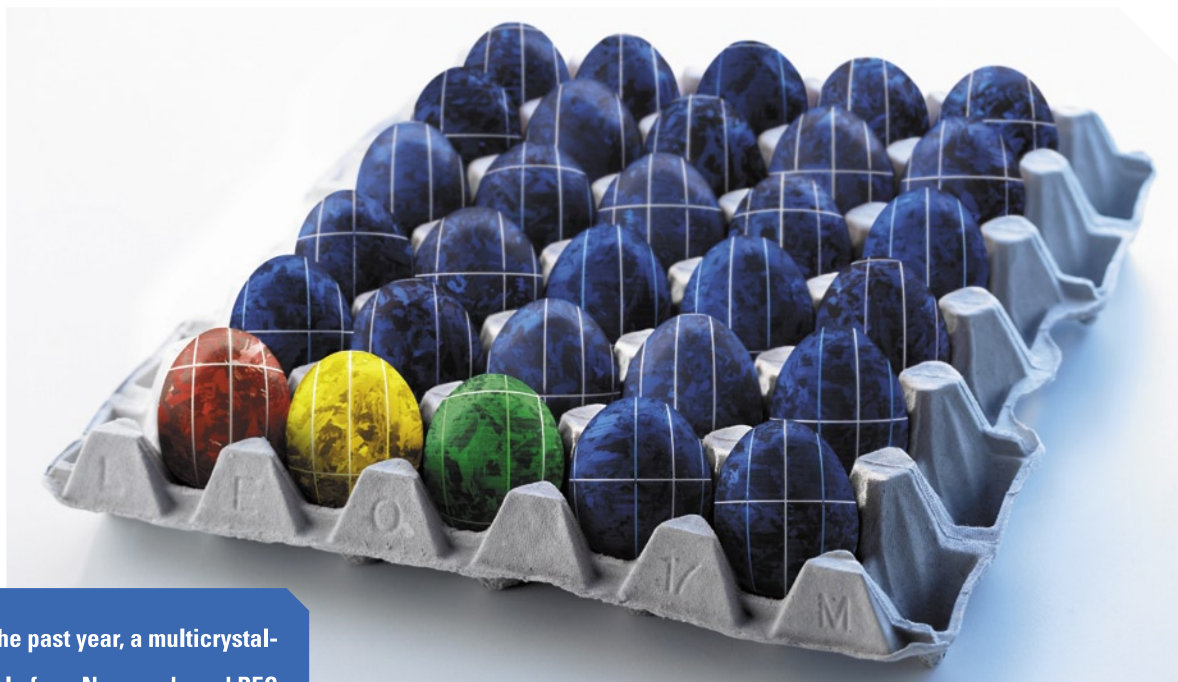
No two modules alike

Every module is different, but performance ratios allow for a direct comparison of annual yields



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During the past year, a multicrystalline module from Norway-based REC delivered the highest output among the devices in PHOTON Lab's test field in Germany. The site is home to 123 different models in all. Of these, 46 were installed as of the beginning of 2011, allowing for a full year of metrics to be gathered. Siliken, a Spanish module maker that produced the top device in 2010, came in second by a narrow margin in the current ranking, with a device that also uses multicrystalline cells. Third place, however, was a surprise.

Even a bad module can be good in and of itself: that is the surprise revealed by PHOTON Laboratory's 2011 module yield measurements, which were completed on Dec. 31. We are speaking of the NT-125AX from Taiwan-based Nexpower Technology Corp., a micromorphous thin-film module. Though it did not deliver the highest output on the test field, it was certainly close. If it weren't for some unfortunate design flaws, it would perhaps have been able to outperform the top-ranked model, the REC230AE from Norway's Renewable Energy Corp. ASA (REC).

This year, PHOTON Lab didn't just determine the total yield of each of the 123 models on the test field, as was the case last year (see 2/2011, p. 64); the lab also calculated the monthly yield for each module in the test over the course of 2011 and compared it to the average yield of all the other modules during the same period (see article, p. 64). The results are intended to show the relative performance of each module under different irradiance and ambient temperature conditions. For example, some devices deliver more output in the summer (like the Nexpower Technology Corp. module) relative to the others. Others perform less well in winter (also like the Nexpower module). Others perform at around average under all conditions (like the Mage Powertec Plus 225/6PJ from Mage Solar AG). It turns out that these comparisons reveal several distinct patterns of module behavior throughout the year (see article, p. 64).

PHOTON Lab's outdoor module tests: Results of 2011 yield measurements

Ranking	Manufacturer	Model	Production dates	Installed in	Performance ratio	Yield (kWh/kW)	Deviation from best (%)
1	REC ASA	REC230AE*1	2007-2010	2010	90.8%	1,150.4	Best of 2011
2	Siliken SL	SLK60P6L 230Wp	–	2009	89.6%	1,135.6	1.3%
3	Nexpower Technology Corp.	NT-125AX*1	2009-2010	2010	89.6%	1,135.4	1.3%
4	CH Solar GmbH & Co. KG	CH Solar 180 mono*1	Through 2010	2010	89.1%	1,129.2	1.8%
5	CSG PV Tech Co. Ltd.	CSG180S1-35/36*2	2008	2010	89.0%	1,127.7	2.0%
6	CNPV Solar Power SA	CNPV-185M	2006	2010	88.8%	1,126.0	2.1%
7	Win Win Precision Technology Co. Ltd.	Winaico WSP-235P6	–	2010	88.8%	1,125.2	2.2%
8	Solarworld AG	Sunmodule Plus SW 225 mono	2009	2010	88.7%	1,124.4	2.3%
9	Bisol d.o.o.	BMU-215-2/221	2007	2010	88.2%	1,118.4	2.8%
10	CSG PV Tech Co. Ltd.	CSG230M2-30*3	2008	2010	88.2%	1,118.0	2.8%
11	Upsolar (Shanghai) Co. Ltd.	UP-M180M*1	2010-2011	2010	88.1%	1,116.4	3.0%
12	Trina Solar Energy Co. Ltd.	TSM-225PC05	–	2010	87.8%	1,112.6	3.3%
13	Conergy AG	Conergy PowerPlus 220P	2009	2010	87.7%	1,111.7	3.4%
14	Trina Solar Energy Co. Ltd.	TSM-180DC01	2007	2009	87.6%	1,110.6	3.5%
15	Aleo Solar AG	aleo S_18 225	2005	2010	87.6%	1,110.4	3.5%
16	Kioto Photovoltaics GmbH	KPV 210 PE*1	2008-2010	2009	87.4%	1,108.3	3.7%
17	Sunpeak / Alpexsolar*4	ALP235W*1	2009-2010	2010	87.4%	1,107.1	3.8%
18	PV Power Technologies Pvt. Ltd.	PVQ3 220	2008	2009	87.3%	1,106.0	3.9%
19	Hanwha Solarone Co. Ltd.*5	SF160-24-1M175 (scac)	–	2010	87.2%	1,105.3	3.9%
20	S-Energy Co. Ltd.	SM-220PA8	–	2009	87.1%	1,104.0	4.0%
21	Win Win Precision Technology Co. Ltd.	Winaico WSP-230P6	2009	2009	87.0%	1,103.2	4.1%
22	Mage Solar AG	Mage Powertec Plus 225/6PJ*1	Through 2011	2009	86.9%	1,101.4	4.3%
23	Sonalis GmbH*6	SL-180CE-36M	–	2010	86.8%	1,099.8	4.4%
24	Frankfurt Solar GmbH	FS215W-POLY	–	2009	86.4%	1,095.2	4.8%
25	Perfectenergy (Shanghai) Co. Ltd.	PEM-180/185-72M-SCC	2008	2010	86.1%	1,091.7	5.1%
26	Shell Solar GmbH*7	Shell SQ 150-C*1	Through 2005	2006	86.1%	1,091.0	5.2%
27	Emmvee Photovoltaics GmbH	ES-230P60*8	2008-2011	2010	86.1%	1,090.8	5.2%
28	Solarworld AG	Sunmodule Plus SW 210 poly*9	2004	2006	85.8%	1,087.6	5.5%
29	Sunrise Solartech Co. Ltd.	SRM 180D72-GE	–	2009	85.6%	1,085.3	5.7%
30	First Solar Inc.	FS-265*1	2006-2011	2007	85.5%	1,083.3	5.8%
31	Evergreen Solar Inc.	EC-120*1	2004 - 2006	2006	85.1%	1,079.1	6.2%
32	Sovello AG	Pure Power SV-X-200 (LV)*1	2009-2011	2011	85.1%	1,079.0	6.2%
33	Shell Solar GmbH	Shell PowerMax Eclipse 80-C*1	2005-2006	2007	84.9%	1,076.2	6.5%
34	Photowatt International SAS	PW 1650-175W	2005 (purchased)	2006	84.7%	1,073.7	6.7%
35	Solar-Fabrik AG	SF 130/4-130*1	2006-2010	2010	83.0%	1,051.9	8.6%
36	Canadian Solar Inc.	CS6A-170P	2007 (purchased)	2007	82.6%	1,047.4	9.0%
37	Isofoton SA	I-110/24*1	Through 2005	2006	82.1%	1,041.0	9.5%
38	Hanwha Solarone Co. Ltd.*5	SF160 M5-24 (175 W)*1	–	2007	81.8%	1,036.4	9.9%
39	Kyocera Corp.	KC170GT-2*1	Through 2006	2006	81.7%	1,034.9	10.0%
40	Isofoton SA	IS-170/24*1	2007	2009	81.0%	1,027.2	10.7%
41	Solar-Fabrik AG	SF 145A*1	2003-2004	2005	80.3%	1,017.3	11.6%
42	Schott Solar AG	ASE-300-DG-FT (300 W)*1	1997-2006	2007	80.3%	1,017.1	11.6%
43	Sunways AG	MHH plus 190 (190 Wp)*1	2003-2005	2005	80.1%	1,015.5	11.7%
44	Evergreen Solar Inc.	ES-180-RL*1	2006-2008	2007	79.8%	1,011.9	12.0%
45	BP Solar International Inc.	BP 7185 S*1	–	2005	79.7%	1,009.5	12.2%
46	Sharp Corp.	NT-R5E3E*1	2003	2005	78.2%	990.9	13.9%

*1 no longer manufactured, *2 previous model designation: CSG180S1-35/1589×807, *3 previous model designation: CSG230M2-30/1640×992, *4 manufacturer Alpexsolar, distribution via Sunpeak-Vertrieb Unternehmensgruppe Ratio-Data, *5 previously manufactured by Solarfun Power Holdings Co. Ltd., *6 for supplier Ningbo Qixin Solar Electrical Appliance Co. Ltd., *7 now manufactured by Solarworld AG, *8 previous model designation: ES-200-P60(230), *9 previous model designation: Solarfun Power Holdings Co. Ltd.

Presenting the measurements in this way is the first major innovation in analyzing long-term module yield performance data since PHOTON Lab began these tests 7 years ago with just three models. Until now, the lab has been content to measure efficiency under standard test conditions (STC) for each module and to compare these against the monthly and annual yields that the devices produced on the test field in Aachen, Germany.

The test field is rapidly growing: in 2011 alone, 77 new models were added, making PHOTON Lab's outdoor facility the largest of its kind in the world. Naturally, an annual yield cannot yet be determined for the newest models – they haven't been onsite for a full year. Therefore, the performance ratios for these modules are not indicated in the lab's test results. Performance ratio takes into account the amount of solar electricity produced in relation to the solar irradiance available and the efficiency of the device under STC. A performance ratio of 100 percent would mean that a module with a 15-percent conversion efficiency, for example, produced 150 kWh under 1,000 kWh per m² of solar irradiance in a year. A module with only a 10-percent efficiency that produces 100 kWh under the same conditions would therefore also have a performance ratio of 100 percent. Hence, knowing these values allows for a direct comparison between modules

The PHOTON performance ratio logo: Sorting the wheat from the chaff

Module data

The company listed in this field is the firm that supplied the device. In most cases, this is the company that produced the module. Some companies order devices from other manufacturers and then rebrand them as their own (in which case, the name of the former is listed, rather than the name of the original manufacturer).

Performance ratio

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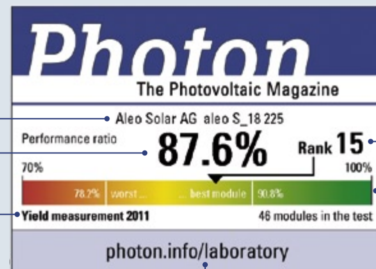


Yield measurement 2011

This indicates that the yield measurements used to calculate the data in the box were taken during 2011.

photon.info/laboratory

Further information on PHOTON Laboratory, the test field and the yield tests can be found at this website.

Modules in the test

This indicates how many modules successfully completed a full year of testing during the year in question, allowing the reader to gauge the significance of each module's rank.

Ranking

All solar modules that have been installed on the test field since January 2011 and successfully completed a full year of measurements have been ranked based on their performance ratios. Several modules exhibited ratios that were nearly identical, and these modules can be considered virtually indistinguishable with regard to the ranking. For instance, it's possible that NT-125AX from Taiwan-based Nexpower Technology Corp. should have outranked the Spain-based SLK60P6L 230Wp from Siliken SL, coming in second rather than third (see table, p. 49). The differences between the performance ratios of the two modules were within the margin of error of the tests. Changes in the weather can also affect the ranking. What is clear, however, is that a highly ranked module will consistently outperform a poorly ranked module.

Color bars

The color bars depict the rank of performance ratios stretching from 70 to 100 percent. Vertical white lines indicate the respective positions of the worst- and the best-performing modules in the test, with the worst appearing to the left and the best to the right (and the values for each appearing beside them). The position of the module in question in relation to the worst and best performers is indicated by a black triangle.

that use different cell technologies and have different degrees of efficiency. The lab previously used kilowatt-hours per kilowatt per year as a basis of comparison, since the degree of efficiency here is also calculated using STC power. However, the result was directly dependent on annual irradiance levels. During the years with high irradiance, the value was greater than during years with lower irradiance, so that a direct comparison over a number of years was not possible. Using performance ratio instead cancels out the impact of fluctuating irradiance levels. But there are still so-called second-order effects: the temperature is usually lower during years with weaker sunlight, so that modules with poor temperature coefficients exhibit comparably higher yields than during sunny and warm years. However, these effects are far less significant than the yield changes resulting from fluctuating annual solar irradiance.

The highest performance ratio, and thus the highest output – 1,150.4 kWh per kW of STC power – was recorded by the lab for the aforementioned REC230AE from REC; it has a performance ratio of 90.8 percent. The SLK60P6L 230Wp from Spain-based Siliken SL is a close second (and uses multicrystalline silicon cells as well). This module was No. 1 in the 2010 ranking. The NT-125AX micromorphous thin-film module from Nexpower Technology Corp. follows in third place, close on the heels of the first two. In fact, the performance of the runner up and the No. 3 module only deviate from the winner by 1.3 percent, which lies within the margin of error of the testing equipment used by PHOTON Lab - about 1.8 percent.

The modules with the poorest yields are the modules that have spent the most time on the test field. In comparison to the front-runner, which was installed in 2010, devices installed earlier exhibited 6 to 10 percent lower yields. There are several possible explanations for this. For one, the modules have never been cleaned (nor will they ever be); their efficiencies therefore decreased as they got dirtier. This is not a drawback of the test though – in fact, it was explicitly intended. Since, in the end, the tendency of a module to become dirty is also one of its characteristics. The more effort manufacturers make to give their modules dirt-repellant properties (keyword: »lotus effect«), the more they can expect that their modules will still be delivering good yields after years.

Naturally, symptoms of aging can play a role. Some modules suffer from so-called light-induced degradation, an effect that can mostly be seen in monocrystalline solar cells with too much oxygen in their silicon. Also, penetrating water vapor or moisture decrease modules' efficiencies and, as a result, their outputs. All of these effects are understood, however, and can be eliminated through the use of the right materials and manufacturing processes. Conclusion: a module can degrade, but it doesn't have to. A module that degrades presents a heavy financial loss for the owner of a solar plant. Therefore, the PHOTON Lab field test is intended to show which modules are stable for the long term.

Furthermore, there are indications that the weak-light behavior of newer models is better. That, in turn, could be due to the improvement of manufacturing processes, for instance, in the insulation of cell edges. Thus, modules with newer technology naturally have an advantage over modules that were produced in older production facilities with less sophisticated manufacturing processes.

But there are also exceptions to the rule. The SQ 150-C module from Shell Solar GmbH (which was incorporated by Solarworld AG) has been on the test field since 2006; its output can, however, keep up with many modules from 2009 and 2010. The same goes for the FS-265 from First Solar Inc., which has been monitored by the PHOTON Lab since 2007. The solar module's country of origin seems to have little impact on its annual yield. Of the modules in the top class – with yields that deviated by up to 3.5 percent from the top-ranked device – about a third came from Europe and the US. The other two-thirds were from Asia. In the middle class – with yields that deviate by up to 6 percent – the breakdown is roughly the same.

In the current test program, as in the past, yields have been standardized to the STC power of the modules. PHOTON Lab determined these for most devices before measurements began using the lab's sun simulator under STC (25 °C, 1,000 W of irradiance at the module level, AM 1.5 spectrum). For those devices that were installed on the test field before the solar simulator was acquired, the STC power measured by the manufacturer was used as a reference. These are marked accordingly in the table. With this approach, the lab is safeguarding itself from the influence of the manufacturer on the test results by requesting, under the test agreement, modules whose performance was at the upper end of the positive tolerance range or even beyond. Nonetheless, there is a tendency in many companies to exceed the tolerance: many of the modules that the lab has tested show higher powers than what is stated by the manufacturer. This does not play a role in the lab's measurement procedures because the lab principally uses the STC power values measured in-house.

Since regular module buyers may receive devices with lower STC powers, PHOTON Lab completely dispenses with the nominal power information provided by the supplier. In any case, the lab recommends that installers pay for their goods based on STC power measured at the end of the production processes – that is, according to flash data – rather than based on nominal power values of any kind. The installer can then guarantee its customers yields based on the actual power stated on the customers' invoices, not based on nominal power.

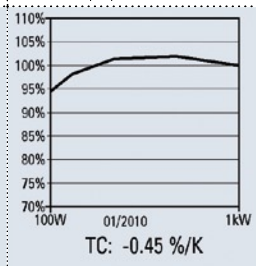
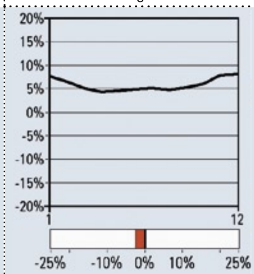
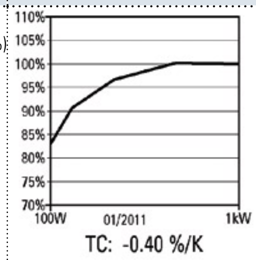
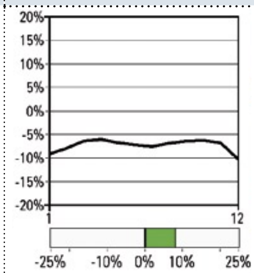
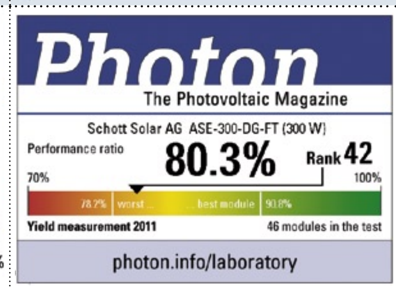
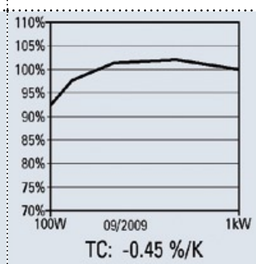
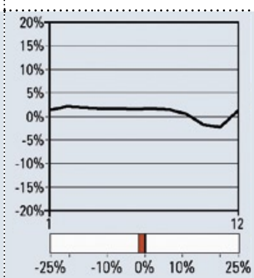
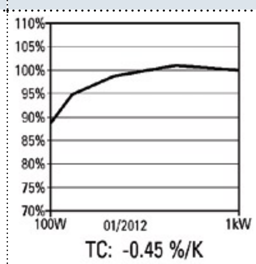
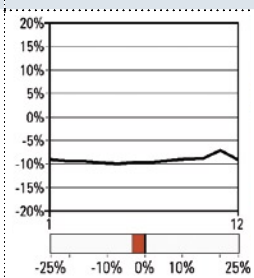
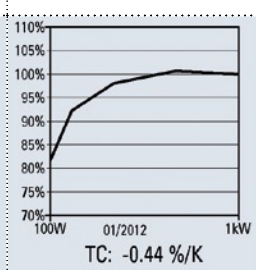
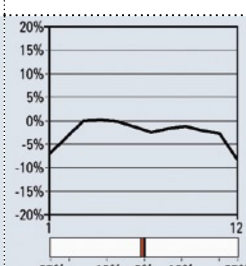
PHOTON Lab also improved the measurement procedures with the enlargement of its test field: each module is equipped with a measurement device of its own, which scans its voltage-current characteristic every second. As a result, the lab collects 8 kilobytes of data per second for each module. In addition, temperature, wind and irradiance data are obtained by several weather stations on the test field. Together, the data is transmitted through a dedicated line to servers in the lab and transferred into databases there. In the event that the data line fails – which has definitely happened before – the test results are saved in each module's measurement device in the meantime. For this purpose, each device has been outfitted with a small Linux computer of its own with 32 gigabytes of flash memory.

PHOTON Lab measured the weak-light behavior of modules in its sun simulator.

Until recently, it wasn't possible for the measurement devices to record the characteristic curves of certain high-performance modules every second – the devices were ill-suited to these modules, which responded sluggishly to changes to their voltage-current characteristics, due to the high parasitic capacity of these modules. This mainly affected products from Sunpower Corp., as well as Sanyo Electric Co. Ltd. Now, through an improvement to the measurement devices, this limitation is a thing of the past. The new devices can adjust their measurement speed to the module being tested. Moreover, since they can accommodate the characteristic curve in forward and reverse directions, they can also check the accuracy of the measurement independently. The measurement is valid only when both curves overlap. As of Jan. 1, modules from Sunpower have been added to the test field. Initially, they are in trial operation. Once the data from the new module measurement devices has been validated, this data will also be published in the monthly reports.

Andreas Rosenberger, Philippe Welter

Detailled results of PHOTON's 2011 yield measurements (continued)

Module data	Measurements	Module characteristics Weak-light behavior temperature coefficient (TC)	Measured data in comparison Yield (Jan. - Dec.) / below TC both variations to average	Ranking
REC ASA **REC230AE*1 / Multi** Sweden P_{STC}: 228.6 W Manufactured: 2007-2010 Area: 1.65 m²	**Yield 2011:** E/P_{STC}: 1,150.4 kWh/kW (--) E/module area: 159.7 kWh/m² Performance ratio: 90.8% Installed in: 2010 **Yield December:** E/P_{STC}: 22.4 kWh/kW			
Schott Solar AG **ASE-300-DG-FT (300 W)*1 / Ribbon** USA P_{STC}: 308.1 W*2 Manufactured: 1997-2006 Area: 2.42 m²	**Yield 2011:** E/P_{STC}: 1,017.1 kWh/kW (-11.6%) E/module area: 129.2 kWh/m² Performance ratio: 80.3% Installed in: 2007 **Yield December:** E/P_{STC}: 18.6 kWh/kW			
S-Energy Co. Ltd. **SM-220PA8 / Multi** South Korea P_{STC}: 224.4 W Manufactured: – Area: 1.59 m²	**Yield 2011:** E/P_{STC}: 1,104.0 kWh/kW (-4.0%) E/module area: 156.1 kWh/m² Performance ratio: 87.1% Installed in: 2009 **Yield December:** E/P_{STC}: 21.0 kWh/kW			
Sharp Corp. **NT-R5E3E*1 / Mono** Japan P_{STC}: 187.9 W*2 Manufactured: 2003 Area: 1.30 m²	**Yield 2011:** E/P_{STC}: 990.9 kWh/kW (-13.9%) E/module area: 143.1 kWh/m² Performance ratio: 78.2% Installed in: 2005 **Yield December:** E/P_{STC}: 18.8 kWh/kW			
Shell Solar GmbH **Shell PowerMax Eclipse 80-C*1 / CIS** USA P_{STC}: 90.8 W*2 Manufactured: 2005-2006 Area: 0.86 m²	**Yield 2011:** E/P_{STC}: 1,076.2 kWh/kW (-6.5%) E/module area: 113.7 kWh/m² Performance ratio: 84.9% Installed in: 2007 **Yield December:** E/P_{STC}: 19.0 kWh/kW			

*1 no longer manufactured, *2 P_{STC} has not been determined by a PHOTON Lab flasher measurement, *3 previous model designation: CSG180S1-35/1589x807, *4 previous model designation: CSG230M2-30/1640×992, *5 previous model designation: ES-200-P60(230), *6 previously manufactured by Solarfun Power Holdings Co. Ltd., *7 now manufactured by Solarworld AG, *8 previous model designation: SW 210 poly, *9 for supplier Ningbo Qixin Solar Electrical Appliance Co. Ltd., *10 manufactured by Alpexsolar, distribution via Sunpeak-Vertrieb Unternehmensgruppe Ratio-Data. **Note:** The numbers in parentheses in the »Measurement data« column represent the deviation of the module's yield from that of the top-ranked device, expressed as a percentage. The dates beneath the »Weak-light behavior temperature coefficient (TC)« graphs indicate when the data in the graphs were gathered.