2nd Annual Atlas/NIST Workshop
November 14, 2013

# Quantifying PV Module Microclimates, and Translation into Accelerated Weathering Protocols

*Along the path to a weathering standard*

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# Topics

- Background: PV weathering standards and related work efforts
- Part I.  Microclimate analysis
- Part II.  Translation to an accelerated weathering protocol

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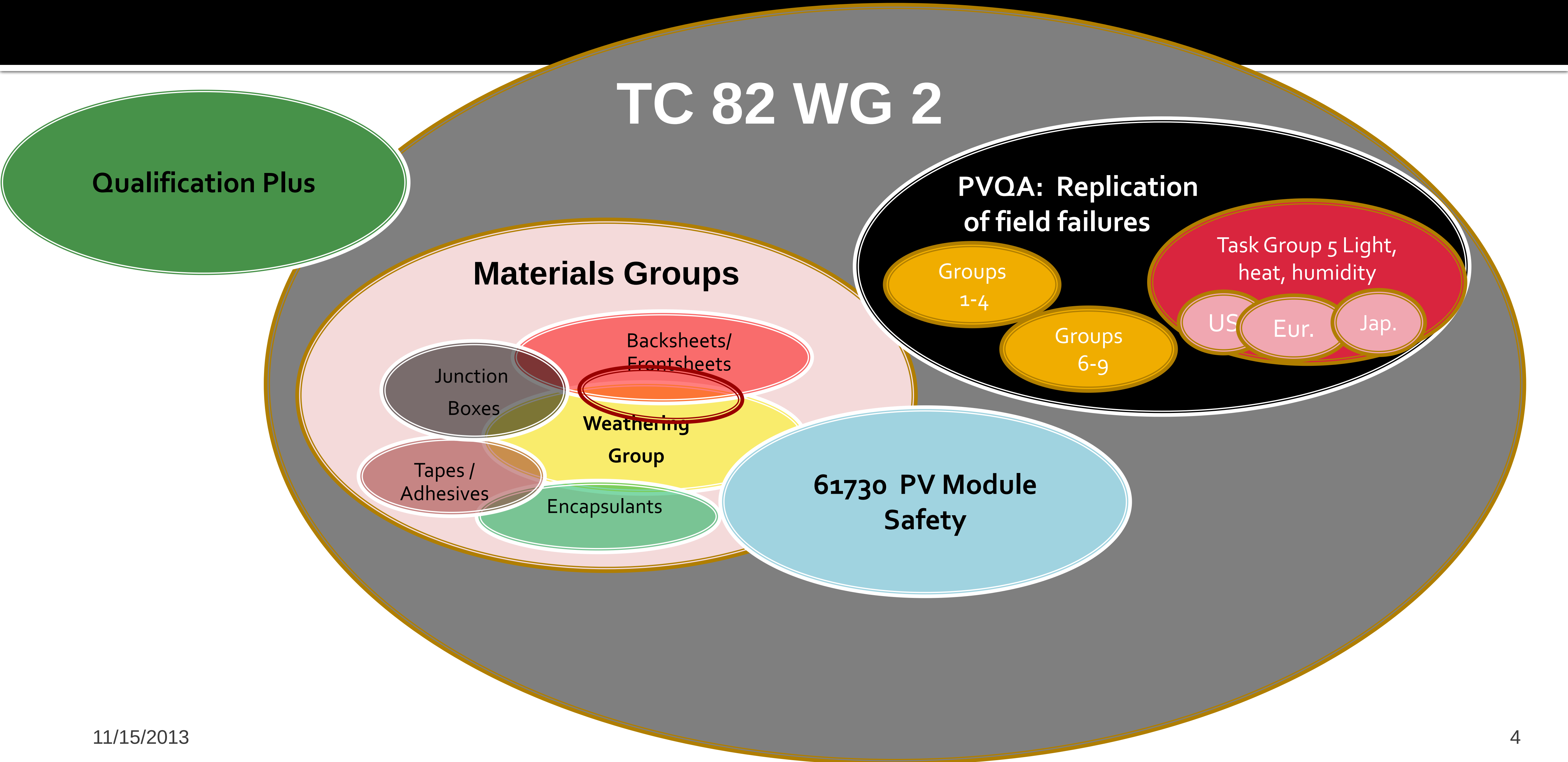
- Qualification Plus discussion

# PV Standards and Weathering

- IEC 61730, 61215; UL 1703, 746C
  - Different environmental stress conditions
  - Very little UV exposure
  - Field data demonstrating UV induced failures
- Numerous Standards efforts addressing weathering in development
  - IEC
    - 61730 ed 2 (MST-94)
    - 62788 (PV component standards)
  - Qualification Plus

# PV Standards Weathering Efforts



# Project Roadmap

Check Point #1: Reviewed at IEC TC 82 WG2 (10/6)

Qualification Plus: Request for Steady State Exposure

| Phase 1. Baseline Information Defined | Phase 2: Improve; add protocols with cycling | Phase 3: Gather data | Phase 4 |
|---|---|---|---|
| **Machine Settings:**<br>- define related existing weathering standards<br>- define target microenvironments<br>- translate microenvironments to machine settings<br>- select "top 10" list | **Machine Settings:**<br>- Review/revise prior list<br>- Develop protocols with cycling<br>- Reselect "top 10" list | **Review Data**<br>- PVQA testing<br>- Outdoor data<br>- Module data<br>- other? | **Machine Settings:**<br>- Review/revise prior list<br>- Reselect "top 10" list<br>- Recommend suite of weathering regimes (1-3) for inclusion in Backsheet Standard |
| **Test Methods**<br>- list tests from backsheet standard draft<br>- select "top 10" list | **Test Methods**<br>- refine as needed<br>- re-select "top 10" list | **Test Methods**<br>Round Robin testing (TMs)<br>Improve as needed | **Test Methods**<br>Round Robin testing (weathering and TMs) |
| **Sample Definition**<br>initial: glass/encapsulant/backsheet<br>a) glass side (sun side) facing light source<br>b) back side facing light source<br>revise after "top 10" TM list is complete | **Sample Definition**<br>Revise as needed<br>Refine Sample Prep<br>how to specify glass, encapsulant, lamination conditions… | **Sample Definition**<br>Revise as needed | **Sample Definition**<br>Revise as needed |

# Qualification Plus

- Summarizes some test methods intended for incorporation into Standards
- Intended as an early adaptation of pending standard tests.
- Goals:
  - Detect product weaknesses observed in the field that might be overlooked or under queried by IEC 61215 and IEC 61730
  - Optimize these test procedures more fully before they become standards,
  - Allow manufacturers to begin to use the new tests in anticipation of the new standards, and
  - Provide customers with additional information for choosing products that will last longer in the field.

- Includes:
  - PID
  - Thermal cycling
  - UV exposures
    - Encapsulant Materials,
    - J-Box
    - Cables and Connectors
    - → **Backsheet**
  - Bypass Diode Thermal Test
  - Enhanced Hotspot

# Part I. PV Microclimate Analysis – steady state

- Quantify the range of microclimates experienced by backsheets in a PV module, including:
  - Ambient Climate
    - Temperate => Sanary, France
    - Extreme (hot/dry) => Arizona
    - Extreme (hot/humid) => Miami
  - Contributions from the application (mounting type:
    - Roof (5°)
    - Rack (Latitude)
    - Track (2D tracking)

# Weathering / Backsheet group discussions

| | Name | Organization | Regulars | Test Methods and Sample Prep group |
|---|---|---|---|---|
| 1 | Axel.Borne | DuPont | x | x |
| 2 | Bill Brennan | DuPont-Teijin | x | x |
| 3 | Jim Bratcher | Honeywell | x | x |
| 4 | Kurt Scott | Atlas | x | x |
| 5 | Bill Gambogi | DuPont | x | x |
| 6 | Dave Burns | 3M | x | |
| 7 | Marc Brandenburg | Furon | x | |
| 8 | Mike Kempe | N-REL | x | |
| 9 | Sean Fowler | Q-Lab | x | |
| 10 | Takao Amoka | Toray | x | |
| 11 | Greg O'Brien | Arkema | | x |
| 12 | Chris Fluekinger | UL | | |
| 13 | Howard Creel | 3M | | |
| 14 | Karlheinz Brust | Krempel | | |
| 15 | Michael Koehl | Fraunhofer | | |
| 16 | Nicolas Bogdanski | TUV-Rheinland | | |
| 17 | Sarah Kurz | N-REL | | |
| 18 | Tim Peshek | CWR University | | |
| 19 | Tom Earnst (DuPont) | DuPont | | |

# 1. Irradiance Data

- Goal: establish references for:
  - Irradiance set points
  - Total Solar and TUV data
  - Backside versus Frontside irradiance levels

# Maximum Irradiance Levels

Spectral Irradiance at 340 nm (W/m2/nm)

- Data from:
  - **Handbook of Material Weathering, 3rd Ed.,** 2003
  - Atlas Data
- Value depends on:
  - Latitude
  - Humidity/cloud cover/pollution
    - Lauder, New Zealand: ➔ 0.91
  - Time of year
    - AZ, winter solstice ➔ 0.37
    - AZ, summer solstice ➔0.70
  - Elevation
    - Boulder, CO, USA; September: ➔ 0.90
    - Mauna Loa, HA, USA, June ➔1.03

**Table 5.1 Spectral Irradiance at 340 nm (examples of the highest recorded values)**

| Location | Latitude | Longitude | Elevation, m | Date | Irradiance, $W m^{-2} nm^{-1}$ | Ref. |
|---|---|---|---|---|---|---|
| Mawson, Antarctica | 67.6°S | 62.9°E | | 11-12-1990 | 0.28[a] | 9 |
| McMurdo, Antactica | 77.51°S | 166.40°E | | 23-12-1992 | 0.33[a] | 10 |
| Palmer, Antarctica | 64.8°S | | | 14-23-1988 | 0.30 | 11 |
| Uccle, Belgium | 50.47°N | 4.21°E | 105 | 24-6-1994 | 0.39[b] | 6 |
| Reading, UK | | | | 20-6-1995 | 0.36 | 12 |
| Miami, Florida, USA | 25.52°N | 80.27°W | 3 | 21-4-1999 | 0.59 | 13 |
| Homestead, Florida, USA | 25.46°N | 80.45°W | | 24-4-1999 | 0.65 | 13 |
| Phoenix, Arizona, USA | 33.54°N | 112.08°W | 610 | 20-5-1999 | 0.70 | 13 |
| Phoenix Arizona, USA | 33.54°N | 112.08°W | 610 | 7-6-2000 | 0.70 | 13 |
| Phoenix, Arizona, USA | 33.54°N | 112.08°W | 610 | 28-9-1999 | 0.62 | 13 |
| Phoenix, Arizona, USA | 33.54°N | 112.08°W | 610 | 4-11-1998 | 0.50 | 13 |
| Buckeye, Arizona, USA | 33°N | 113°W | 890 | 30-9-1999 | 0.63 | 13 |
| Mauna Loa, Hawai | 19.533°N | 155.578°W | 3405 | 15-7-2000 | 0.9329 | 14 |
| Mauna Loa, Hawai | 19.533°N | 155.578°W | 3405 | 30-6-1988 | 1.029[c] | 14 |
| Boulder, Colorado, USA | 39.991°N | 105.261°W | 1730 | 9-7-2000 | 0.8962 | 14 |
| Lauder, New Zealand | 45.04°S | 169.68°E | 370 | 9-1-1998 | 0.980[c] | 15 |
| Lauder, New Zealand | 45.04°S | 169.68°E | 370 | 29-12-1997 | 0.913[d] | 15 |
| Jungfraujoch, Austria | 46.548°N | 7.9835°E | 3576 | 24-6-1999 | 0.832 | 16 |

a - measured, b - recalculated from 325 nm, c - extreme, cloud enhanced, d - typical maximum, near clear sky

| date | Season | Location | Solar 339-340 (W\m2\nm) |
|---|---|---|---|
| 3/21/2001 | Spring\Fall Equinoxes | Phoenix | 0.63 |
| 6/21/2001 | Summer Solstice | Phoenix | 0.7 |
| 12/21/2001 | Winter Solstice | Phoenix | 0.37 |
| | | | |
| 3/21/2001 | Spring\Fall Equinoxes | Miami | 0.64 |
| 6/21/2001 | Summer Solstice | **Miami** | 0.69 |
| 12/21/2001 | Winter Solstice | **Miami** | 0.52 |
| | | | |
| 3/21/2013 | Spring Equinox | Sanary | 0.58 |
| 6/21/2013 | Summer Solstice | Sanary | 0.7 |
| 1/21/2013 | Winter Solstice | Sanary | 0.34 |

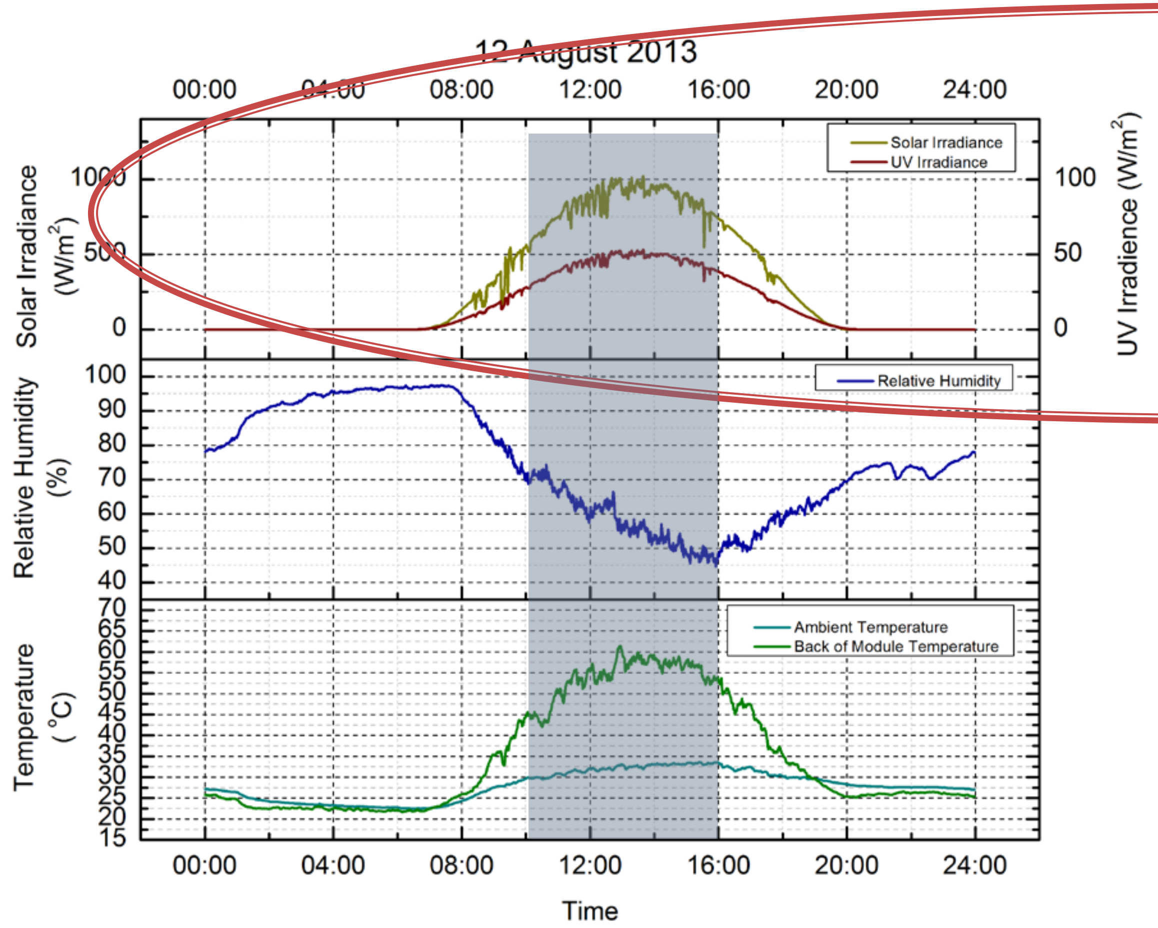
1 Sun, 340nm
0.5 W/m2/nm

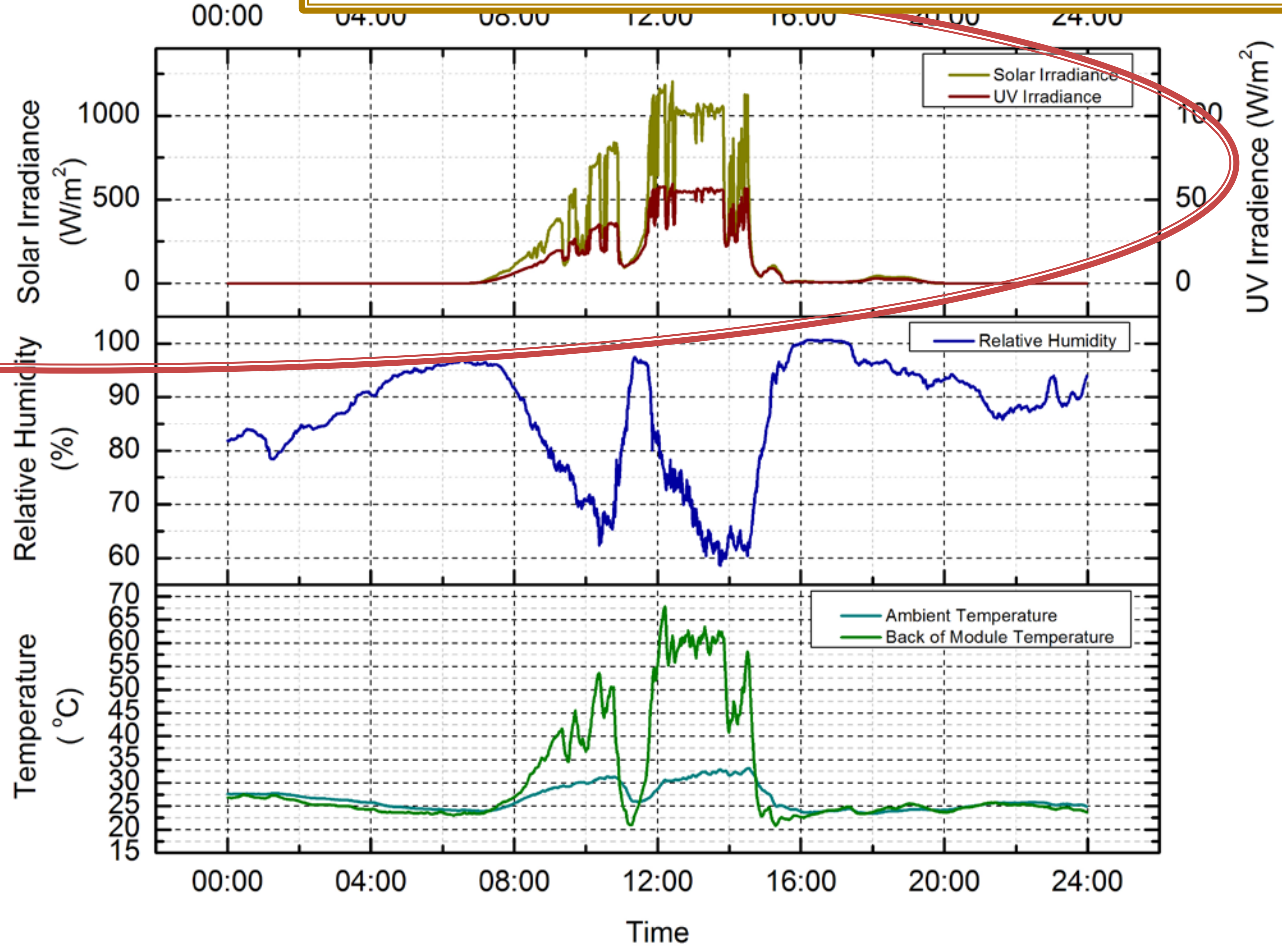
"Typical Max" 340nm
0.7 W/m2/nm

# Total Solar and TUV
# Cocoa Beach, Florida
# Sunny and Cloudy days in August

TUV as % of Total Solar constant during peak hours

| | 10A - 4P % of TS | 10A - 4P % of TUV | Full day TUV % of TS | 10A-4P TUV % of TS |
|---|---|---|---|---|
| ***12-Aug*** | 72 | 72 | 5.2 | 5.2 |
| ***24-Aug*** | 84 | 83 | 5.7 | 5.6 |
| ***month*** | 73 | 73 | 5.5 | 5.5 |



# Annual Total Solar, TUV

| | | | *front side* | |
|---|---|---|---|---|
| **Location** | **Appl. Type** | **Max Irr @340 nm** | **AnnualTotal Solar (mod) (MJ/m2)** | **Annual TUV (MJ/m2)** |
| Desert (Phoenix) | lat-rack | 0.7 | 8612 | 347 |
| Desert (Phoenix) | track | | 11948 | 538 |
| Desert (Phoenix) | roof | | 7850 | 353 |
| Temperate (Sanary, FR) | lat-rack | 0.7 | 6848 | 322 |
| Temperate (Sanary, FR) | track | | 9481 | 446 |
| Temperate (Sanary, FR) | roof | | 6116 | 287 |
| Hot/Wet (Miami) | Rack | 0.69 | 6750 | 334 |
| Hot/Wet (Miami) | Track | | 8711 | 415 |
| Hot/Wet (Miami) | Roof | | 6475 | 334 |

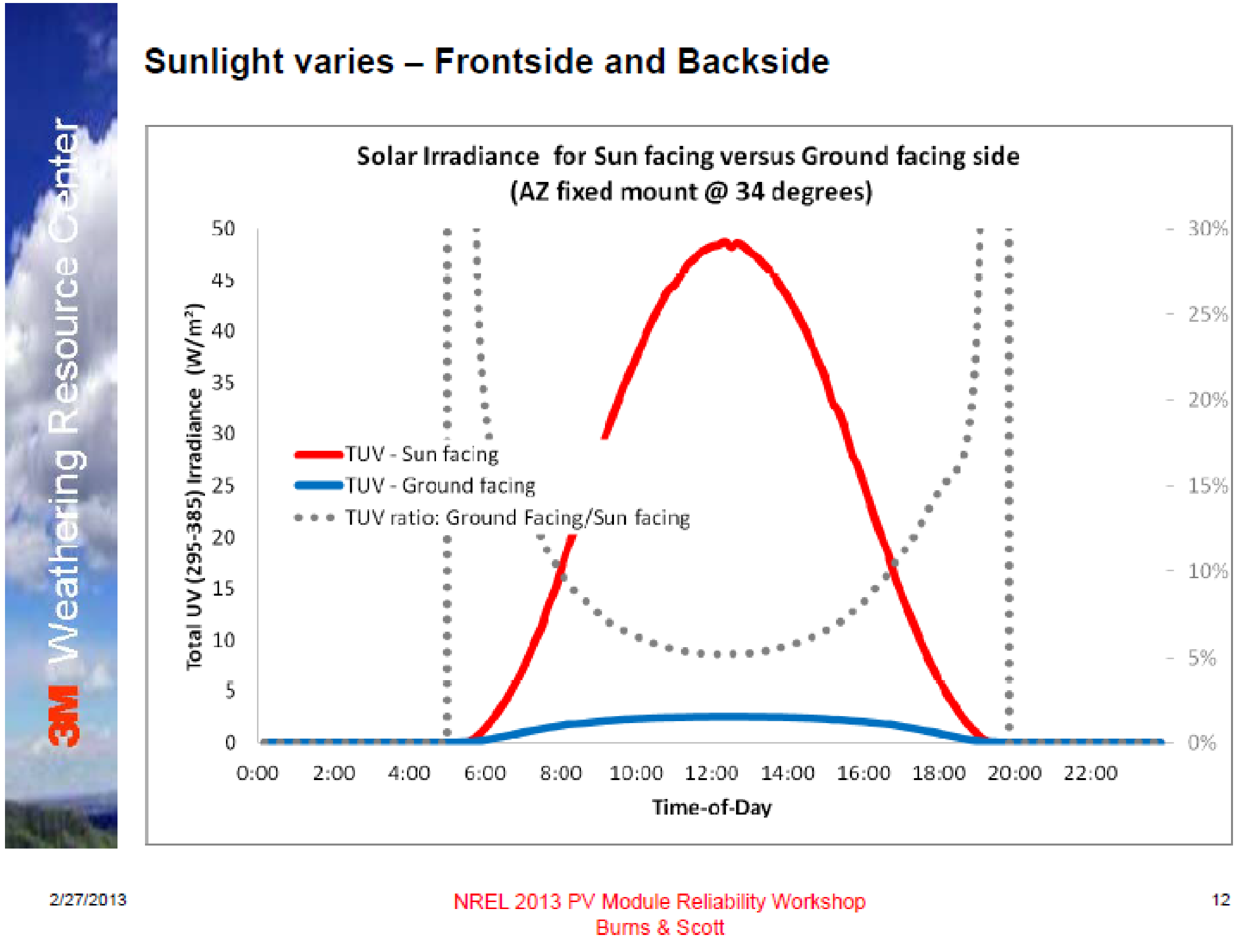
TS data (modeled) from Medianorm 7.0

%TUV not readily available for tracking; used 5° values

Phoenix and Miami are 10 year average values

Sarany data is from 2010,2013

# Backside versus Frontside Irradiance Levels




**BACKSIDE IRRADIANCE DATA:**

- 3M, May 2011 at DSET:
  - TS backside as % of TS front side = ~10%
  - TUV backside as % of TUV front side = ~7%
- DuPont:
  - TUV backside as % of TUV front side = 12%
- Fraunhofer: %TUV varies between
  - 5% for 23° (south-oriented POA) and
  - 20% (vertical mounting) of the horizontal UV irradiation.

# Miami, Phoenix, and Sanary Irradiance

| | | | *front side* | | Annual TUV Bkside MJ/m2 % Albedo = | | |
|---|---|---|---|---|---|---|---|
| **Location** | **Appl. Type** | **Max Irr @340 nm** | **AnnualTotal Solar (mod) (MJ/m2)** | **Annual TUV (MJ/m2)** | **5%** | **10%** | **20%** |
| Desert (Phoenix) | lat-rack | 0.7 | 8612 | 347 | 17 | 35 | 69 |
| Desert (Phoenix) | track | | 11948 | 538 | 27 | 54 | 108 |
| Desert (Phoenix) | roof | | 7850 | 353 | 18 | 0 | 0 |
| Temperate (Sanary, FR) | lat-rack | 0.7 | 6848 | 322 | 16 | 32 | 64 |
| Temperate (Sanary, FR) | track | | 9481 | 446 | 22 | 45 | 89 |
| Temperate (Sanary, FR) | roof | | 6116 | 287 | 14 | 0 | 0 |
| Hot/Wet (Miami) | Rack | 0.69 | 6750 | 334 | 17 | 33 | 67 |
| Hot/Wet (Miami) | Track | | 8711 | 415 | 21 | 41 | 83 |
| Hot/Wet (Miami) | Roof | | 6475 | 334 | 17 | 0 | 0 |

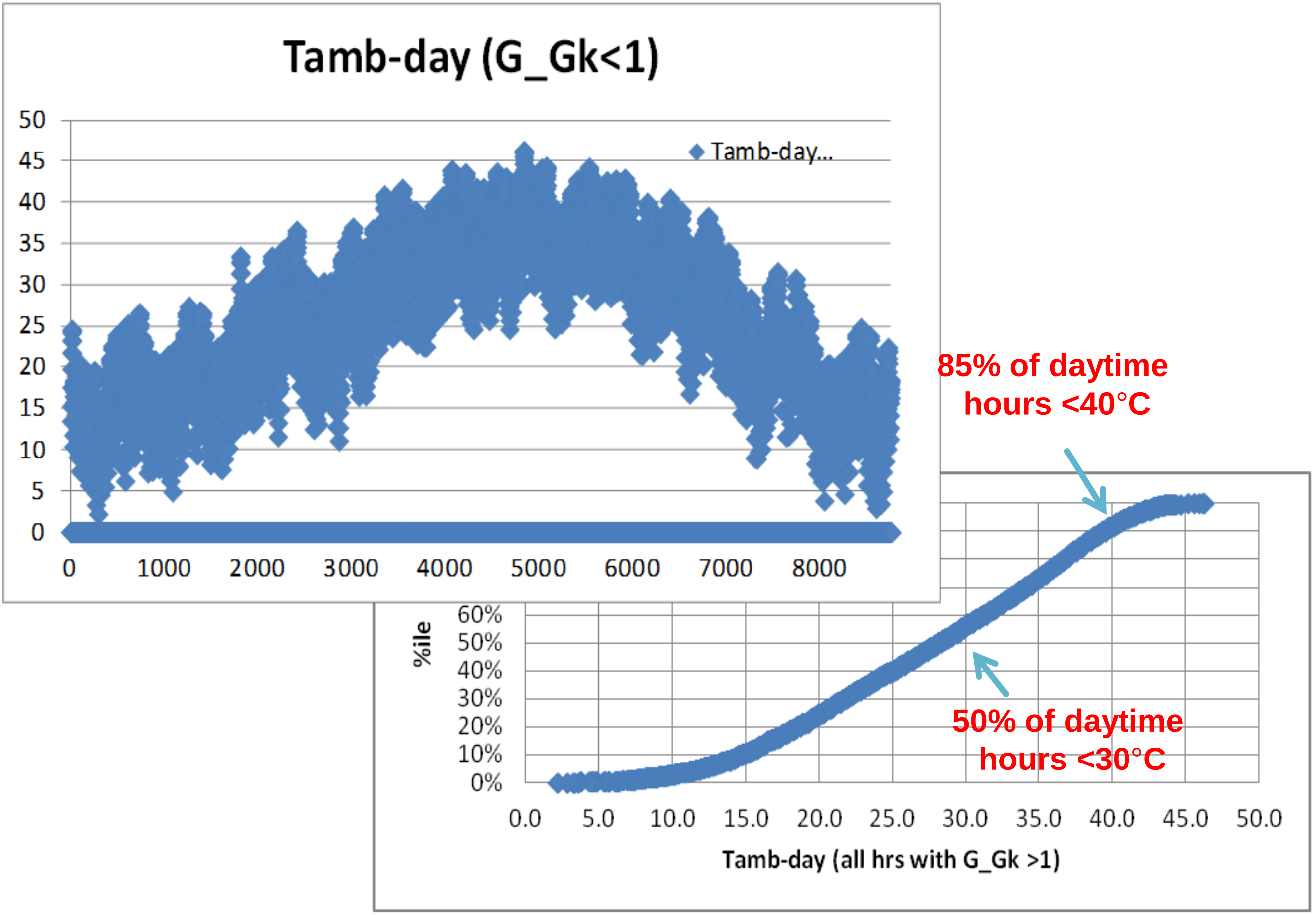
# 2. Temperature Data

Goal: Establish reference temperatures for each microclimate

- Looking for a temperature that will
  - Accelerate actual degradation mechanisms — As high as possible
  - Limit mechanisms that do not occur — But not too high

# Phoenix Ambient Temperatures

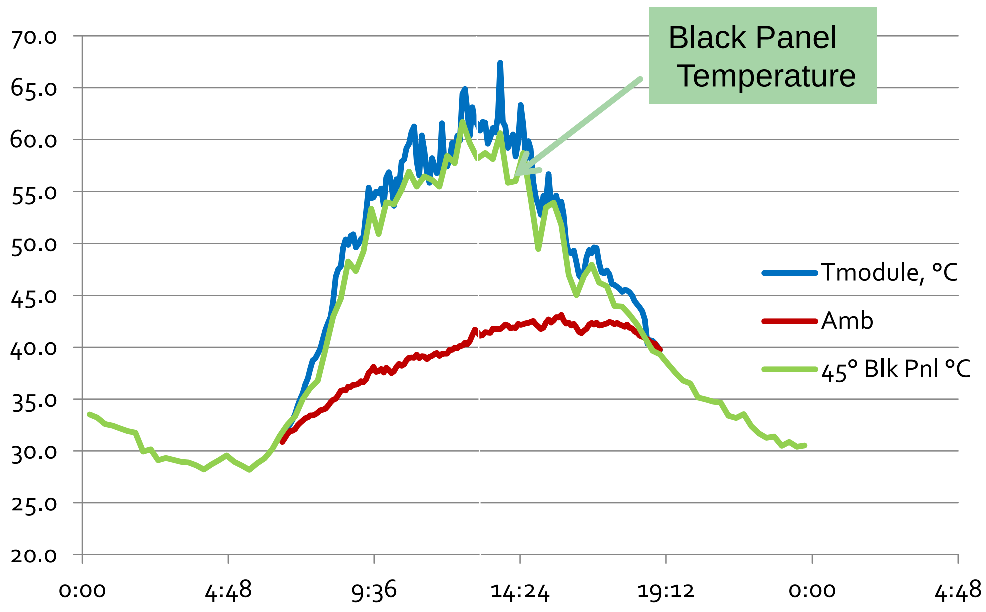
## PHOENIX T(AMB) OVER 1 YEAR. DAILY, AND CUMULATIVE TMAX



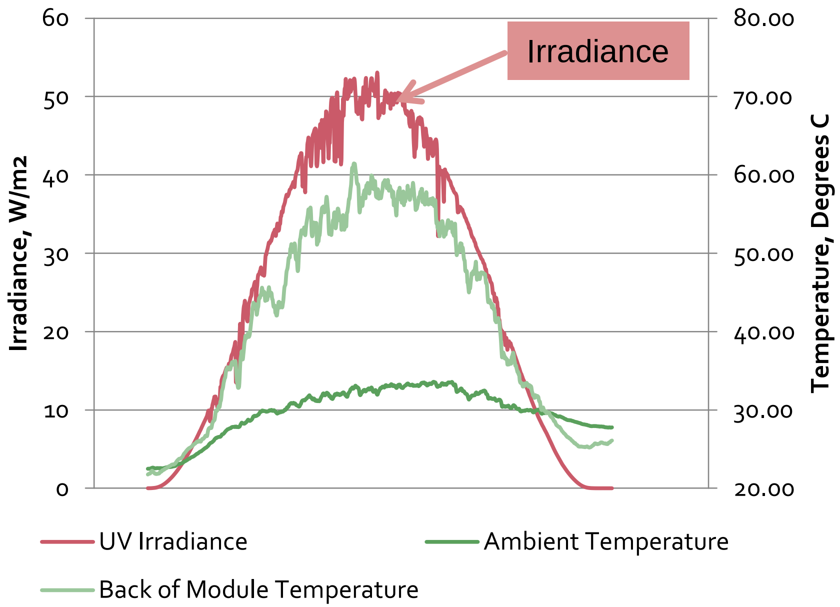

- For Translation to Accelerated Weathering Setpoint T:
  - **Philosophy: run at or near maximum conditions all the time**
- What is a maximum Temperature?
- Consider concept of **"Typical Max T"**
  - 85%ile T:
  - For Phoenix**: Typical Max T(amb) = 40°C**

# Arizona and Florida Temperatures
# Ambient and Rack Mounted Modules

Phoenix, August 2013

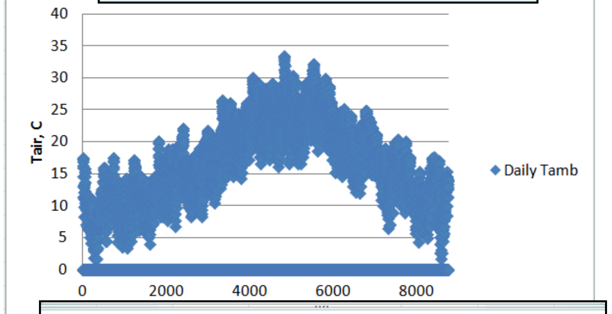


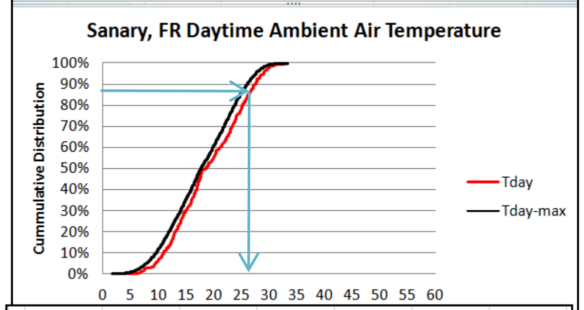

Cocoa Beach, August 2013

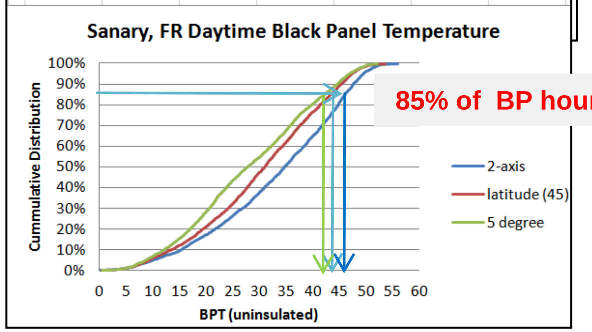


# Ambient, Black Panel Temperature Data
# Phoenix, Sanary, Miami over 1 year: hourly, cumulative hours

## Sanary, France

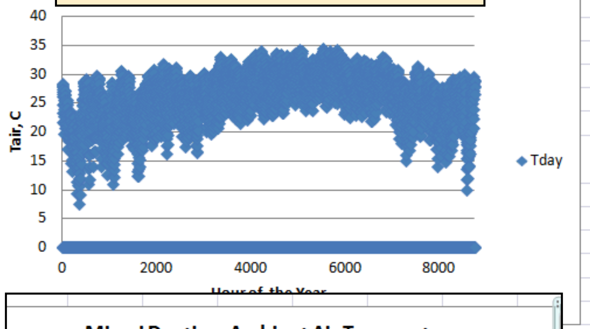


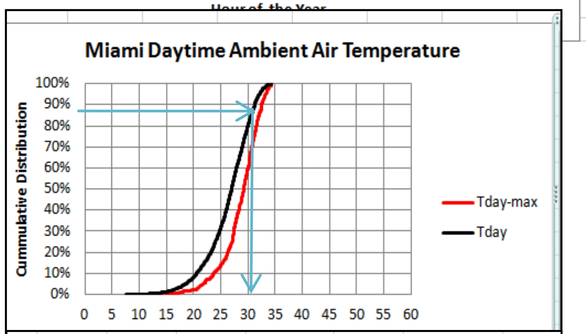



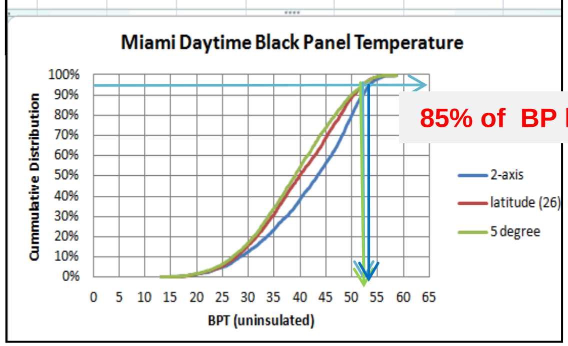




85% of BP hours <44°C

## Miami, FL, USA

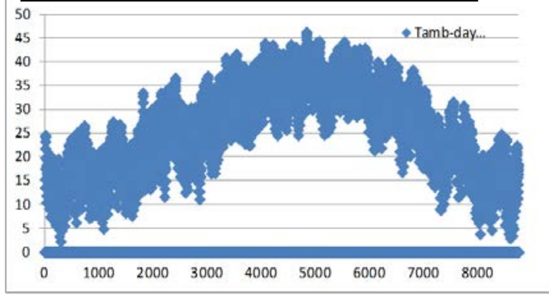


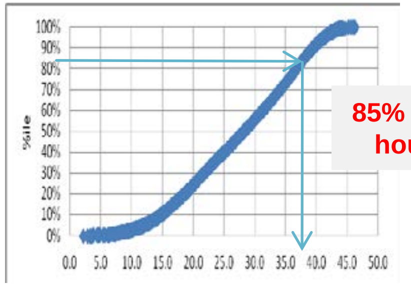




85% of BP hours <49°C

## Phoenix, AZ, USA



85% of daytime hours <40°C

85% of BP hours < 55°C

# Phoenix Module Temperatures, Measured and Modeled

## Temperature of Buildling Applied Photovoltaic BAPV Modules: Air Gap Effects (Tamizhmania et al)

| | | | |
|---|---|---|---|
| Mani's paper | Roof | | |
| Tmodule (max) obs. | 92.73C | | |
| Roof model, no wind | Tm= 0.05(Irrad) + 0.64*Tamb+15.82 | | |
| | Ir | Tamb | Wind speed |
| | 993.5 | 41.9 | 1.2 |
| Tmodule (max) )calc. | 89.9 | | |

| Highest Tmod | |
|---|---|
| Date | 10/17/2009 |
| Time | 12:42 |
| Tamb (°C) | 41.9 |
| Irradiance (W/m2 | 993.5 |
| Wind Speed (m/s) | 1.2 |
| **module T** | **92.7** |
| ΔT | 50.8 |

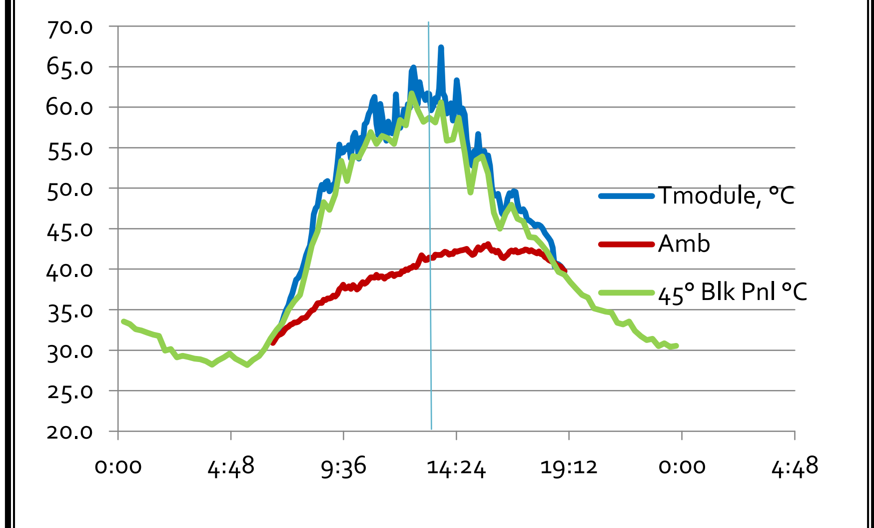
**Phoenix**
Calc Tmodule (max):

Tmodule, Roof: 90°C
Tmodule, Rack: 70°C
Tmodule, Track: 70°C

## Evaluation of High Temperature Exposure of Rack Mounted Photovoltaic Modules (King Model)

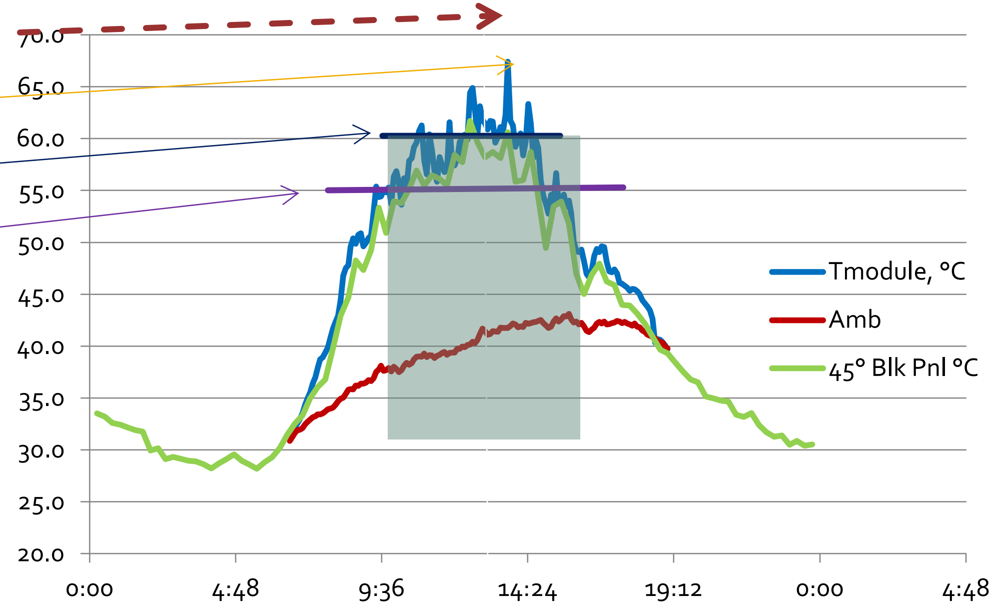
| | | | |
|---|---|---|---|
| NREL 2009 paper, Max Tmod (location not specified) | Rack | Tmax=75C | |
| | Roof | Tmax=96C | |
| *Tmodule, using Mani's data:* | | | |
| Rack Model, Tm=Tamb + Irr*e(-3.473-0.0594*WS) | | | 72.7 |
| Roof Model, Tm=Tamb + Irr*e(-2.98-0.0471*WS) | | | 89.6 |

**3M Data, Phoenix, July 1, 2013**



# Phoenix Rack Mounted Modules: Logical Temperature Setpoint Options

- .
  - NREL model, w Tamb (max) 73 °C
  - Actual Tmod (max) 68 °C
  - "Average" Tmod (max) 60 °C
  - "Typical Max" BPT ($85^{th}$%) 55 °C



# "Logical" Temperature Descriptors:

# BPT, and Calculated from "Typical Max Tamb"

- Rack Mounted:
  A. Modeled T(amb) = "Typical Max"
  B. $85^{th}$ %ile BPT.

| ***Rack Mount*** | Ir | "Typical Max" Tamb | Tmodule (Calc w/ Typ max T) | 85th %ile BPT |
|---|---|---|---|---|
| Sanary | 967 | 27 | 57.0 | 44 |
| Phoenix | 994 | 42 | 72.7 | 55 |
| Miami | 1050 | 33 | 65.6 | 49 |

*Rack Model, Tm=Tamb + Irr*e(-3.473-0.0594*WS)*

- Roof Mounted:
  - Model with Typical Max

| ***Roof Mount*** | Ir | "Typical Max" Tamb | Tmodule (Calc w/ Typ max) |
|---|---|---|---|
| Sanary | 943 | 27 | 80.3 |
| Phoenix | 994 | 42 | 92.3 |
| Miami | 950 | 33 | 84.4 |

*Roof Model: Tm= 0.05(Irrad) + 0.64*Tamb+15.82*

# Microclimate descriptors: UV and T

| | | | *front side* | | Annual TUV Bkside MJ/m2 % Albedo = | | | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **Appl. Type** | **Max Irr @340 nm** | **AnnualTotal Solar (mod) (MJ/m2)** | **Annual TUV (MJ/m2)** | **5%** | **10%** | **20%** | **Module T (°C)** |
| Desert (Phoenix) | lat-rack | 0.7 | 8612 | 347 | 17 | 35 | 69 | 59-73 |
| Desert (Phoenix) | track | | 11948 | 538 | 27 | 54 | 108 | |
| Desert (Phoenix) | roof | | 7850 | 353 | 18 | 0 | 0 | 92 |
| Temperate (Sanary, FR) | lat-rack | 0.7 | 6848 | 322 | 16 | 32 | 64 | 44-57 |
| Temperate (Sanary, FR) | track | | 9481 | 446 | 22 | 45 | 89 | |
| Temperate (Sanary, FR) | roof | | 6116 | 287 | 14 | 0 | 0 | 80 |
| Hot/Wet (Miami) | Rack | 0.69 | 6750 | 334 | 17 | 33 | 67 | 49-66 |
| Hot/Wet (Miami) | Track | | 8711 | 415 | 21 | 41 | 83 | |
| Hot/Wet (Miami) | Roof | | 6475 | 334 | 17 | 0 | 0 | 84 |

# 3. Humidity Data

**Goal: Establish humidity references for each microclimate**

# Relative Humidity: Some typical days

Using Moisture Content to understand microclimate humidity

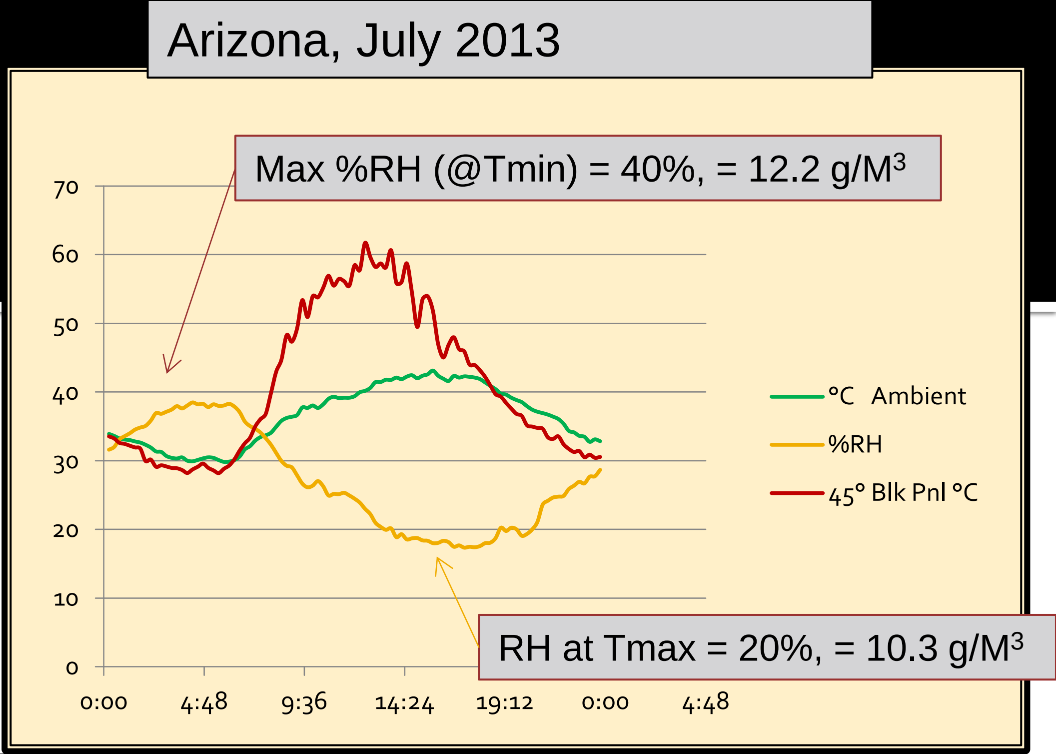
Arizona

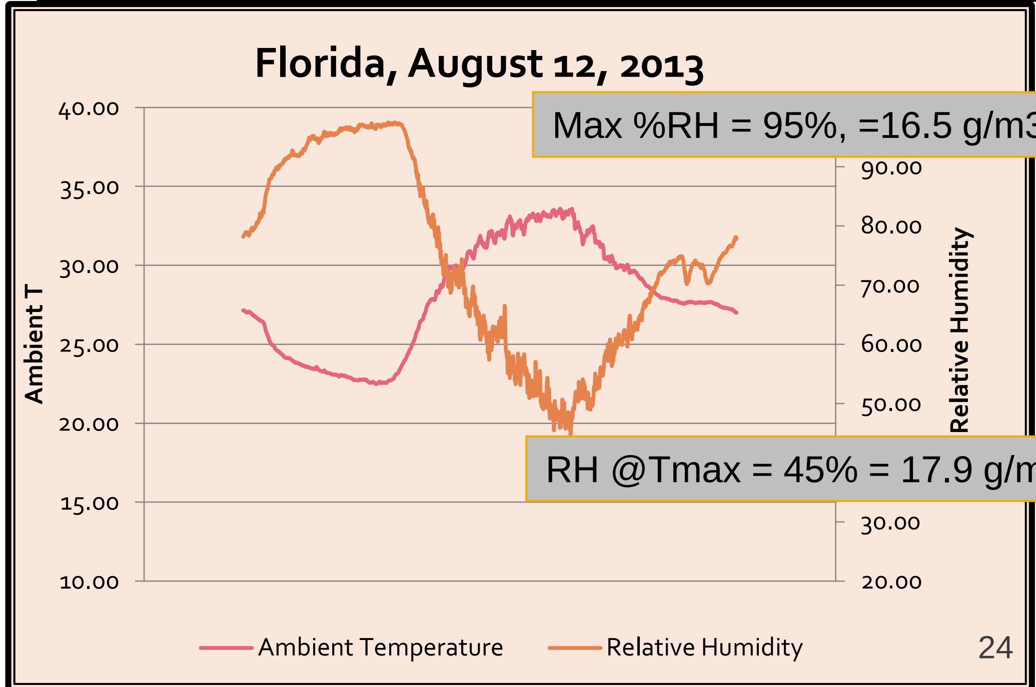
| T | RH | g/M3 | RH (est) |
|---|---|---|---|
| 30 | 40 | 12.2 | |
| 40 | 20 | 10.3 | |
| 70 | | 11 | 5.5 |
| 90 | | 11 | 2.6 |

Miami

| T | RH | g/M3 | RH (est) |
|---|---|---|---|
| 22 | 95 | 16.5 | |
| 35 | 45 | 17.9 | |
| 70 | | 17 | 8.6 |
| 90 | | 17 | 4.1 |

Ref: Absolute Humidity at 85/85 = 299 g/M3



# Microclimate Descriptors: UV, T, Humidity

| | | | *front side* | | Annual TUV Bkside MJ/m2 % Albedo = | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Appl. Type** | **Max Irr @340 nm** | **AnnualTotal Solar (mod) (MJ/m2)** | **Annual TUV (MJ/m2)** | **5%** | **10%** | **20%** | **Module T (°C)** | **Abs. Hum. (g/M$^3$)** |
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| Hot/Wet (Miami) | Rack | 0.69 | 6750 | 334 | 17 | 33 | 67 | 49-66 | 17 |
| Hot/Wet (Miami) | Track | | 8711 | 415 | 21 | 41 | 83 | | |
| Hot/Wet (Miami) | Roof | | 6475 | 334 | 17 | 0 | 0 | 84 | |

# Part II. Translation into artificial weathering set points

# A simple task...

From "*Handbook of Material Weathering, 4th Ed", Wypych:*

- Many scientists have been seeking the Ultimate Enlightenment, the meaning of life, the elixir of youth, the missing link, or the perfect unified field theory.
- On a more mundane level, the weathering researcher is seeking the instant weathering predictor.
- With this amazing device,  the investigator would place a sample in the machine, switch on, and come back next day to:
    a) find out how long the final product will last, having been stressed in every possible way, in every part of the world, under the sea, on mountain top, in the desert, in polluted cities, in space, in the tropics, in the arctic, in thunderstorms, in hurricanes, and in all seasons.
    b) The machine tells you how the product will fail, and
    c) how to fix it.

# Qualification Plus (Backsheet Section)
# US members of IEC Backsheet / Weathering Group, Plus

- Kurt Scott - Atlas
- Sean Fowler – Q-Lab
- Nancy Phillips – 3M
- Bill Gambogi – DuPont
- Tom Earnest – DuPont
- Jim Bratcher – Honeywell
- Greg O'Brien – Arkema
- Mike Kempe – NREL
- John Wohlgemuth – NREL
- Sarah Kurtz - NREL

# Accelerated Weathering Testing

## For Product Development:

A. Screening Tests
- Highly Accelerated Tests
- No materials understanding used
- False positives/negatives tolerated

B. Material Specific Testing
- Shift from Highly Accelerated Tests
- To Thoughtfully Accelerated Tests
  - Ser vice life perspective
  - Philosophy: understand failure modes, run at maximum conditions where the same failure modes are observed as in the field

## For Standards:

C. "Agnostic Testing"
- Materials Independent
- Gives some confidence that a new product will work during its service life
- Example: encapsulants
  - EVA, polyolefins, silicones, new ideas
  - Anything that will work in the field should pass the test

- Philosophy: run at or near typical maximum values observed in the application
  - Rule of thumb: limit acceleration to 10X
    - 25 years ➔ 2.5 years!
      - Delta testing: Up to 10x: look for change, as opposed to a failure
    - Accelerating >10x, expect errors; may see failures that don't occur in real world

# *Arriving at a steady state artificial weathering exposure recommendation…*

1. **Define the target climate**
   a) **Start with an easy climate** (Sanary used as benchmark)
   b) **Start with an aggressive climate (Phoenix)**
2. **Be mindful of "acceleration factors"** (more than 10X risks faulty conclusions)
   - **Temperature:**
     - Acceleration is dependent on activation energies; for Tave = 29C
       - 70 °C: 10x – 100x, 90 °C: 20x – 1000x
3. **Utilize "Typical Max" values for Irr. and T settings, double Abs. Humidity**
4. **Time: Constrain exposure time to < 6 month (= 4000 h exposure)**
5. **Established Standards: use as reference**
   - **ASTM D7869: Max Setpoint: 0.8 W/m2/nm, ChT 50°C, BPT 70°C, 50%RH, 4200 h**
6. **User capability:**
   - **Settings must be within capabilities of "Relatively Common" weathering machines**
   - **Minimize the number of machine set points needed**

# Backside 25 year doses

| | | | | | |
|---|---|---|---|---|---|
| Phoenix, Latitude Mount annual irradiance (347 MJ, | | | | | |
| | | dosage (kJ) | hours to dose at Xe (340/DF) | | |
| % Albedo | 25 yr TUV (MJ/m2) | 340 equivalent (MJ) | 0.35 | 0.55 | 0.8 |
| 10 | 868 | 12.1 | 9641 | 6135 | 4218 |
| 12 | 1041 | 14.6 | 11567 | 7361 | 5060 |
| 20 | 1735 | 24.3 | 19278 | 12268 | 8434 |
| | | | | | |
| | | | dosage (kJ)= W/m2*3.6*hours | | |
| | | | hours=dosage/(3.6*W/m2) | | |
| | | | | Test done in 6mths | |

# QUESTION: Which, or how many, microclimate targets?

- **Option 1: an "easy" climate** (Sanary - Mediterranean)
- **Option 2: must work in all climates**
- **Option 3: what's reasonable to do in 6 months?**
- **Option 4: differentiate, for example:**
  - **Arizona Roof: high T, no backside UV**
  - **Arizona Rack: high backside UV, lower T**

# Qualification Plus: Backsheet Weathering Recommendations

# Machine Setpoints

- **Frontside**
  - Xe(340) 0.8 W/m2/nm/ 50C ChT, 50%RH, 70C BPT.
  - Exposure time:  max out at 6 months real time = 4000 h
- **Backside**
  - Xe(340) 0.8 W/m2/nm/ 50C ChT, 50%RH, 70C BPT.
  - Exposure time:  aiming for 25 years dosage,  = 4000 h
    - UV Dosage ~ 25 years, Arizona, 10% Albedo

# Weathering Samples

OPTIONS:

1. **Coupon #1:** A "matched component " coupon (Glass/Encapsulant/Encapsulant/Backsheet
   - Who's choosing the materials?
     - selected by the component supplier for data sheets
     - Selected by the module manufacturer for qualification
   - Test data includes:
     - encapsulant name and UV transmittivity.
     - Evaluation tests on next page
2. **Coupon #2:** G/E/E/TRL/BS
3. **1 cell mini-module**
4. **Backsheet only** (not under consideration, except as in coupon #2)

# Evaluation tests:

Green: we're in agreement
Red: we're not in agreement
Yellow: mixed:

A. Coupon #1: Glass/E/E/BS Coupon tests (2 different samples front side exposure, backside exposure)
   - visual inspection for cracking (front side and backside?)

B. Coupon #2: Glass/e/e/trl/bs (2 different samples frontside and backside exposure)
   - yellowing
   - T&E,
     - Pass fail criteria options:
       - 70% retention of initial values? Or, minimum value – how to correlate with the actual stresses in a module

C. Mini-module tests
   - 1 cell mini module
     - Wet hi-pot
     - Visual

~~D. Backsheet only~~

- Options to offer to reviewers
  - A
  - A&B
  - A,B,D
  - C
  - A&B OR just C