PVMRWS – 2014

Utilization of PV module microclimates to establish pathways to accelerated weathering protocols

Presented by:
Nancy Phillips, 3M Company and Kurt Scott, Atlas Material Testing Technology
(Reporting on work being done by weathering group)

Motivation:

"Outdoor testing is a must, but it takes m too long to be of much use as a decisio maker. We clearly can not wait 25 yea even a significant fraction of 25 years t introduce a new product. Therefore we must develop and utilize accelerated te to qualify these new products."

John Wohlgemuth

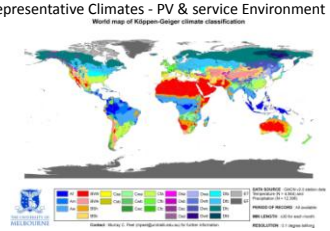
Accelerated Weathering Goals

- Capture the degradation reactions doing the bulk of the damage in the microclimate
- Ignore degradation reactions not occurring in the microclimate
- Compress the test duration to get results comparable to real life.

- All of the above are material specific: what to do to for a test that is aiming to be not material specific?

Considerations:

Representative Climates - PV & service Environment



Considerations:

- Representative Climates:

Hot Arid
(e.g. Phx , AZ)

Northern Temperate

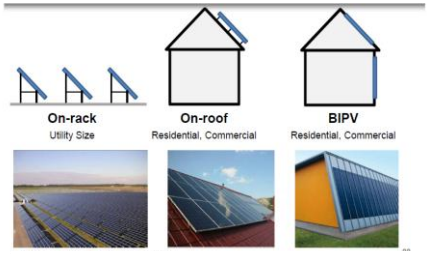
(e.g Sanary, Fr)

Tropical\Subtropical

(e.g. Mia. FL)

Ground Cover Reflection - Albedo

Module Mounting



Climate Data Analysis

Irradiance Data

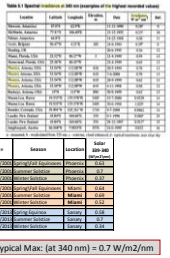
Goal: establish references for:

- Irradiance set points
- Dosage levels by climate/application

Reviewed Maximum for pre-selected Geographies

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



date	Season	location	Solar 300-340 W/m2/nm
3/21/2005	Spring/Fall Equinoxes	Phoenix	0.63
6/21/2005	Summer Solstice	Phoenix	0.7
12/21/2005	Winter Solstice	Phoenix	0.37
3/21/2005	Spring/Fall Equinoxes	Miami	0.64
6/21/2005	Summer Solstice	Miami	0.69
12/21/2005	Winter Solstice	Miami	0.53
3/21/2005	Spring Equinox	Sanary	0.68
6/21/2005	Summer Solstice	Sanary	0.7
12/21/2005	Winter Solstice	Sanary	0.39

Typical Max: (at 340 nm) = 0.7 W/m2/nm

Total Irradiance data and analysis – Phoenix

		front side			backside
Location	Appl. Type	Total Solar (MJ/m2)	TUV (5% of TS) (MJ/m2)	%TUV/Total Solar from data	TUV (MJ/m2)	TUV Bkside MJ/m2
Desert (Phoenix)	lat-rack	8612	431	4.03	347	35
Desert (Phoenix)	track	11948	597	4.50	538	54
Desert (Phoenix)	roof	7850	392	4.50	353	0

Total Solar data:

- From Meteonorm 7.0, compares well to Atlas data (all based on TS = 290-3000nm)
- "Roof mounting" defined as = 5 degree, south facing
- %TUV data: Rack and Roof data from AWSG 10 year average 1999-2008

Backside Irradiance Data:

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

Miami, Phoenix & Sanary - Time to Dose

– 1 yr equivalence in Xe @ 0.7 w/m²/nm @ 340nm

				front side			backside (refl = 10%)		
Location	Appl. Type	Exp	Annual/Total Solar (mod) (MJ/m2)	Annual TUV (MJ/m2)	time to 1 year dose @ 0.7	tcf	Annual TUV Bkside (MJ/m2)	time to 1 year dose @ 0.7	tcf
Desert (Phoenix)	lat-rack	34	8612	347	1354	6	35	135	65
Desert (Phoenix)	track	2 axis	11948	538	2097	4	54	210	42
Desert (Phoenix)	roof	5	7850	353	1378	6	0	0	
Temperate (Sanary, FR	lat-rack	45	6848	226	881	10	23	88	99
Temperate (Sanary, FR	track	2 axis	9481	341	1331	7	34	133	66
Temperate (Sanary, FR	roof	5	6136	220	859	10	0	0	
Hot/Wet (Miami)	Rack	26	6750	334	1303	7	33	130	67
Hot/Wet (Miami)	Track	2 axis	8711	415	1617	5	41	162	54
Hot/Wet (Miami)	Roof	5	6475	334	1303	7	0	0	

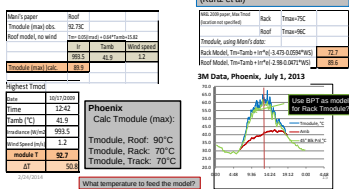
Temperature Data

- Goal:
  - Establish a target temperature to represent the microclimates
    - Average T
    - Max T
    - "Typical Max T"
    - Effective T (materials specific)

Phoenix Module – Modeled and measured

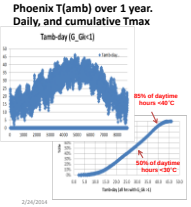
Temperature of Buildling Applied Photovoltaic BAPV Modules: Air Gap Effects (Tamizhmania et al)

Evaluation of High Temperature Exposure of Rack Mounted Photovoltaic Modules (Kurtz et al)



Phoenix Ambient Temperatures

Phoenix T(amb) over 1 year. Daily, and cumulative Tmax



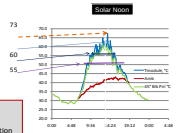
Plan

- Analysis:
  - Define ambient conditions
  - Model module temperatures
  - Where available, compare to module data
- Translation to T during Accelerated Weathering:
  - **Philosophy: run at or near maximum conditions all the time**
- Consider concept of **"Typical Max T"**
  - 85%ile T
  - For Phoenix: **Typical Max T(amb) = 40°C**

Temperature Setting Options

(Rack Mounted)

- Plausible "max Tmod"
  - NREL model, w Tamb (max) °C
  - Actual Tmod (max) 68 °C
  - "Average" Tmod (max) °C
  - "Typical Max" Tmod (85%) °C



- Goal:
  - A temperature that will
    - Accelerates actual degradation mechanisms
    - Limit mechanisms that do not occur

Estimating Module Temperatures: BPT, and Calculated from "Typical Max T(amb)"

- Rack Mounted:
  - A. Modeled T(amb) = "Typical Max"
  - B. 85th %ile BPT.
- Roof Mounted:
  - Model with Typical Max
- Will be collecting real data
- Key question:
  - What's the "right" or "best Temperature setting?

Rack Mount	Irr	"Typical Max" Tamb	Tmodule (Calc w/ Typ max)	BSh %ile BPT
Sanary	967	27	57.0	44
Phoenix	994	42	72.7	
Miami	1050	33	65.6	49

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

Roof Mount	Irr	"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*

Humidity Data

Goal: Establish a target humidity to represents each microclimate

- Options
  - Maximum %RH
  - %RH at Maximum T
  - RH (wa)
  - Moisture content

Relative Humidity: Some typical days

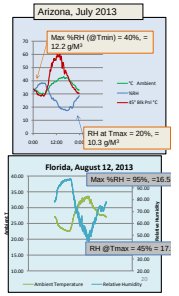
Using Moisture Content to understand microclimate humidity

Arizona

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

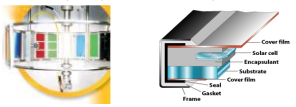
Miami

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



Specimens – what to test?

1. Film or simple coupon?
2. Mock-up – Mini module?



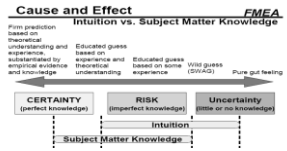
Depends on question being asked –

- opt 1. Materials Screening – A better than B? - **suitable for IEC 62788*?**
- opt 2. Will there be attachment issues over time? – **a must for IEC 61730-2** & 61215**
- opt 2. Will safety be maintained in PV stack ? – a **must for IEC 61730 & 61215*****

* MEASUEMENT PROCEDURES FOR MATERIEALS USED IN PHOTOVOLTAIC MODULES
** PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION – PART 2: REQUIREMENTS FOR TESTING
*** CYSTALINE SILICON TERRESTRIAL PHOTOVOLTAIC (PV) MODULES- DESIGN QUALIFICATION AND TYPE APPROVAL

Future work – Consensus & Validation

- Addressing Open questions
- Developing Interim standards e.g. "Qualification plus"
- Refinement and Validation



Summary: Microclimate Descriptors

Indicated RH numbers

Summary of Xe (340) Setpoint Options

- Xe @ 340 setting (W/m2):
  - 1.4
  - 0.7
  - 1.1
  - 0.5
- Temperature (°C)
  - 70 (WPT)
  - 90 (WPT)
  - 70 (BPT)
- Humidity (%RH)
  - 50% (@ 70°C
  - Uncontrolled at 90°C
  - Uncontrolled at 70°C
  - 15% at 90°C
  - 35% at 70°C