Cold Climate Degradation

An Analysis of Double-Axis Tracked, E-W Vertical, and Fixed-Tilt Photovoltaic Deployments in Alaska

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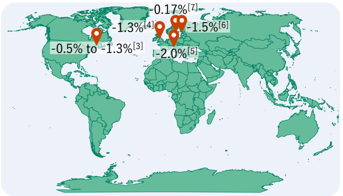
INTRODUCTION

1

- Photovoltaics pushing towards higher latitudes due to low cost, distributed nature, and energy accessibility
- Degradation rates depend on technology type, tracking type, mounting configuration, climate



Global average all climates = -0.8% per year [1]
Global median module-level = -0.5% per year [1]
USA median system-level = -0.75% per year [2]

COLD CLIMATE RELIABILITY

- Performance & reliability uncertainty at high latitudes due to extreme operating conditions like snowfall, freeze-thaw cycles, high wind loads [1]
- Only a few studies have examined cold climate PV degradation rates so far, values ranging from -0.2% to -2.0% per year [3-7]

GOAL: Add to existing sparse cold climate degradation literature using site data in Alaska

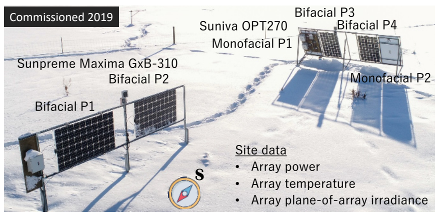
ANALYZED SITES

2

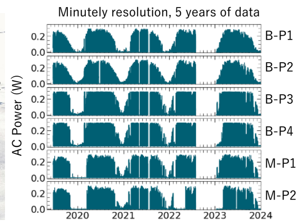
FIXED-TILT SITE

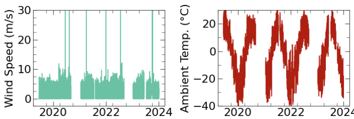
Fairbanks, Alaska, 65°N 148°W

Bifacial test-site maintained by Alaska Center for Energy and Power, using monofacial PERC & frameless bifacial SHJ modules[8]



Site data
- Array power
- Array temperature
- Array plane-of-array irradiance





Site meteorological station
- Wind speed
- Ambient temperature
- GHI, DNI, DHI
- Albedo

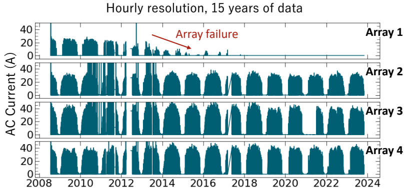
Point of contact for data: Chris Pike, cpike6@alaska.edu

DOUBLE-AXIS SITE

Fairbanks, Alaska, 65°N 148°W

Four-array double-axis tracking site maintained by the Cold Climate Housing Center using AI-BSF technology [9]

Trackers are turned off during winter months, around November to March



Site data
- Array power
- Array temperature
- Array plane-of-array irradiance
- Tracking information

Rooftop meteorological station
- Wind speed
- Ambient temperature

Data publicly available at: http://cchrc.rcs.alaska.edu

METHODOLOGY

Plots for E-W vertical bifacial (B-P1) case

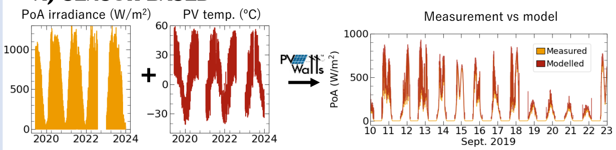
General procedure completed using RdTools, available on GitHub [10]
PV site data accessed using NREL's PVDRDB

3

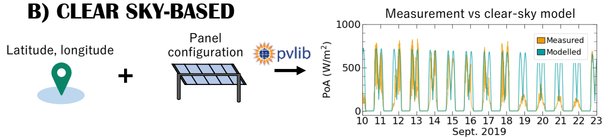
1) NORMALIZE

Normalize measured insolation with modelled insolation.

A) SENSOR-BASED

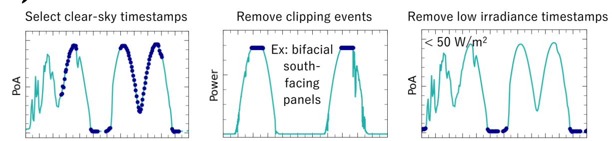


B) CLEAR SKY-BASED



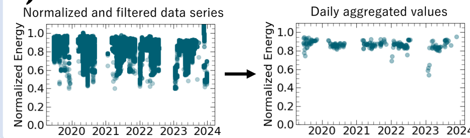
2) FILTER

Exclude invalid data or data that would create bias in the analysis.



3) AGGREGATE

Aggregate normalized and filtered data into daily insolation values.

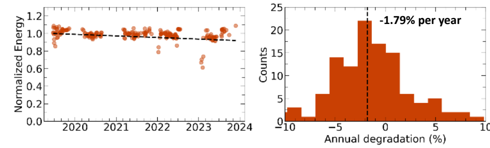


- Average daily irradiance & temperature weighted value
- Reduces high error data from morning and evening

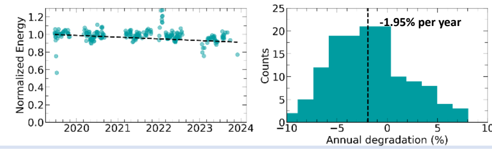
4) DEGRADATION

Calculate year-on-year degradation rates by comparing rate of change between the same days of different years.

A) SENSOR-BASED



B) CLEAR SKY-BASED



DEGRADATION RESULTS

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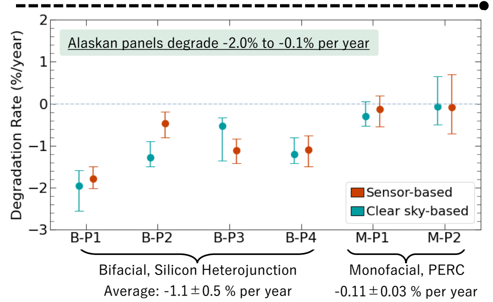


Bifacial, Silicon Heterojunction
Average: -1.1 ± 0.5 % per year

Monofacial, PERC
-0.11 ± 0.03 % per year

Analysis completed for fixed-tilt site so far

Notable trends
- Clear-sky & sensor-based analysis give comparable results
- No significant difference between vertical and south-tilted panels – more data required

Summary of degradation analysis results, sensor-based method

	Configuration	Tech.	Degradation (%/year)	Data Points	Bimodality	Mean Deviation	Skewness
B-P1	E-W Vertical	SHJ	-1.79	121	0.724	2.41	-0.08
B-P2			-0.47	140	0.990	1.81	0.08
B-P3	South-Tilted		-1.11	126	0.996	2.41	-0.09
B-P4			-1.10	123	0.895	2.50	-0.12
M-P1	South-Tilted	PERC	-0.13	161	0.990	3.27	0.07
M-P2			-0.08	105	0.963	3.83	0.03

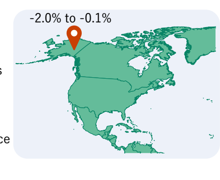
Technology-driven
- Bifacial SHJ degrading faster than monofacial PERC
- SHJ literature survey reported median degradation rate of -0.8% per year, most data falling -0.5% to -1.0% per year [12]
  ↳ Alaskan degradation ⇧
- Common SHJ failure mechanisms are passivation loss and encapsulant browning [12]
- SHJ hydrogen migration and degradation of a-Si:H/c-Si interface known to occur, can be caused by moisture and UV exposure [11,12]
- Monofacial PERC degradation rates previously reported typically fall between -0.5% to -0.9% per year [2,11]
  ↳ Alaskan degradation ⇩

CONCLUSIONS

5

↳ Analyzed 5-year degradation rates of 6 panels deployed in Fairbanks, Alaska, finding degradation rates between -2.0% to -0.1% per year

↳ Technology-driven: Variation in degradation rates across 6 different panels is primarily driven by different cell technologies, not system configuration



Future Work
- Examine Alaskan module degradation mechanisms using electroluminescence
- Complete analysis for 15-year double-axis tracking site
- Explore other potential site data available for Alaska & the Canadian Arctic

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ACKNOWLEDGEMENTS

This work was authored [in part] by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number 34910. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

PVRW, February 27-29, 2024
Lakewood, Colorado,
NREL/PO-5K00-89053