DANISH
TECHNOLOGICAL
INSTITUTE

Performance of roof integrated and free-mounted thin-film photovoltaic modules under Danish climatic conditions

Danish Technological Institute
Energy and Climate Division

Performance of roof integrated and free-mounted thin-film photovoltaic modules under Danish climatic conditions

Ivan Katic
Energy and Climate Division
Danish Technological Institute

October 2012

Preface

The report concludes the work regarding the performance measurements on commercial thin-film PV modules in Denmark. The work is part of the project Thi-Fi-Tech - Application of thin-film technology in Denmark financed by PSO ForskEL project no. 2008-1-0030.

The following persons have participated in this part of the project:

Ivan Katic, M.Sc., Danish Technological Institute
Søren Poulsen, M.Sc., Danish Technological Institute
Marc Galang, Assisting student, Danish Technological Institute
Frerk Haase, IT Dipl.Ing. , Danfoss Solar Inverters

Thi-fi-tech has been carried out by a team consisting of:

Danish Technological Institute (project leader), Danish Building Research Institute, En^{2}tech, EnergiMidt A/S, PhotoSolar A/S, Gaia Solar A/S, Caspersen & Krogh Arkitekter A/S, Entasis, Esbensen Rådgivende Ingeniører A/S, Arkitema A/S, Danfoss Solar Inverters A/S.

The project is documented in the following reports:

Application of thin-film technology in Denmark – Thi-Fi-Tech. Summary Report

With the following annex reports:

1 Feasibility study - Application of thin-film technology in Denmark
2 Performance of roof integrated and free-mounted thin-film photovoltaic modules under Danish climatic conditions
3 Assessment of indoor light and visual comfort when applying solar cells in transparent facades
4 Impact on indoor climate and energy demand when applying solar cells in transparent facades
5 *product development*
6 *small-scale*
7 *medium- and large- scale*

The reports are available at www.solenergi.dk

Performance of roof integrated and free-mounted thin-film photovoltaic modules under Danish climatic conditions 1st printing, 1st edition, 2012

Energy and Climate Division

Content

1. Introduction 4
2. Measurement setup 5
3. Electronic loads 8
4. Base line measurements 9
5. Data analysis 10
6. Results 11
   Module degradation 11
   Effect of irradiance 13
   Effect of temperature 14
   Module efficiency measurements 16
7. Summary 22

1. Introduction

In recent years there has been a rapid development within the area of thin film photovoltaic modules with respect to increased life time, efficiency and power. However, the market is still dominated by traditional crystalline PV modules, mainly because they have proven their performance and reliability for decades. Thin film PV comes in a variety of materials and visual expressions, and could be an interesting alternative in many applications, in particular BIPV. For this to happen, the lifetime and performance under realistic operating conditions must be well-documented.

The main objective of the current measurement and demonstration project has been to perform a realistic side-by-side comparison of the most promising thin film technologies for on-grid PV power systems in the Danish climate. Some manufacturers of thin film modules claim that their specific technology delivers more energy than crystalline modules with same power due to better characteristics at elevated temperatures or low irradiance. The project could hopefully reveal this.

The samples of different modules have been mounted on outdoor racks at Danish Technological Institute, and each module equipped with its own maximum power point tracker. The PV modules have been set up in pairs, where one has an open back side, and the other completely blocked by insulation material, thus simulating the thermally worst possible case of roof integration. The resulting operating temperatures have been recorded, together with the electrical performance.

The measurement period was from July 2011 – August 2012, however IV curves have been recorded since March 2009 where the modules were installed.

2. Measurement setup

The basic idea of the side-by-side test was to measure the annual performance of as many different thin film modules as possible, representing the most commonly used PV materials such as amorphous and microcrystalline silicon, CI(G)S and CdTe. For practical reasons, the test had to be limited to two modules of each type, where one is mounted with open back side, the other on an insulated surface without any ventilation at all.

The modules are mounted on fixed racks with an inclination of 45° and facing due south. Each module had to run on its own electronic load in order to be able to measure the instantly available maximum power during the entire measurement period. This was one of the most difficult challenges in this project.

The two module racks seen from behind.

<u>Data for the different module types:</u>

Type	**Length mm**	**Width mm**	**P Watt**	**Isc Amp**	**Uoc Volt**
REFERENCE Shell Solar polyX si	1225	580	71	5,1	21,8
Mitsubishi MA100T2 a-Si	1415	1115	100	1,17	141
Schüco SPV 70-TF CIS	1236	840	70	2,2	54
Würth WSG0036E075 CIS	1205	607	75	2,4	43,1
Kaneka HB105 Tandem a-Si mikroX	1210	1080	105	2,4	71
Qcells Calyxo CX	1200	600	60	1,07	88,2

The 12 tested modules have been labelled according to the following table (Label F was used for a temporary module not included in this report):

Mounting	Label	Name	Type	Nameplate rating Wp	Nominal module efficiency
integrated	C1	Mitsubishi MA100T2	a-Si	100	0,063
integrated	A1	Würth WSG0036E075	CIS	75	0,103
integrated	D1	Kaneka HB105 Tandem	a-Si/µX-Si	105	0,086
integrated	B1	Schüco SPV 70-TF	CIS	70	0,095
integrated	E1	Shell snr 6299	Poly-X	71	0,101
integrated	G1	Qcells	CdTe	60	0,083
open	C2	Mitsubishi MA100T2	a-Si	100	0,063
open	A2	Würth WSG0036E075	CIS	75	0,103
open	D2	Kaneka HB105 Tandem	a-Si/µX-Si	105	0,086
open	B2	Schüco SPV 70-TF	CIS	70	0,095
open	E2	Shell snr 6368	Poly-X	70	0,100
open	G2	Qcells	CdTe	60	0,083

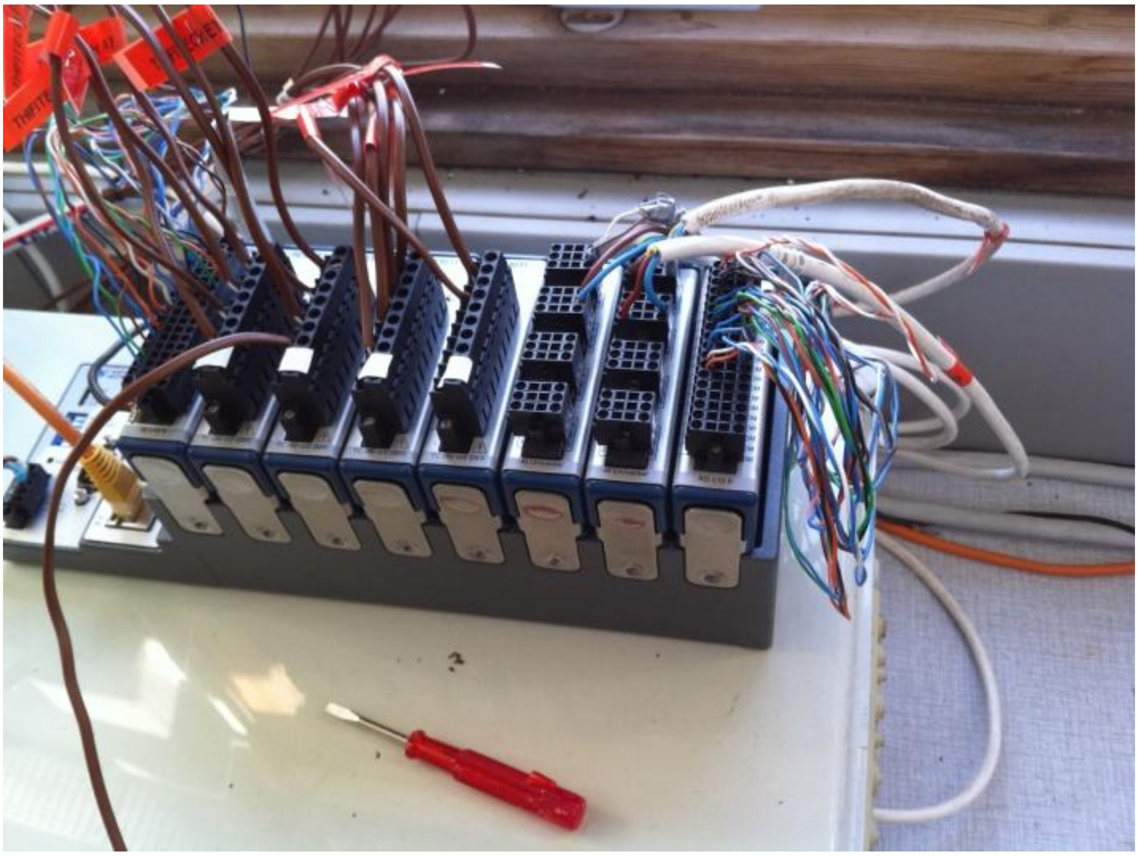
<u>Measured parameters:</u>

For each of the modules the instrumentation consists of a voltage, current and temperature meeasurement. Besides this, the climatic data are measured with irradiance, temperature and wind speed sensors placed near the modules.

Parameter	Sensor	Signal
Global irradiance	Pyranometer (Eppley)	mV
In plane irradiance 1	Pyranometer (Eppley)	mV
In plane irradiance 2	Referencecelle (ESTI)	mV
Amb. temperature	Pt100	Ohm
Wind speed	Anemometer	mA
PER PV MODULE:		
Current	Danfoss unit	mV
Voltage	Danfoss unit	mV
Temperature	Thermocouple	mV

Data acquisition and control

The measurements are managed by a compact data logging system running in stand-alone mode, but connected to the LAN network. The system is very robust, and was running without any major problems after the project specific software had been developed and debugged. One of the eight plug-in modules is an analogue output module used to control the load on each individual PV module.



DAQ system: National Instruments CompactRIO (stand-alone unit with battery power)

3. Electronic loads

Danfoss Solar Inverters were responsible for the development of a very flexible load and signal processing system for the PV modules. Based on common inverter cabinets with adequate cooling capacity, a set of specially designed print boards were developed to take care of load management and signal processing of current and voltage measurements.
Each load is controlled via a signal from the central data acquisition and control system, based on National Instruments CompactRIO platform.

A simple MPPT (maximum power point tracking) algorithm was programmed in Labview so the voltage of each module could be regulated in a uniform way. The calculation of MPP operating voltage was simply set as a fixed percentage (70%) of the open circuit voltage and updated every minute. This gives a relatively rough but stable voltage regulation and as long as all modules are handled equally it should still be possible to compare the performance from one module to another.

Due to some problems with interference or EMC noise from an unknown source it was very difficult in practice to obtain smooth regulation on all systems at all times, so unfortunately there are invalid data in some cases. One of the channels (no 0) was finally closed permanently because it induced noise in all the other channels when it was operating. The module was therefore left in open circuit most of the reporting period. This error-tracing phase of the project caused major delay.

A total of four Danfoss power dissipation units, each with three inputs, were built for the project by Danfoss who also installed them at Danish Technological Institute. They will serve as a permanent test platform for other modules in the future.

Electronic loads built by Danfoss Solar Inverters for the project

4. Base line measurements

One well-known difficulty in PV performance measurements is that the actual power of the PV modules can be quite different from the nameplate value. When a comparison from one technology to the other is made, then it must be clarified if the calculated yield is related to the nameplate or the actually measured power values. The question is mainly relevant for amorphous silicon, where it is well-known that some initial (Staebler-Wronski) degradation is induced when the modules are exposed to the sun.
In this project we have measured the IV curve of each module with a curve tracer a few times per year and so documented the long-term development in actual nominal power. The energy in kWh per kWp has been calculated with the nameplate rating as base, which gives much sense to the end user who pays an amount per kW installed power.
Most of the modules were received in March 2009 where the first baseline IV curves were recorded, but later on the CdTe modules arrived and were included in the measurements from September 2010. (At the same time a single special CIS module was removed)

Channel	Mounting	Label	Name	Type	Nameplate rating Wp	Measured Wp approx.
0	integrated	C1	Mitsubishi MA100T2	a-Si	100	96
1	integrated	A1	Würth WSG0036E075	CIS	75	70
2	integrated	D1	Kaneka HB105 Tandem	a-Si/µX-Si	105	98
3	integrated	B1	Schüco SPV 70-TF	CIS	70	68
4	integrated	E1	Shell snr 6299	Poly-X	71	(55)
5	integrated	G1	Qcells	CdTe	60	53
6	open	C2	Mitsubishi MA100T2	a-Si	100	85
7	open	A2	Würth WSG0036E075	CIS	75	65
8	open	D2	Kaneka HB105 Tandem	a-Si/µX-Si	105	91
9	open	B2	Schüco SPV 70-TF	CIS	70	77
10	open	E2	Shell snr 6368	Poly-X	70	65
11	open	G2	Qcells	CdTe	60	57

Comparison of nameplate values and measured STC performance.

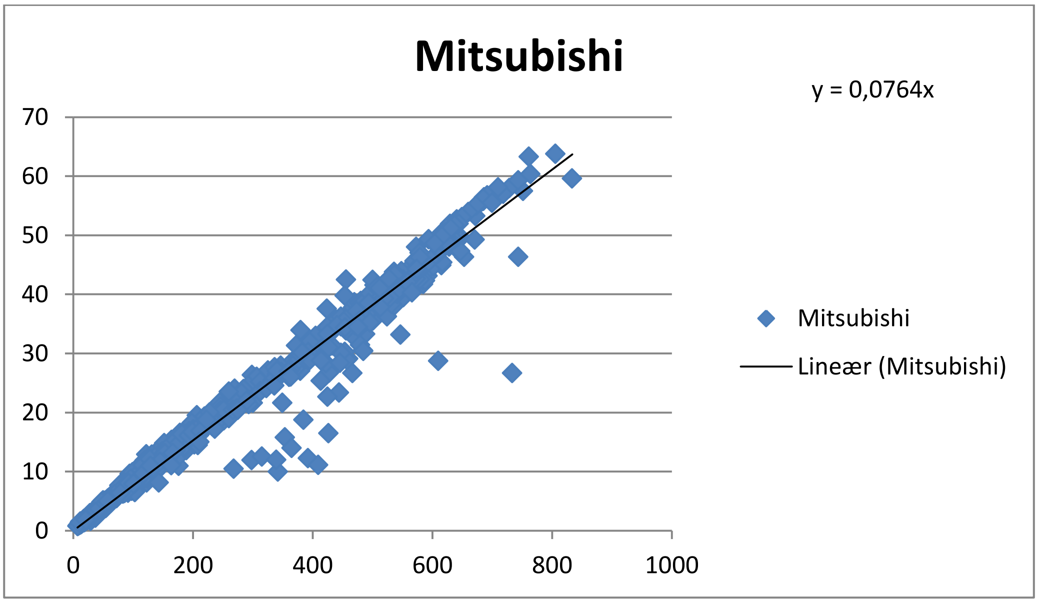
For module E1 there was a bad connection in the junction box. The uncertainty of the power rating is estimated to +/- 5%

5. Data analysis

The following methodology has been used for data analysis of the collected time series (5 minute instantaneous values)

1) Calculation of accumulated electricity production on a monthly basis. Missing or erratic data are replaced by values calculated from a best fit curve to the raw data as shown below
2) Calculation of average module efficiency based on data around noon (10 a.m. to 3 p.m.) In this time interval the sun is more or less perpendicular to the module surface, and there are no shadows.
3) Plot of voltage and current as a function of solar irradiance in order to check function of the MPP tracking.
4) Sorting of data according to irradiance and temperature
5) Search for monthly maximum temperature on back of each PV module

The results of the data analysis is presented in the next chapter



Example of monthly PV power variation with solar irradiance

6. Results

Module degradation

One of the objectives in the project was to document the real degradation of the different technologies under real operation. It is well-known that 1st generation amorphous silicon exhibits initial power degradation when exposed to sunlight, and this is documented in the measurements.

Measurements are taken from IV curve analyzer PVPM 6020. Besides the current and voltage, the apparatus calculates the internal resistance in the modules. The automatic calculation of series resistance Rs and parallel resistance Rp should not be considered as accurate values, but nevertheless they clearly indicate that the IV curve is significantly changed for some of the modules. The series resistance is increased, the parallel resistance decreased, or both. This leads to lower fill factor (FF) and thereby lower peak power values in some of the modules.

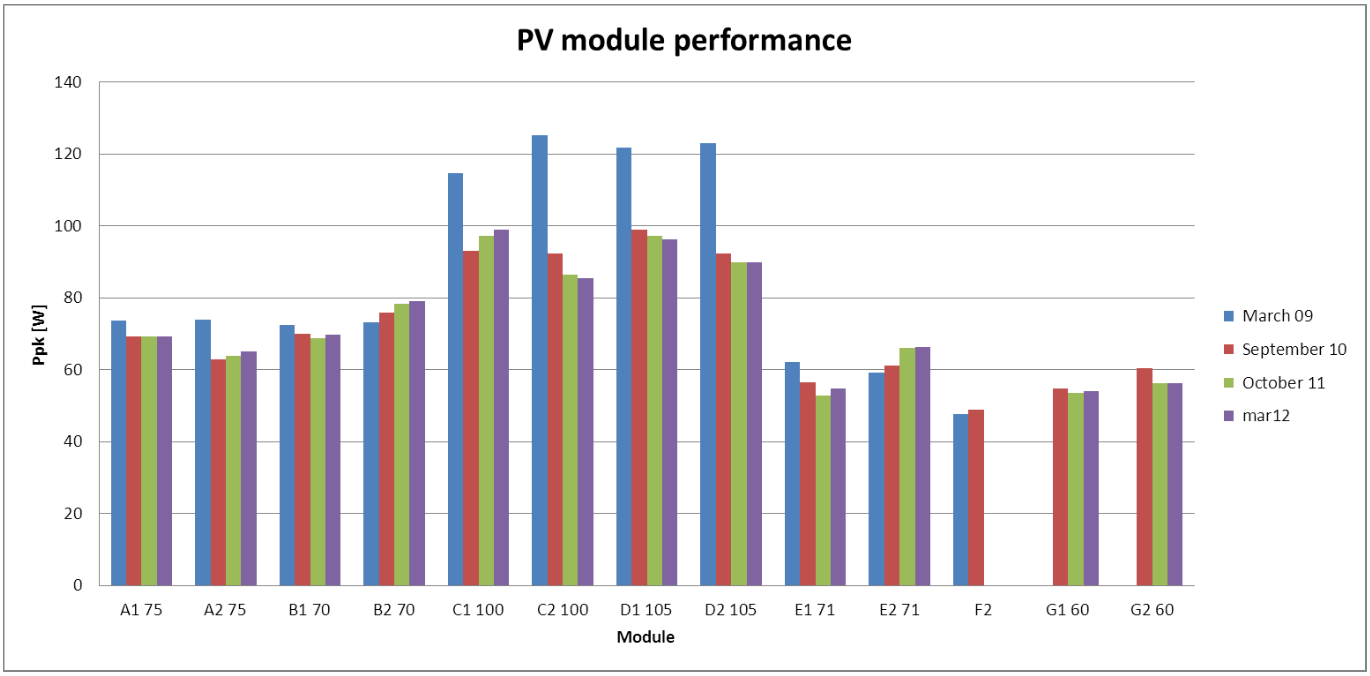
Measured values	Initial value		Initial value		Initial value		
	Rs	Rs	Rp	Rp	FF	FF	FF change
A1 CIS	2.8	5.8	>1k	>1k	0.7	0.65	-0.05
A2 CIS	3.3	2.13	>1k	>1k	0.69	0.59	-0.10
B1 CIS	9.9	11.4	>1k	>1k	0.63	0.61	-0.02
B2 CIS	10.1	6.8	>1k	>1k	0.62	0.65	-0.03
C1 a-Si	25.1	59.5	>5k	>3k	0.67	0.61	-0.06
C2 a-Si	22.6	82.6	>5k	>3k	0.68	0.58	-0.10
D1 a-Si/µX-Si	4.1	9.3	>2k	>1k	0.69	0.64	-0.05
D2 a-Si/µX-Si	4.0	14.8	>2k	>1k	0.69	0.60	-0.09
E1 poly-X	1.1	2.5	-	-	0.67	0.55	-0.12
E2 poly-X	1.4	0.7	-	-	0.65	0.69	-0.04
G1 CdTe	41.5	54.4	>3k	>2k	0.57	0.54	-0.03
G2 CdTe	39.5	50.0	>3k	>2k	0.57	0.56	-0.01

PV module degradation after long term outdoor exposure (spring 2009 – autumn 2011)

It must be noticed that for the a-Si modules the so-called Staebler-Wronski effect is a well-known phenomenon leading to initial degradation.

Unfortunately, one of the polycrystalline reference modules E1 also changed unexpectedly, so it could not be used for direct comparison with the other modules during the last part of the project. Later, after dismounting the module, it was evident that a bad connection had occurred in the junction box and was responsible for the degradation, not the solar cells.

There is no general evidence that the modules without back ventilation are more prone to degradation than their ventilated twins. The measured STC power values for all the modules are illustrated below:



A,B= CIS C= a-Si D = a-Si/µX-Si E= poly-X F=CIS(excluded) G = CdTe

The numbers below the bar graph shows the nameplate ratings in Wp. Index 1 refers to the integrated modules. The uncertainty is about 5% in these measurements, so smaller deviations should not be interpreted as degradation.

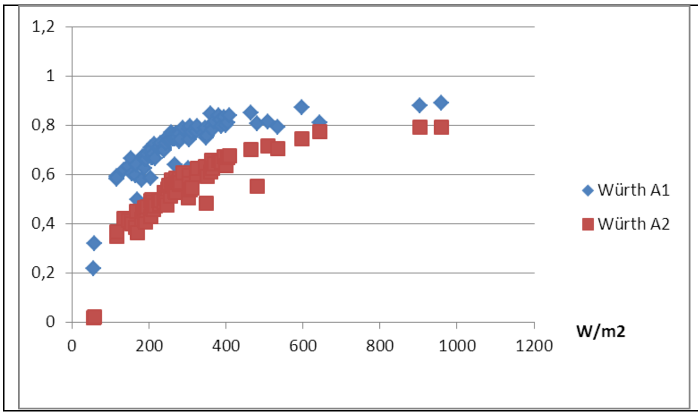
Observations

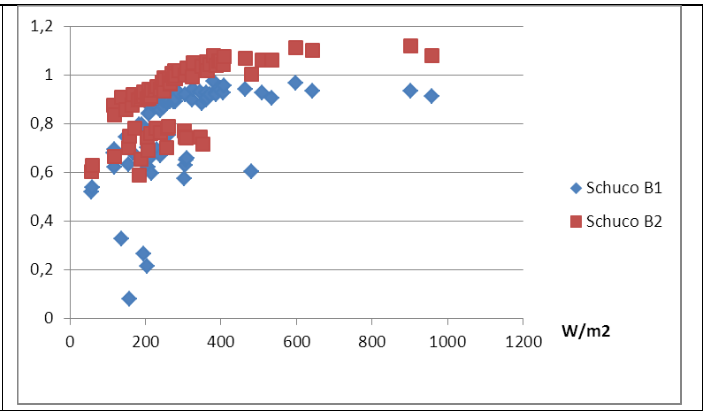
Corrosion of terminals and heat damage of junction box on module E1.

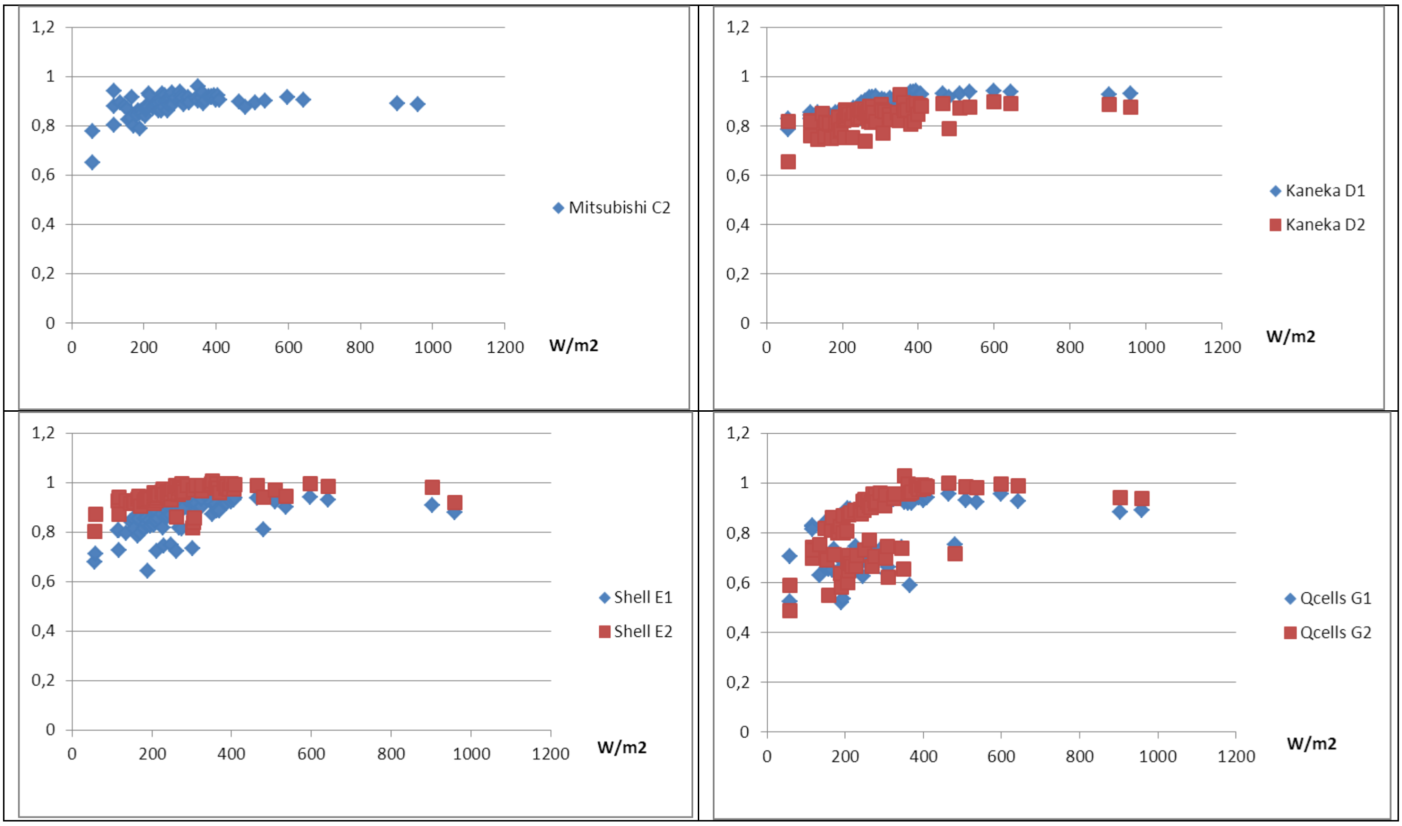
It seems that the temperature has been critically high for some of the modules that have been fully closed on the back side. The overall highest temperature measured was 85°C for one of the CIS modules (A1). The extreme degree of insulation used in this experiment is therefore not recommended in real installations. At least the junction box with diodes must have some ventilation.

Effect of irradiance

Many distributors of PV modules claim that their particular technology delivers more energy per kWp or is better in overcast weather etc. With the current project it has only partly been possible to identify any significant difference regarding the technologies in such. It is likely that any possible differences drown in the uncertainty of the measurements, including a noise problem with the MPP trackers. Only with one of the CIS modules (A2), there is a clear trend that the module efficiency actually decreases at lowered irradiance. This is in opposition to some manufacturers claim that they should be better in low light conditions. There is likely a defect in this particular module as the phenomenon is not seen in the other twin module.







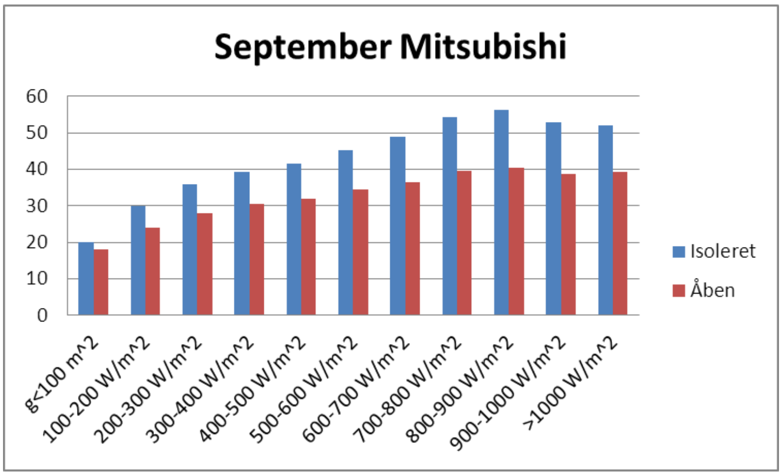
Relative module power as a function of irradiance based on nominal power. Module temperature in the interval 25-40°C (August 2012)

A,B= CIS C= a-Si D = a-Si/µX-Si E= poly-X G = CdTe

The best low light performance is seen for module types C, D and E which are almost equally good.

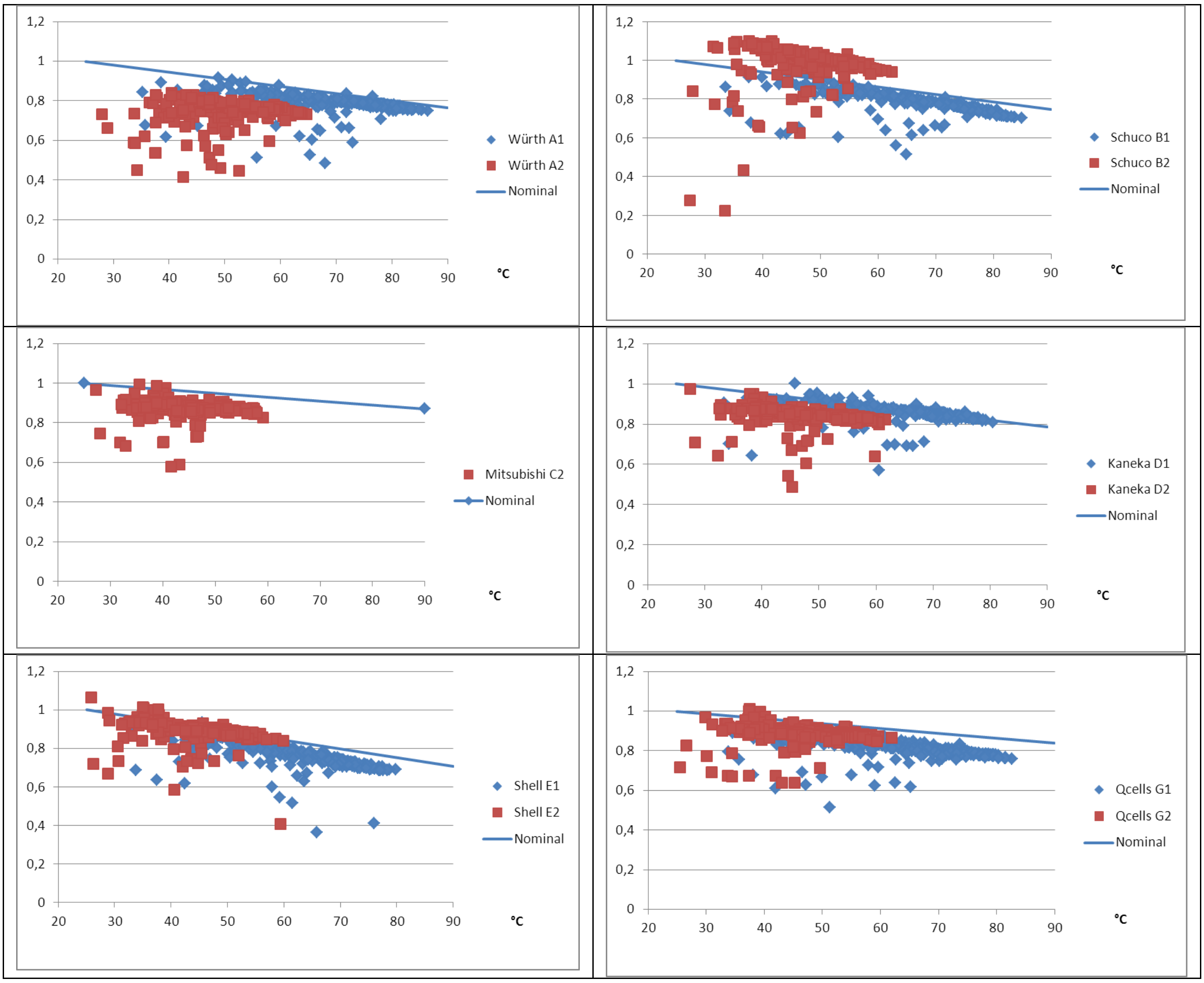
Effect of temperature

The measured back side temperature is significantly higher for the insulated modules as shown. As irradiance increases, this difference becomes more and more clear, but wind speed does also have an influence, which may be the reason that the temperature difference lower again at the highest irradiance levels where there are only few data points.



Typical operating temperature as a function of irradiance. Depending on the temperature coefficient, the corresponding difference in electrical yield would be 0-7%.

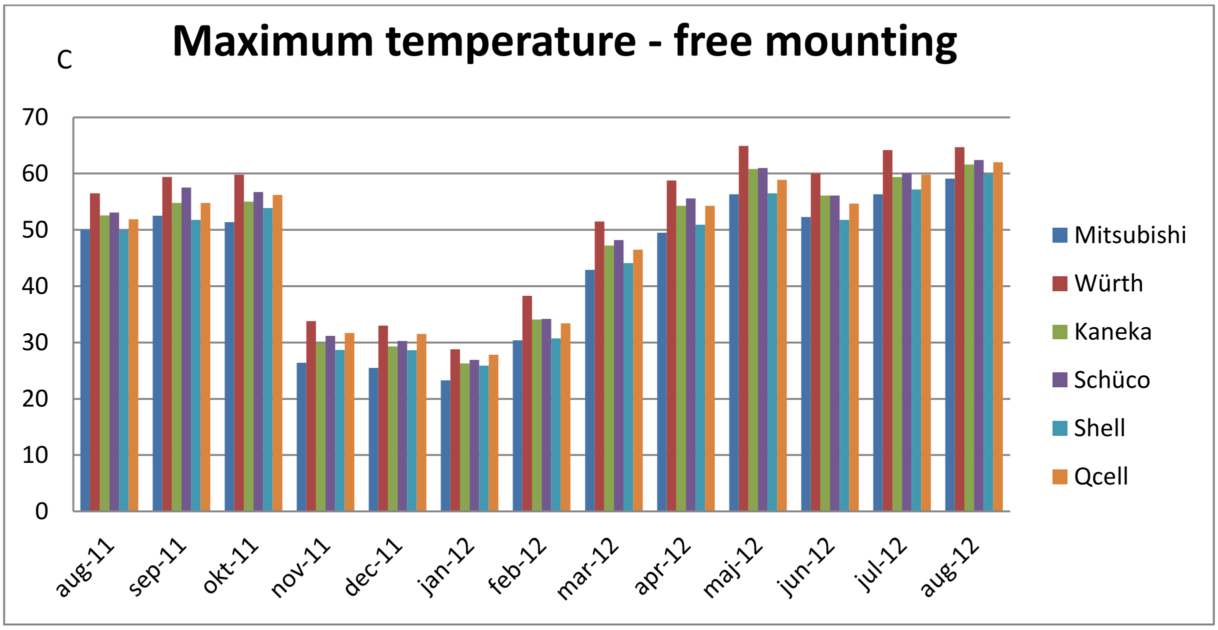
For comparison, the monthly efficiency for each pair of modules has been calculated so that the direct influence of elevated temperature of the insulated module can be identified. Please notice that the module pairs are not completely identical which could add a small bias to the curves.

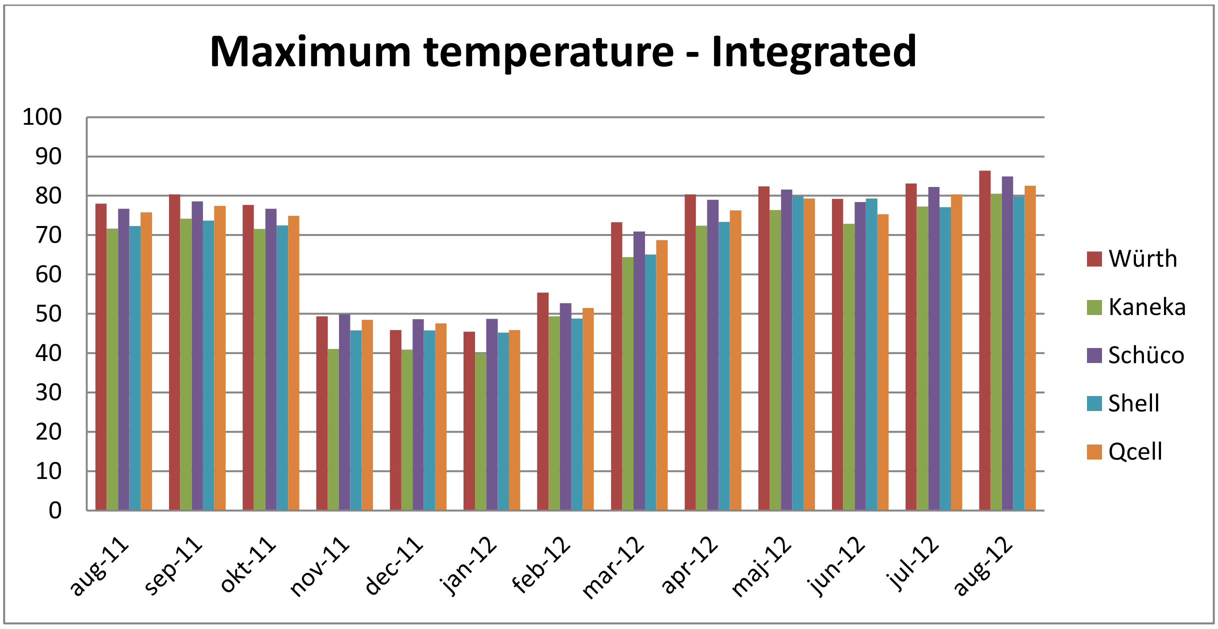


Relative module power as a function of module temperature, based on nominal power. Irradiance values above 600 W/m2 (August 2012). Most of the thin films exhibit a lower temperature coefficient than the reference crystalline module E.

A,B= CIS C= a-Si D = a-Si/µX-Si E= poly-X G = CdTe

Data sheet	*Würth*	*Schüco*	*Mitsubishi*	*Kaneka*	*Shell*	*Qcells*
Pmpp %/K	*-0,36*	*-0,39*	*-0,20*	*-0,33*	*(-0,45)*	*-0,25*



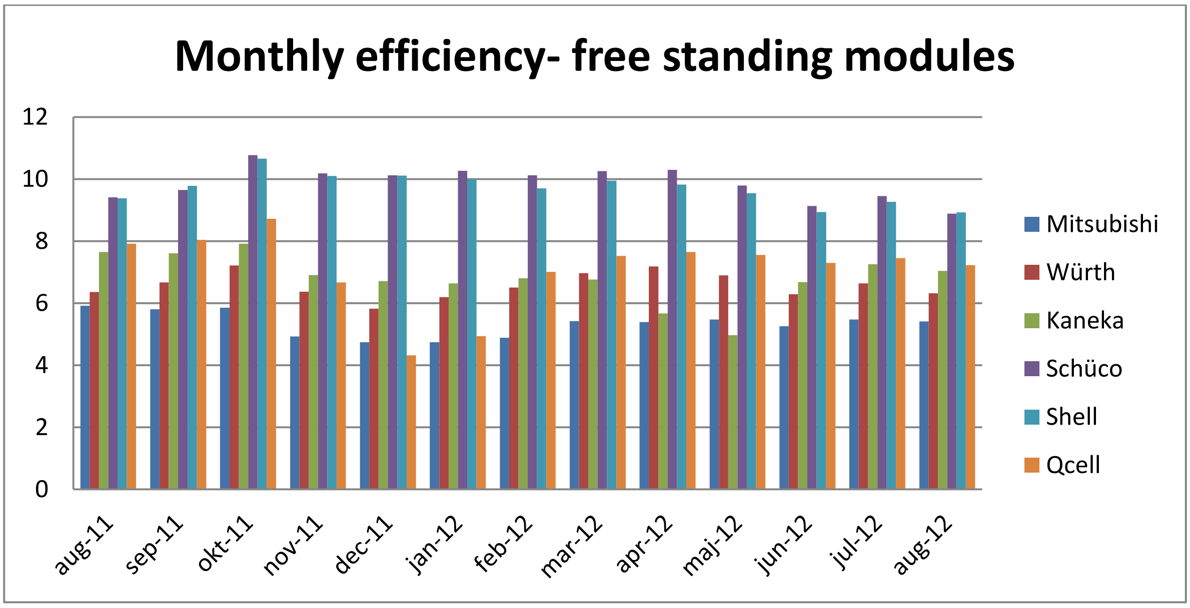


In general it can be seen that for the same type of module, the maximum temperature goes 15-20 K higher than the corresponding open air module.

Module efficiency measurements

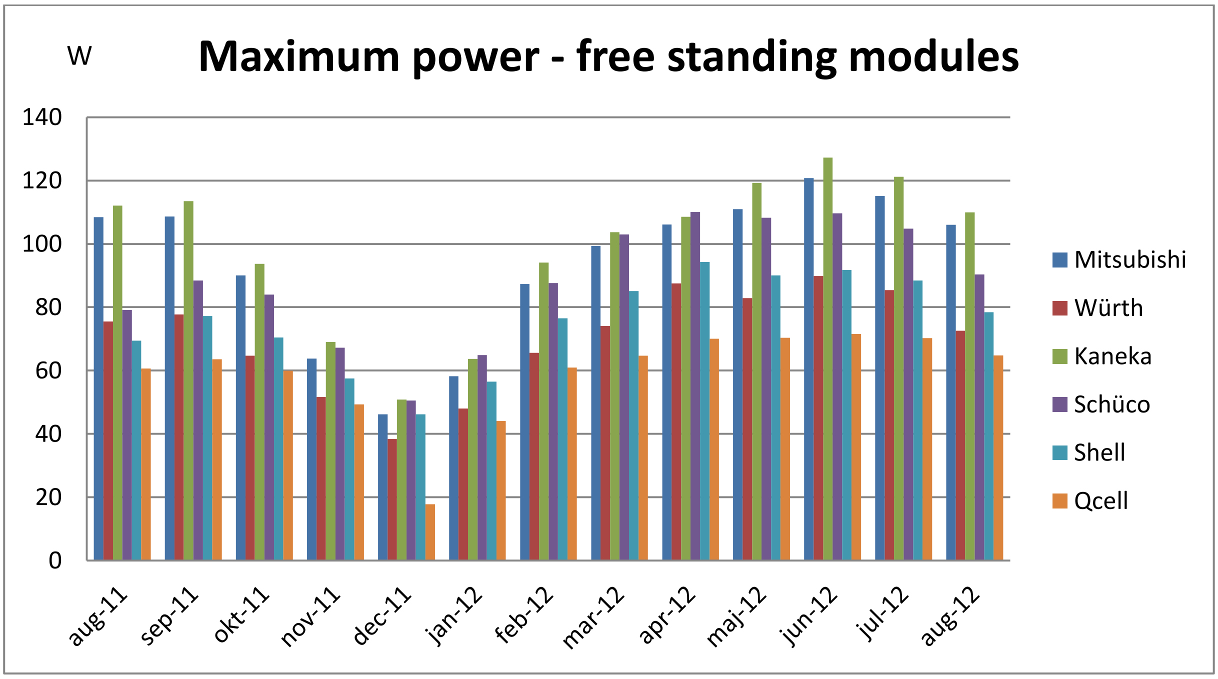
For each module the actual monthly energy efficiency is now compared with the nominal efficiency for that particular month. This value is defined as the module performance ratio. For the integrated modules, data are not available for a full year due to a technical fault, but there are valid measurements from both summer and winter:

The energy efficiency of each module was calculated on a monthly basis and presented in the following.



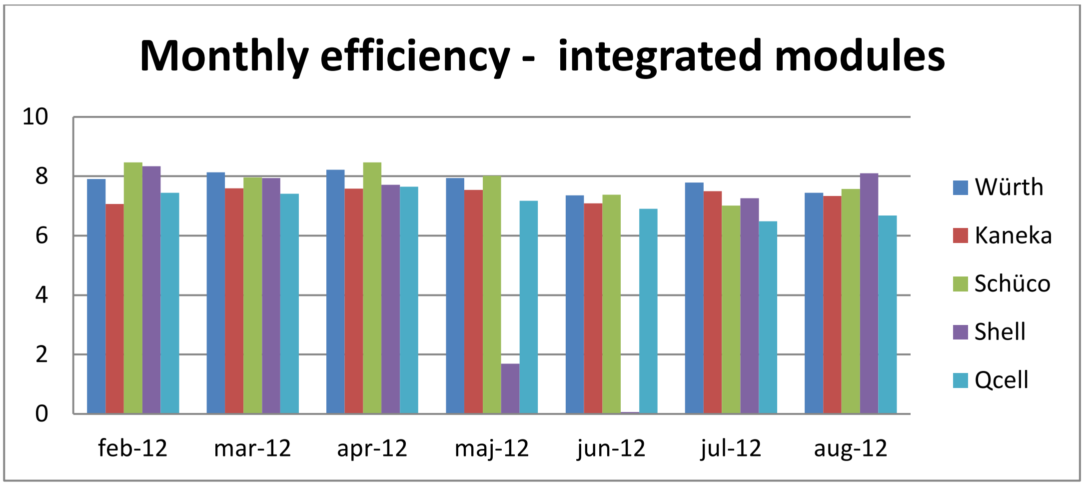
PV modules with open-rack mounting

It is interesting to observe that there are big differences in the monthly efficiency cycles, for example the Qcell module has very low winter efficiency, whereas the efficiency of the reference Shell module is relatively constant. This pattern confirms the efficiency variation as a function of irradiance.



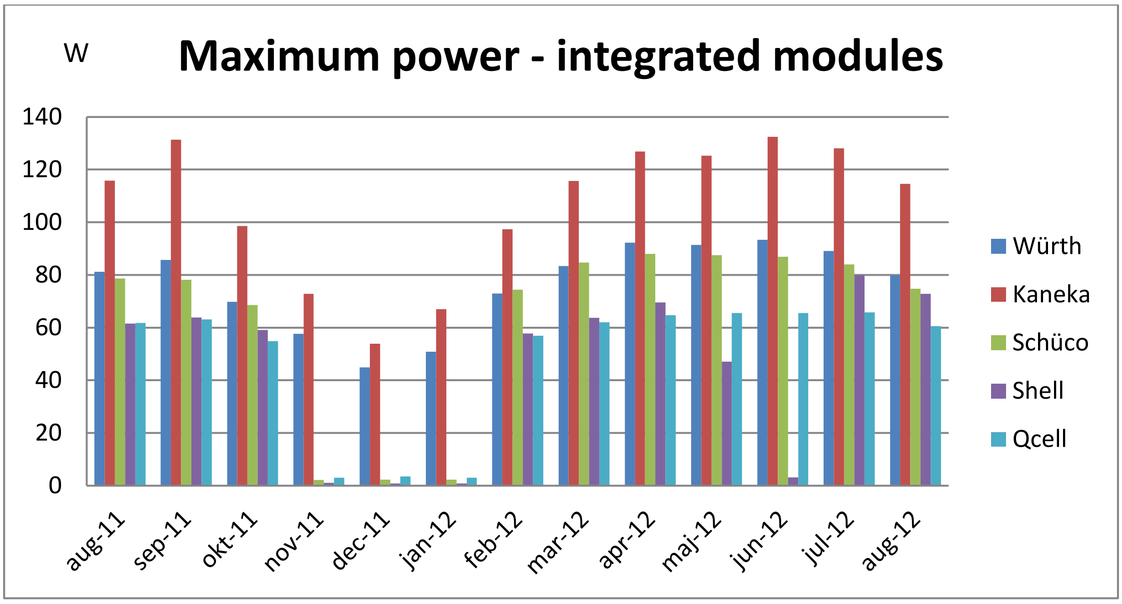
Maximum power determined as maximum instantaneous value measured during the month. Data shows that in the summer months the nominal power values are exceeded

For the PV modules with integrated mounting there is less data available for analysis.



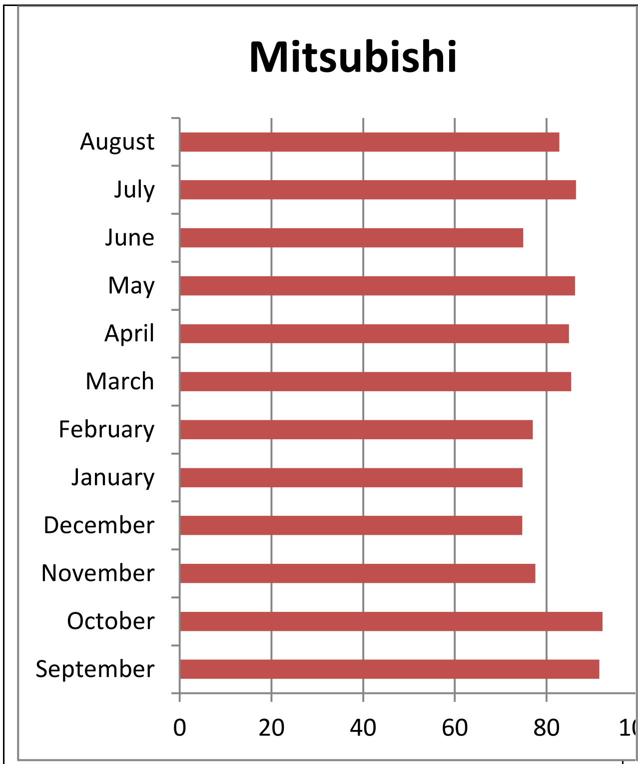
PV modules with integrated mounting

The measurement period for this part of the system is not a full year, but nevertheless the efficiency looks much more constant for most of the modules. This is likely because the high summer temperatures cause the efficiency to drop, and in the winter it is the low irradiance that determines the performance. In May and June there has been a fault on the Shell reference measurement.

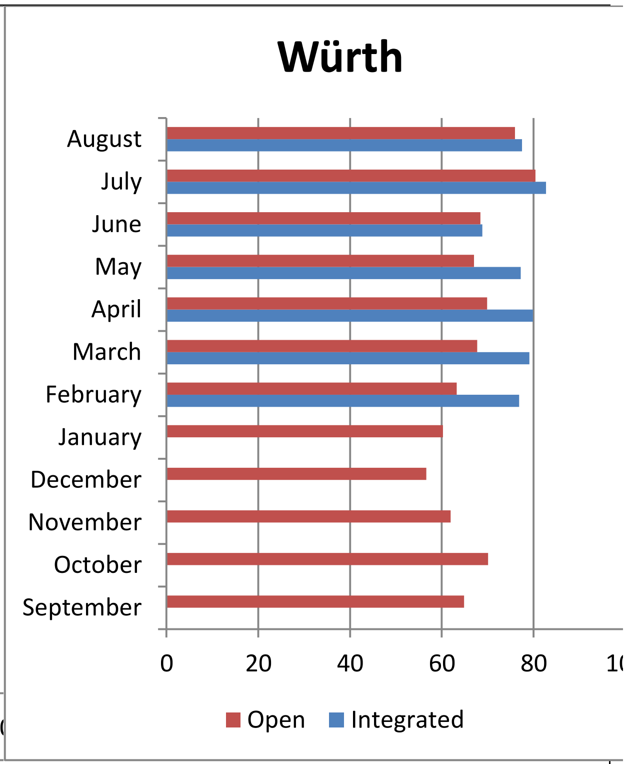


Most of the modules exceed the nominal power values in short time periods.

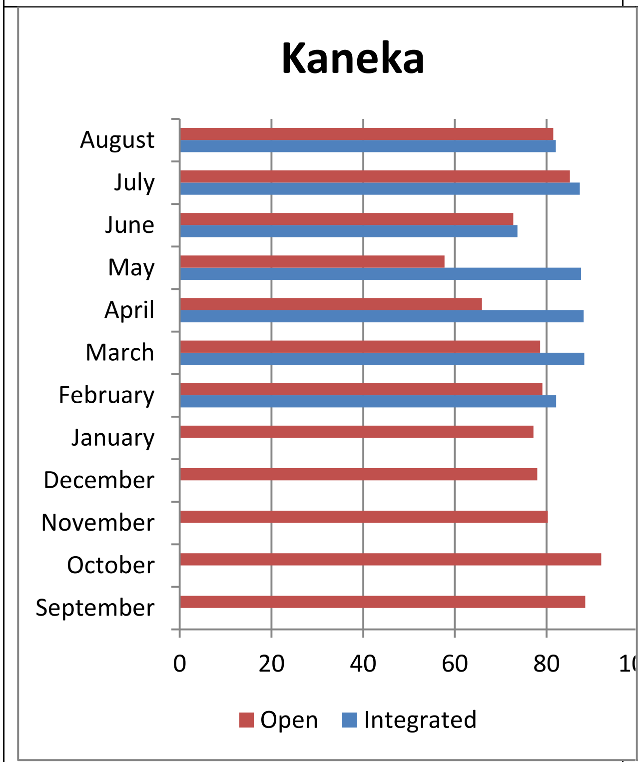
Calculation of monthly yield was based on regression analysis of the data in order to fill out missing data and eliminate erratic data values for example caused by shadows on module or irradiance sensor. For the integrated modules data from the first 5 months was discarded due to an error in the data acquisition system that was discovered too late.



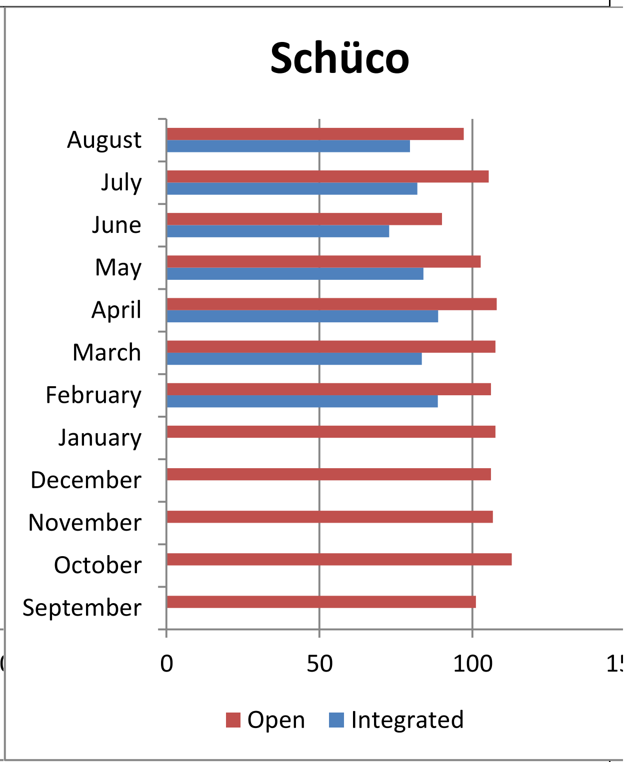
The module was only measured in free standing mode. Generally lower performance than expected.



The module that is integrated performs best, but this is due to a deficiency in the open rack module, which for unknown reason has increased series resistance

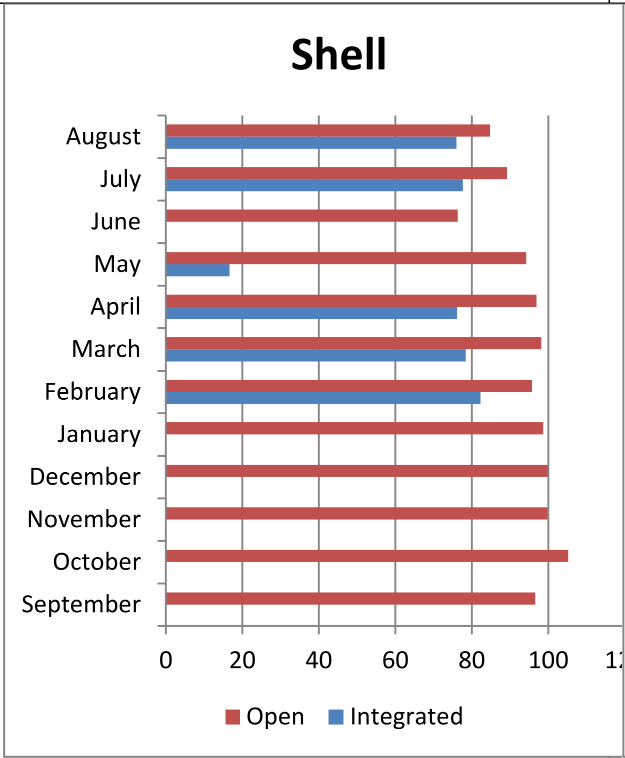


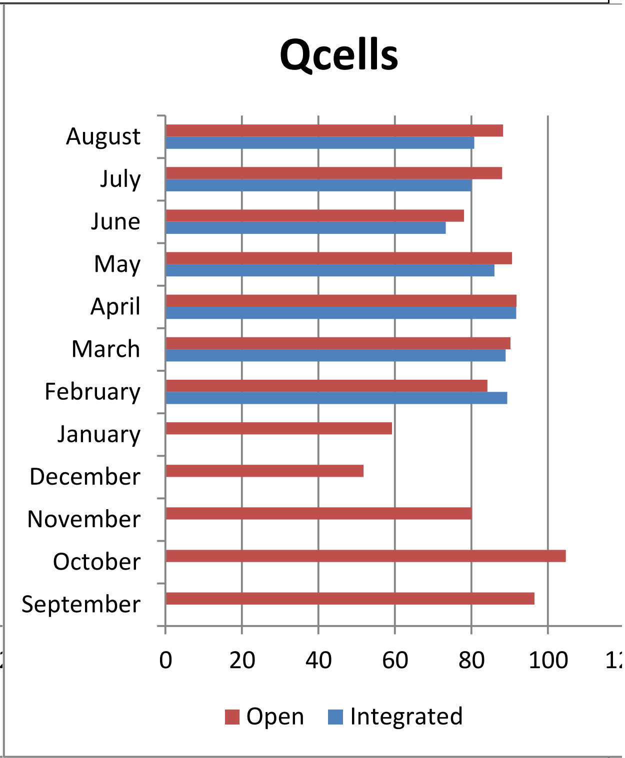
Deviations in May and April without any obvious explanation. Good low light/winter



The generally better performance of the open mounted module follows the theoretical *performance but generally lower yield than expected.*

behaviour due to increased temperature. Excellent low light performance.





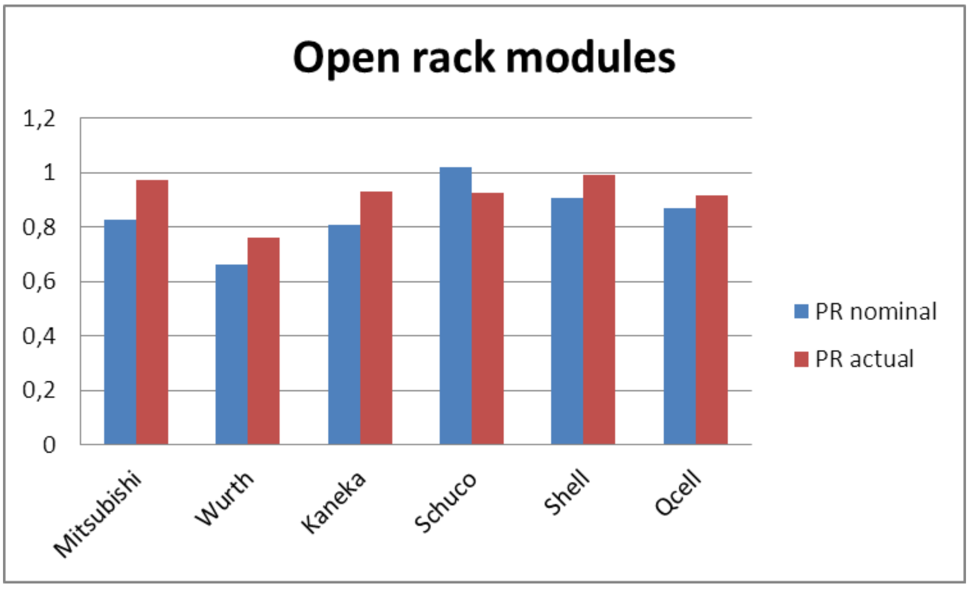
The generally better performance of the open mounted module follows the theoretical behaviour due to increased temperature. In June and May there was a bad connection to the integrated module. Excellent low light performance, but some reduction due to high temperature in summer.

The performance of the two modules is very close and shows that temperature does not play a major role for the yield of this module type. The strong dip in winter indicates a bad low light performance.

It must be noticed that only two samples of each module type are **not sufficient** as a base for general conclusions of the specific performance and efficiency of the tested modules. Also, the test site has also not been ideal and completely free from shading. However, it is possible to see some trends in the specific behavior of the different modules.

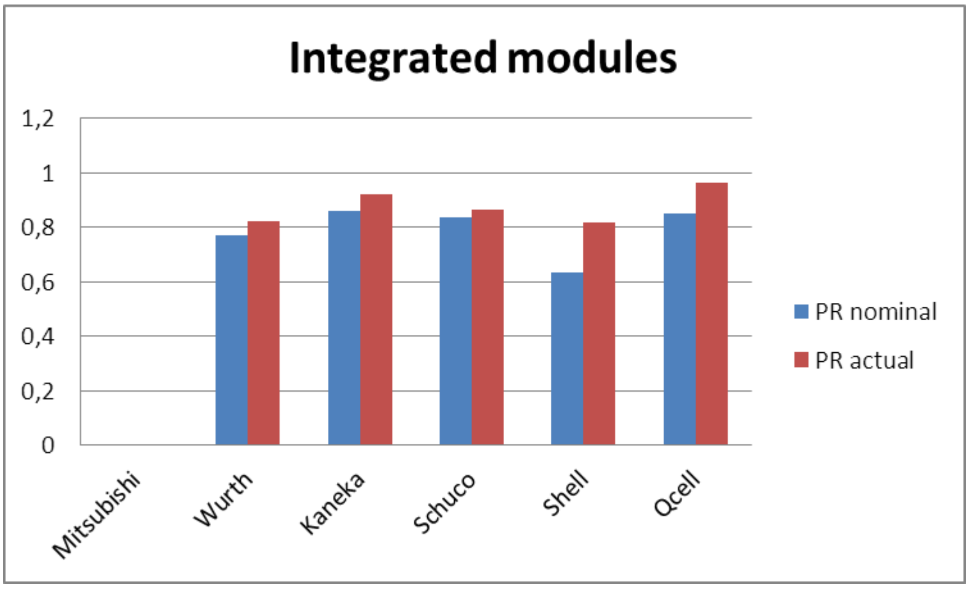
Average values for the performance ratio based on measured Wp values are:

	Mitsubishi	**Wurth**	**Kaneka**	**Schuco**	**Shell**	**Qcell**
	a-Si	CIS	a-Si/mC	CIS	Poly X	CdTe
PR actual open	0,97	0,76	0,93	0,93	0,99	0,92
PR actual integ.		0,82	0,92	0,86	0,82	0,96
Ratio		0,93	1,01	1,07	1,21	0,95



Performance ratio for open rack modules.

The module from Würth is possibly damaged, but the rest seem to perform very well and uniformly if the measured peak power is used as base for the calculations. Interestingly, none of the thinfilm modules perform better than the reference.



Performance ratio for integrated modules.

Also in this case the performance ratios are relatively close, but significantly lower than for the open rack modules. This can be explained by elevated temperature, but for the Qcells module the performance is actually higher than for the ventilated counterpart. Modules based on CdTe are known to have a nonlinear temperature coefficient that also varies with the irradiance level, this could be a likely explanation for this phenomenon. It must also be emphasized that the inaccuracy of the PR measurement is at least +/- 5% .

7. Summary

A lot of lessons have been learned from this project that was quite ambitious regarding the open air measurements. The data acquisition and analysis revealed the real practical difficulties with such a comparison of PV modules:

- When measuring small differences in module performance, measurement accuracy becomes very demanding
- Several factors have uncontrollable influence on the measurements and may be difficult to filter later on, such as shadows, cabling problems, EMC noise etc.
- When comparing the efficiency and energy output from different module technologies it is important to define the nominal power values, and that is a problem if the modules are not stable during the period.
- The very limited number of samples makes it difficult to draw statistically valid conclusions regarding the performance of each brand.

Despite the difficulties, the project succeeded in developing the special measurement equipment needed, and this will subsequently be used in other projects and tasks.

The overall conclusion of the energy performance of the tested modules can be summarized as:

- It is not possible to see any significant difference in specific annual energy yield or performance ratio when the actual peak power is used as base.
- If the nominal power is used as base for the calculations, there are large differences, but no systematic variation related to a specific module technology.
- The open mounted crystalline reference module perform at least as good as any of the thin films, also at low irradiance levels where some thin film manufacturers claim they have an advantage.
- The low temperature coefficients of amourphous silicon and CdTe was confirmed, for the other technologies it was difficult to see a clear trend.
- There is generally a lower production from the integrated modules compared to the open mounted as expected. The difference is 0-10% for the thin films but 19% for the crystalline reference modules. This result is possibly caused by a bad connection.
- All the modules survived the test without any visible defects (except the melted junction box in E1) and stabilized at a power level lower than the nameplate value.

Appendix- Data sheets

A-Würth:

Modules in standard version

CIS modules of Würth Solar are delivered in glass/glass compound with or without frame. The front glass used is extremely translucent and protects the module even against toughest environmental conditions.

The standard modules are submitted to laboratory tests for a wide spectrum of operating conditions and are produced according to strict guidelines of quality. The customer can get a test certificate for each type of module.

It will be a pleasure for us to provide you with further information on request

WS 31045	WS 31046	WS 31047	WS 11007/75	WS 11007/80	WS 31050/80
35,0	55,0	80,0	75,0	80,0	80,0
16,5	16,5	16,5	35,0	36,0	120,0
2,12	3,33	4,85	2,15	2,22	0,67
22,0	22,0	22,0	44,5	45,5	160,0
2,29	3,56	5,19	2,36	2,50	0,72
24,3	24,3	24,3	49,0	50,2	177,0
13,8	13,8	13,8	29,3	30,2	101,0
-0,29	-0,29	-0,29	-0,29	-0,29	-0,29
-0,36	-0,36	-0,36	-0,36	-0,36	-0,36
605 x 605	605 x 905	605 x 1.205	605 x 1.205	605 x 1.205	605 x 1.205
6,5	9,7	12,8	12,7	12,7	12,6
①	③	③	②	②	①*

* cable Ø 2,5 mm² with MC plug

Connection variants		
① 2 connecting buttons with cable socket	② Socket (MC/PV-JB/K-2/2.5)	③ Socket
		
Dimension: 30 x 50 x 12 mm (W x L x D)	Dimension: 55 x 91 x 13 mm (W x L x D)	Dimension: 100 x 158 x 35 mm (W x L x D)

B - Schüco:

Schüco CIS thin-film modules

Key electrical data	Module output categories		
Output data (except NOCT) under Standard Test Conditions (STC)*:	SPV 70-TF	SPV 75-TF	SPV 80-TF
Rated output (Pmpp)	70 Wp	75Wp	80Wp
Effective output tolerance (Δ Pmpp)	+5 % /-0 %	+5 % /-0 %	+5 % /-0 %
Guaranteed minimum output (Pmpp min.)	70W	75 W	80W
Rated voltage (Umpp)	37,6V	40,5V	41,0V
Rated current (Impp)	1,85A	1,85 A	1,95A
Open circuit voltage (Uoc)	54V	55,5V	56,5V
Short circuit current (Isc)	2,2A	2,2A	2,26A
Module efficiency	8,8 %	9,5 %	10,1 %
Temperature coefficient α (Pmpp)	-0,39 % / °C	-0,39 % / °C	-0,39 % / °C
Temperature coefficient β (Isc)	+0,04 % / °C	+0,04 % / °C	+0,04 % / °C
Temperature coefficient χ (Uoc)	-0,19 % / °C	-0,19 % / °C	-0,19 % / °C
Temperature coefficient δ (Impp)	+0,004 % / °C	+0,004 % / °C	+0,004 % / °C
Temperature coefficient ε (Umpp)	-0,26 % / °C	-0,26 % / °C	-0,26 % / °C
Normal Operating Cell Temperature (NOCT)**	48 °C (± 2 °C)	48 °C (± 2 °C)	48 °C (± 2 °C)
Max. permissible system voltage	1.000V	1.000 V	1.000 V
Active module area	1203 x 610 mm	1203 x 610 mm	1203 x 610 mm

* Intensity of solar radiation 1000 W/m², air mass 1.5, cell temperature 25°C

** Intensity of solar radiation 800 W/m², ambient temperature 20 °C, wind speed 1 m/s

Key mechanical data	
Outer dimensions (l x w x h)	1235 x 641 x 35 mm
Design of aluminium frame	Anodised, black
Front glass	Toughened safety glass (TSG)
Weight	12,5 kg
Connection system/cross section of solar cable	Multi-contact type 3 / 2.5 mm²
Lengths: Positive cable / negative cable	100 cm ± 5 cm / 100 cm ± 5 cm

Miscellaneous	
Weight of packing unit	26 kg
Schüco installation system	PV-Light
Schüco Art.-No. End clip	Typ 39-1
Schüco Art.-No. Intermediate clip	Typ 39-2
Schüco Art.-No. SPV 70-TF	256018
Schüco Art.-No. SPV 75-TF	256019
Schüco Art.-No. SPV 80-TF	256020
Packing unit	2 modules

Guarantee	
Electrical classification	Safety class II
Product standard	IEC 61646
Product guarantee	5 years
Output guarantee to 90 % $P_{mpp\,min}$	10 years
Output guarantee to 80 % $P_{mpp\,min}$	20 years

Output				
70 to 80 Wp	▶	Optimised power density	▶	Highest yields
Positive output tolerance	▶	Rated output is achieved or exceeded		
Design and production				
Optimised labelling	▶	Individual rated output data on module and packaging		
Anodised aluminium frame	▶	Meets the highest quality standards		
Bypass diodes	▶	Prevents the active module area from overheating		
Extended product and output guarantee	▶	Investment security and reliable system operation		
Highest Schüco quality				
Manufactured in accordance with current quality standards	▶	Tests to determine performance data; data listed for each module		

C - Mitsubishi:

A Greener Earth for Tomorrow

Mitsubishi Thin Film Photovoltaic Module

The MHI MA series is a new line of cost-effective photovoltaic modules installable in any site not subject to mounting space constraints.

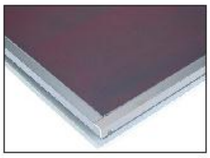
MHI realized a high-performance, high-quality, manufacturing process for the large modules using advanced PCVD (plasma chemical vapor deposition), a key proprietary technology for the mass production of thin film (amorphous silicon) photovoltaic modules.

A thin film photovoltaic module is made from silane gas by depositing thin layers of semiconductor alloys on a glass substrate. In addition to its environmental advantages over the crystalline photovoltaic module (less energy used for manufacturing, less silicon required, shorter energy payback time), the thin film photovoltaic modules has a weatherproof structure and performs stably under high temperatures during summer. These features make the MA series an ideal solution for BIPV (building integrated photovoltaics) and grid-connected power systems for commercial and residential facilities.

Quality and Safety

The MA series is awarded the following international certifications:

- Certified by TÜV Rheinland Product Safety GmbH (IEC61646, Safety Class II)
- Manufactured in an ISO 9001 certified factory



Limited Warranty

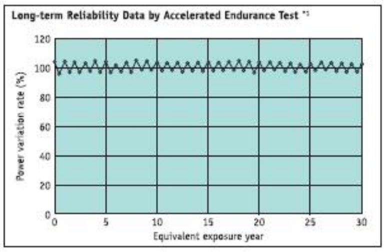
The MA series is covered by the following limited warranty:

- Power output for 20 years (maintain more than 80% of minimum rated power)
- Free from defects in materials and workmanship for 2 years

Please contact your local representative for the full terms of the above warranties.

Long Term Reliability

MHI's thin film photovoltaic modules maintain stable power output over a long period. The test results performed by the third party organization indicate very few variations in power generation in 30 years usage.



*1: Accelerated endurance test result by AIST (National Institute of Advanced Industrial Science and Technology)

MA100

Nominal maximum power of 100 watts.
MA100T2 is the advanced module in terms of product reliability and customer satisfaction.

Major Improvements of MA100T2

- 3-series connection is available by 600 V of maximum system voltage.
- MA100T2 is easy to install and connect.

The largest (1.4 m x 1.1 m) and most cost-effective module is the MA100 encased in an aluminum frame. The MA100 is especially well suited for the grid-connected systems of commercial buildings and industrial facilities. Very high voltage makes it easy to design layouts and cabling configurations with fewer connections for most applications.

MA100 Principal Specifications

Model	MA100T2
Module type	Amorphous Silicon (PIN single junction)
Mechanical characteristics	
Dimensions	L 1,414 x W 1,114 x T 35 mm
Weight	Approx. 21 kg
Electrical characteristics	
Maximum power	100 W
Maximum power voltage	108 V
Maximum power current	0.93 A
Open circuit voltage	141 V
Short circuit current	1.17 A
Maximum system voltage	600 V

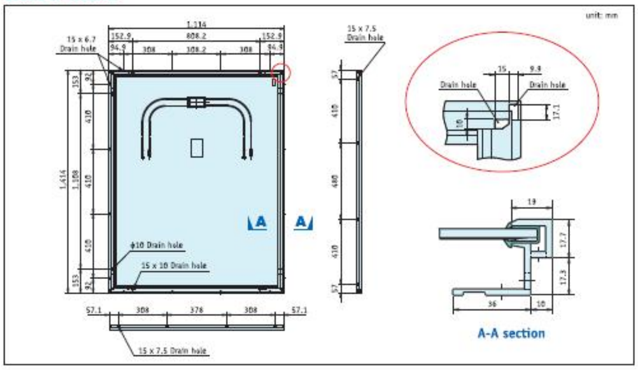
Temperature coefficients	
Maximum power (W)	-0.20%/°C
Maximum power voltage (V)	-0.32%/°C
Maximum power current (A)	+0.14%/°C
Open circuit voltage (V)	-0.33%/°C
Short circuit current (A)	+0.09%/°C

Measurements made under the standard test conditions (STC):

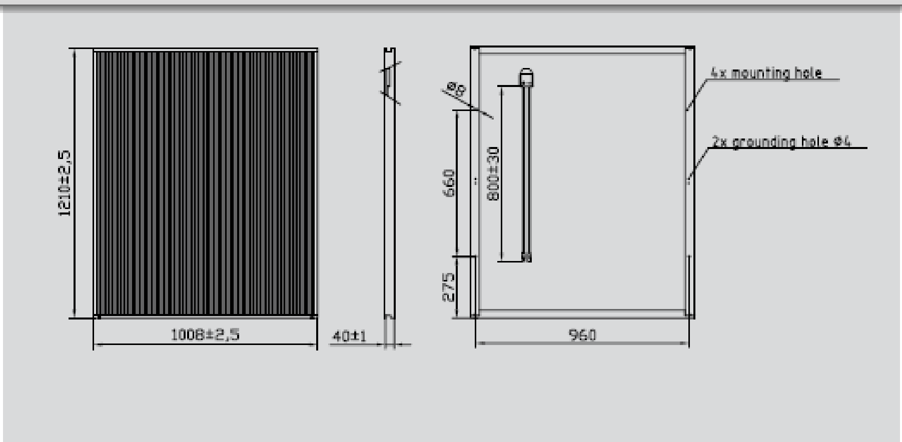
- Irradiance of 1 kW/m²
- Spectrum of AM1.5
- Module temperature of 25°C

* MHI reserves its rights to change without prior notice the contents of this data.

Outline of MA100T2



D - Kaneka:



Dimensioned drawing Kaneka HB100, HB105, HB110

TECHNICAL DATA

Kaneka		HB100		HB105		HB110	
		Stabilised values	Initial values	Stabilised values	Initial values	Stabilised values	Initial values
Nominal peak power	Wp	100.0	130.0	105.0	136.5	110.0	143.0
Guaranteed minimum power	Wp	95.0	123.5	99.7	129.6	104.5	135.8
Nominal voltage	V	53.5		53.5		54.0	
Nominal current	A	1.87		1.96		2.04	
Open circuit voltage	V	71.0	81.7	71.0	81.7	71.0	81.7
Short-circuit voltage	A	2.25		2.40		2.50	
Temperature coefficient of I_{sc}	%/K	+0.10		+0.10		+0.10	
Temperature coefficient of U_{oc}	mV/K	−248		−248		−248	
Temperature coefficient of P_{max}	%/K	−0.33		−0.33		−0.33	
Length	mm	1210		1210		1210	
Width	mm	1008		1008		1008	
Height	mm	40		40		40	
Weight	kg	18		18		18	
Mounting holes Ø 8 mm	Pieces	4		4		4	
Article numbers		260040100		260040105		260040110	

Attention:
The laser lines must run vertically and the module has to be installed with at least 5° inclination. Please observe the installation instructions.

* The complete warranty conditions are binding as per your relevant version, a copy of which can be requested from your IBC SOLAR specialist partner.

Electrical values under standard test conditions: 1000 W/m²; 25 °C; AM 1.5.
Subject to technical changes for further improvements.

11-2008

G - Qcells

MECHANICAL SPECIFICATION

Length × Width	1200 mm × 600 mm
Thickness	6.9 mm (20.0 mm including junction box)
Weight	12.0 kg
Front Cover	3.2 mm glass
Back Cover	3.2 mm glass
Frame	None
Cell Type	Cadmiumtelluride/Cadmiumsulphide (CdTe/CdS)
Junction Box	Schutzart IP 65
By-Pass Diode	None
Cable Length	600 mm (+ cable) / 800 mm (- cable)
Connector	Multicontact MC4

ELECTRICAL CHARACTERISTICS

PERFORMANCE AT STANDARD TEST CONDITIONS (STC: 1000 W/m², 25°C, AM 1.5 SPECTRUM)									
PRODUCT NAME			CX42	CX45	CX47	CX50	CX52	CX55	CX57
Nominal Power (+2.5/-0 Wp)	P_{max}	[W]	42.5	45.0	47.5	50.0	52.5	55.0	57.5
Short Circuit Current	I_{sc}	[A]	1.03	1.03	1.04	1.06	1.06	1.06	1.07
pen Circuit Voltage	V_{oc}	[V]	84.2	84.9	85.8	86.5	86.7	87.6	88.2
Current at Maximum Power	I_{mp}	[A]	0.76	0.79	0.81	0.83	0.86	0.87	0.90
Voltage at Maximum Power	V_{mp}	[V]	55.9	57.3	58.7	60.0	61.2	63.1	64.3
PERFORMANCE AT NORMAL OPERATING CELL TEMPERATURE (NOCT: 800 W/m², 50 ± 2°C, AM 1.5 SPECTRUM)									
PRODUCT NAME			CX42	CX45	CX47	CX50	CX52	CX55	CX57
Nominal Power(+2.5/-0 Wp)	P_{max}	[W]	34.7	36.8	38.8	40.8	42.9	44.9	46.9
Short Circuit Current	I_{sc}	[A]	0.88	0.88	0.90	0.91	0.91	0.91	0.92
Open Circuit Voltage	V_{oc}	[V]	82.2	83.0	83.9	84.5	84.8	85.5	86.2
Current at Maximum Power	I_{mp}	[A]	0.67	0.69	0.71	0.74	0.75	0.77	0.79
Voltage at Maximum Power	V_{mp}	[V]	54.9	56.4	57.8	59.1	60.2	62.0	63.2

PERFORMANCE AT LOW IRRADIANCE

The typical relative change in module efficiency at an irradiance of 200 W/m² in relation to 1000 W/m² (both at 25°C and AM 1.5 spectrum) on request.

TEMPERATURE COEFFICIENTS (AT 1000 W/m², AM 1,5 SPECTRUM)			
Temperature Coefficients of Isc	α	[%/K]	+0.02
Temperature Coefficients of Voc	β	[%/K]	-0.24
Temperature Coefficients of Pmax	γ	[%/K]	-0.25

1) Unless otherwise indicated, all measurement values given are nominal values with a tolerance of ±5 %. Valid indoor measurement of STC performance is obtained by pre-treating the modules before measurement by 1 hour light soaking (at about 1000 W/m² in open circuit) followed by cool down to 25°C.

PROPERTIES FOR SYSTEM DESIGN

Safety Class			II
Maximum System Voltage	V_{sys}	[V]	1000
Maximum Reverse Current	I_R	[A]	2.0

See the Application Guideline and Mounting Instruction for further information on approved installation and use of this product.

QUALIFICATIONS AND CERTIFICATES

IEC 61646; IEC 61730 Application Class A; CE-Mark

Safety Class II

Q-CELLS MODULES
manufactured by Calyxo GmbH
OT Thalheim, Sonnenallee 1a
06766 Bitterfeld-Wolfen, Germany
TEL +49 (0)3494 368 980-0
FAX +49 (0)3494 368 980-111
EMAIL calyxo@calyxo.com
WEB www.calyxo.com

Q.CELLS

Example of I-V curve measurement with PVPM 6020 measuring device

Module E1 (Shell)