Breakout session: Silicon

Discussion leader: Peter Hacke

Scribe: David Miller

8:00 – John Wohlgemuth (BP Solar) – Failure Modes of Crystalline Si Modules and How to Eliminate Them

8:30 –Govindasamy Tamizhmani (Mani) (TUV Rheinland PTL) – Experience with Qualification and Safety Testing of Silicon Modules

9:00 – Discussion: Are there field failures that are not caught by the current qual test? Are there new failure modes that need to be studied? Do high system voltages cause new module failures?

9:30 – Break

10:00 – Dirk Jordan (NREL) – Degradation Rates—What Do We See?

10:30 – James Bing (New Energy Options) – Decades in the Installed Environment—Do Silicon Modules Really Last More than 20 Years?

11:00 – Discussion: Is the performance in the field adequate? If not, what is needed—better QA, qual test?

Failure Modes of Crystalline Si Modules

John Wohlgemuth, Daniel W. Cunningham, Andy Nguyen, George Kelly and Dinesh Amin

- **Broken interconnects – thermomechanical fatigue, stress concentration**
- **Broken Cells- need optical and mechanical test/inspection, multiple ribbons.**
- **Corrosion- need optical and mechanical test/inspection, strong interactions between moisture, metallization, and EVA**
- **Delamination and/or loss of elastic properties, control of materials, extensive accelerated testing**
- **Encapsulant discoloration – 6 mo 8x UV testing**
- **Solder bond failures – multiple solder bonds, for mechanical backup to j-box connection, do not depend on pottant**
- **Broken glass - Hot-spot, arcs, improper mounting**
- **Hot Spots – bypass diodes, screen cells with high leakage current**
- **Ground faults- avoid mounting behind the cell area**
- **Junction box and module connection failures- workmanship, QC, qualified parts**
- **Structural failures – follow mnf. Instructions, design to load**

Summary

bp solar

- **Crystalline Si Module reliability and performance**
  - **Very good but still with room for improvement**
  - **Not all modules are created equal, poor material selection, improper assembly and processing will yield different degradation rates and lifetimes**
- **New Module Technology**
  - **Can't test for 25 years before releasing commercial products**
  - **Strong accelerated test programs required.**
  - **Process controls required to assure production modules perform as well as test modules.**

John Wohlgemuth: Questions & Answers

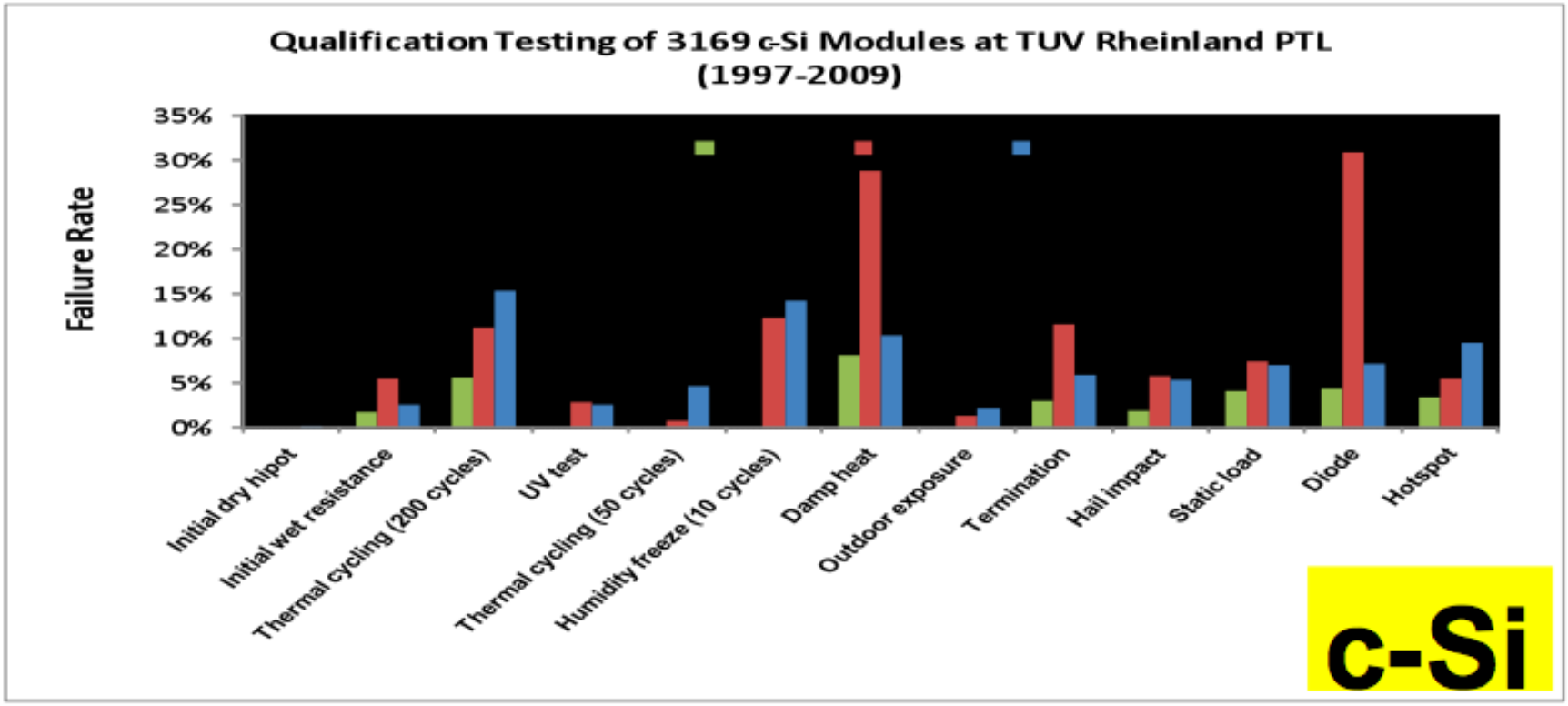
- **Q: pottant in j-box – how is this different than EVA and bus-bar**
- **A: you want another mechanical "hold" in addition to solder bond**
- **Q: new low cost encapsulants on the market … why stick to EVA**
- **A: not that significant cost savings; many are thermoplastics, and high T performance questions.**

Mani G. TamizhMani

Experience with Qualification and Safety Testing of Photovoltaic Modules

Test Results @ TUV Rheinland PTL

- **Qualification Test Results of PV Modules (IEC 61215/61646)**
  (3636 modules [87% c-Si]; 20 different countries; 1997-2009 [13 years of data])
  - c-Si: 1997-2005 *vs.* 2005-2007 *vs.* 2007-2009
  - Thin-film: 1997-2005 *vs.* 2005-2007 *vs.* 2007-2009
- **Safety Test Results of PV Modules (IEC61730; ANSI/UL1703)**
  - c-Si: Temperature test – 140 modules (2006-2009)



- 1997-2009 (13 years): Top 4 failure rates

- Damp heat failure rates: 2007/2005 = increased; 2009/2007 = decreased
- Thermal cycling failure rates: 2007/2005 = increased; 2009/2007 = increased
- Humidity freeze failure rates: 2007/2005 = increased; 2009/2007 = increased
- Diode failure rates: 2007/2005 = increased; 2009/2007 = decreased

Out of the box (initial) wet resistance failure (!!!) : 2005 – 2%; 2007 – 5%; 2009 – 3%

Summary

Qualification Testing: c-Si

- Damp heat failure rates: 2007/2005 = increased; 2009/2007 = decreased
- Thermal cycling failure rates: 2007/2005 = increased; 2009/2007 = increased
- Humidity freeze failure rates: 2007/2005 = increased; 2009/2007 = increased
- Diode failure rates: 2007/2005 = increased; 2009/2007 = decreased

Qualification Testing:Thin-Films

- Damp heat failure rates: 2007/2005 = increased; 2009/2007 = decreased
- Thermal cycling failure rates: 2007/2005 = increased; 2009/2007 = decreased
- Humidity freeze failure rates: 2007/2005 = increased; 2009/2007 = decreased
- Static load failure rates: 2007/2005 = decreased; 2009/2007 = increased

Safety - Temperature Testing: Polymeric Substrate (c-Si)

- $T_{avg\text{-}norm\text{-}Voc}$: 84°C
- $T_{max\text{-}norm\text{-}Voc}$: 97°C

Mani:
Questions & Answers

- **Q: after hail test, wet resistance … why is that the case for c-Si in post-stress?**
- **A: not clear what after hail test, modules fail wet resistance; adhesion on back might be compromised?**
- **Q: where is damp heat failing?**
- **A: between j-box & laminate**
- **Q: Does that mean sealant at j-box not working properly**
- **A: Yes, bad adhesion there**
- **Q: In US only safety test is required… well what does CA use as crieria?**
- **A: IEC tests performance at STC required there, not full qual test**

National Renewable Energy Laboratory
Innovation for Our Energy Future

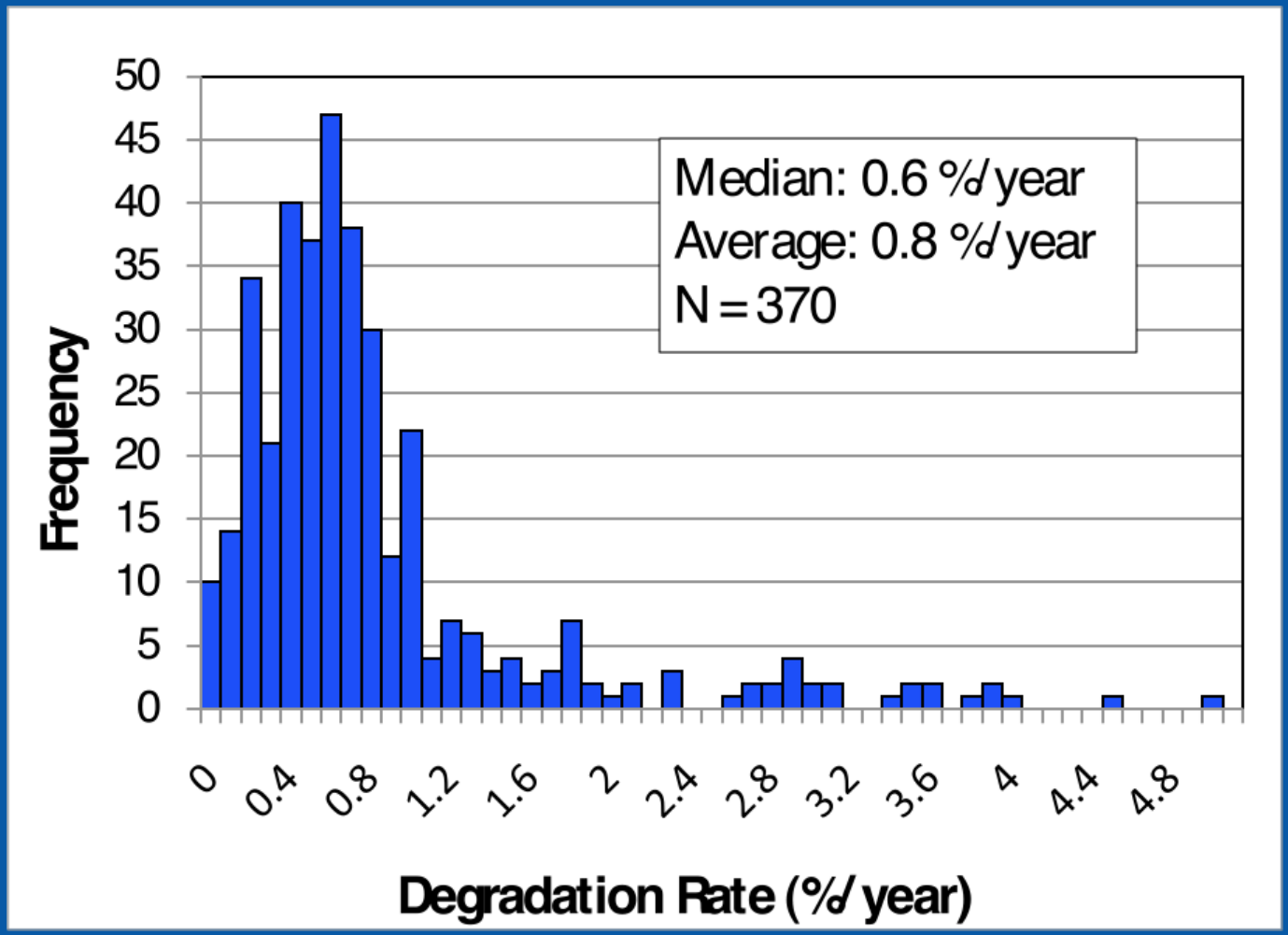
Degradation Rates

NREL

Dirk Jordan

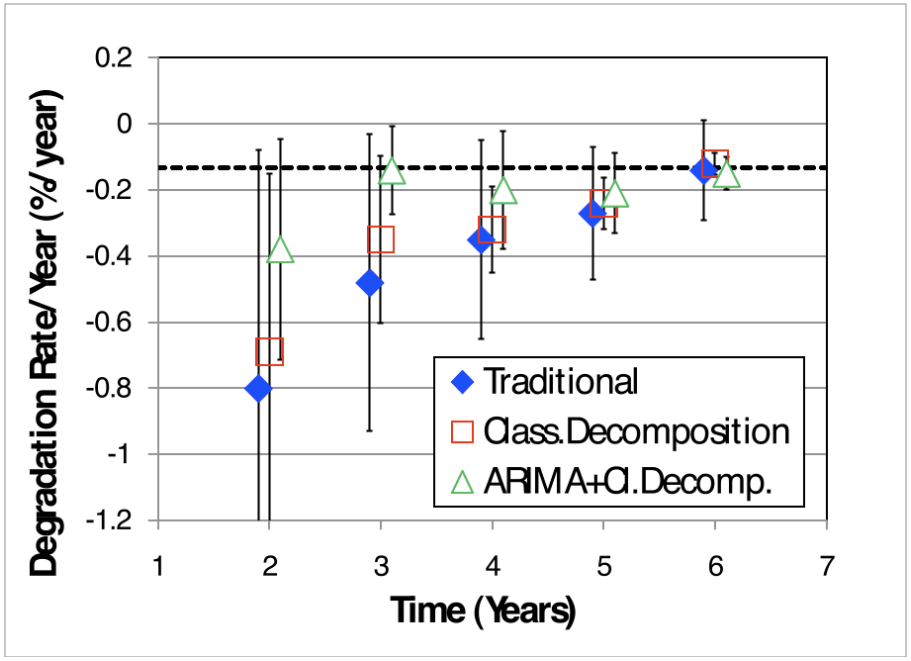
Feb-19-2010

Degradation Rates (R_d) most often reported

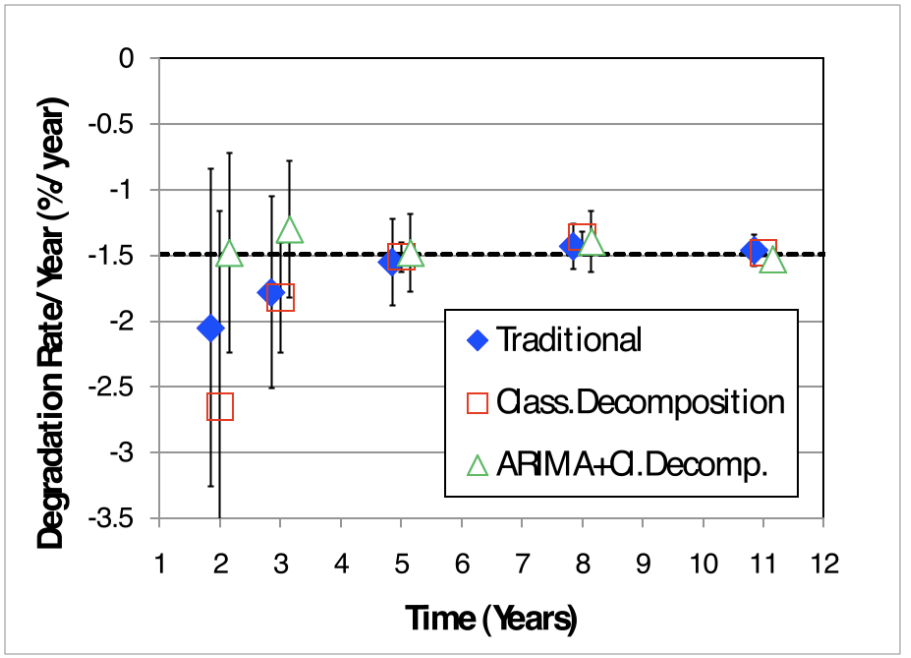


Degradation Rate in shorter Time

multi-Si



a-Si



- Degradation rates were calculated for each method starting with the first 2, 3 years etc.
- The a-Si module was in the field for over 6 months before data collection commenced.
- For longer times all three methodologies converge to the same rate.
- Traditional & Cl.Decomp. show increasing bias for shorter time but w/in uncertainty.

Conclusion

- Analysis of >40 modules showed why 3-5 years traditionally required to determine R_d
- Introduced 2 new methods to determine R_d (Class.Decomp., ARIMA+Decomp.)
- ARIMA most robust against outliers
- Introduced method to correct data shifts
- ARIMA seems to able to determine R_d more quickly → limited by numbers of degree of freedom → need more data points → sample weekly
- Using shorter time intervals increases noise but holds promise

Dirk Jordan: Questions & Answers

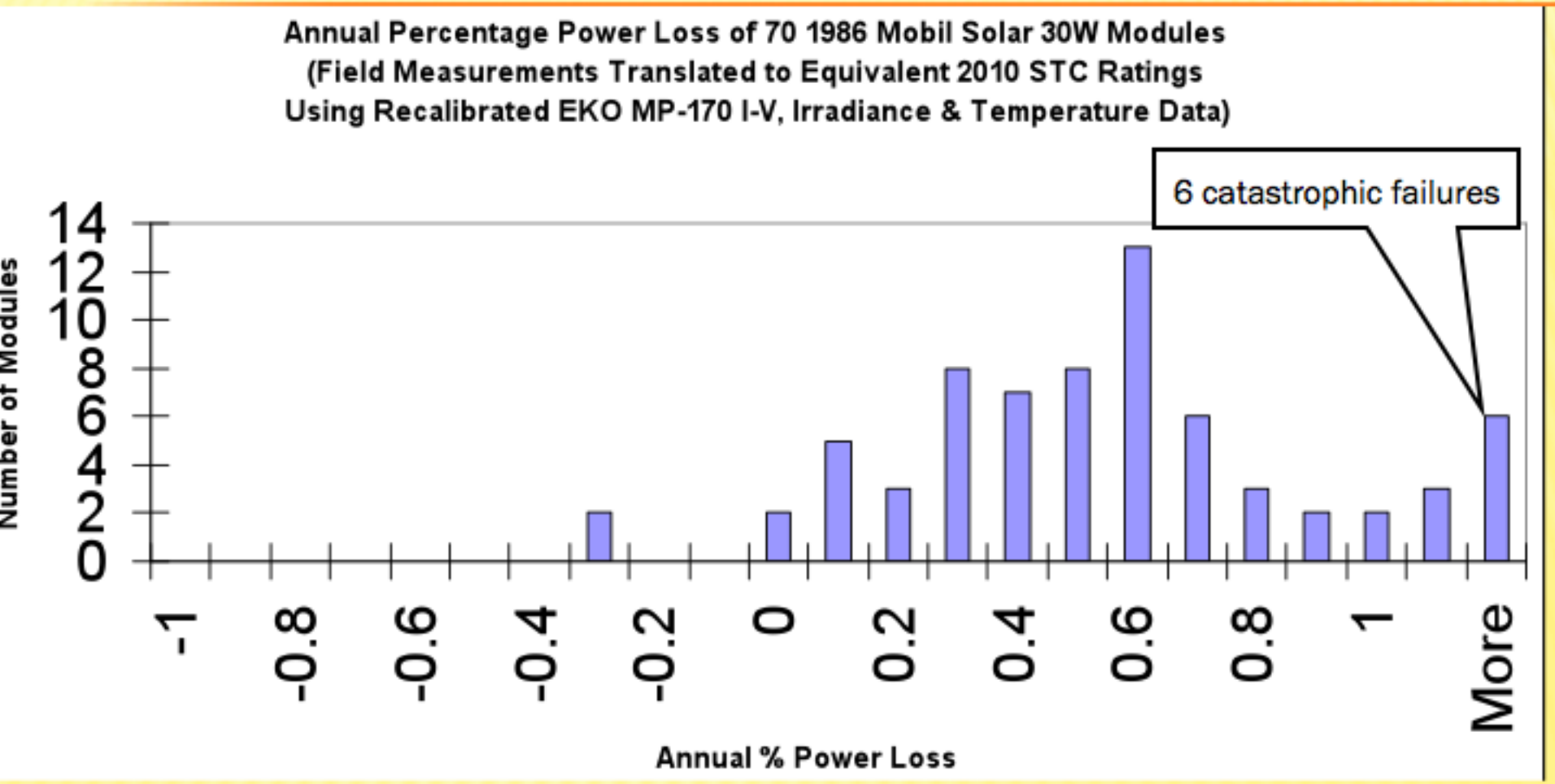
- Q: would some ‘true trends’ give you the opposite results? Would ARMIA ever render contradictory results?
- A: ARIMA does not handle sudden shifts very well. Can compensate this situation prior to analysis. Non-linear trends use a function rather than linear fits

Decades in the Installed Environment: Do Silicon Modules Really Last More than 20 Years? Preliminary Findings

NREL PV Module Reliability Workshop
2/19/2010

James M. Bing, PE
President
New Energy Options, Inc.
410 Great Road, B-6
Littleton, MA 01460
jbing@newenergyoptions.com

Percentage Power Loss Per Year
Mobil Solar Ra-30-12H Module Retest



Conclusions

- Yes, silicon modules –at least the ones that we looked at-- really do last more than 20 years.
- It may be the case that some of the Mobil Solar modules that we examined started out their lives with substantially higher STC ratings than their data sheets indicated.
- Quantifying a rate of power loss is difficult if you are not certain of the original rating. You can't tell how far you have come unless you know where you started from.
- Know your instruments.

James Bing: Questions & Answers

- Q: What was the module construction (encapsulant/backsheet)
- A: unknown, but being sent to NREL
- Q: Anything stand out from initial inspection
- A: Browning of encapsulant; c-Si modules look good;
- Q: what about catastrophic failures (poly-Si)?
- A: not clear why they were ½ power
- Q: cleaning procedure, where the modules dirty?
- A: c-Si – tilted at 60 deg, not “horribly” dirty, were measured before & after. procedure: windshield washer fluid, brush & squeegee

Discussion summary – Si module failures

- tests because the rate of damage is at a rate that is less than could be detected.
- Pr. M: Qual test captures catastrophic problems.
- A: J-box quality is **difficult** to assess on manufacturing line. J-box material or manufacturing issue.
- **A: Inverter box… operating life of 10 years vs. module life of 20-25 years.**
- **Pr. M: A lot of the instances are related to production quality.**
- **JW: No qualification procedure/test for inverter exists. Qualification mark (ISO) may or may not help with this issue**.
- **MQ: Inverters need a qual test. Examining commercial and residential inverters. Ranking concerns by risk. Currently investigating the performance (and excursions) at sites. Considering component-level issues (grease, capacitor).**
- Q: What about microinverters?
- MQ: Could be considered separately (centralized vs. distributor located inverters). Module scale inverters will likely interact w/ module itself. Centralized won't have same air-circulation issues. No electrolytic capacitors. Module scale… thermal management expected to be big issue within inverter & where it is attached on the module. Where and how mounted are important considerations.
- Pr. M: **Microinveter on module requires change in module qual test.**

Discussion summary – Si field performance (1)

- Q: what are main mechanisms of long term-degradation to focus upon?
- JW: 1. **quality**- occasional details may lead to catastrophic failure
- 2. **0.5%/year – mostly moisture driven** (improve encapsulation & metallization schemes)
- Pr. M: quality has improved over time; new IEC hot spot test (based on ASTM method) will be coming out soon – this may prove more difficult for manufacturers to pass, and should be helpful for module performance
- PH: Is performance adequate? Is soiling important? Mounting of module (installation) problems
- Q: Should the backsheet truly be breathable?
- JW: Most thin film manufacturers try to keep H2O out. In c-Si this has resulted in more problems (EVA continues to cure – delamination) than allowing the moisture in.
- PH: Outgassing renders bubbles. H2O can still get in through sides & j-box when a glass substrate is present.