Sensitivity of Modelled Bifacial PV Module Gain to Albedo Granularity Levels

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Abstract

With the resurgence of bifacial modules in recent years due to falling processing costs and technology improvements, accurate energy modelling of bifacial systems has become an important topic of discussion in the solar industry. An input of importance for determining rear-side gains is the ground albedo, but industry consensus has not yet been developed with respect to the albedo time-step granularity that should be utilized in modelling. Using measured albedo and meteorological data at two Texas sites, this study examines the effect of albedo resolution on modelled bifacial gain. Using CASSYS modelling software, it was determined that for both sites the albedo measurement granularity is unlikely to have a material impact on bifacial gain when considered in context of the overall energy generation of a PV system.

Data Collection and Processing Methodology

- GHI was measured using SR30 pyranometers (two at Site 1, one at Site 2), and DHI and DNI were measured using a SPN1 pyranometer. Additional GHI measurements were obtained using the albedometer at both sites.
- Temperature and wind speed were measured using a WS500 sensor.
- Broadband albedo was measured at both sites using an SRA20 albedometer, consisting of two ISO 9060 secondary standard pyranometers.
- Analog output signals were measured using a CR1000 datalogger, which also applied manufacturer temperature correction and applied heat to the pyranometer domes to suppress dew and ice.
- Cleaning and leveling of albedometers took place weekly at both sites.
- Data samples were taken every three seconds and averaged over one hour intervals. Data was taken for a period of one year at Site 1 and three months at Site 2.
- The following filters were applied to the data:
  - GHI was averaged between the two sensors (in the case of Site 1, if the value differed between the two sensors by >2%, the median value of the two GHI sensors and the GHI reading of the albedometer was taken).
  - GHI values <10W/m^2 were set to zero and albedo in these hours was also set to zero to avoid angular error effects (GHI in these hours represented around 0.1% of annual GHI)
  - Albedo was filtered such that values with missing data, negative values, or values greater >1 were set to equal the data two weeks ahead.
  - Further erroneous albedo data-points from Site 1 were identified and a filter for any values >0.3 was added to instead use the two week ahead data (GHI in these hours represented around 0.3% of annual GHI).
  - Wind speed was filtered such that values >15m/s were replaced either with the average values in the preceding and subsequent hours, or the two week ahead value
- Hourly albedo was further processed to generate values with varying granularity

Representative System Model Specifications

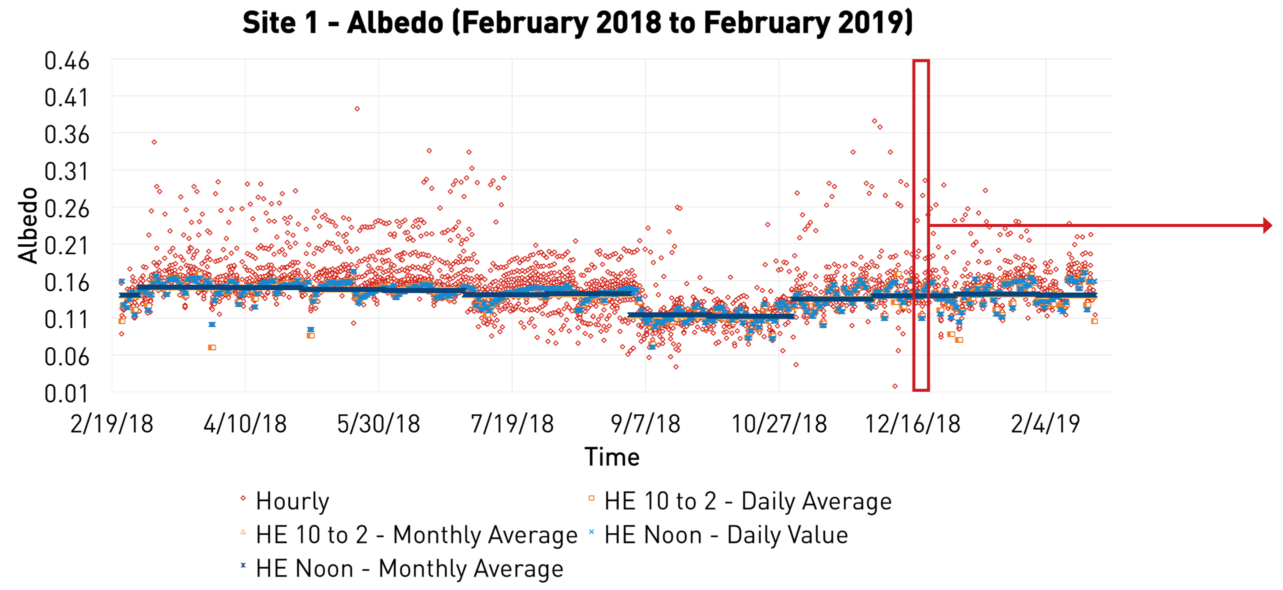
CASSYS uses a view-factor bifacial model based on NREL's "Practical Irradiance Model for Bifacial PV Modules" with slight differences in the CASSYS model for the calculations of partial array shadings, the front reflected component of irradiance, and incidence angles for ground reflected and diffuse components of the irradiance. CASSYS also assumes an isotropic sky, and the model parameters in the table below were used for both sites in this study:

System Parameter in CASSYS	Value
Tracker Limits	±52° (SAT)
Tracker Height	1.5
Number of Rows	100
GCR	0.35
Bifaciality Factor	72%

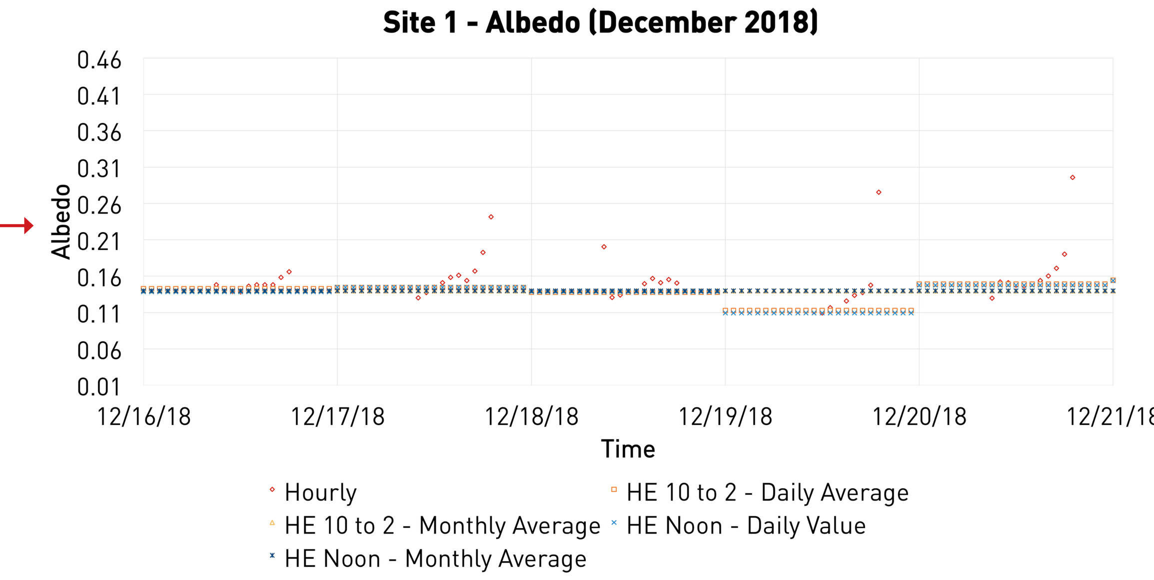
Data and Results – Site 1

Albedo Data

Site 1 - Albedo (February 2018 to February 2019)

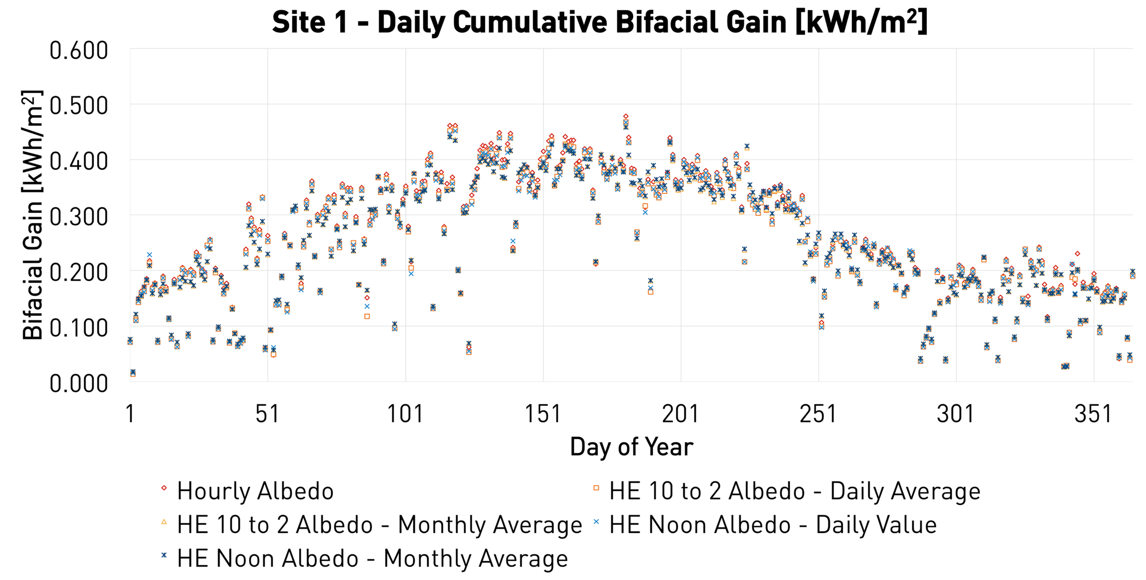


Site 1 - Albedo (December 2018)



Results

Site 1 - Daily Cumulative Bifacial Gain [kWh/m²]



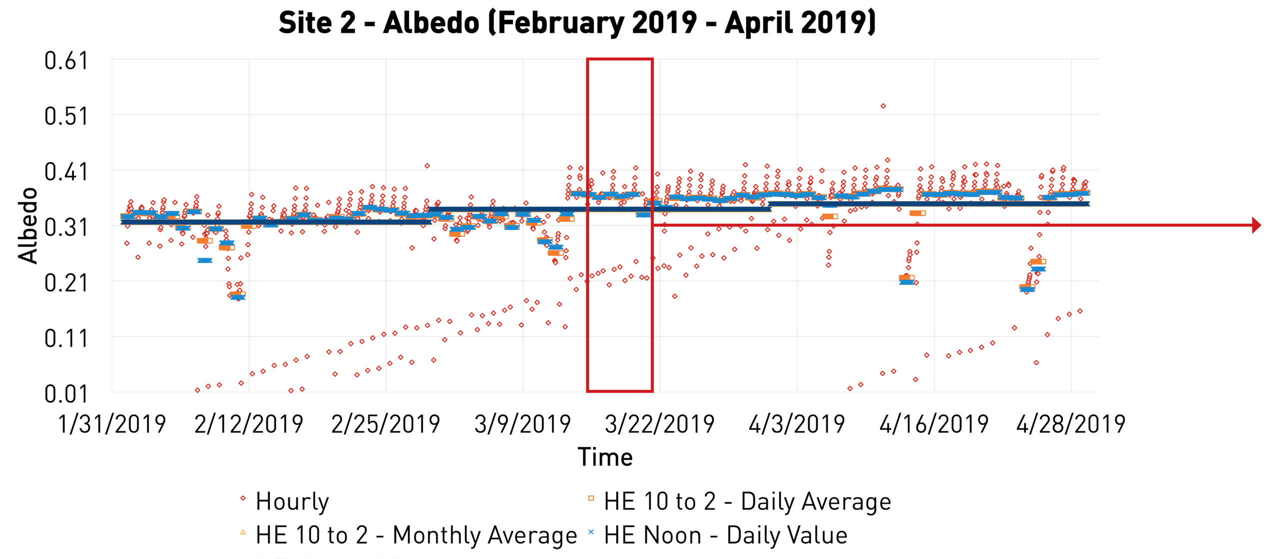
Site 1 - Monthly Bifacial Gain: % of Annual Front Side Irradiation

Month	Hourly Albedo	HE 10 to 2 Albedo - Daily Average	HE 10 to 2 Albedo - Monthly Average	HE Noon Albedo - Daily Value	HE Noon Albedo - Monthly Average	Mean ± Std. Dev.
January	0.23%	0.22%	0.22%	0.22%	0.22%	0.22% ± 0.00%
February	0.22%	0.22%	0.21%	0.22%	0.21%	0.22% ± 0.00%
March	0.40%	0.39%	0.39%	0.39%	0.39%	0.39% ± 0.00%
April	0.45%	0.44%	0.44%	0.44%	0.43%	0.44% ± 0.01%
May	0.52%	0.50%	0.50%	0.50%	0.50%	0.51% ± 0.01%
June	0.54%	0.53%	0.53%	0.53%	0.53%	0.53% ± 0.01%
July	0.52%	0.51%	0.51%	0.51%	0.51%	0.51% ± 0.00%
August	0.48%	0.47%	0.47%	0.48%	0.48%	0.48% ± 0.00%
September	0.32%	0.31%	0.31%	0.31%	0.31%	0.31% ± 0.00%
October	0.24%	0.24%	0.23%	0.24%	0.23%	0.24% ± 0.00%
November	0.23%	0.23%	0.22%	0.23%	0.22%	0.23% ± 0.00%
December	0.21%	0.20%	0.20%	0.20%	0.20%	0.20% ± 0.00%
Annual	**4.36%**	**4.26%**	**4.22%**	**4.27%**	**4.23%**	**4.28% ± 0.06%**

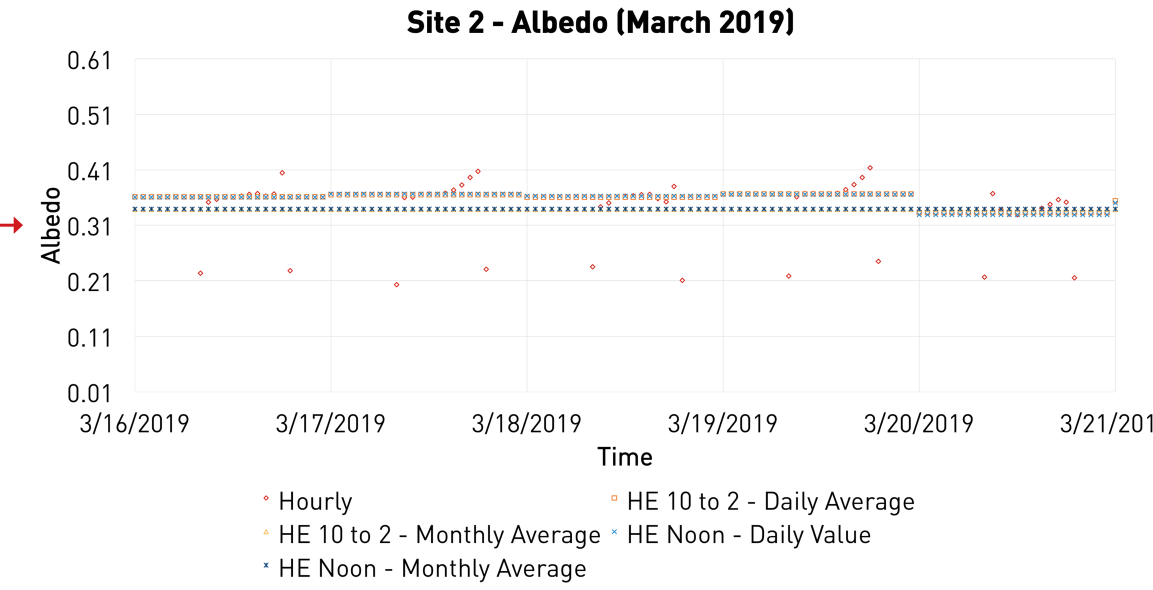
Data and Results – Site 2

Albedo Data

Site 2 - Albedo (February 2019 - April 2019)

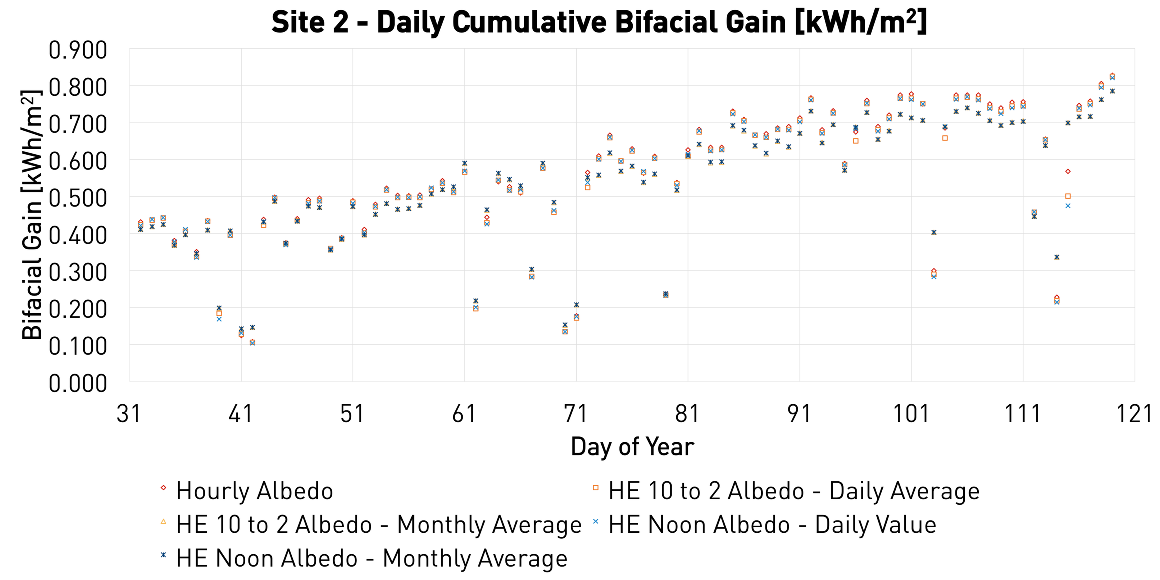


Site 2 - Albedo (March 2019)



Results

Site 2 - Daily Cumulative Bifacial Gain [kWh/m²]



Site 2 - Monthly Bifacial Gain: % of Cumulative Months Front Side Irradiation

Month	Hourly Albedo	HE 10 to 2 Albedo - Daily Average	HE 10 to 2 Albedo - Monthly Average	HE Noon Albedo - Daily Value	HE Noon Albedo - Monthly Average	Mean ± Std. Dev.
February	1.93%	1.91%	1.88%	1.91%	1.87%	1.91% ± 0.02%
March	2.76%	2.73%	2.69%	2.74%	2.69%	2.73% ± 0.03%
April	3.31%	3.26%	3.21%	3.25%	3.21%	3.26% ± 0.04%
Cumulative	**8.00%**	**7.90%**	**7.77%**	**7.90%**	**7.77%**	**7.89% ± 0.09%**

Conclusions and Next Steps

Based on the results from both sites, it is evident that the selection of albedo granularity (hourly versus daily versus monthly) has a limited impact on rear irradiation as a percent of monthly or annual irradiation. While hourly albedo values that have large deviations from the average can occur in shoulder hours, irradiation in these hours tends to be low. This results in a limited impact of albedo granularity on site energy generation relative to other modelling inputs.

There are a number of further areas of exploration relevant for expanding upon and validating the results presented in this study. Subsequent analyses with respect to albedo granularity should be carried out for:

- Longer periods of data.
- Different site locations such as sites with differences in latitude, ground cover type and weather patterns including snow.
- Different system parameters including GCR, tracker height and module spacing.

Site 1 - Albedometer

Site 2 - Albedometer

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