

Different annual yields of south and west oriented photovoltaic panels feeding-in

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1. Cause of studies

In September 2008 we published test results of annual yields of smallest photovoltaic panels (as a downscaled experiment) in various alignments and inclinations. (Also see 'Energy yield from photovoltaic panels considering different inclinations and orientations' on our homepage). This publication encountered a surprisingly large interest. In numerous emails, telephone calls and personal discussions we were asked to support this study with large series panels in grid feed-in operation.

Due to an insufficient dimensioned test area we were unable to reconstruct all inclinations and orientations of the test series in 2008 with large panels. Exemplarily, our intention was to determine the difference in south and west oriented alignments (both with inclinations of 28°) in test series of more than two years. (As already mentioned, with large panels and grid feed-in operations)

Standing in for crystalline panels, we chose two panels of 'SCHOTT poly 165' and three panels of 'Solartechnics SN-GS-40D' (a-Si), standing in for thin film.

All panels were operated south oriented for one year succeeded by one year of west orientation, each with inclinations of 28°.

On one hand we used a premium quality global irradiance measuring device as reference (Pyranometer) type CMP3 of manufacturer Kipp & Zonen. Such devices are also being used by German Meteorological Services. On the other hand we chose crystalline as well as thin film panels for comparison. For the crystalline reference we used ANTARIS ASM 175 and for thin film reference Kaneka Z-EA D075.

In each case two panels of ANTARIS ASM 175 and two panels of Kaneka Z-EAD075 were operated south oriented with inclinations of 28° throughout the complete studies from April 1st, 2009 until March 31st, 2011.

At completion of one year the energy yield was compared with yields of the mentioned test panels (SCHOTT poly 165 and Solartechnics SN-GS-40D).

2. Structure of studies

Image 1 displays the Pyranometer (global irradiance measuring device) we used.



Img 1: Pyranometer CMP3, Kipp & Zonen

Image 2 shows 3 Solartech panels west oriented (foreground). In the background to the right are the south oriented panels.



Img. 2: Solartech panels, oriented westbound

Even with levelling solar altitudes the panels must not shadow one another (see Img. 3)



Img. 3: Even at flattish positions of the sun there is no shadow

In the foreground of image 4 one of two west oriented SCHOTT panels are visible. Three Solartechnics panels are in the background to the right. All the way in the rear panels are visible oriented south.



Img. 4: One of the two SCHOTT panels oriented west.



Img. 5: Both SCHOTT panels oriented west displayed from behind

3. Conducting the tests

Photovoltaic panels can only furnish optimum capacity if the MPP range (Maximum Power Point) of strings and inverters coincide, which is vital for exact executions of measuring tests, whereupon we paid particular attention to. The individual photovoltaic panel types were being interconnected to strings between two to three panels (depending on the individual MPP voltage). Grid feed-in takes place by an inverter type 'Mastervolt Soladin 600' and a corresponding ENS (electrical network monitoring device). The input of direct current and input DC voltage of each inverter were recorded by a data logging computer and a multimeter in conjunction with the measuring data of the global irradiance measuring device in time intervals of one minute. Yields of tested panels could subsequently be calculated upon the basis of those data.

4. Test results

During ascertaining and evaluating of test results the following has to be considered:

- The amount of global irradiance is reckoned as kWh/m²
- The energy yield indications of the photovoltaic panels are referred to as kWh.
- In order to reach MPP adaptation between individual inverters and photovoltaic module strings the panels had to be switched in sequence according to following scheme:
 - SCHOTTSolar poly 165, 2 pcs in sequence, total nominal power 330 Wp
 - Solartechincs SN-GS-40, 3 pcs in sequence, total nominal power 120 Wp
 - ANTARIS ASM 175, 2 pcs in sequence, total nominal power 350 Wp
 - Kaneka Z-EA D075, 2 pcs in sequence, total nominal power 150 Wp

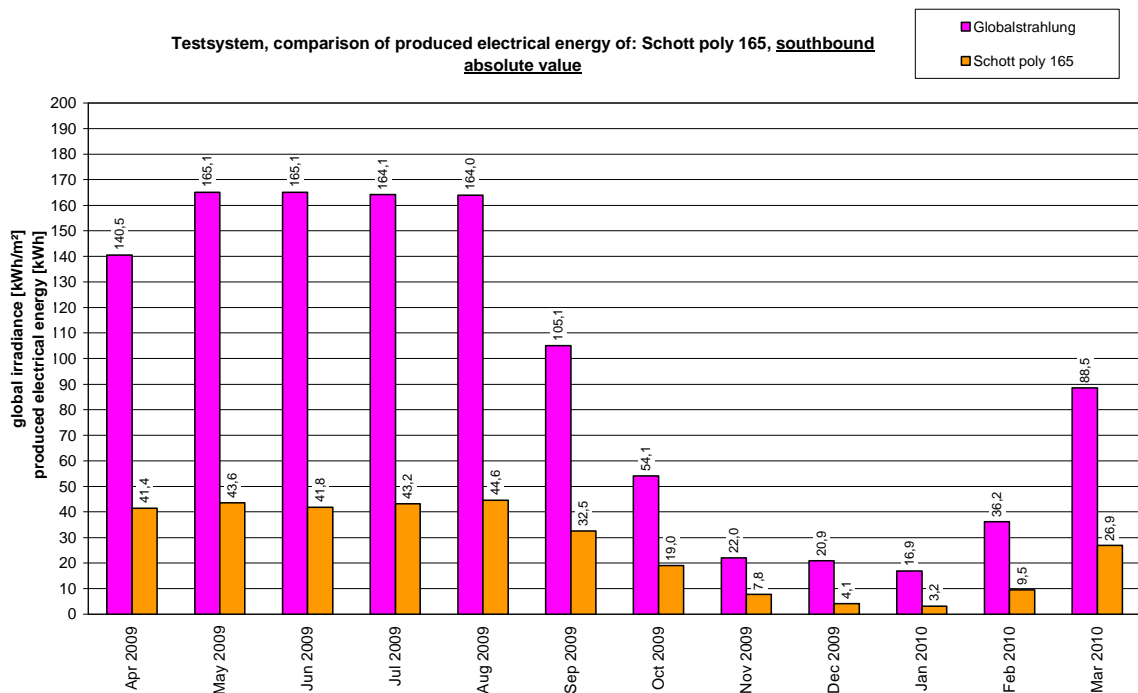
Table 1 shows datasheet results (face value) of assigned panels

pv panel	nominal maximum power [Wp]	nominal voltage [V]	nominal current [A]	Type
SCHOTTSolar poly 165	165	35.1	4.7	crystalline
ANTARIS ASM 175	175	35.8	4.91	crystalline
Solartechnics SN-GS-40D	40	47	0.86	a-Si
Kaneka	75	67	1,12	a-Si

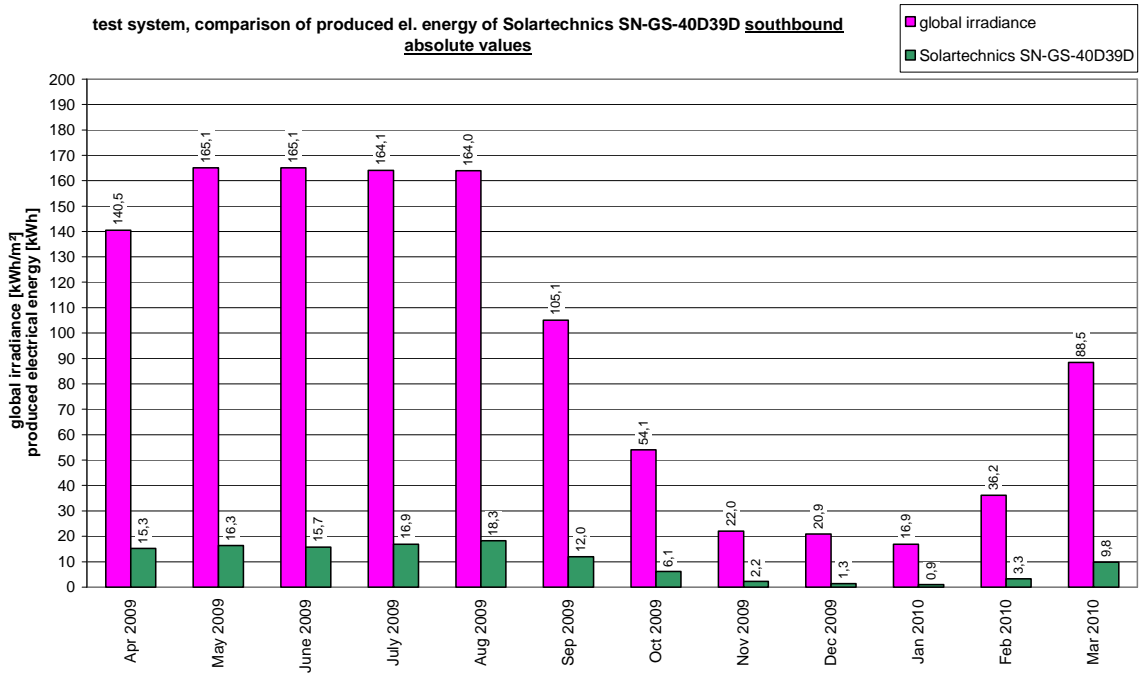
Table 1: spreadsheet results

4.1. Evaluations on basis of global irradiance readings

Monthly values of global irradiance as well as monthly yields of southbound SCHOTTSolar and Solartechnics panels in a time period from April 2009 thru March 2010) are displayed in graphs on img 6 and img 7.

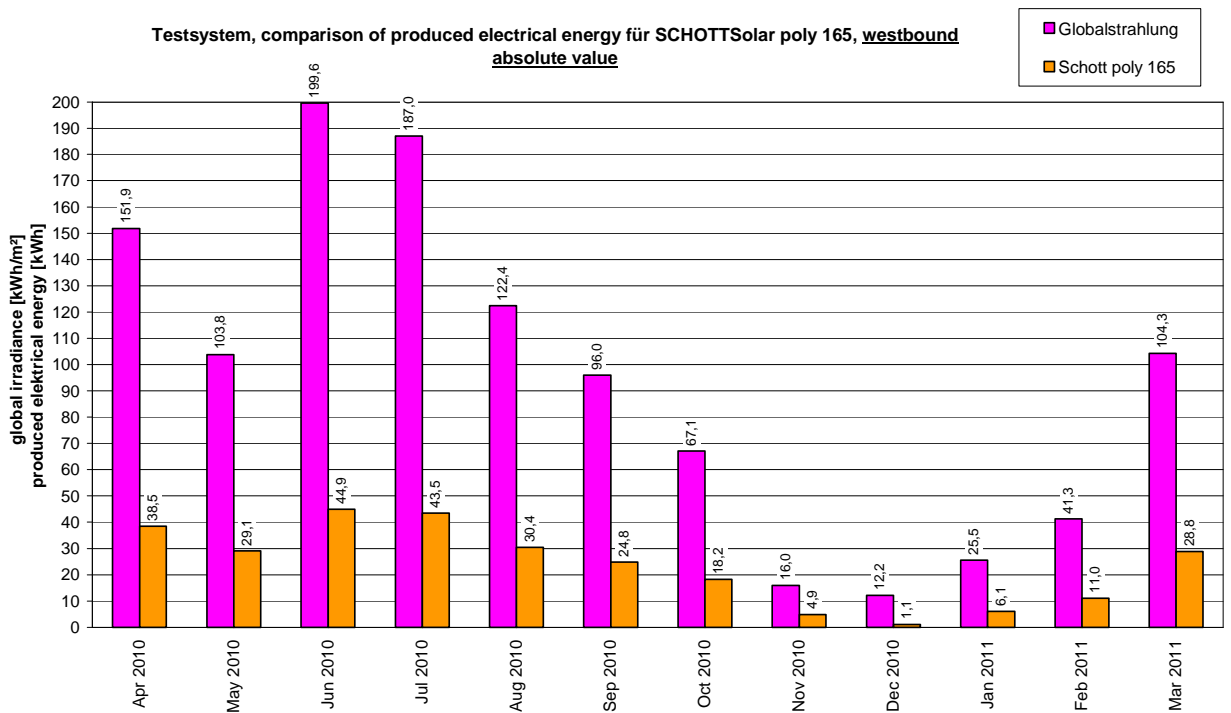


Img. 6: global irradiance, as well as monthly yields of SCHOTTSolar panels oriented southbound

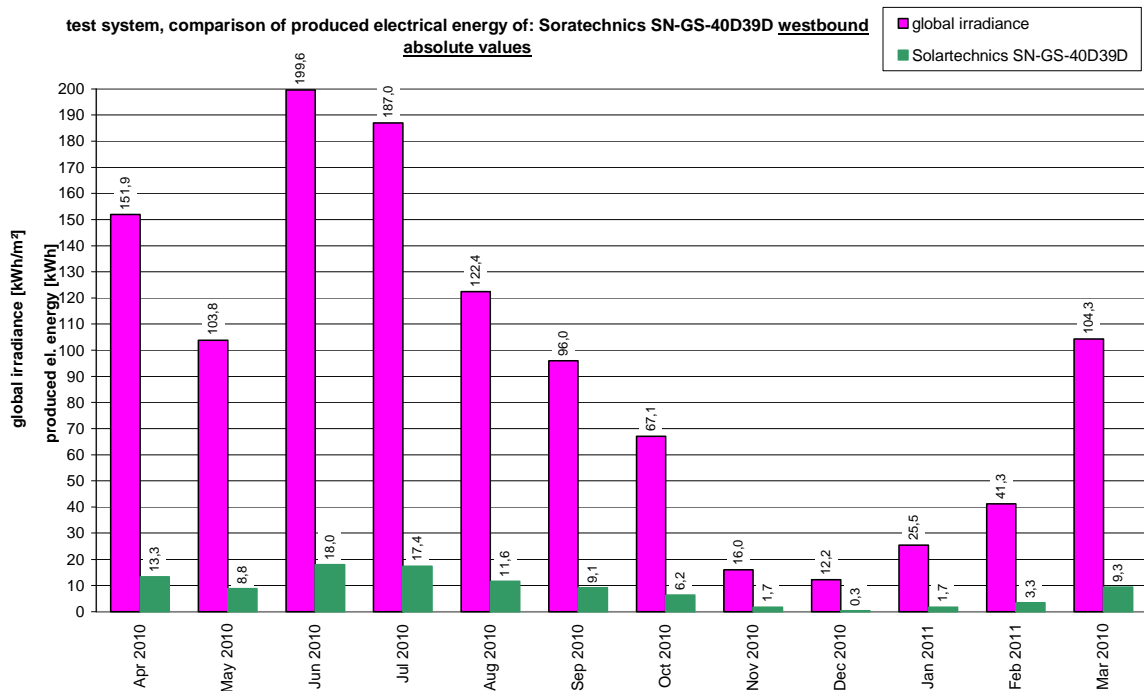


Img. 7: global irradiance, as well as monthly yields of Solartechnics panels oriented southbound

Monthly values of global irradiance as well as monthly yields of westbound SCHOTTSolar and Solartechnics panels (period April 2010 thru March 2011) are displayed in graphs on img 8 and img 9.



Img. 8: Global irradiance as well as monthly yields of SCHOTTSolar panels oriented westbound



Img.9: Global irradiance as well as monthly yields of Solartechncs panels oriented westbound

Conclusion:

South orientation (see Img. 6 and 7)

The annual sum of global irradiance within the measured time period of April 2009 thru March 2010 amounted to 1142.5 kWh/m². Within this time frame the SCHOTTSolar panels reached a yield of 317.6 kWh and the Solartechncs panels reached a yield of 117.1 kWh. This implies following ratios of the individual panel yield to the global irradiance:

- SCHOTTSolar poly 165: $317.6 / 1142.5 = 0.278$
- Solartechncs SN-GS-40D: $117.1 / 1142.5 = 0.103$

West orientation (see Img. 8 and Img. 9):

Analogue to south orientations here are the values of west orientations (time period from April 2010 thru March 2011):

- Annual yield of global irradiance: 1127.1
- Annual yield of SCHOTTSolar panels: 281.3 kWh
- Annual yield of Solartechncs panels: 100.7 kWh
- Ratios of individual panel yield to the global irradiance:
 - SCHOTTSolar poly 165: $281.3/1127.1 = 0.249$ kWh
 - Solartechncs SN-GS-40D: $100.7/1127.1 = 0.089$ kWh

Results of yield differences between south and west orientations, with a reference value of global irradiance:

- For crystalline (SCHOTTSolar poly 165): $0.249/0.278 = 0.896$ equates to 89.6%
- For a-Si thin film (Solartechnics SN-GS-40D) $0.089/0.103 = 0.864$ equates to 86.4%

Results:

Compared with the global irradiance the crystalline west oriented panels generated 89.6 % whereas the a-Si thin film panels generated a yield of 86.4 (inclination of 28° each) based upon an optimal south orientation.

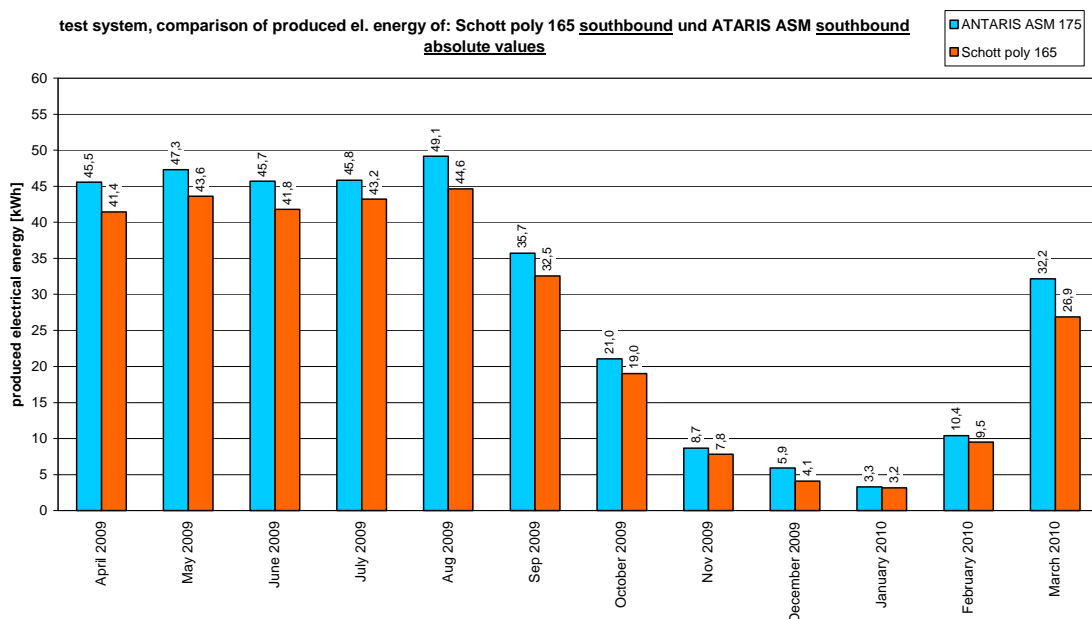
4.2. Evaluations in comparison with other crystalline and a-Si thin film panels

Design related conversion factor:

As you can see on chart no.1, the nominal power ratings of both crystalline (SCHOTTSolar, ANTARIS) as well as the two a-Si thin film panel types (Solartechnics, Kaneka) differ. In order for the evaluations, however, to get a reliable reference, a so-called design-related conversion factor was determined.

Therefore all 4 panel types were operated south oriented for one year (April 2009 thru March 2010) at first. Thereafter the design related conversion factors could be determined.

Monthly yield of the south oriented SCHOTTSolar and ANTARIS panels (time period from April 2009 thru March 2010) are displayed on img 10.



Img. 10: Monthly yield of ANTARIS and SCHOTTSolar panels, time period April 2009 – March 2010, south oriented

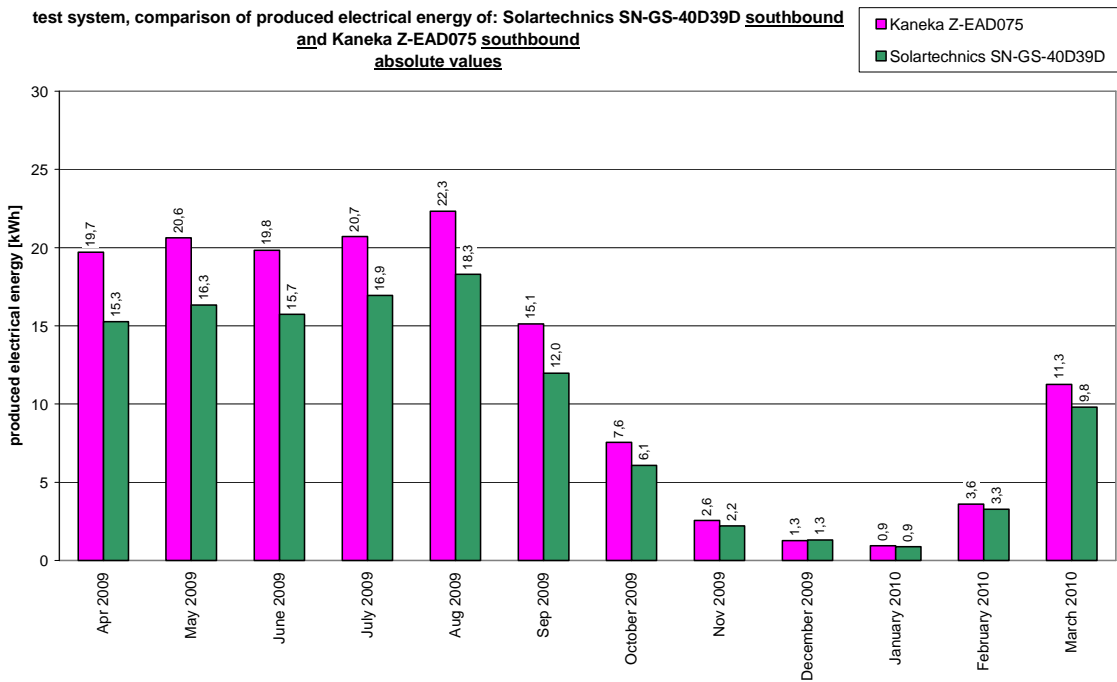
Annual yield:

- ANTARIS ASM 175: 350.6 kWh
- SCHOTTSolar poly 165: 317.6 kWh

So that these SCHOTTSolar panels could reach the same energy yield as the ANTARIS panels, their values would have to be converted with the factor $350.6 / 317.6 = 1.104$ (design related conversion factor).

This also applies in similarity to a-Si thin film panels (Solartechnics, Kaneka):

Img. 11 shows monthly yields of south oriented Solartechnics and Kaneka panels (time period: April 2009 until March 2010)



Img. 11: Monthly yields of south oriented Kaneka and Solartechnics panels from April 2009 until March 2010

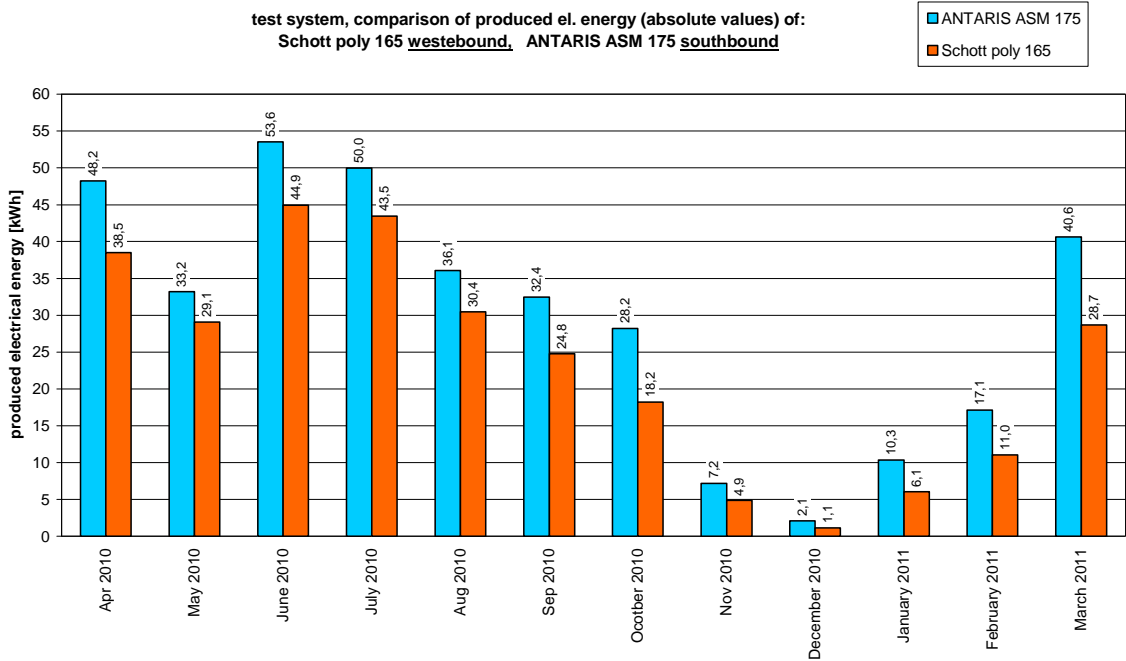
Annual yields:

- Kaneka Z-EAD075: 145.5 kWh
- Solartechnics SN-GS-40D: 118.1 kWh

Design related conversion factor: $145.5 / 118.1 = 1.232$

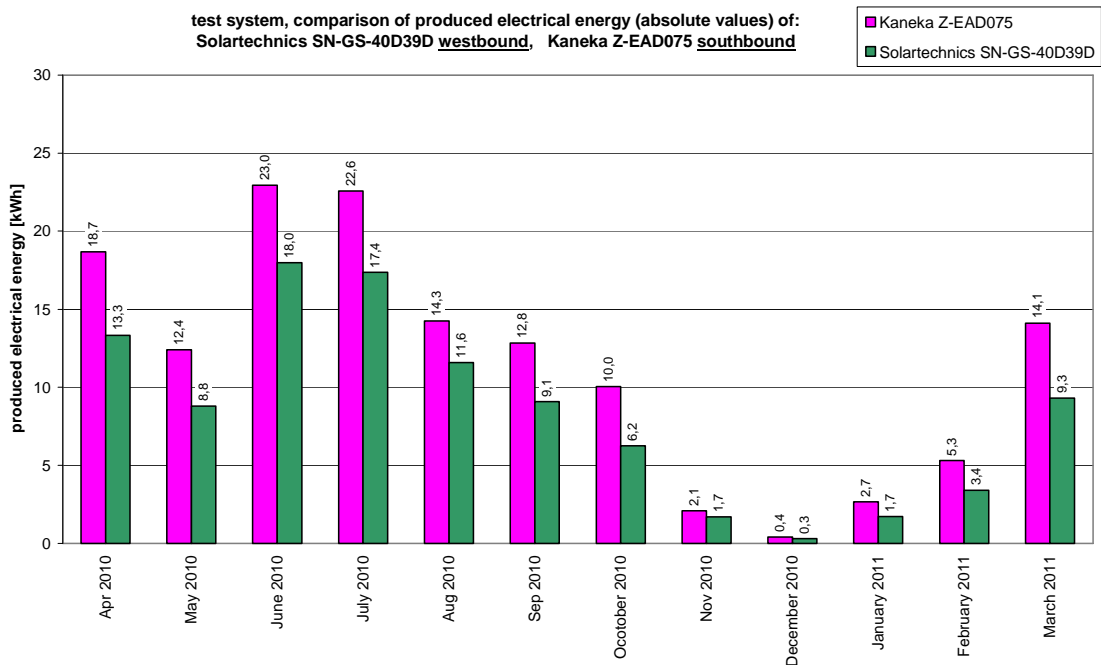
Succeeding ascertaining the design related conversion factors the crystalline as well as the a-Si thin film panels could be compared pertaining the differences in yield between a south and a west oriented alignment.

The monthly yield in the time period from April 2010 thru March 2011 of the (south oriented) ANTARIS panels and the (west oriented) SCHOTTSolar panels are displayed in the chart on image 12.



Img. 12: Monthly yields of ANTARIS and SCHOTT Solar panels in a time period from April 2010 thru March 2011.

The monthly yields of the south oriented Kaneka and west oriented Solartech panels from April 2010 thru March 2011 are displayed in the chart on image 12.



Img. 13: Monthly yields of Kaneka and Solartech panels during a time period from April 2010 thru March 2011.

Conclusion:

Crystalline panels

Annual yields:

- ANTARIS ASM 175: 359.0 kWh
- SCHOTTSolar poly 165: 281.5 kWh
- SCHOTTSolar poly 165 with design related conversion factor:
 - o 281.2 kWh x 1.104 = 310.4 kWh

Results:

$310.4 \text{ kWh} / 359.0 \text{ kWh} = 0.865 = 86.5\%$

Oriented west, the crystalline panels still reach a yield of 86.5% compared to an optimal south orientation (with a 28° inclination).

a-Si thin film panels:

Annual yields:

- Kaneka Z-EAD075: 138.4 kWh
- Solartechnics SN-GS-40D: 100.8 kWh
- Solartechnics SN-GS-40D with a design related conversion factor:
 - o 100.8 kWh x 1.232 = 124.19

Results:

$124.19 \text{ kWh} / 138.4 \text{ kWh} = 0.897 = 89.7 \%$

Oriented west the a-Si panels still reach a yield of 89.7% compared to an optimal south orientation (with a 28° inclination).

Summary (see chart no. 2):

Reference:	Yield west oriented crystalline [%]	Yield west oriented thin film [%]
Global irradiance	89.6	86.4
Same panel type (crystalline respectively a-Si) south oriented	86.5	89.7

Chart 2: Proportional differences

Final conclusion:

West oriented crystalline as well as a-Si thin film panels remain a yield between about 86% to about 90% (in this case in a inclination of 28° each) compared to an optimal south oriented alignment. This is also true for the chart values. During the time when for one the global irradiance measuring device and again when south oriented crystalline, respectively a-Si thin film panels were used as references, there were variations which will be referred to (see 5.) in the following error reflections.

5. Error reflections

Proportional differences of values in chart no. 2 have various causes. At this point we would like to reflect on this:

- The global irradiance device that was being used measures the global irradiance with very accurate precision - undoubtedly the global irradiance is the primary criteria for the yield – but it cannot give details on:
 - o Wind force
 - o Air temperature
 - o Panel temperature
 - o Soiling of panels

These facts however immediately influence performance and yield.

- When using crystalline or a-Si thin film panels as reference values degradations within a measuring time period (two years after all) do play a humble role.

Beginning these test series, we ensured that initial degradations (especially a-Si panels) had already taken place.

The panels degrade (somewhat) at different levels within crystalline and a-Si groups.

- Nevertheless, all results remain within the prediction of approximately 86% and just under 90%.

6. Equipment:

Device:	Type:	Manufacturer / Vendor:
Multimeter	Fluke 45	Fluke
Multimeter	Fluke 89 IV	Fluke
Inverter	Soladin 600	Mastervolt
Self-actuating permitting connecting device	ENS 26	UfE
Measuring computer	GX 260	Dell
Software	MS Visual Basic 6.0	Microsoft
Software	MS Excel 2003	Microsoft
Pyranometer	CMP 3	Kipp & Zonen
Photovoltaic panels	ASM 175	ANTARIS Solar
Photovoltaic panels	Poly 165	SCHOTT Solar
Photovoltaic panels	Z-EAD 075	Kaneka
Photovoltaic panels	SN-GS-40D 39 D	Solartechnics

Waldaschaff, April 12th, 2011

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