Technology Validation: Assessing Real-world Energy Generation of Bifacial Modules

1. Problem Statement

New technologies often show great potential in ideal or modeled conditions, however real world performance is uncertain. Accurately assessing the performance of new technologies in real world situations is both challenging and critical. It is not always possible to coordinate on-site measurements to match with good weather conditions, and characterizing the contribution of different factors (such as albedo) requires simultaneous data acquisition. Continuously monitoring module performance (IV curves), front, and rear irradiance allows for real-world performance assessment and a better understanding of the impacts of new technologies.

2. Our Approach

We deployed MSI IV DAQs alongside front and rear facing reference cells to allow for detailed analysis of bifacial gain in changing conditions throughout the day, to assess bifacial impact on energy generation. Quantifying bifacial gain enables substantially more accurate energy generation forecasting, and Morgan Solar has developed tools enabling us to:

- Measure and analyze bifacial gain directly
- Assess the % of rear-side irradiance captured as energy
- Validate bifacial performance models
- Assess seasonal variation of bifacial performance

3. Results

This test protocol allows us to directly assess the impact of bifaciality on energy production in an operational solar field. By comparing front and rear side irradiance with the Pmp of the module in a wide range of conditions we were able to assess bifacial performance at two sites. Bifacial contribution was found to vary significantly both between sites and in different weather conditions. These insights enable significant improvements in energy forecasting models and reduce uncertainty in energy claims.

Bifacial Power Assessment:

Front and Rear Side Energy Contribution

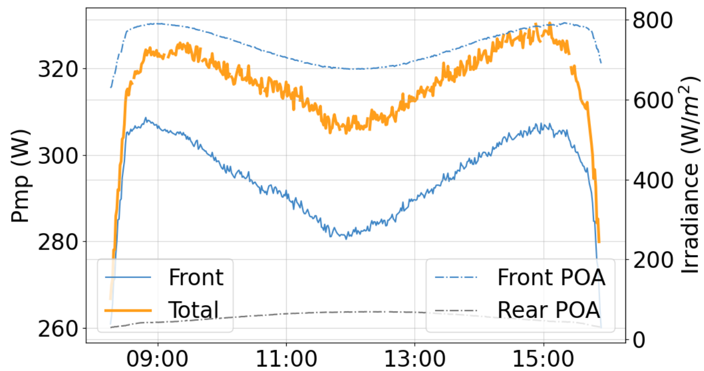

Fig 1: Power Produced, site 1 rear/front irradiance= 0.07

Energy Ratio (total/front)	105.24%
Irradiance Ratio (total/front)	107.21%
Bifacial Efficiency	72.65%
Bifacial Gain (kWh)	5.23%

The percent of rear-side irradiance captured is analyzed using a bifacial efficiency:

$$Bifacial\ Efficiency = \frac{Rear\ Side\ Energy}{Rear\ Irradiance} = \frac{(Energy\ Ratio - 1)}{(Irradiance\ Ratio - 1)}$$

Bifacial Gain is calculated as:

$$Bifacial\ Gain = \frac{Bifacial\ Yield - Monofacial\ Yield}{Monofacial\ Yield}$$

Site Dependent Bifacial Gain

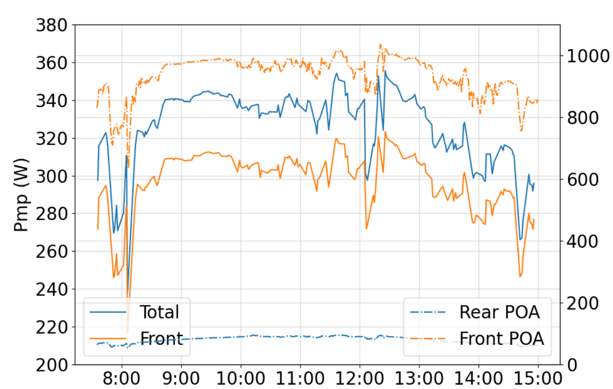

Fig 2: Power Produced at site 2 (urban), rear/front irradiance = 0.08
Model applies to sites with more complex irradiance and albedo conditions

Energy Ratio (total/front)	107.27%
Irradiance Ratio (total/front)	108.57%
Bifacial Efficiency	84.88%
Bifacial Gain (kWh)	7.27%

The contribution of the rear cells on the bifacial module varies based on local impacts: for example, ***the rear-side bifacial gain of the same technology deployed at two different sites is 5.23% and 7.27%.***

Time Dependent Bifacial Gain

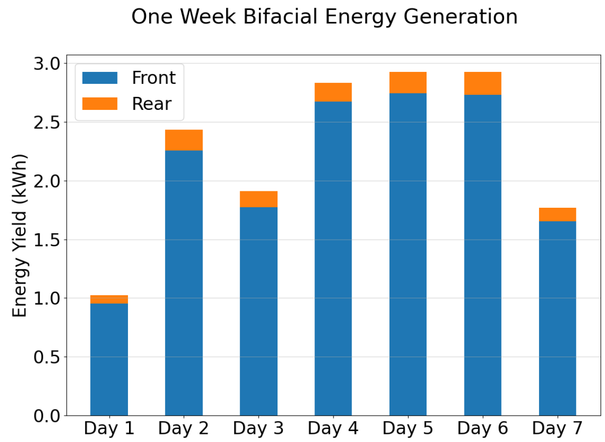

Fig 3: Variation in Rear-Side Contribution with Time

Bifacial contribution also varies with time and weather conditions. Assessing the *yield* impact of bifaciality unlocks a real-world understanding of bifacial energy generation as opposed to simplified/modeled scenarios.

A better understanding of site-specific bifacial gain allows better yield forecasting, and affirms the bankability of a specific bifacial gain.

Rear Irradiance Dependent Bifacial Gain

Continuous data collection allowed us to build a model of bifacial contribution and validate it by comparing the power produced by the bifacial module to a control (monofacial) module. This additional datapoint allows us to plot change in effective yield with variance in rear-side irradiance and generate an improved site-specific bifacial yield forecasting model including site-dependent bifaciality factors, allowing for location specific energy generation forecasting.

	Site 1	**Site 2**
Measured Bifacial Gain at 64.5 W/m^2 Rear irradiance (kWh)	8.23 %	7.16 %
Expected Rear-side Power	31.27 W	27.21 W

4. Implications and Significance

As is the case with many new technologies, bifacial panels often make performance claims based on ideal or modeled conditions. ***Performance models developed with actual site-measured data enable far greater certainty in bifacial performance forecasts.*** Using MSI IV DAQs on an installed and functioning solar plant, it is possible to isolate and assess effective bifacial efficiency and bifacial gain. Bifacial gain was found to vary significantly between sites; our studies have found up to 31% variance in bifacial contribution depending on local module configuration.

Assessing and affirming bifacial energy gain has material implications on modeling and bankability of this new technology. Morgan Solar continues to develop our tools and analysis methods to address difficult questions and assess energy impacts of novel technologies in the ever-evolving solar landscape.