# Bio - Raja V. Pulikollu Ph.D

- Dr. Pulikollu is Technical Executive at EPRI. He has 20 years of experience in developing and implementing innovative asset management technologies to reduce costs and improve performance, safety, and reliability.



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# Hot Weather Impacts on Renewable Energy Critical Systems

GENERATION

## ERCOT 2024 Summer Weatherization Workshop

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Noah Myrent – EPRI

# KEY ASPECTS

## Nonprofit
Chartered to serve the public benefit, with guidance from an independent advisory council.

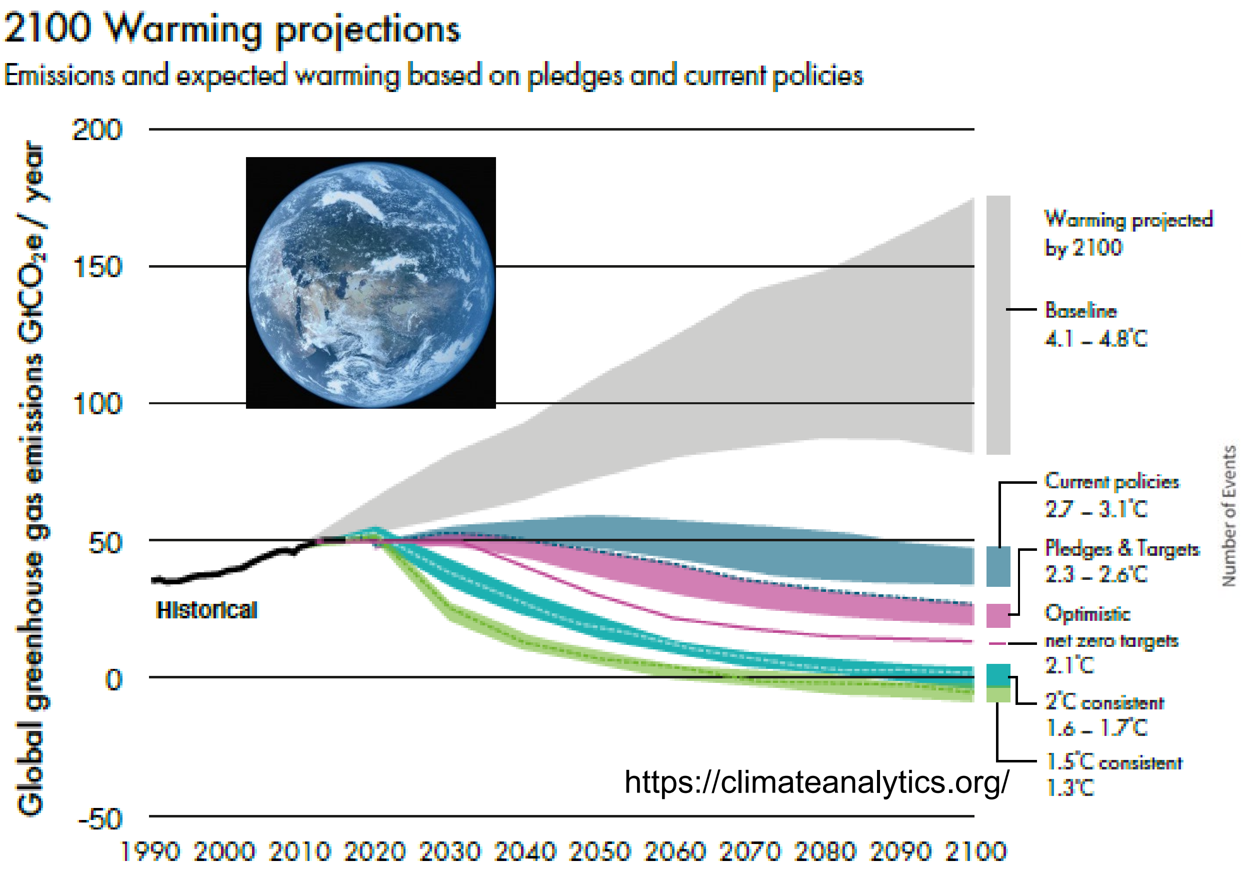
## Thought Leadership
Systematically and imaginatively looking ahead to identify issues, technology gaps, and broader needs that can be addressed by the electricity sector.

## Independent
Objective, scientific research leading to progress in reliability, efficiency, affordability, health, safety, and the environment.

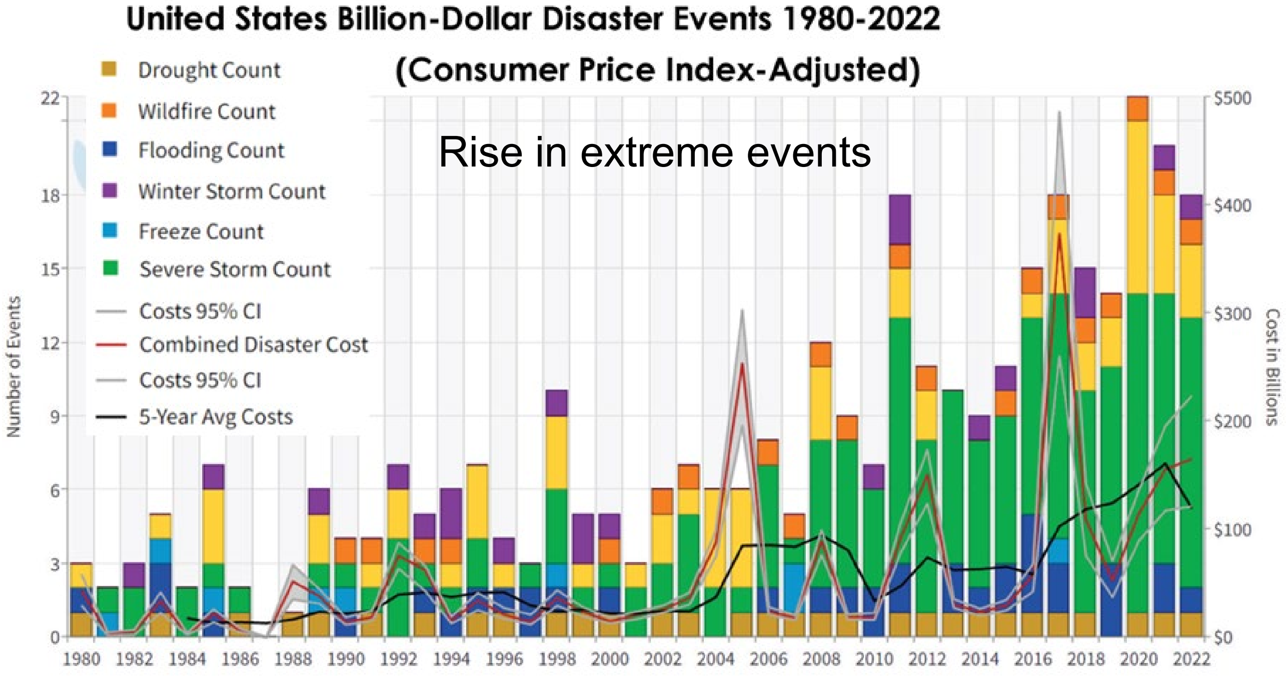
## Scientific and Industry Expertise
Provide expertise in technical disciplines that bring answers and solutions to electricity generation, transmission, distribution, and end use.

## Collaborative Value
Bring together our members and diverse scientific and technical sectors to shape and drive research and development in the electricity sector.

# Renewables Supports Net-Zero Goals




Source: Climate Action Tracker, December 2020.




*Source: NOAA National Centers for Environmental Information (NCEI)*

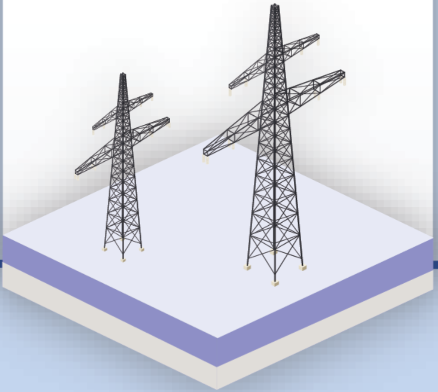
*U.S. Billion-Dollar Weather and Climate Disasters(2022).*

# Potential Energy System Impacts from Extreme Weather and Climate Change

### Energy Demand
Extreme temperatures increase electricity and fuel demands beyond capacity

### Electric Grid
Wind, ice, floods and wildfires damage power lines and other infrastructure

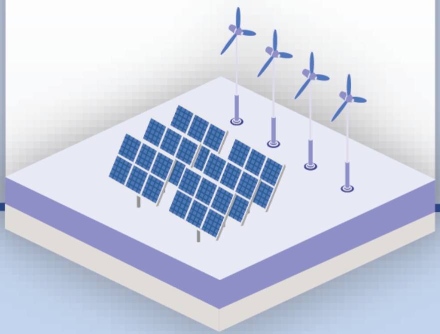
Extreme heat decreases transmission/ distribution capacity



### Wind, Solar and Geothermal
Extreme weather damages on and offshore facilities

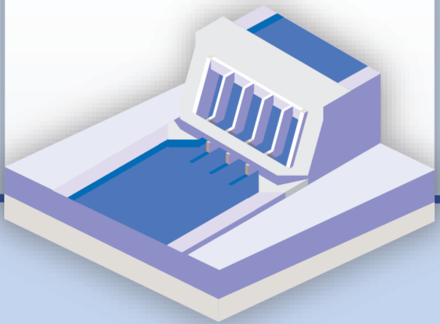
Cloudy or stagnant conditions reduce solar and wind production

Drought limits water-intensive geothermal production



### Hydropower
Drought and decreased snowpack/runoff reduce electricity production

Flooding damages equipment and disrupts operations



### Oil, Gas, and Coal
Extreme winds damage on and offshore platforms

Flooding damages production and storage facilities

Drought and severe storms constrain drilling, refining, fracking, mining and transport

**Climate change impacts all aspects of the energy system.**

*Source: Adapted from NCA Volume 5, Chapter 5*



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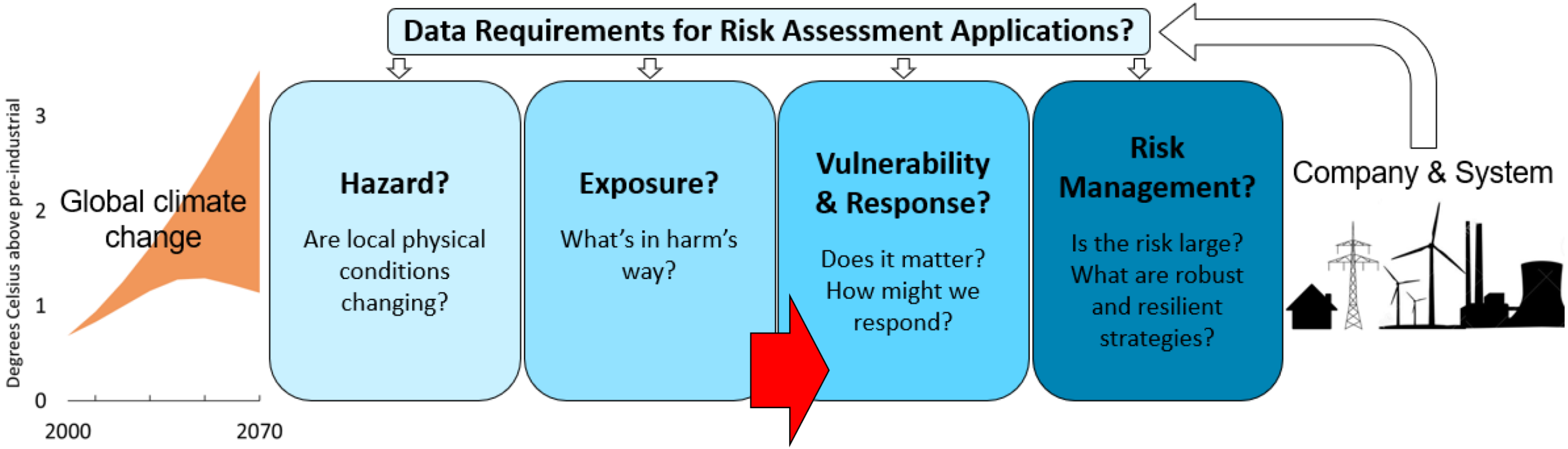
# Climate Risk Framework

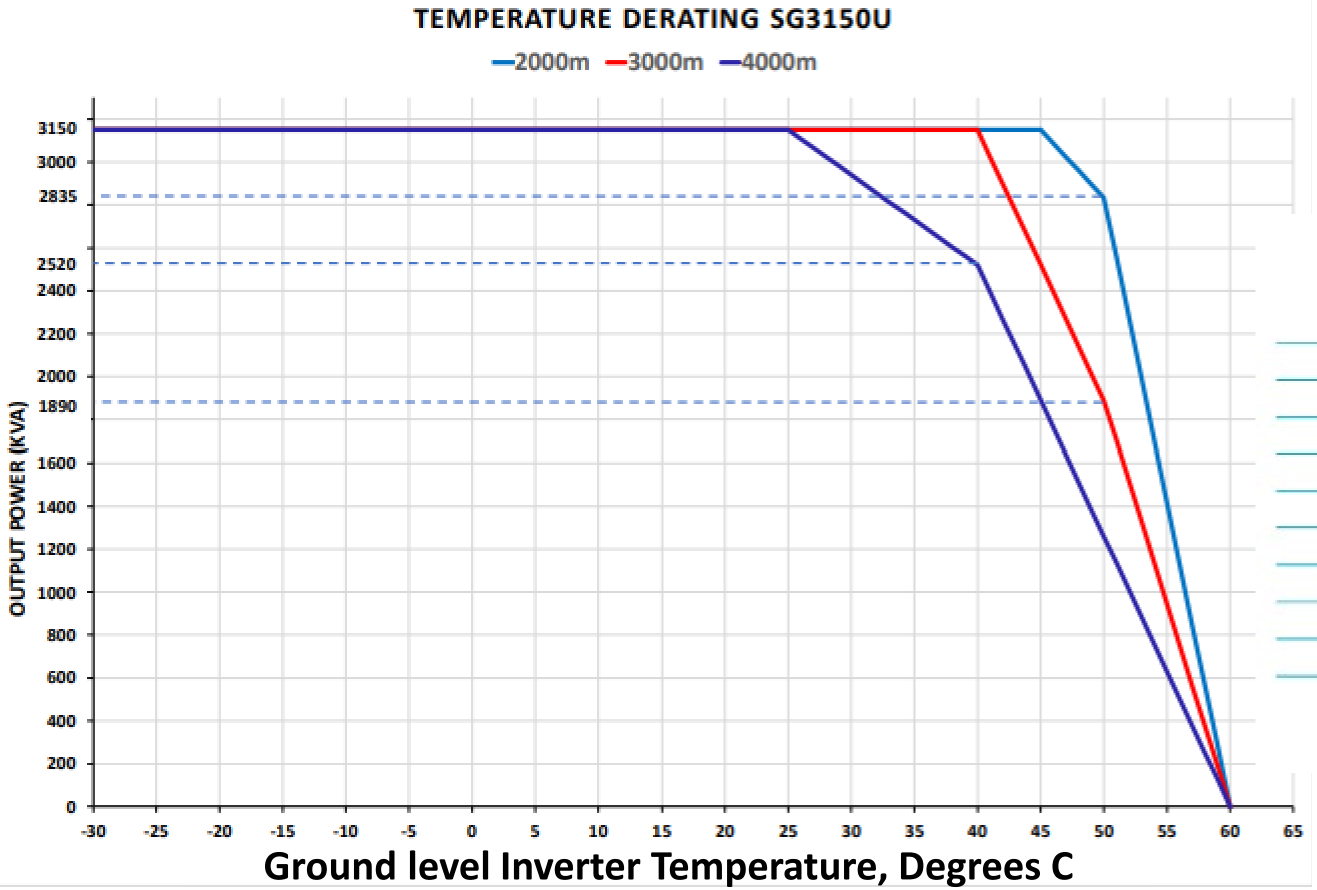
What does climate change mean for a company/system?

Requires knowing more than whether the climate is changing



# Climate Risk Assessment – Solar Example

## Common Solar Inverter Derate Curve : High Ambient Temperature




**Ambient Temperature, Degrees F**

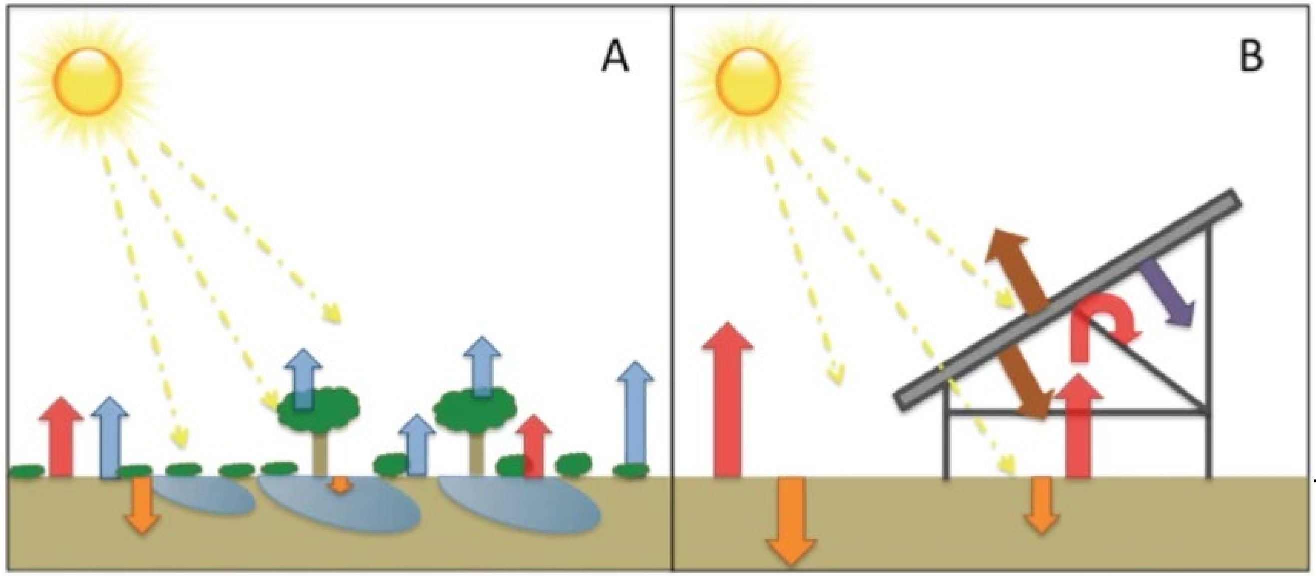
| Weather Zone | 95th Percentile Maximum Average 72-Hour Temperature | 99th Percentile Maximum Average 72-Hour Temperature |
|---|---|---|
| North | 96.1° | 98.0° |
| North Central | 95.4° | 97.8° |
| West | 92.9° | 93.9° |
| Far West | 92.7° | 95.0° |
| East | 91.6° | 96.8° |
| Coast | 90.1° | 92.1° |
| South Central | 92.3° | 93.0° |
| Southern | 88.9° | 92.2° |
| Valley | 88.6° | 89.2° |
| Panhandle | 90.3° | 91.3° |

*Table 67: Historical Maximum Average 72-Hour Temperature Data*

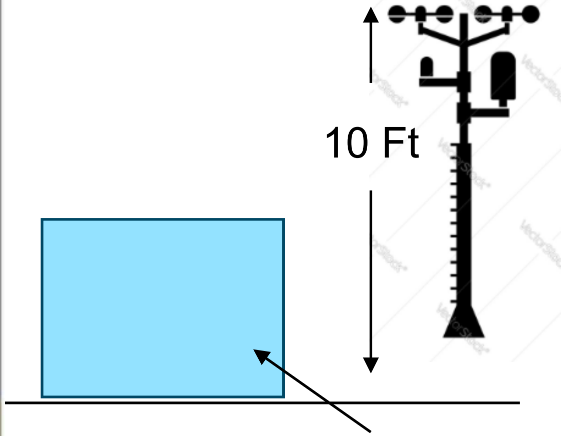
https://interchange.puc.texas.gov/Documents/52691_6_1221755.PDF

- Significant reductions in facility power level at high temperatures experienced in the Southwest.
- Similar temperature derate curves apply to battery energy storage inverter systems

# Climate Risk Assessment – Solar Example
## Temperature Measurements




**Midday Energy Exchange**




Ground level inverter

temperature measurement

- Extremely important to achieve agreement between "Facility Ambient" temperature and Inverter derate temperature measurement
- Project planning and agreement on temperature measurements needs to be achieved at the EPC/Owner contract level

Barron-Gafford, G., Minor, R., Allen, N. et al. ***The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures.*** Sci Rep 6, 35070 (2016). https://doi.org/10.1038/srep35070

# High Ambient Temperatures Accelerate Fatigue in Electrical Components

*IGBT Fatigue – Issue in Wind, Solar, BESS*

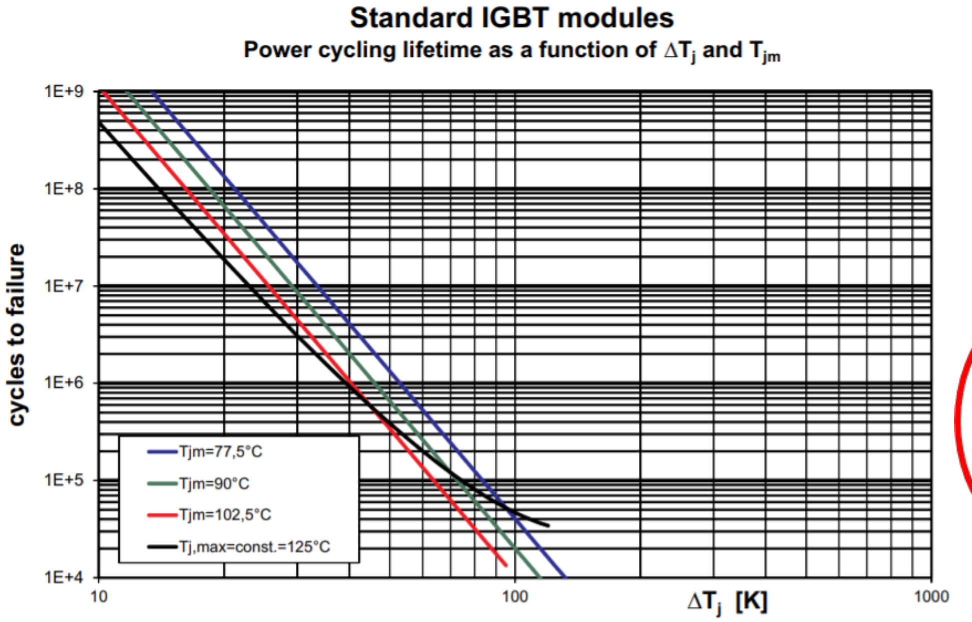
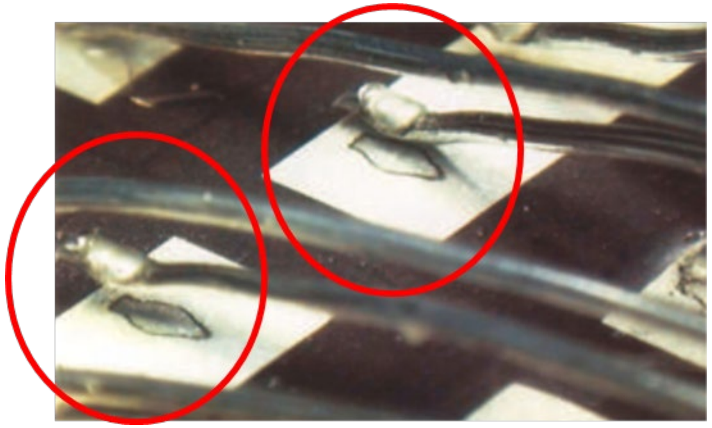


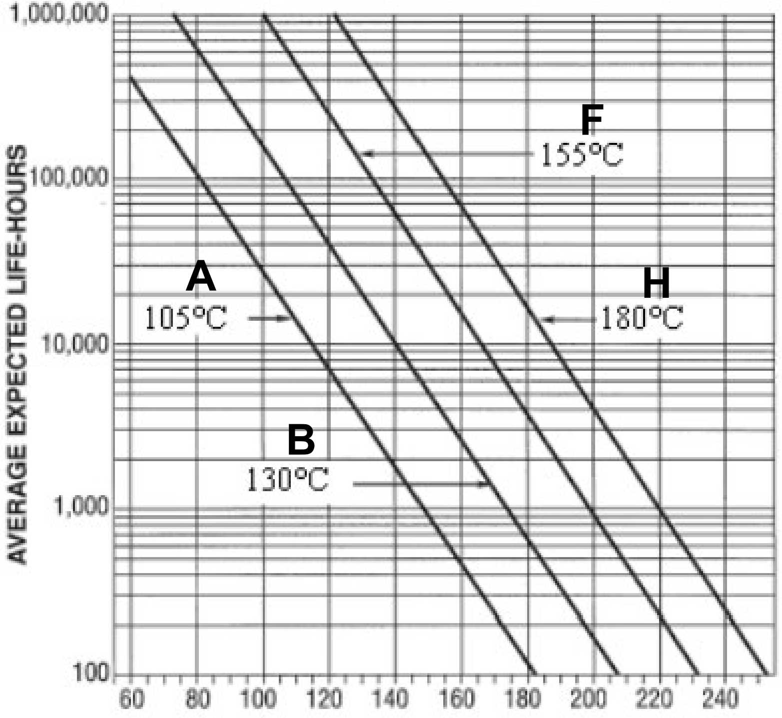

Figure 2.7.16 Dependency of the power cycling value $N_f$ as a function of the temperature cycling amplitude $\Delta T_j$ and the mean temperature $T_{jm}$ for standard IGBT modules

**Tjm = IGBT Junction Mean Temperature**
**ΔTj = Change in junction temperature due to power fluctuations**

**IGBT Bond Wire Fatigue**



*Generator Winding Thermal Fatigue for Four Insulation Systems – Issue in Wind*




**Winding Temperature Rise+ Ambient Temperature, Degrees C**

- Consistent high ambient temperatures can reduce design life by years. This must be properly accounted during the project planning and O&M process.



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# Climate Hazards and Adaptation Strategies – Wind Turbine  Example

| Field | Description | Example |
|---|---|---|
| Impact ID | Unique for each impact | 1.1 |
| Primary Concern | A loose sub-categorization within the asset class | Wind Turbine |
| Sub-System/Component | Further refinement of specific components | Rotor Blades |
| Impact | Brief description of a potential vulnerability | Icing reduces or shuts down production |
| Specific Impact Mechanism | Relationship between hazard and component | Blade icing can cause output reductions ranging from 20% (moderate) to 80-100% (severe) |
| Climate Hazard Threshold | When does the climate hazard become a concern? | Temp < 34F AND (Rel. Humidity > 0.75 and/or Rain > .001") |
| Threshold Type | Code, standard, rule of thumb, operational limit, etc. | Rule of Thumb |
| Component Threshold | When does the component begin to malfunction? | Blades lose X% production when ice accretion is Y |
| Consequence - Category | Outage, derate, accelerated aging, worker safety, environmental compliance, others? | Derate |
| Consequence - Numerical (if applicable) | If consequence is a derate, what percent is likely? | 20% for moderate, 80-100% for severe |
| Short term or Term Impact | Does the impact go away when the hazard does? | Short |

| Climate Variable | Primary system/component impacted | Adaptation Options |
|---|---|---|
| Air Temperature (High) | Drivetrain<br>Lubricants<br>Production Efficiency<br>Electronics | Heat exchangers – channel width considerations<br>Coolant – higher glycol ratio<br>Need to check temperature ranges of all electronic components |



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# EPRI Climate Resilience and Adaptation Initiative (READi)

CLIMATE READi
RESILIENCE AND ADAPTATION INITIATIVE

- **COMPREHENSIVE:** Develop a *Common Framework* addressing the entirety of the power system, planning through operations
- **CONSISTENT:** Provide an informed approach to climate risk assessment and strategic resilience planning that can be replicated
- **COLLABORATIVE:** Drive stakeholder alignment on adaptation strategies for efficient and effective investment

| Workstream 1 | Workstream 2 | Workstream 3 |
|---|---|---|
| **Physical Climate Data & Guidance** | **Energy System & Asset Vulnerability Assessment** | **Resilience / Adaptation Planning & Prioritization** |
| • Identify climate hazards and data required for different applications<br>• Evaluate data availability, suitability, and methods for downscaling & localizing climate information<br>• Address data gaps | • Evaluate vulnerability at the component, system, and market levels from planning to operations<br>• Identify mitigation options from system to customer level<br>• Enhance criteria for planning and operations to account for event probability and uncertainty | • Assess power system and societal impacts: resilience metrics and value measures<br>• Create guidance for optimal investment priorities<br>• Develop cost-benefit analysis, risk mitigation, and adaptation strategies |


## Deliverables: Common Framework

- Climate data assessment and application guidance
- Vulnerability assessment
- Risk mitigation investment
- Recovery planning
- Hardening technologies
- Adaptation strategies
- Research priorities



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