



## Performance of Bifacial Photovoltaic Dual-Axis Trackers in a High-Latitude, High-Albedo Environment

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### Introduction

Although solar capacity is growing rapidly in northern regions of the US, driven by lower PV costs, snow build-up on modules in winter can reduce energy yields by 1-12 percent a year. Identifying technologies and designs that maximize energy production under low-light, snowy conditions could further improve the economics of PV at high latitudes and expand solar resources in those area

### Objectives

The aim of this research was to:

- Quantify annual energy yields for bifacial dual-axis trackers in a wintry climate
- Compare the performance of different bifacial module technologies against monofacial modules
- Evaluate the overall tracker performance in terms of backside shading and tracking accuracy

### Methods

In 2017, we installed two dual-axis tracker systems in Vermont, populating half of each tracker with monofacial modules; the other half with bifacials. Each tracker has two strings of ten modules each; one string per tracker is bifacial, the other is monofacial. Monofacial and bifacial modules on the same tracker have the same form factor and similar electrical characteristics. Each tracker has a DC monitoring system (string-level current and voltage sensors), plane-of-array reference cells and back-of-module thermocouples. We also installed a tripod-mounted albedometer at a height of 1.2m above the ground and a camera that captured frontside images every 15 minutes.

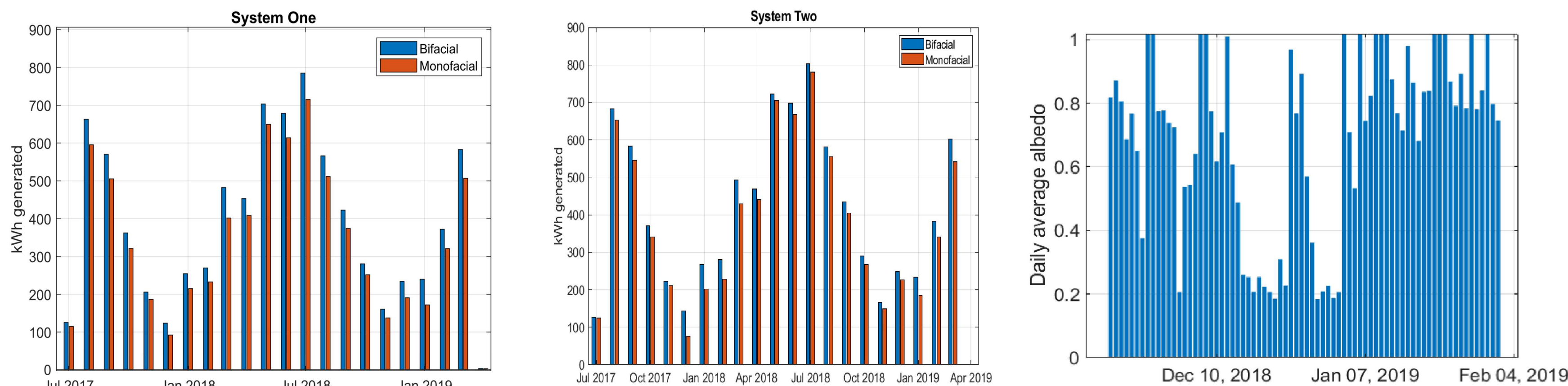
| PV System   | No Modules | No cells | Module Technology          | Cell Type      | Max Power | Frame Type | Backsheet   |
|-------------|------------|----------|----------------------------|----------------|-----------|------------|-------------|
| Tracker One | 10         | 60       | Monofacial                 | c-Si, P type   | 290W      | Framed     | White       |
|             | 10         | 60       | Bifacial (92 % infacility) | c-Si, N type   | 290W      | Frameless  | Glass       |
| Tracker Two | 10         | 72       | Monofacial                 | c-Si, P type   | 325W      | Framed     | White       |
|             | 10         | 72       | Bifacial (62% bifaciality) | c-Si mono PERC | 325W      | Framed     | Transparent |

### Results and Discussion

Over the course of two years, we measured DC output at a frequency of every 5 seconds (averaged per minute) for each subarray. The results are presented here.

#### Energy Performance

- The bifacial string on Tracker One, generated 13 percent more power over the course of the study than the monofacial string. Tracker Two, which had less efficient mono-PERC cells, saw a percentage increase of 11 percent.
- The largest bifacial gains are seen in winter [Figure 3] when snow on the front of the module blocks solar radiation and snow on the ground reflects solar insolation to the rear.
- Although the Tracker Two bifacials outperformed Tracker One bifacials, the difference was 403 kWh, or less than 5 percent, with a temperature correction to 25 degrees C.



The bifacial subarray consistently outperforms the monofacial string, resulting in a 13-percent energy yield for Tracker One and 11 percent for Tracker Two.



Figure 1. Bifacial dual-axis Tracker System Two. 72-cell bifacial modules populate the left half; 72-cell monofacials are on the right. Back-to-back plane-of-array EETS reference cells on the lower edge of the module measure irradiance on both sides of the tracker platform (right).

#### Snow Shedding as a Contributor to Performance

Our data show that snow sheds faster from bifacial modules than from monofacials, further increasing the bifacial advantage. We surmise that irradiance entering the backside warms the bifacial modules and accelerates shedding, as evidenced by the increase in bifacial gain that occurs when bifacial module temperatures increase, causing snow to shed. [Figure 10].



Figure 4. Time-stamped images of Trackers One and Two demonstrate that bifacial modules shed snow more quickly than the monofacial modules and that frameless modules (right) shed more quickly than framed (left).

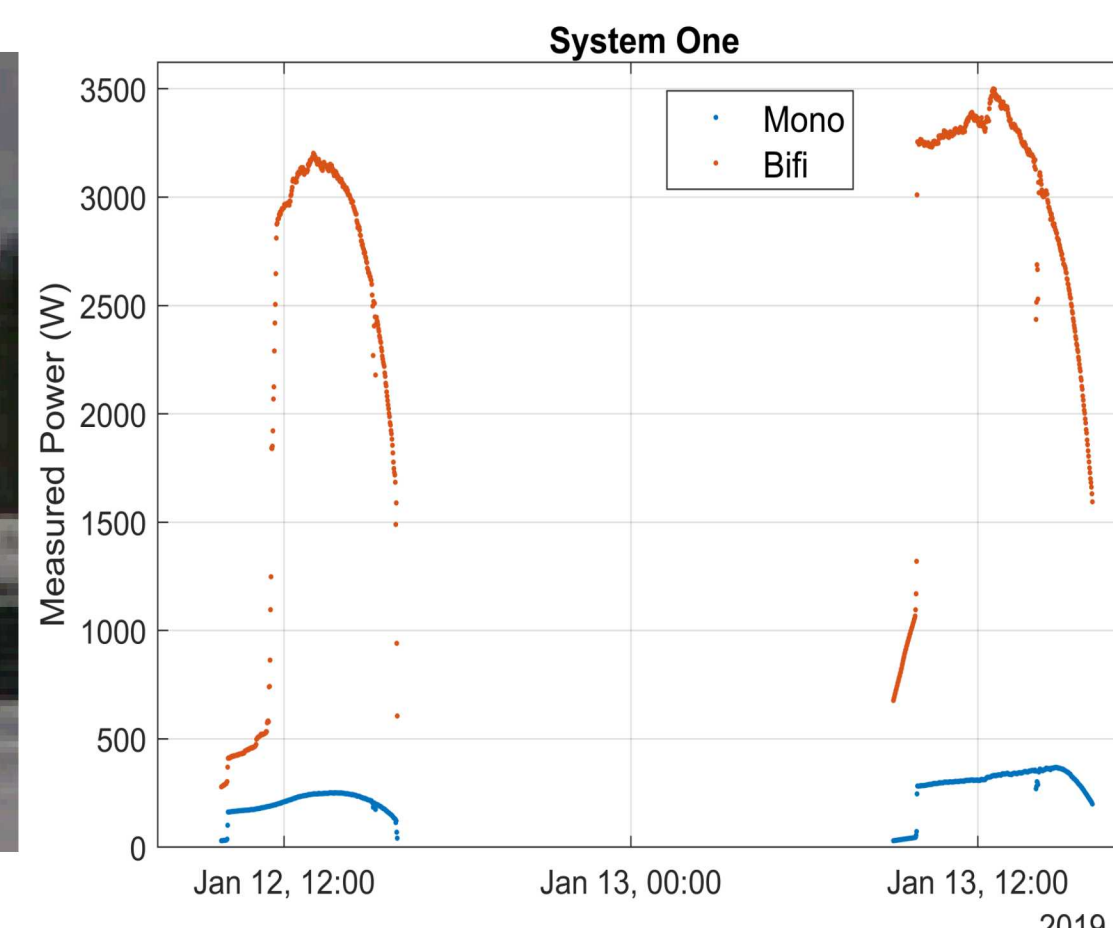


Figure 11. Data for power output from System One shows that the monofacial modules shed snow 1.75 days after the bifacial modules shed snow, resulting in measurable differences in power production.

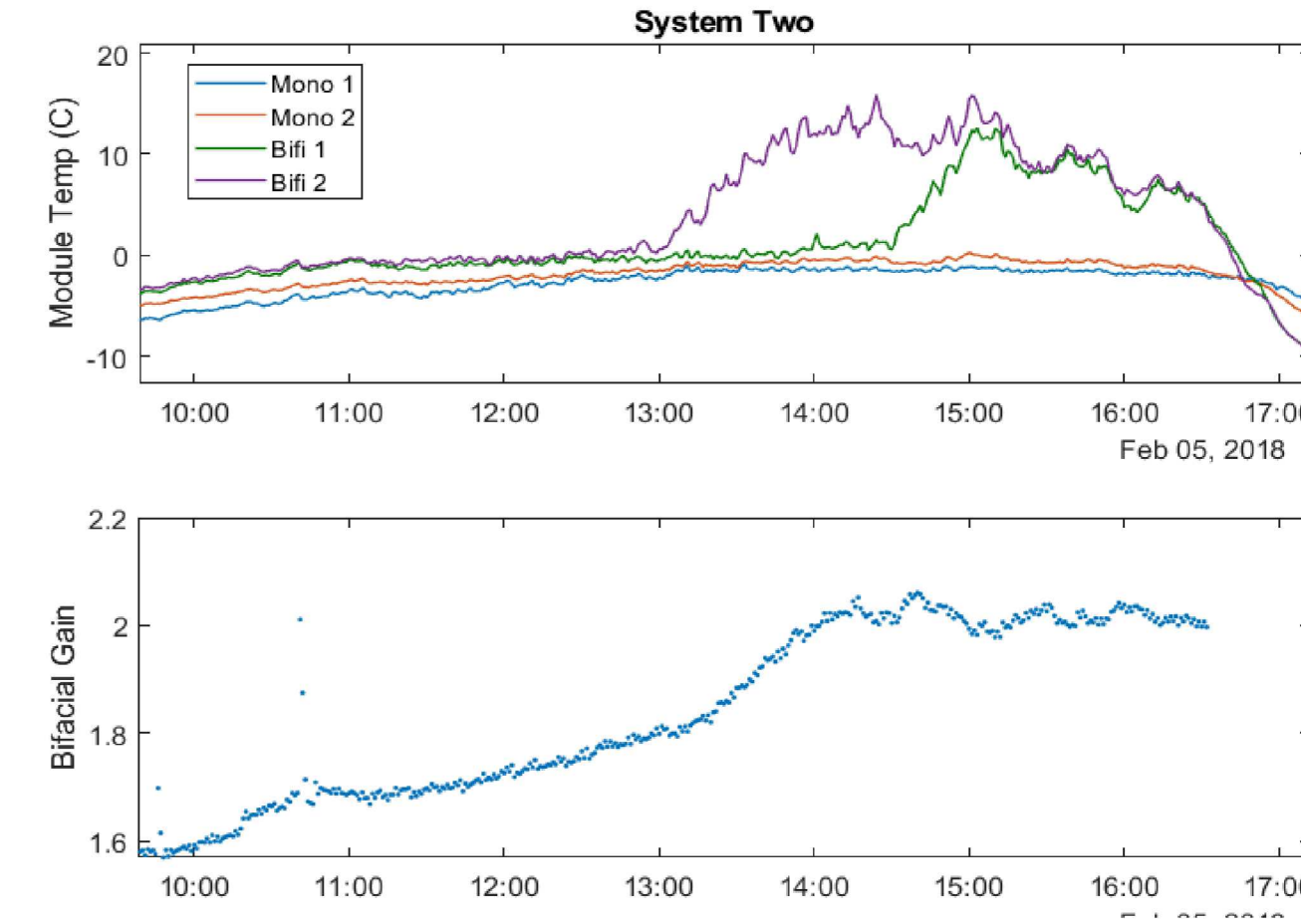
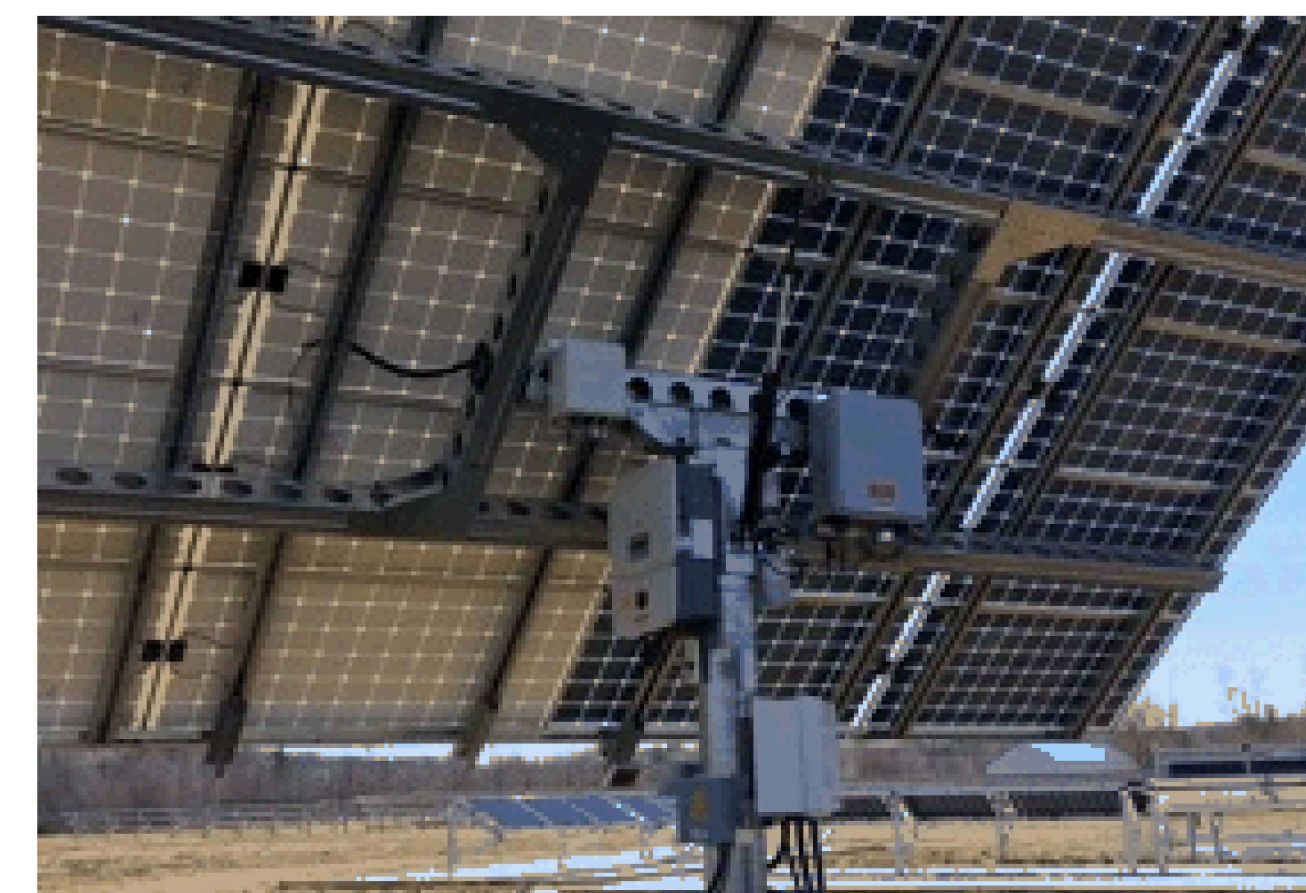


Figure 10. Back-of-module temperatures (top) and bifacial gain (bottom) are depicted for a 7-hour period in February 2018. As snow slides from the bifacial modules, the difference in back-of-module temperature increases between the bifacial and monofacial modules and bifacial gain increases.



Backside of Tracker One, which was not designed for bifacial modules, shows support structure that partially shades the backside.

#### Tracker Performance

Because the trackers were not designed for bifacial modules, their support structure partially blocks the backside. Calculated total energy losses from backside shading, however, were only 1.6 percent for Tracker One and 1.1 percent for Tracker Two. A redesign could improve those percentages, but the economic value would have to be considered.

To verify tracking accuracy, we measured the error of the trackers' elevation and cross-elevation axes with in-plane tracking-error monitors. Our analysis shows consistent tracking between September 2017 and August 2018, with errors of less than 5 degrees.

### Conclusions

Our study shows that bifacial dual-axis tracker systems generate significantly more energy than monofacial dual-axis tracker systems. The bifacial subarray on Tracker One produced from 13 to 14 percent more power per year on average than the monofacial string; bifacials on Tracker Two produced from 11-12 percent more. These results suggest that bifacial dual-axis trackers are a viable—and easy—path to lower levelized cost-of-energy for PV in northern climates.

These gains reflect the:

- Choice of cell type, module design and tracker architecture, with more efficient cells generating more kWhs than less-efficient cells
- Reflectivity and high-albedo of snow
- Accelerated snow shedding enabled by 1) frameless modules and 2) backside irradiance that increases module temperature
- Height of the modules relative to the ground, which increases total light reaching the backside
- Ability of two-axis trackers to maximize the amount of direct normal irradiance striking the front of the array

Overall, our work strongly suggests there are measurable energy advantages to deploying bifacial dual-axis PV systems in regions that consistently see snow in winter.

### References

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