Impacts of albedo estimation method on energy estimates

Halley Darling, Renn Darawali, and Lucila D. Tafur | UL Solutions | halley.darling@ul.com

November 14, 2023

INTRODUCTION

During solar energy estimation for bifacial systems, selecting any singular satellite model for albedo can lead to high albedo uncertainty as multiple available satellite modeled albedo datasets often differ significantly at a given location. Direct use of on-site albedo measurements increases confidence in albedo magnitude for a specific time frame, however, may lack coverage for year-to-year albedo variability (IAV) from snow or vegetation. This study investigates:

1) differences in energy estimation between several satellite-modeled albedo sources and on-site measurements
2) IAV impacts on energy estimation
3) the necessity of measure-correlate-predict (MCP) analyses on albedo

Objective: Determine the impact of albedo data source on net energy for a sample bifacial project.

METHODS AND ANALYSIS

Test Setup:

- 34 on-site albedo measurement stations, each with a minimum of one year, covering varying regions of the U.S.
- Three individual satellite models of monthly average albedo, labeled models A, B, and C.
- Two long-term satellite models with year-and-month albedo, labeled 1 and 2.

PVsyst Analysis:

- Test case is a single inverter block of a generic 440W bifacial solar panel with 80% bifaciality, unlimited single-axis trackers.
- For each site, 5 monthly albedo sources were varied: on-site albedo, a “PVsyst generic” albedo of 0.20 for every month, and models A, B, and C.
- Results in Net Energy (EGrid) for each test case.

IAV Analysis:

- 5 sites with two years of measured albedo data, compare Year 1 annual albedo to Year 2.
- 2 satellite modeled long-term albedo sources compare regional differences in IAV.

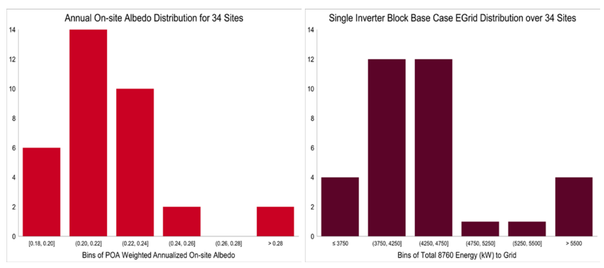

Figure 1 *Distribution of On-site Albedo (top) and resulting Egrid (bottom) for 34 test sites.*

FINDINGS

Despite significant annual differences in albedo, energy impacts were well within ±1% at 1SD.

Annual albedo estimates differ from on-site measurements on average by -0.017 ±0.023 across three models, but only translates to a -0.3% ±0.5% energy difference.

Distribution of individual models’ differences can vary but note the sample of projects within “typical” albedo range may affect these distributions.

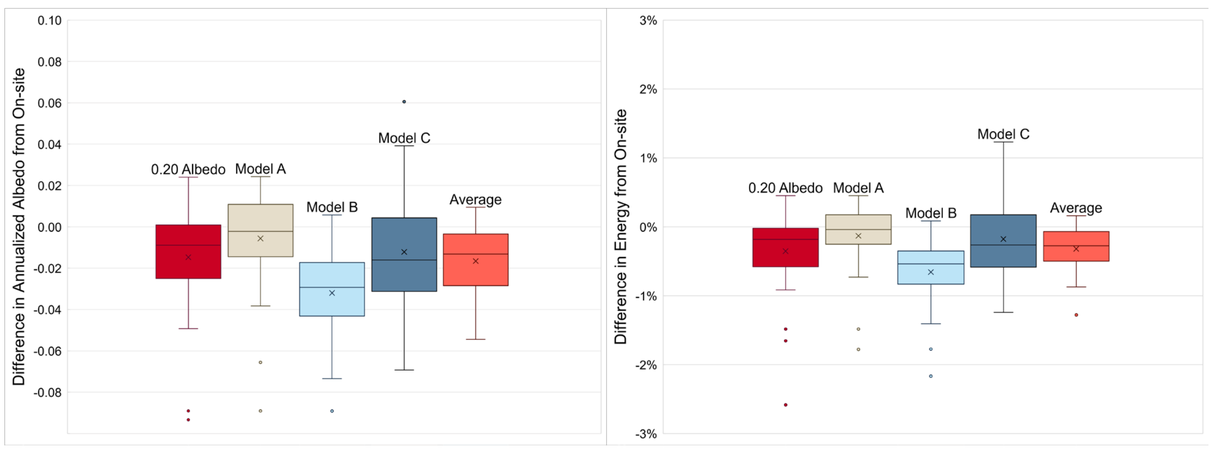

Figure 2 *Distribution Comparison of Albedo (left) and Energy (right) to On-Site Scenario*

FINDINGS (CONTINUED)

Averaging three models monthly before analysis retains the same average differences but reduces standard deviation.

Annual albedo estimates remained an average of -0.017 albedo and -0.3% energy, but standard deviations dropped to ±0.015 albedo and ±0.3% energy. Regressions of albedo difference to energy impact suggest a 1/6 factor for this experiment, i.e., 0.06 annual albedo difference = 1% Energy difference.

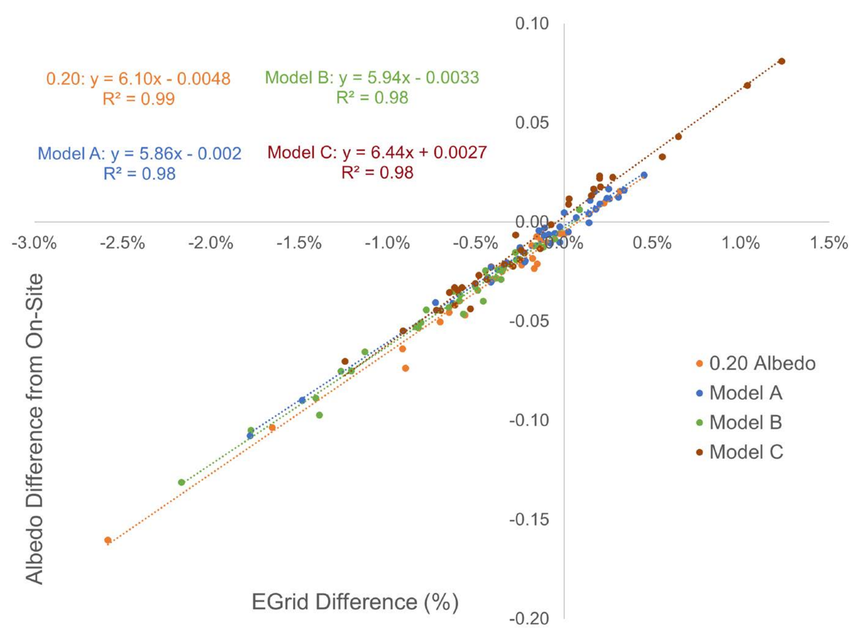

Figure 3 *Absolute Albedo Difference vs EGrid Difference to On-Site Albedo Scenario at 34 Sites for Four Modeled Albedo Sources*

Albedo IAV varies regionally more than by model.

On-site albedo measurement of only one year does not inherently capture IAV, which two timeseries models predict 0.00-0.04 albedo standard year-to-year differences; two years of albedo data at highly varied sites in snow regions may provide additional coverage. Investigating these year-to-year differences at five sites with two years of albedo data demonstrate similar regional IAV differences as modeled.

Site	1 (CA)	2 (PA)	3 (PA)	4 (TX)	5 (OH)
Year 1	0.23	0.29	0.28	0.19	0.25
Year 2	0.22	0.24	0.22	0.18	0.24
Average	0.22	0.26	0.25	0.19	0.24
± (IAV)	**0.00**	**0.02**	**0.02**	**0.01**	**0.01**
Max Monthly	*0.02*	*0.13*	*0.13*	*0.07*	*0.13*

In high IAV environments on-site albedo measured at max or min could result in ~1% annual energy difference from a typical albedo.

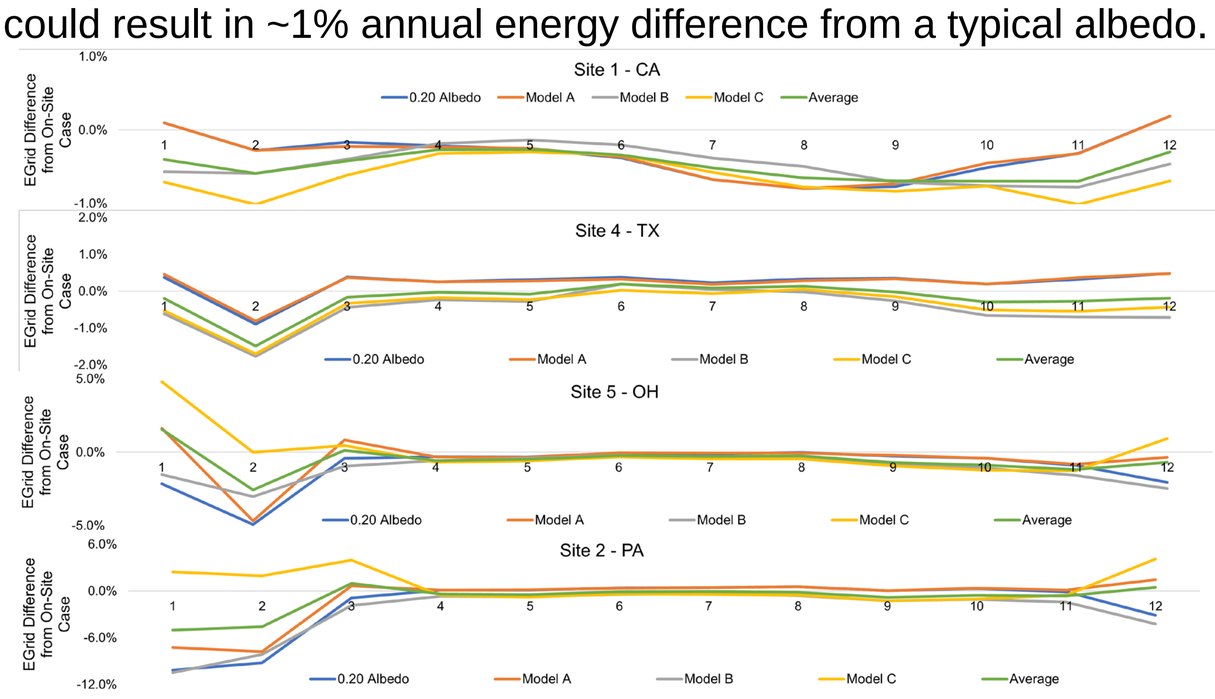

Figure 4 *Four case study sites of monthly differences in energy from the on-site scenario for several modeled albedo data sources. Note that the range of differences increases from ±1% to as high as 12% from top to bottom graphs.*

CONCLUSIONS

- Differences in annual albedo estimates from measured albedo data translate to minimal differences in energy – up to a standard deviation maximum of 0.5%. Utilizing a monthly average from multiple models before estimating energy may serve to further reduce the standard deviation of the energy estimate.
- Due to the low energy sensitivity observed, an MCP analysis on albedo may not result in higher quality energy results, except in environments with extreme IAV, as identified by both long-term modeled albedo and two-year on-site IAV.

UL Solutions

Safety. Science. Transformation.™