Questions Utilities Should Ask to Mitigate PV Technology Risk

Utility/Lab Workshop on PV Technology and Systems

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Introduction – Questions

- What do utilities need to know about a PV system, especially the modules before they invest in the system?
- What model is being utilized to predict the performance?
- What weather data has been utilized to predict the performance?
- How will the performance vary with time?
    - Permanent changes
        - Long term degradation
        - Failure rate
    - Transient changes
- What O&M is necessary to obtain the modeled performance?

Module should be

- Be qualified to IEC 61215 or 61646.
- Be safety certified to UL 1703.
- Be safety certified to IEC 61730 parts 1 and 2.
- Have at least a Class C fire rating if it is going to be used on or near a building.
- Warranted for at least 25 years
- Characterized under all expected operating conditions.

Module Performance – Typically Supplied

STC Values of

- Pmax Isc Voc Ipmax Vpmax

Temperature Coefficients of Isc, Voc and Pmax

Maximum Systems Voltage (600 for US, 1000 for ROW)

NOCT – Cell temp at 800 W/m^2, 20 C ambient, 1 m/s ws

Fuse Rating and maximum reverse current

Tolerance of power (but not of other parameters)

May get performance at NOCT

May get performance at low irradiance (200 $W/\ m^2$)

These values are required by either IEC 61215 or 61646, IEC 61730 and/or EN 50380 (European standard for Module Nameplate and Datasheet)

(Show example Module Spec Sheet)

Do the Modules Meet the Specification?

- The first question should be "Does the STC power meet the specification"?
- A number of publications have pointed out that the most important factor effecting the energy collection (kWhr/kWp) is the Actual Module Power versus the Nameplate Module Power.

(See for example Ransome & Wohlgemuth, "An Overview of 4 years of kWhr/kWp Monitoring at 67 Sites Worldwide", WCPEC-3 , 2003.)

- So ask for 3rd party verification of module power measurements or even make it a part of the procurement,

Why do you need additional Module Information?

Pmax is a non-linear function of irradiance.

Typical PV sizing programs use the following steps:

- Calculate tilted plane hourly irradiance from monthly horizontal plane insolation data.
- Estimate module temperature from the NOCT value.
- Generate hourly Pmax as a function of irradiance and ambient temperature using a 1-diode model.
- Estimate other modules losses (soiling, shading, mismatch, snow, etc.)
- Estimate systems losses (inverter efficiency, Vmax tracking and wiring losses)
- Sum results to get expected energy collection.

Issues

Monthly average data changes the distribution of the irradiance versus insolation curve.

- Modules actually operate at higher irradiances than monthly average predicts. (See figure)

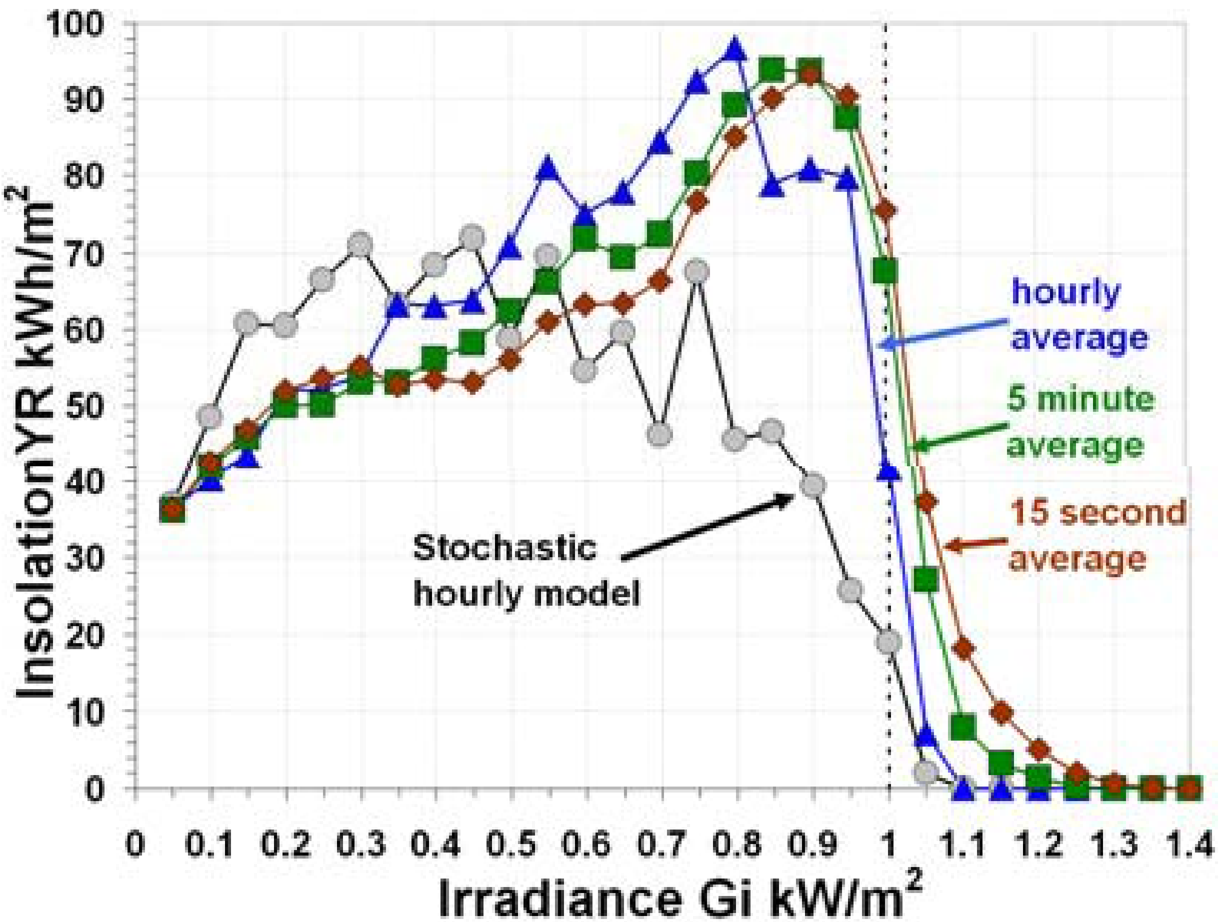
NOCT temperature models are purely linear with respect to irradiance.

- Better thermal models are available & you can do things to make PV modules run cooler. (See figure)

1-Diode model does not do a good job of predicting PV module performance as a function of irradiance.

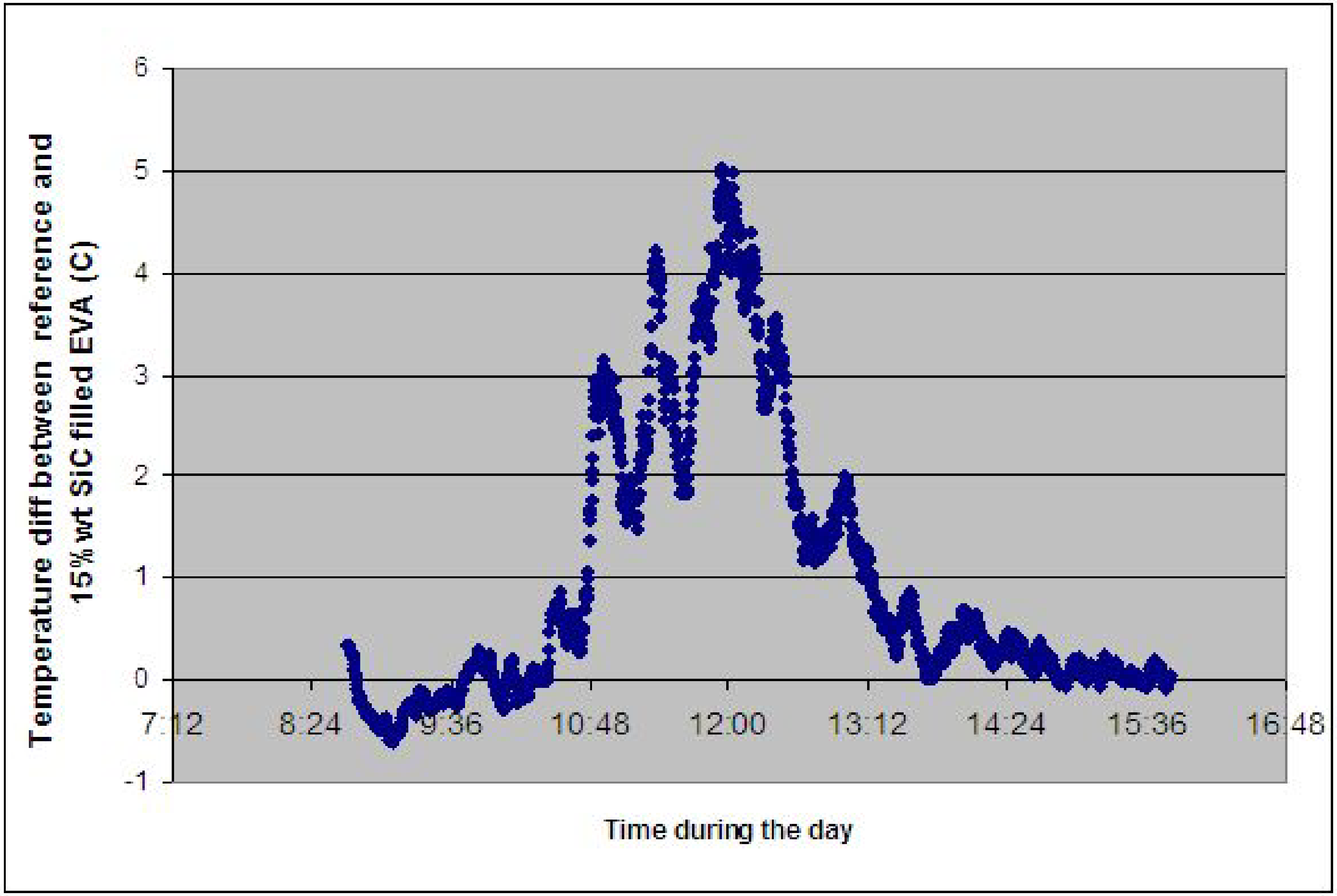
- Where do you get the parameters to use in the model? (See Figure)

Monthly Average vs Hourly vs 5 minute



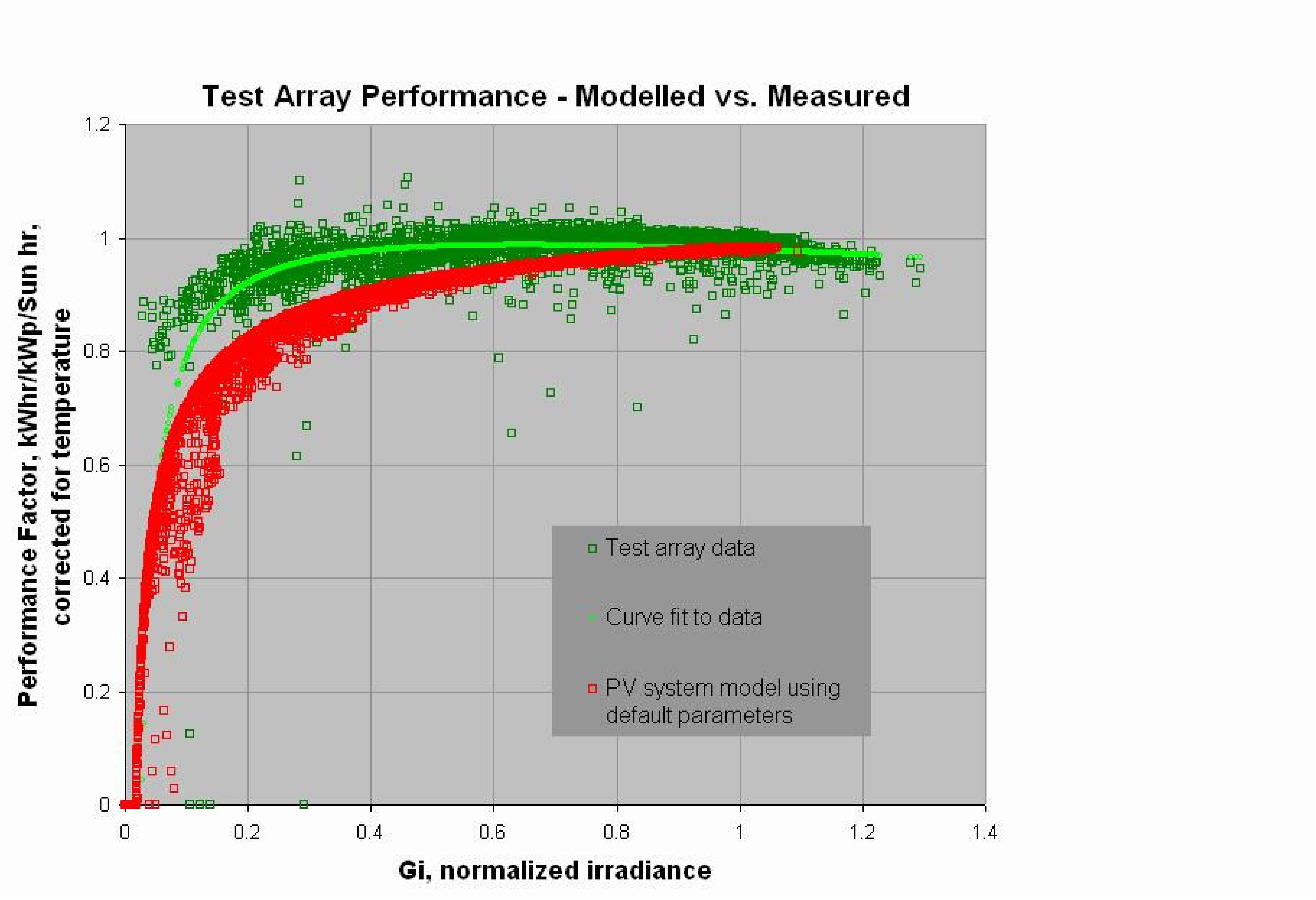
Ransome & Funtan: "Why hourly averaged measurement data is insufficient to model PV system performance accurately", 20 PVSEC, 2005

Changing the thermal performance



Thermocool Technology – Z. Xia, BP Solar

Modeled versus Measured Performance



Wohlgemuth, etal, 34th IEEE PVSC 2009

What should you ask for?

Measured performance as a function of irradiance and temperature. Can use

- Matrix approach from IEC 61853-1 “Irradiance and Temperature Performance Measurements and Power Rating”
- Empirical model based on measured outdoor performance such as King model or Ransome model which give good results over long time periods but may not at specific times.

  (See Kroposki, Marion, King, Boyson & Kratochvil “Comparison of module performance characterization methods” 28th IEEE PVSC, 2000.)

Matrix from IEC 61853-1

Isc, Pmax, Voc and Vmax versus Irradiance and Temperature

IRRADIANCE	**Spectrum**		**Module Temperature**		
$W\text{-}m^{-2}$		15 °C	25 °C	50 °C	75 °C
1100	AM1.5	NA			
1000	AM1.5				
800	AM1.5				
600	AM1.5				
400	AM1.5				NA
200	AM1.5				NA
100	AM1.5			NA	NA

What should you ask for?

Thermal model for performance as a function of irradiance, ambient temperature, wind speed and mounting geometry.

See for example:

E. Skoplaki, J.A. Palyvos, Operating temperature of photovoltaic modules: A survey of pertinent correlations, Renewable Energy 34 (2009) 23–29.

D.L. King, W.E. Boyson, and J.A. Kratochvil, Photovoltaic Array Performance Model, Sandia National Laboratories, SAND2004-3535, (2004).

D. Faiman, Assessing the Outdoor Operating Temperature of Photovoltaic Modules, Prog. Photovolt: Res. Appl. 16 (2008) 307–315.

IEC 61853-2 “Spectral Response, Incidence Angle and Module Operating Temperature Measurements”

Warranties

Typical Module Warranty

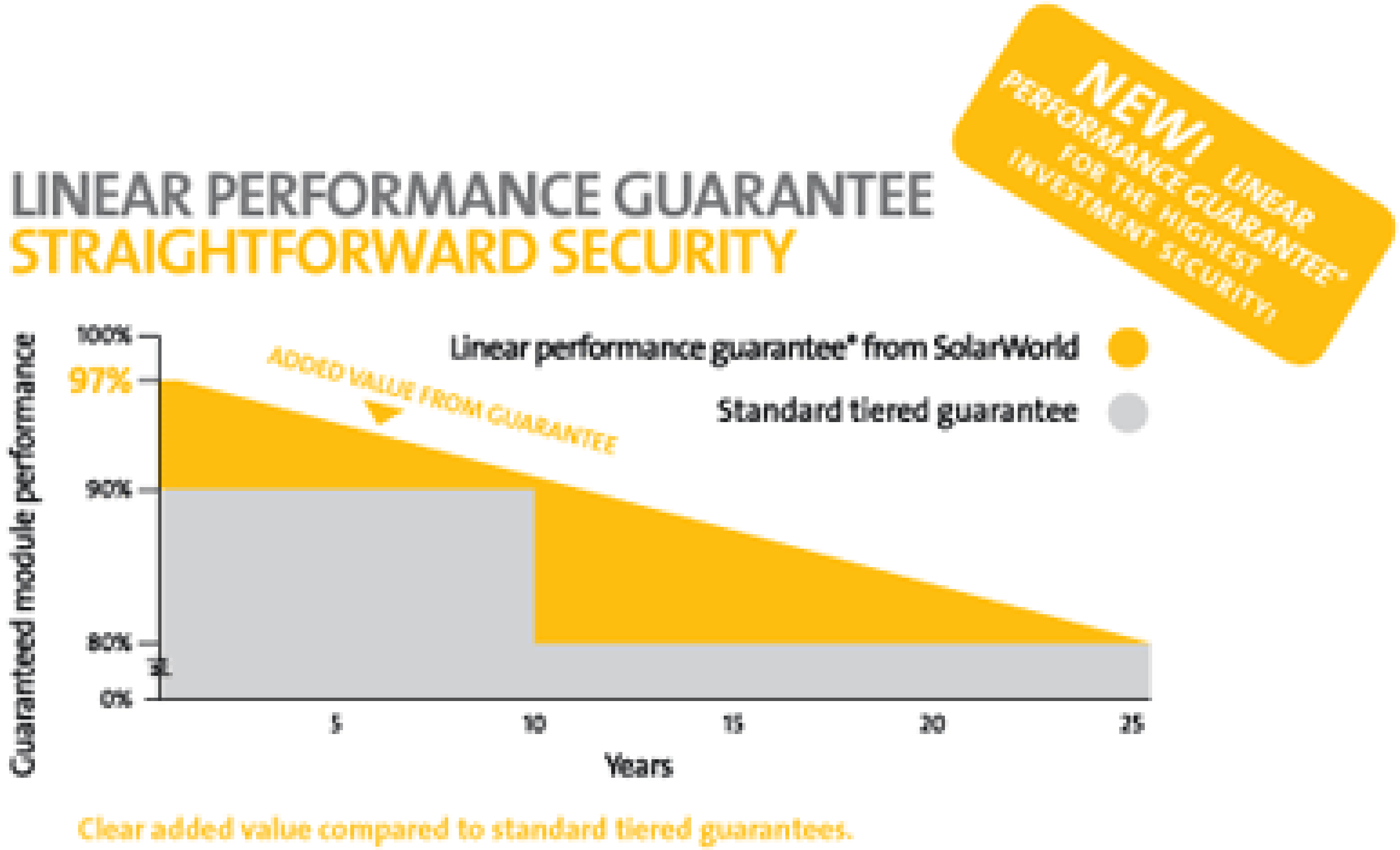
- 90% power warranty for 12 years
- 80% power warranty for 25 years.

New Warranty for Large Systems Purchase

- Initial tolerance and LID accommodation (~3%)
- Then annual degradation rate (~ 0.5% to 0.7%/year)

See Figure

Linear versus Stepped Warranty



From SolarWorld web site

What is behind the warranty?

Ask to see field data on returns and power degradation.

- What percentage of modules are returned on an annual basis?
- How many modules and systems is the degradation rate based on?
- How many years have the modules and systems been deployed?
- Where have modules and systems been deployed?

Ask to see accelerated stress/reliability test data to support the lifetime and degradation rate predictions.

- The Qualification Test levels from IEC 61215 and IEC 61646 are not enough. These check design and infant mortality.
- Need more thermal cycles, longer damp heat and UV testing of materials.

Testing Cry-Si Modules beyond IEC

Manufacturer	DMLC/TC/HF	1250 Hr DH	500 TC
A	Pass	Fail	Fail
B	Pass	Fail	Pass
C	Pass	Fail	Fail
D	Pass	Fail	Pass
E	Pass	Fail	Pass
F	Pass	Pass	Pass
G	Pass	Fail	Pass
H	Pass	Pass	Pass
J	Pass	Fail	Pass
K	Pass	Pass	Pass

Wohlgemuth, etal 23rd PVSEC, 2008

Performance Models – Ask for Validation

Compare initial model results obtained using modeled irradiance with both modeled results using measured irradiance and measured performance using measured irradiance.

The example from Ransome (33rd IEEE PVSC, 2008) shows the differences between calculated and measured energy yields using measured and modeled values of irradiance but correcting the total modeled insolation to be the same as that measured.

In this case about half of the 3% difference is due to how the model deals with the irradiance and about half due to how the model deals with the module.

	Modeled Performance	Measured Performance
Modeled Irradiance	97%	98.9%
Measured Irradiance	98.4%	100%

Weather – What may lead to problems in predicting performance

High levels of diffuse light.

Localized conditions – ground fog & mist, clouds coming off the water

Rapidly moving cloud cover

Long periods without rain can lead to soiling losses

In windy areas modules will run cooler than predicted and so produce more energy

SUMMARY

Accurately predicting the energy production of a PV system over its 25 year life requires:

- The use of a good validated PV model.
- Full characterization of the performance of the modules to be used.
- Accurate prediction of the expected module degradation rate.
- Definition and implementation of an O&M procedure to identify and replace the small fraction of failed modules expected.
- Definition and implementation of an O&M procedure to handle problems with BOS components.

Careful monitoring of the system output versus weather parameters can provide an early indication of problems so they can be remedied before they lead to large losses in energy production.

Summary - So Ask For Modules with

- 3rd party certifications to IEC 61215 or 61646, IEC 61730-1 and 2 and UL1703.
- 3rd party certification of module STC Pmax
- Measured performance as a function of irradiance and temperature (probably from 3rd party)
- Warranty with an annual degradation rate.
- Field and accelerated test data supporting the module warranty.