

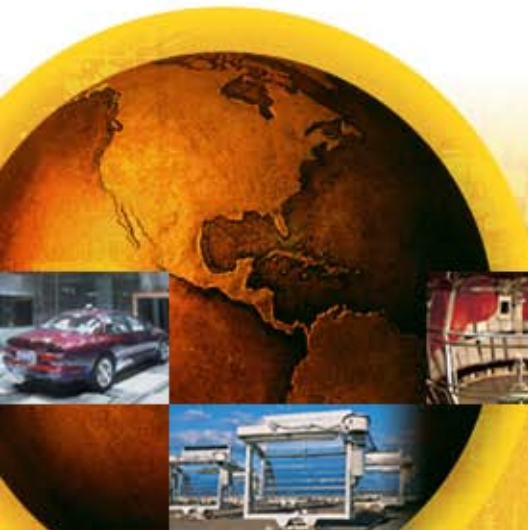
Beyond Qualification: Testing for Long Term PV Module Durability



NREL PV Module Reliability Workshop, 18-19 February, 2010

Allen Zielnik

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Atlas Material Testing Technology LLC

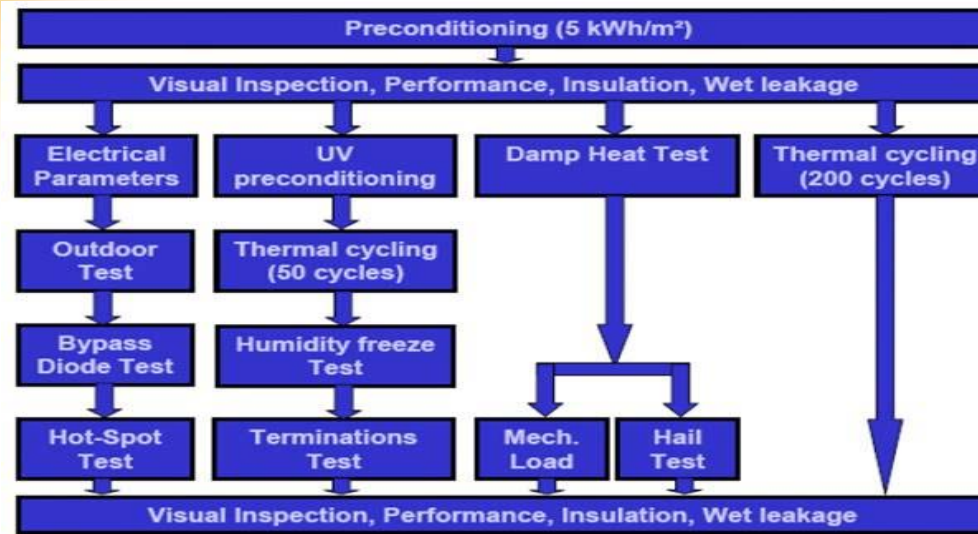


 **ATLAS**
MATERIAL TESTING SOLUTIONS

Experience.
The Atlas Difference.

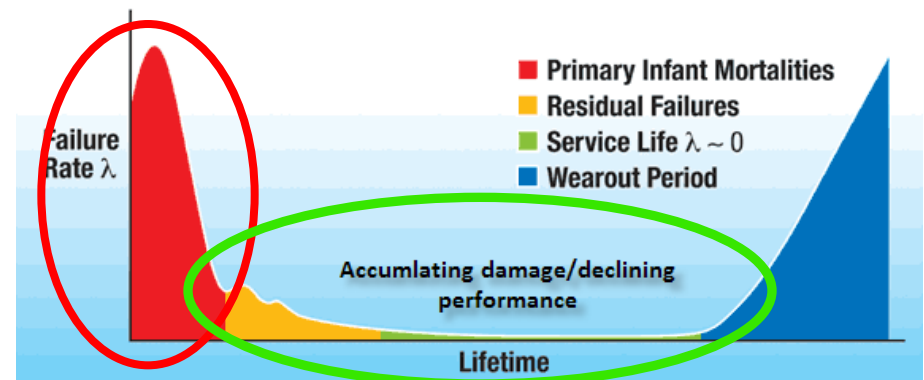
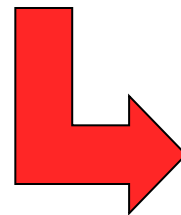


IEC design type qualification tests



IEC 61215 environmental tests

IEC 61646 environmental tests are similar





Perspectives on HALT testing



- “HALT does not attempt to simulate the field environment- only seeks to find design and process flaws by any means possible.
- Intent is to determine failure modes, NOT demonstrate that a product meets specified requirements.
- Not meant to determine reliability but to improve it.
- Test environments are not directly related to real life and may be controversial.
- Time-dependent failure modes may not be revealed.
- Difficult to do on complex structures because of complex loading – FMVT” (failure mode verification testing

- Gregg Hobbs, *recognized originator of HALT & HASS testing*



Weathering test tools

Materials

Cells

Modules

Systems



All photos courtesy



 **ATLAS**
MATERIAL TESTING SOLUTIONS



An empirical approach . . .



- Based on known PV degradation
- Fundamental weathering testing
- Experience of other industries
- An accelerated weather aging protocol, not a service life predictor
- Takes advantage of technology from weathering and reliability testing
- Independent of PV technology
- Complements IEC-type qualification testing
- Acknowledges basic limitations & constraints
- Not pass/fail but provides early known indicators of failure modes



IEC and weathering methods

Design Qualification environmental tests

Intent: Accelerated tests to screen for major materials design and manufacturing flaws which result in premature (infant mortality) failures.

Climate Stresses:

E.g. Temperature-only cycling; UV-only exposure; Humidity-Freeze cycling; Damp-Heat. Most tests delivered to separate modules.

Stress levels and delivery not representative of end-use:
No module goes through all tests; limited to 1 or 2 stresses, e.g., thermal cycling, damp heat, humidity-freeze.

Atlas module weathering tests

Intent: Accelerated environmental durability tests to reproduce likely field failures and estimate service life. Tests target failures resulting for the accumulated damage of long term outdoor exposure.

Climate Stresses (comprehensive):

Alternating cycles of SolarSim-Temperature-Humidity and SolarSim-Temperature-Humidity-Freeze; additional UV, salt spray, condensing humidity and outdoor solar tracking (AZ,FL). Modules under solar operate at max power point.

Stress levels based on climate-derived conditions:
Multiple simultaneous stresses delivered in short and long term cycles and at levels more representative of nature.

“Global Composite” climate condition standard; alternative Hot Arid Desert, Tropical/Subtropical or Northern Temperate climate conditions available.

Optional test modifiers: Coastal/Marine; Alpine/Snow Load; Urban Industrial; Agricultural Chemicals, Dust-Dirt, Acid Rain, Mildew effects.



IEC and weathering methods

Design Qualification environmental tests

Corrosion Testing:
Limited to Damp-Heat test

No long term outdoor exposure.
IEC cautions about shortness of test; most tests are chamber-based with limited stresses.

Few cycles but under harsh conditions:
Designed to stress for infant mortality failures; may induce failures which will not occur in service

Modules exposed non-operational
Only short outdoor test is electrically active under load.

Solar Load:
No solar load in chamber tests – modules at chamber temperature

Atlas module weathering tests

Salt Spray and Condensing Humidity tests and outdoor exposures included.


Uses combination of lab accelerated and outdoor solar tracking exposures with additional outdoor reference modules on one-year exposure in Arizona and Florida.

Higher number of cycles (diurnal >1500) under climate derived conditions designed to stress to longer term environmental effects.

Modules exposed during solar load (lab and outdoor) operated under resistive load at maximum power point.

Modules primarily under full spectrum solar load (natural or SolarSim) for differential heating and solar load effects.

Max module temperature typically < 90°C



Atlas 25^{PLUS}TM comprehensive weathering program

Atlas 25^{Plus} "global composite" environmental test cycle
(other climates available)



1 module



1 module FL



1 module AZ

UV conditioning

Salt spray corrosion

Condensing humidity

Solar – Thermal – Humidity Cycle

Solar – Thermal – Humidity/Freeze Cycle

Arizona solar tracking including peak summer

1-year solar tracking South Florida & Arizona



Total test program duration: 12 months



UV/Corrosion/Moisture stress

	<i>Arid Desert</i>	<i>Tropical / Subtropical</i>	<i>Northern Temperate</i>	<i>"Global"</i>
Corrosion	N/A (optional)	ISO 9227, ASTM B117 200 hours; 5% NaCl pH 6.5-7.2, 35°C, 1.0 to 2.5ml/80cm ² /hour "Neutral Salt Spray Test"	ISO 9227, ASTM B117 400 hours; 5% NaCl pH 6.5-7.2, 35°C, 1.0 to 2.5ml/80cm ² /hour "Neutral Salt Spray Test"	ISO 9227, ASTM B117 400 hours; 5% NaCl pH 6.5-7.2, 35°C, 1.0 to 2.5ml/80cm ² /hour "Neutral Salt Spray Test"
Condensing Humidity	ASTM D2247, 125 hours @38°C or ISO 6270 40 °C	ASTM D2247, 125 hours @38°C or ISO 6270 40 °C	ASTM D2247, 125 hours @38°C or ISO 6270 40 °C	ASTM D2247, 125 hours @38°C or ISO 6270 40 °C
UV preconditioning	IEC 61215 to 30 kWh/m ² (~28 days) UVA/UVB	IEC 61215 to 30 kWh/m ² (~28 days) UVA/UVB	IEC 61215 to 30 kWh/m ² (~28 days) UVA/UVB	IEC 61215 to 30 kWh/m ² (~28 days) UVA/UVB



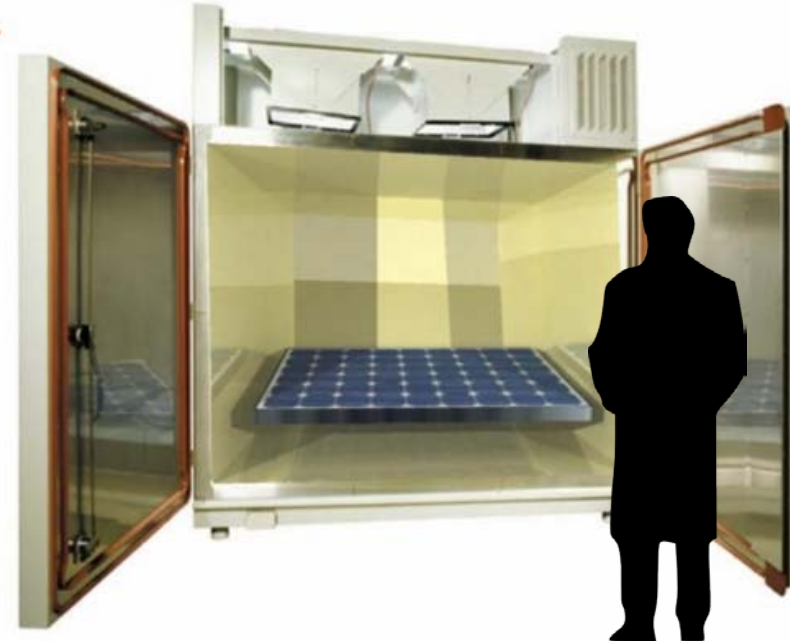
Large Corrosion Chamber



UV Exposure/Preconditioning



Large scale lab accelerated weathering



Full spectrum solar sim AM1 – 1.5

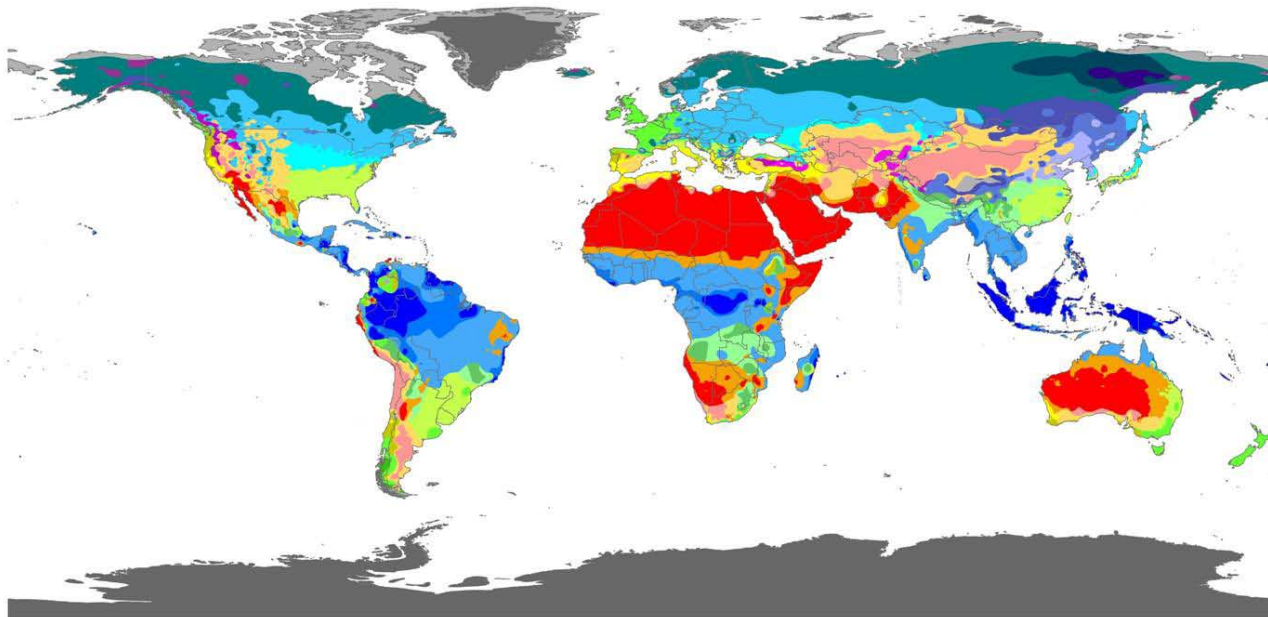
Thermal/Humidity cycling

Freeze/thaw temperature range

Modules under resistive load at
MPP

PV and service environment

World map of Köppen-Geiger climate classification



Af	BWh	Csa	Cwa	Cfa	Dsa	Dwa	Dfa	ET
Am	BWk	Csb	Cwb	Cfb	Dsb	Dwb	Dfb	EF
Aw	BSh	Cwc	Cfc	Dsc	Dwc	Dfc		
	BSk			Dsd	Dwd	Dfd		

Contact : Murray C. Peel (mpeel@unimelb.edu.au) for further information

DATA SOURCE : GHCN v2.0 station data
Temperature (N = 4,844) and
Precipitation (N = 12,396)

PERIOD OF RECORD : All available

MIN LENGTH : ≥ 30 for each month.

RESOLUTION : 0.1 degree lat/long

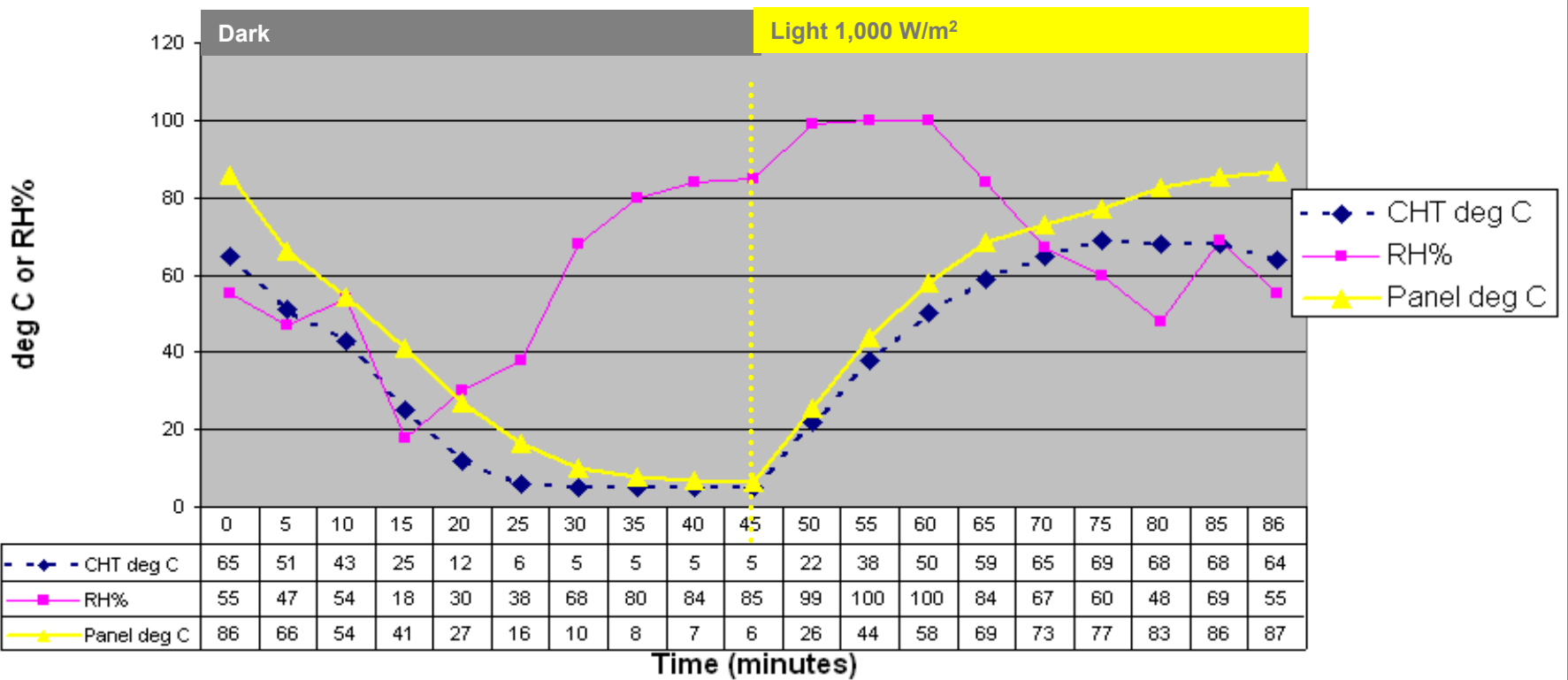


Solar/Environment chamber

	Arid Desert	Tropical / Subtropical	Northern Temperate	"Global"
Temperature-Humidity Cycle with simultaneous Solar SC 2000 or Enviromental Chamber w/Solar	30% RH (turn RH% control off at 40°C) and 65°C →5 °C (dark) in 25 min, hold 20 min. ramp up (ligh 1000 W/m ²) 21 minutes, hold 20 min; repeat Cycle time 86 minutes 16.7cycles per day repeat 9.5 days (158 cycles)	55% RH (turn RH% control off at 40°C) and 65°C →15 °C (dark) in 25 min, hold 20 min. ramp up (ligh 1000 W/m ²) 21 minutes, hold 20 min; repeat Cycle time 86 minutes 16.7cycles per day repeat 7 days (117 cycles)	55% RH (turn RH% control off at 40°C) and 65°C →5 °C (dark) in 25 min, hold 20 min. ramp up (light 1000 W/m ²) 21 minutes, hold 20 min; repeat Cycle time 86 minutes 16.7cycles per day repeat 7 days (117 cycles)	55% RH (turn RH% control off at 40°C) and 65°C →5 °C (dark) in 25 min, hold 20 min, ramp up (light 1000 W/m ²) 21 minutes, noia 20 min; repeat Cycle time 86 minutes 16.7cycles per day repeat 7 days (117 cycles)
Temperature-Humidity Freeze Cycle with Solar	55% RH (turn RH% control off at 40°C) and 65°C →-10 °C (dark) in 40 min), hold 20 min, ramp up (light 1100 W/m ²) 25 minutes, hold 20 min; 105 minute cycle, 13.7 cycles/day, repeat 0.5 day (7 cycles) [4% of total 10 day cycles are freeze]	N/A 55% RH (turn RH% control off at 40°C) and 65°C →+5 °C (dark) in 40 min), hold 20 min, ramp up (light 1100 W/m ²) 25 minutes, hold 20 min; 105 minute cycle, 13.7 cycles/day, repeat 3 days (44 cycles) <i>No freeze in tropics</i>	55% RH (turn RH% control off at 40°C) and 65°C →-10 °C (dark) in 40 min), hold 20 min, ramp up (light 1100 W/m ²) 25 minutes, hold 20 min; 105 minute cycle, 13.7 cycles/day, repeat 3 days (44 cycles) [27% of total 10 day cycles are freeze]	55% RH (turn RH% control off at 40°C) and 65°C →-10 °C (dark) in 40 min), hold 20 min, ramp up (light 1100 W/m ²) 25 minutes, hold 20 min; 105 minute cycle, 13.7 cycles/day, repeat 3 days (44 cycles) [27% of total 10 day cycles are freeze]

Cyclic Weathering Stresses

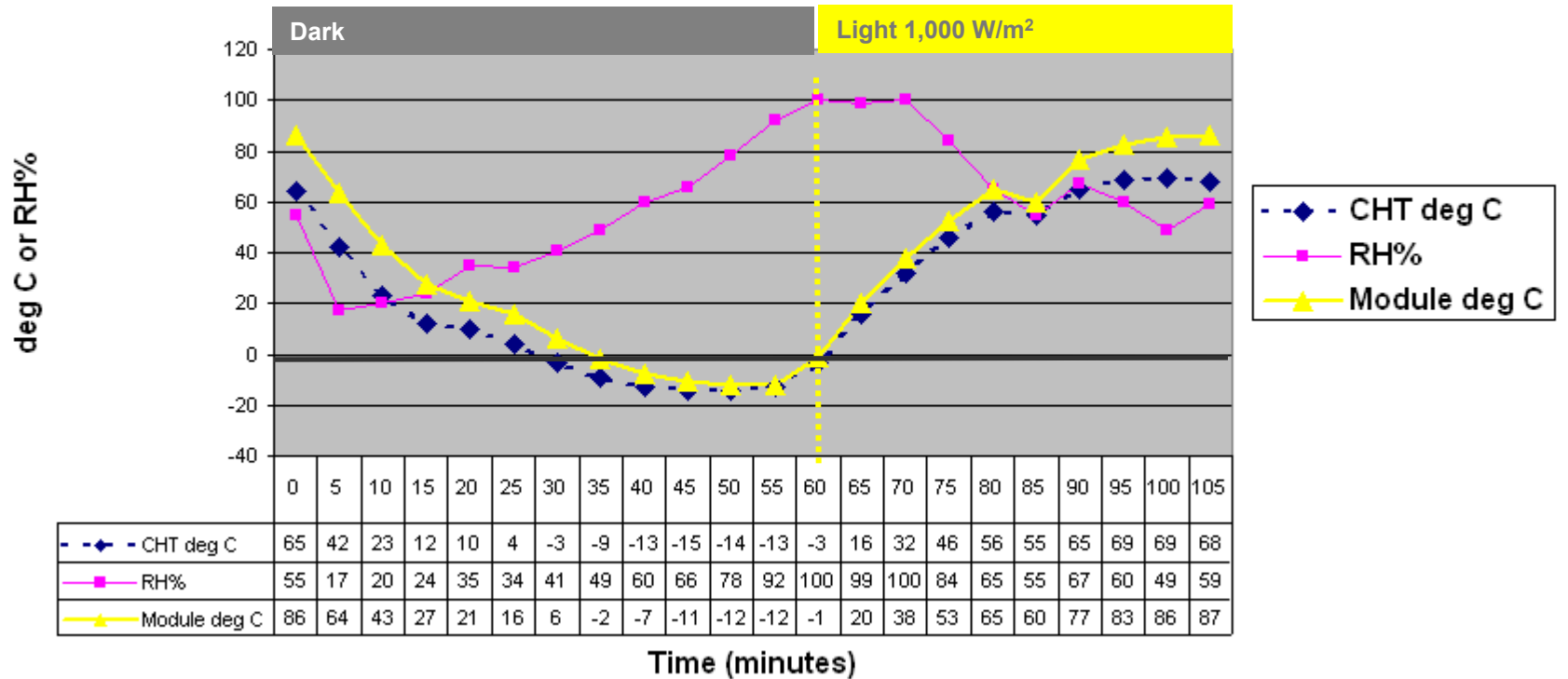
Solar-Temperature-Humidity Cycle





Module temperature tracking

Solar-Temperature-Humidity-Freeze Cycle





Available or in development options



- Marine atmosphere
- Acid rain
- Mold/Mildew growth
- Dust/Dirt pickup & retention
- Urban/industrial fouling
- Agricultural chemical (ammonia)
- Wind blown abrasion



Questions?

More info . . .

White Paper



Photovoltaic Module Weather Durability & Reliability

Will my module last outdoors?

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