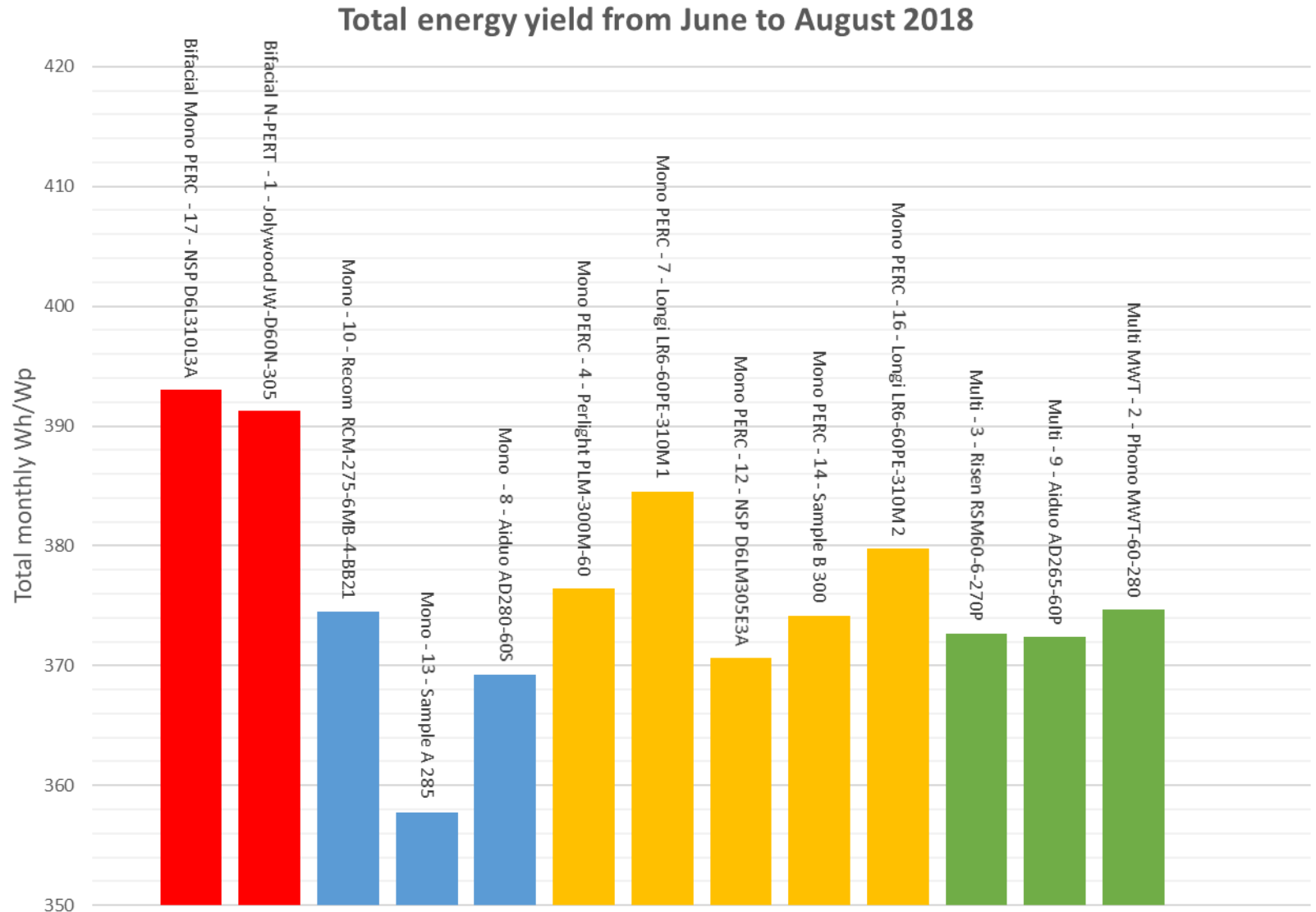
- Different technologies are grouped together so that we can attempt to draw conclusions.
- The area where the bifacial modules have been installed is covered with an artificial material simulating green grass, which has low albedo. Even so, bifacial modules produced almost 5% higher than the average of all.
- Mono PERC had 1%- 2% higher yield than standard mono and multi in June and July, but the trend reversed in August, when direct irradiance was higher.

Relative yield of different technologies from June to August 2018



The outdoor test: first results

- The 2 bifacial products of NSP and Jolywood remain the champions in energy yield over the summer.
- The next two best performers were the 2 monofacial mono PERC samples from LONGi.
- Standard mono and multi products had similar performance.
- We are very excited to have delivered the first batch of energy yield data from the outdoor test field in Xi'an. As we install more samples, gather more datapoints and deepen our analysis, we expect to draw more conclusions and correlations.





Thank you!