Comparative Study on Outdoor Performance of PV Modules with Mono-facial and Bifacial Cells

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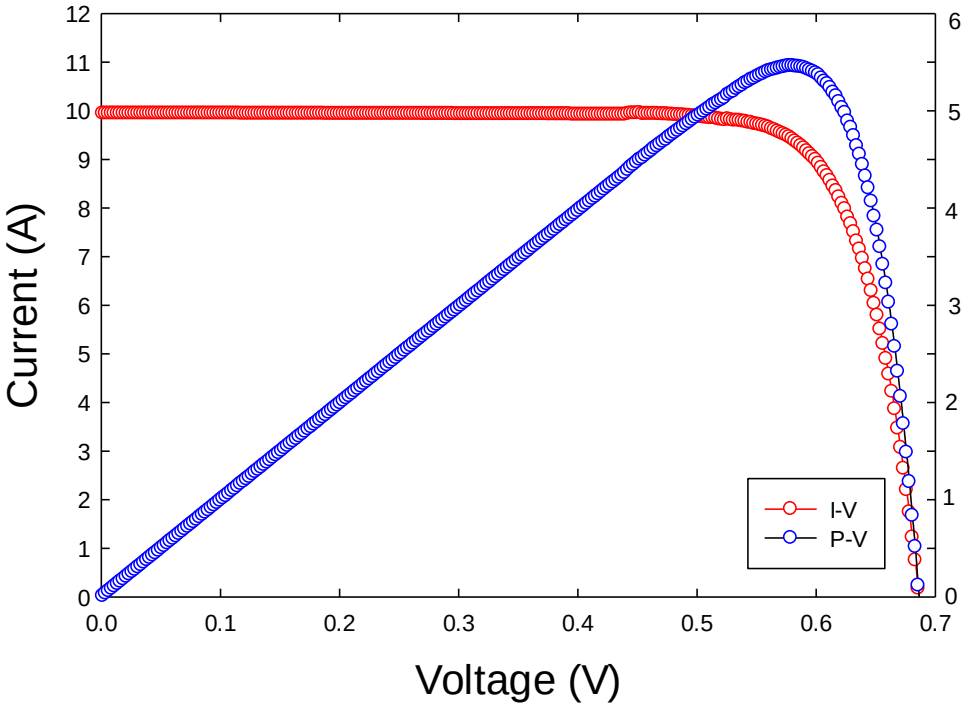
Outline

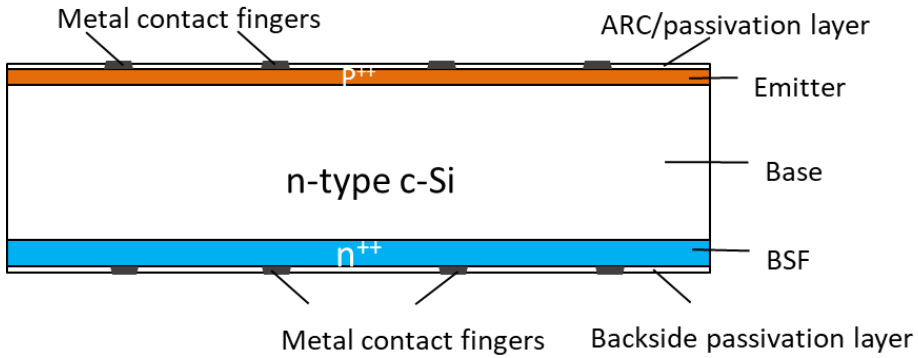
- Introduction
- Bifacial Solar Cells
- PV Modules with Bifacial Cells
- Performance Comparison between Modules with mono-facial and bifacial Cells
  - Double-glass and regular modules with n-type bifacial cells vs. modules with p-type cells
  - Double-glass and regular modules with p-type bifacial PERC cells vs. modules with mono-facial PERC cells
    - Results from modules connected to multichannel I-V tracers
    - Results from modules arrays connected to inverters
- Concluding Remarks

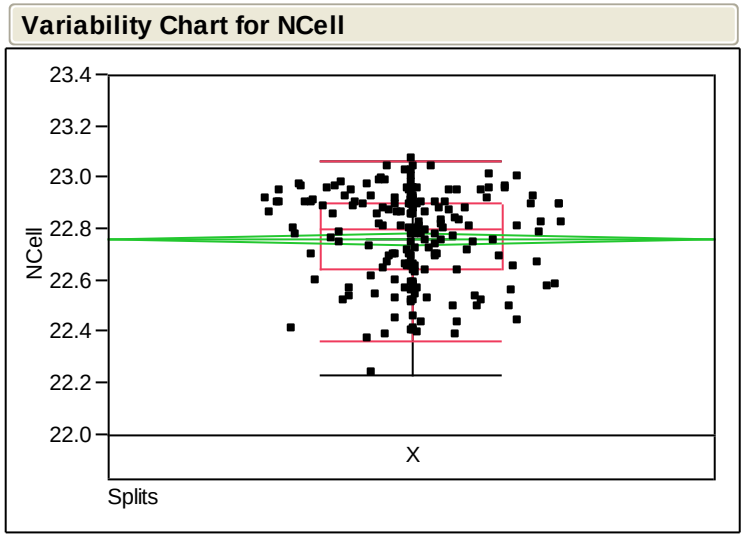
Introduction

- The bifacial nature of silicon wafer based n-type solar cells has long been regarded as a way to generate extra energy by utilizing the diffused, scattered, and reflected lights available to the rear side of a field installed module assembled with such cells
- As p-type PERC cells have become the prevailing technological approach dominating PV industry lately, its backside passivation structure also affords them to be made as bifacial cells to have the performance similar to that of n-type cells on module level
- JA Solar has been conducting comparative study on outdoor performance of PV modules with bifacial cells and mono-facial cells installed side-by-side for better understanding the performance of the field deployed PV modules with bifacial cells. Some results will be shared and discussed in this presentation

n-type Bifacial Cells

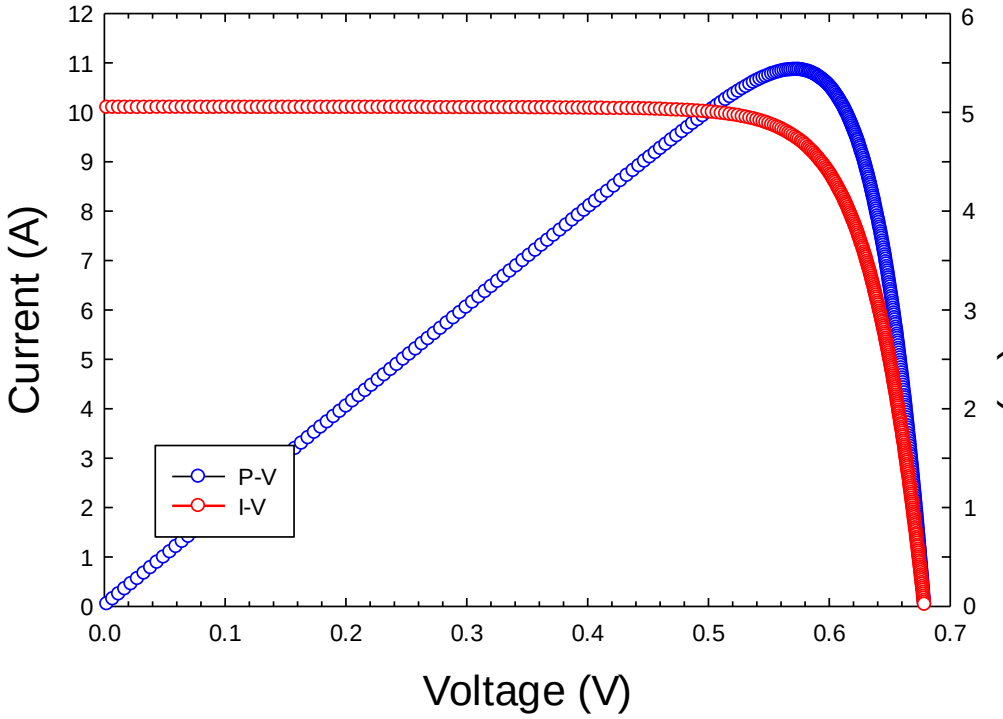


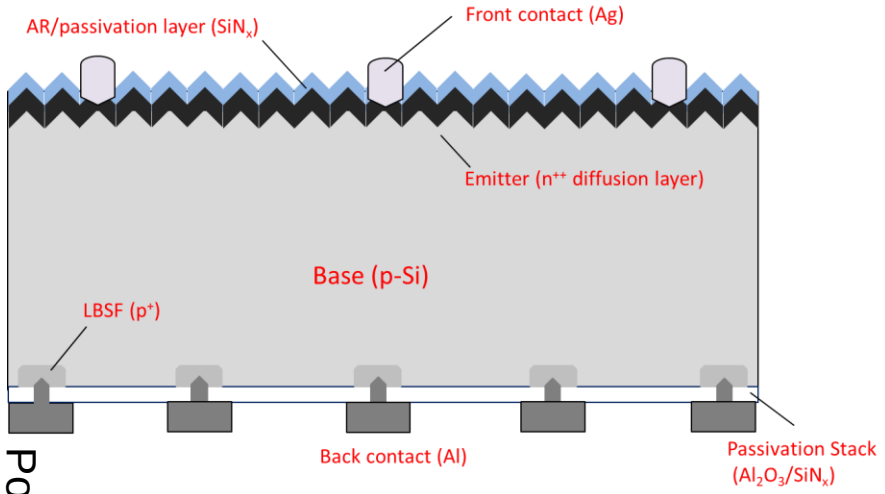


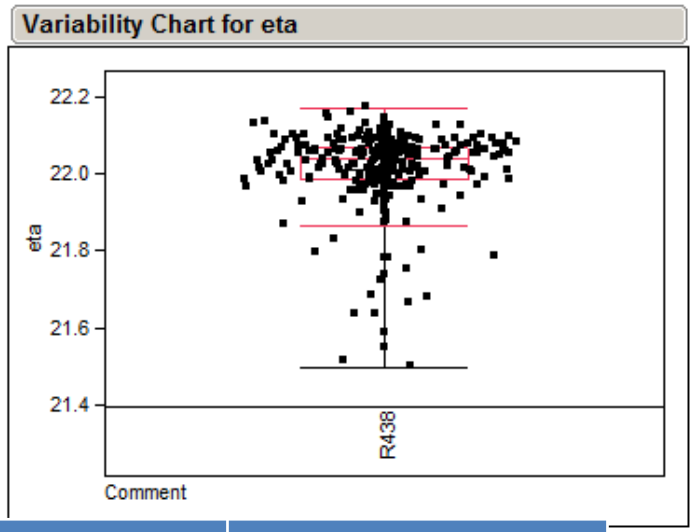


Voc (mV)	Jsc (mA/cm²)	FF (%)	Eta (%)
688.3±2.1	40.82±0.12	80.66±0.25	22.61±0.22

p-type Bifacial Cells



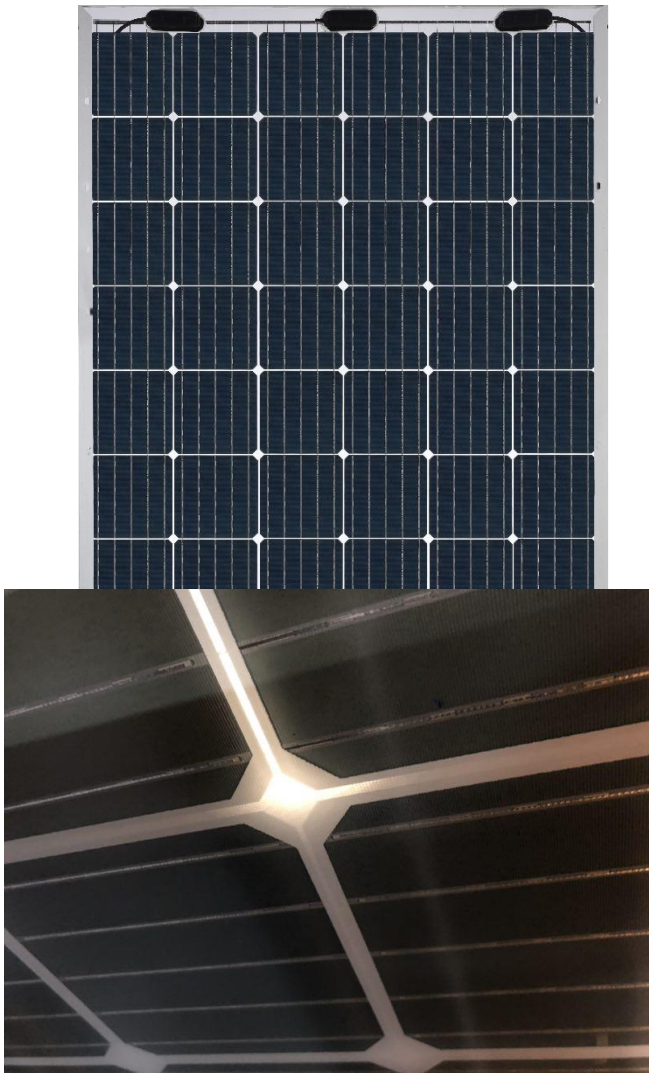




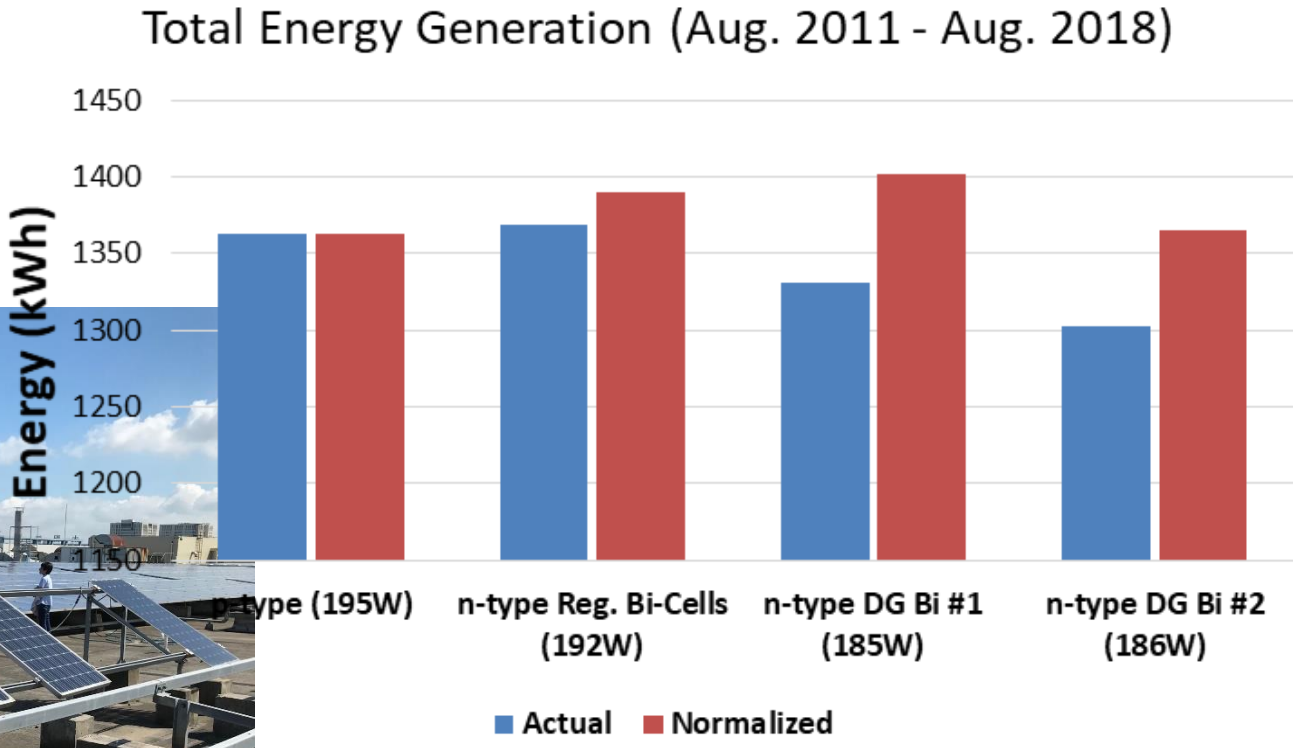
Voc (mV)	Jsc (mA/cm²)	FF (%)	Eta (%)
677.6±2.1	40.78±0.26	79.95±0.25	22.10±0.32

PV Modules with Bifacial Cells

- Modules with front glass and conventional white back sheet
  - No difference from regular modules with mono-facial cells
- Double-glass modules
  - Frameless or framed
- Double-glass modules with patterned white ceramic stripes on the back glass
  - The size of the framed opening is slightly smaller than that of the cells

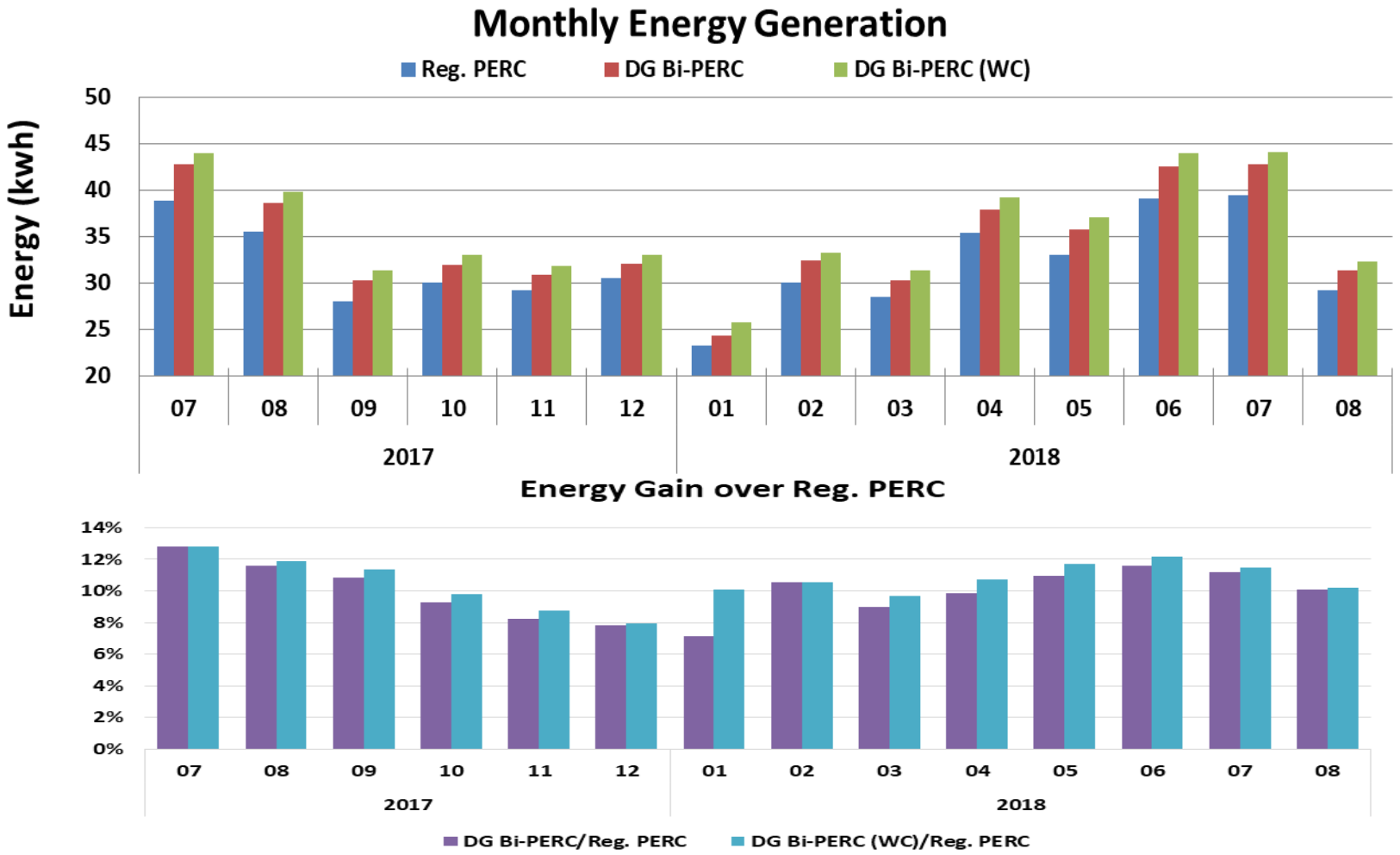


Comparison between Modules with n-type Bifacial Cells and with p-type Mono-facial Cells



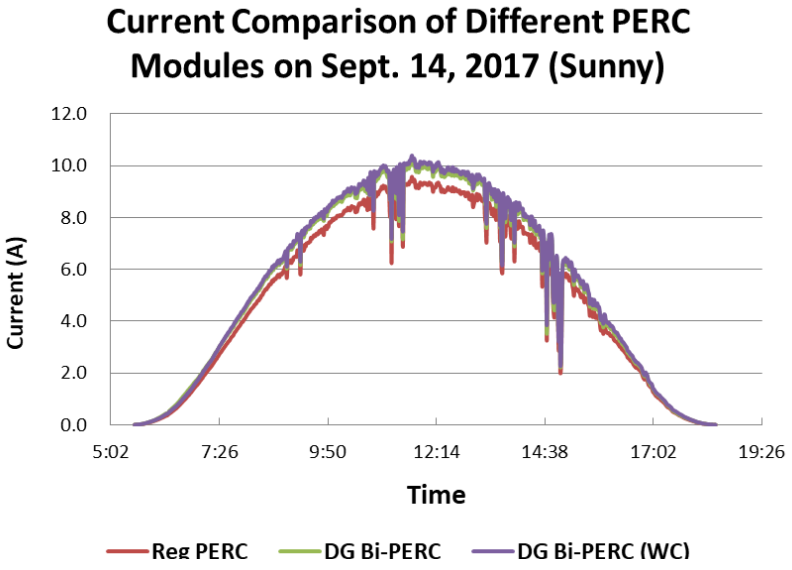
30°-tilt, facing south, individually monitored by micro-inverters

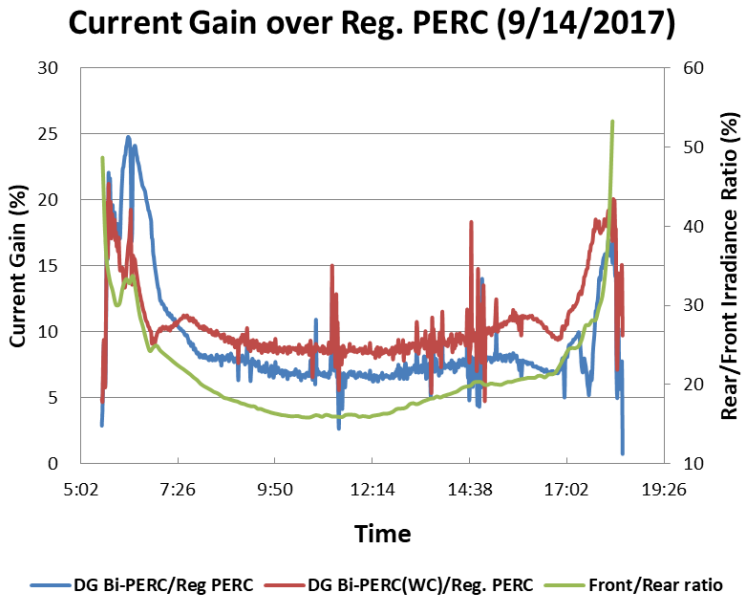
Comparison between Regular PERC and Double-glass Bifacial PERC Modules



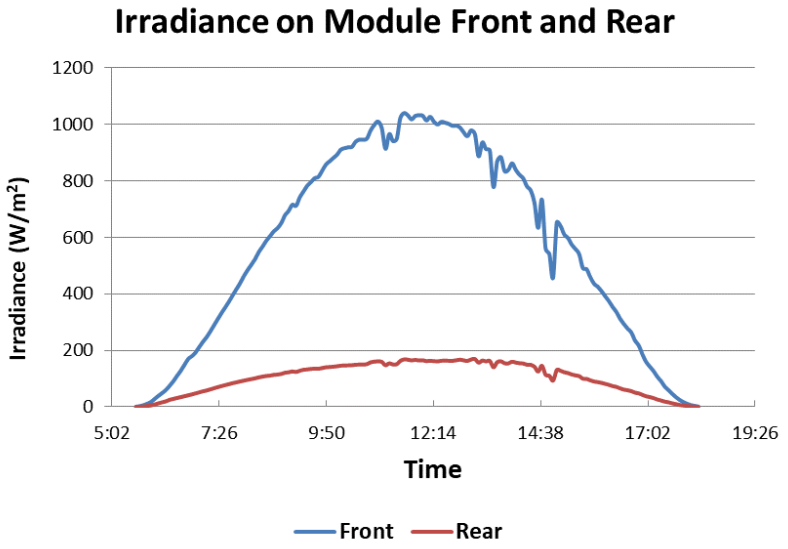
25°-tilt, facing south on concrete floor, individually monitored by a multichannel I-V Tracer

Current Comparison on A Sunny Day

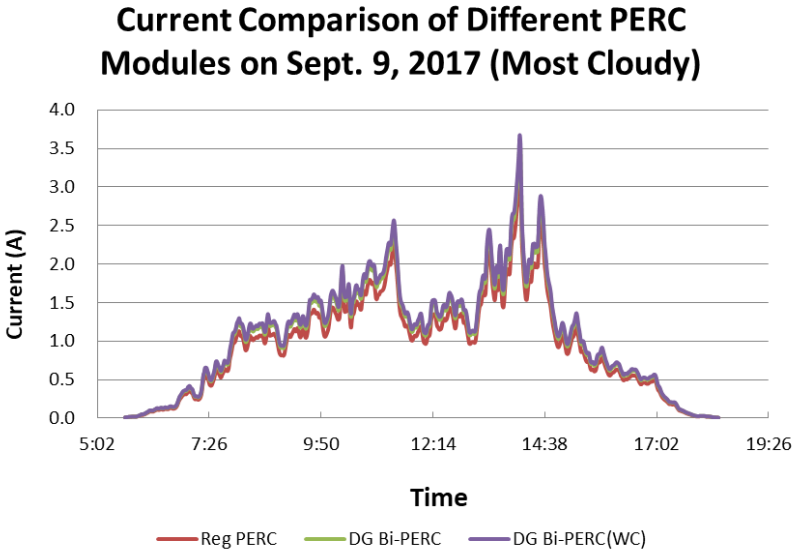


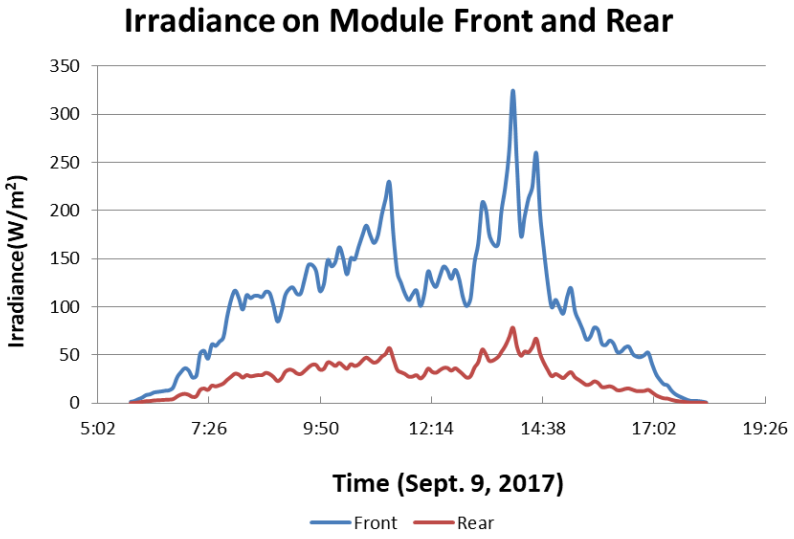


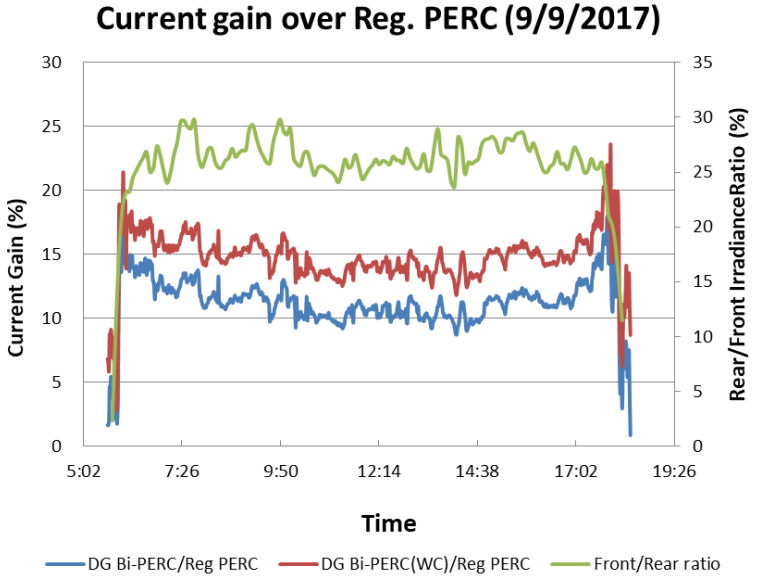
- **The higher current generated by DG Bi-PERC modules results from the contribution from the ability of absorbing lights from backside**
- **The current gain is relatively higher in the early and late hours during a day**



Current Comparison on A Cloudy Day







- **On a cloudy/rainy day, the current gain is even higher for DG Bi-PERC modules as the ratio of irradiance on the rear surface to the front of the modules is much higher than that on a sunny day, mainly because the portion of direct solar irradiance is much weaker or of absence**

Comparison between Three Types of PERC Module Arrays Connected to Inverters

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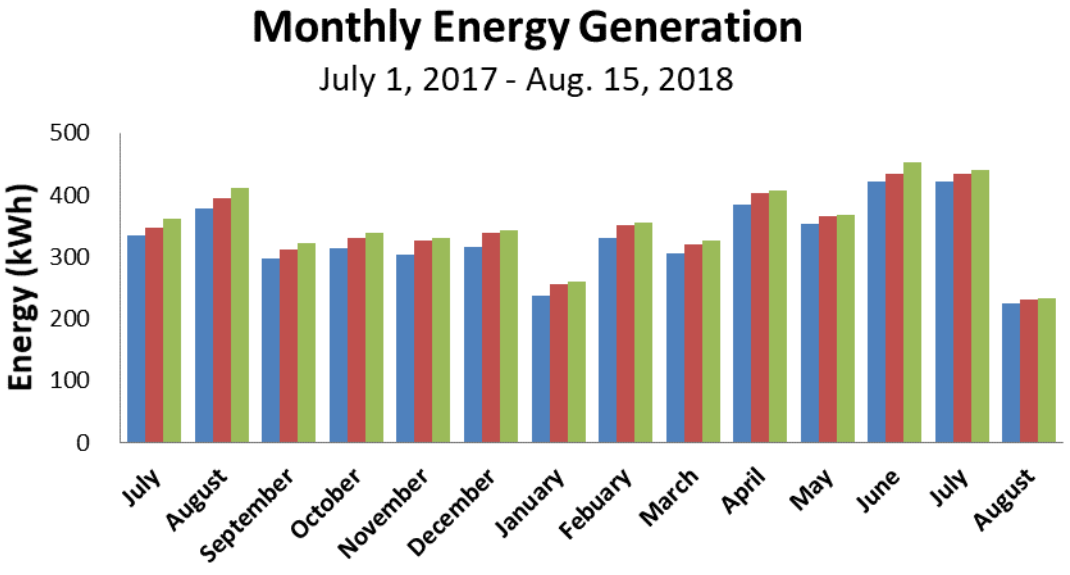
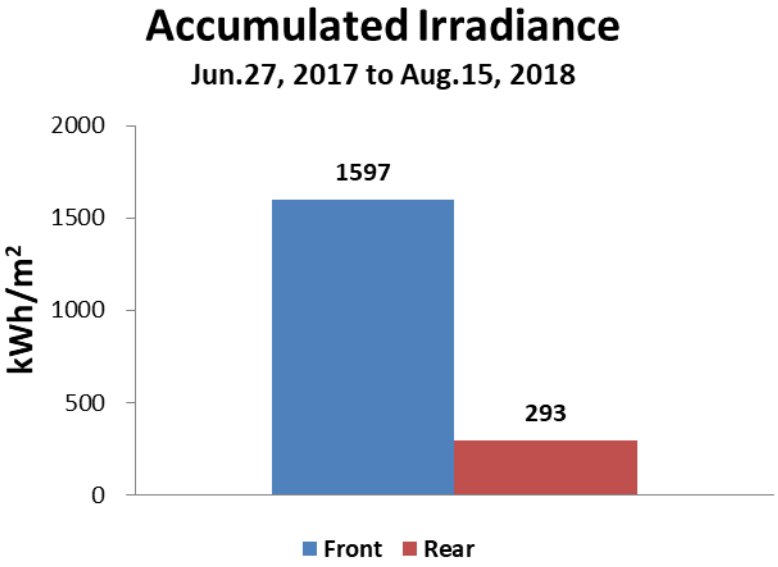
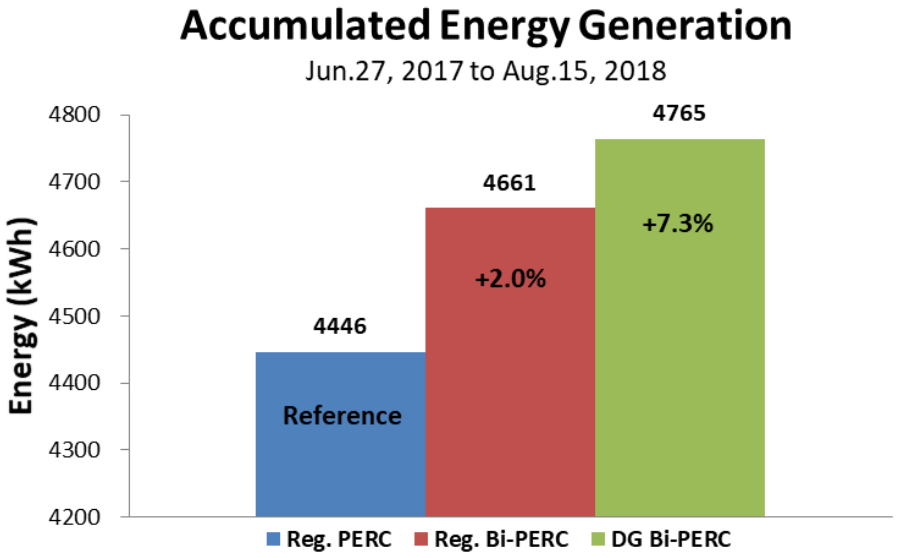
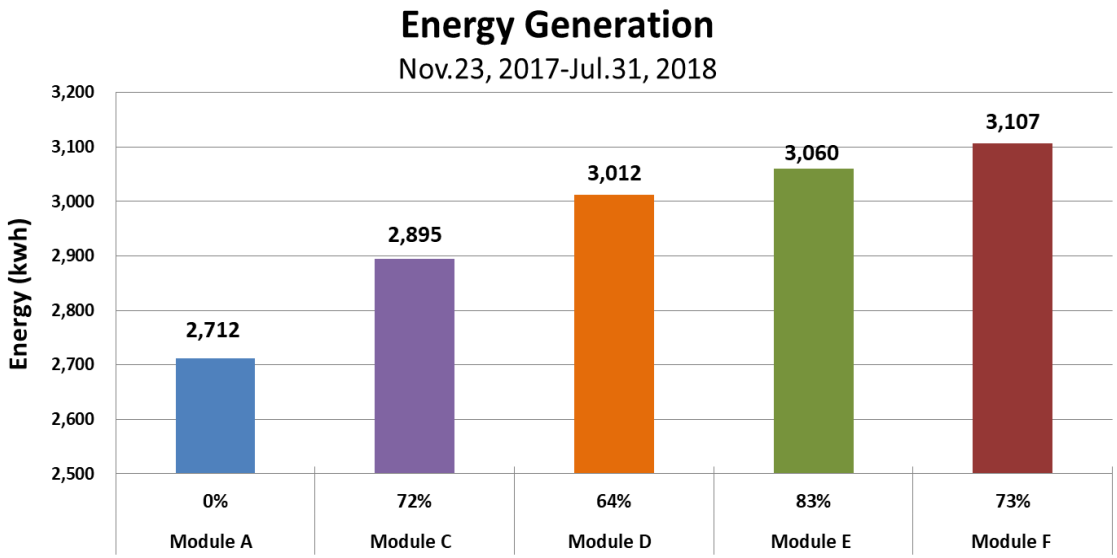




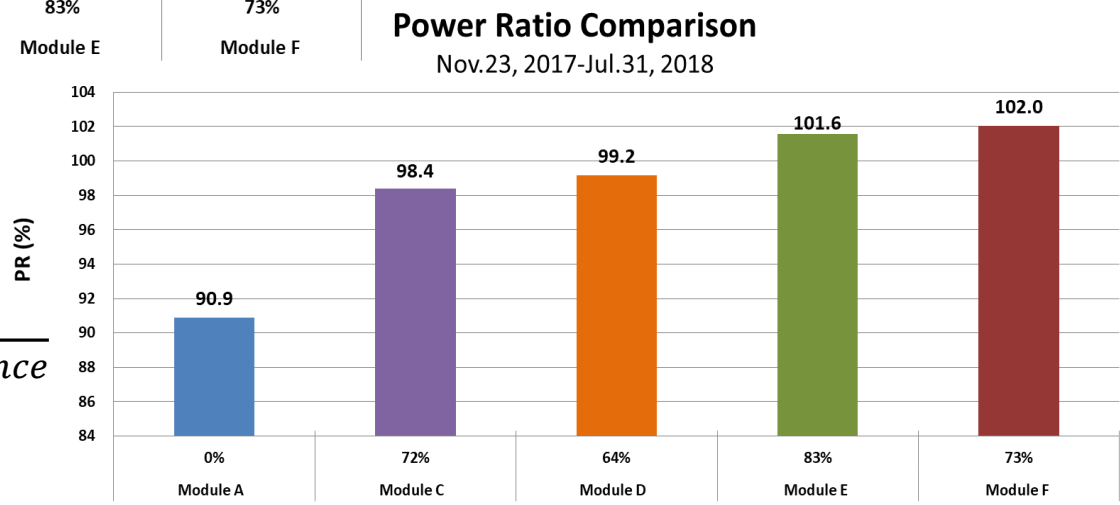


Module Type	No. of Modules	String's total power (kWp)	Install Config.	Module Size (m^2)
Reg. PERC	11	3.245	25^o tilt; Facing south; Concrete floor	1.635
Reg. Bi-PERC	11	3.328		1.635
DG Bi-PERC	11	3.200		1.645

Comparison of the Influence of Bifaciality on Energy Generation



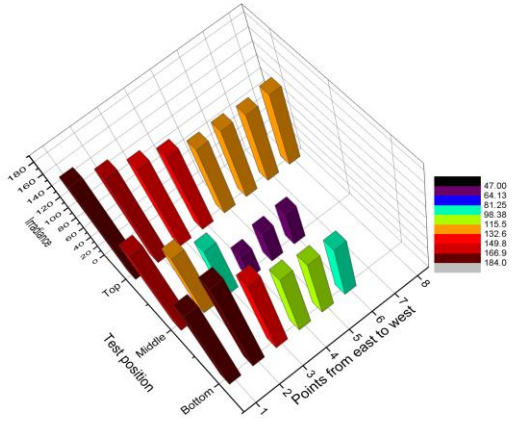
Arrays	A	C	D	E	F
Bifacial Ratio	0	72%	64%	83%	73%
Rated Power	3246	3200	3303	3277	3312



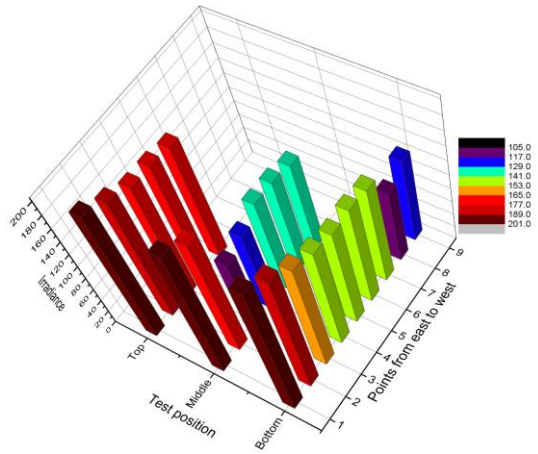
$$PR = \frac{Energy\ Generated}{Rated\ Power} \Big/ \frac{1000W/m2}{Actual\ Irradiance}$$

IEC 61724-1, 2016

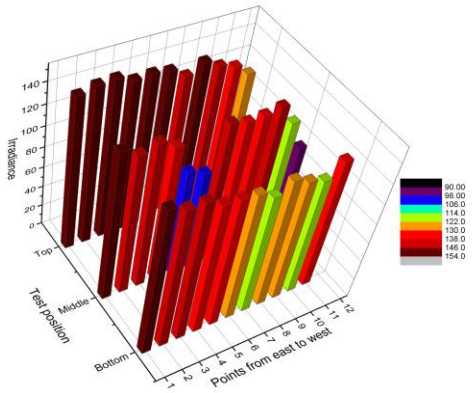
Non-uniform Illumination on Backside



1m



1.5m



1.95m

Test time	Test Conditions	Hight	Spacing between Modules	Non-uniformity
June 2, 2017 9:30-9:54	Irradiance on the front 664-702W/m^2 Direction: from east to west	1.0 m	2 cm	59%
		1.5 m	30 cm	31%
		1.95 m	30 cm	26%

Concluding Remarks

- The comparative study on outdoor performance of modules over the past several years at JA Solar's testing sites has demonstrated that the modules with bifacial cells yield more energy than the modules with mono-facial cells do
- The results collected also indicate that, however, it is difficult to quantitatively predict the extra energy generated from the backside of bifacial modules
- JA's approach is to prioritize the power output from the front of bifacial modules, bifaciality of the modules takes secondary


Thank you
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