BIFACIAL WORKSHOP 2019

PV Evolution Labs (PVEL)

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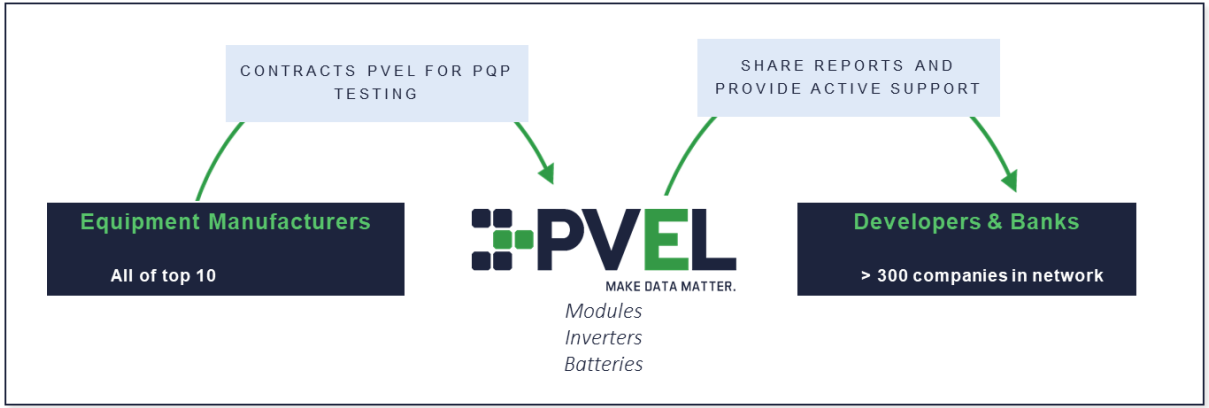
PVEL is the Independent Lab for the Downstream Solar Market



In the solar plants there are two things of critical importance

› Reality

Source: philosophytalk.org

› What you can finance

Source: dgkgrouppc.com

Reality vs. Financial Assumptions

- Ideally there is no difference between actual future production and financial assumptions
- However, in the absence of **data** many assumptions are made
- Without field **Validation** assumptions trend to conservatism
- Cypress Creek Renewables and PVEL have been awarded a DOE grant for $1.7 mm to study and validate bifacial modeling best practices
- We believe today financing is conservative due to lack of data

Objective of studies

1. Deploy bifacial systems with monofacial reference in the field to validate energy modeling practices
   - Bifacial Test Stations: single module IV curves, 2-portrait single axis trackers
   - 4 manufacturers side by side with 1500V Strings on 2 albedos
   - Impact of spectral albedo and temporal change in albedo
2. Measure bifacial mismatch on MW scale systems
   - Tracking and Fixt Tilt
   - Bifacial vs. monofacial
3. Partner with Energy Modeling community for field validation on reduced order models
   - PVSyst, TNO, SAM, Solar Farmer, Plant Predict
4. Develop and validate ray tracing based model
   - Partnership with PV Lighthouse: inter and intra module mismatch, spectrum, albedo, mechanical design considerations, etc.
5. Stakeholder Engagement
   - Provide updates and share data with banks, developers, engineering firms

Assumptions made today

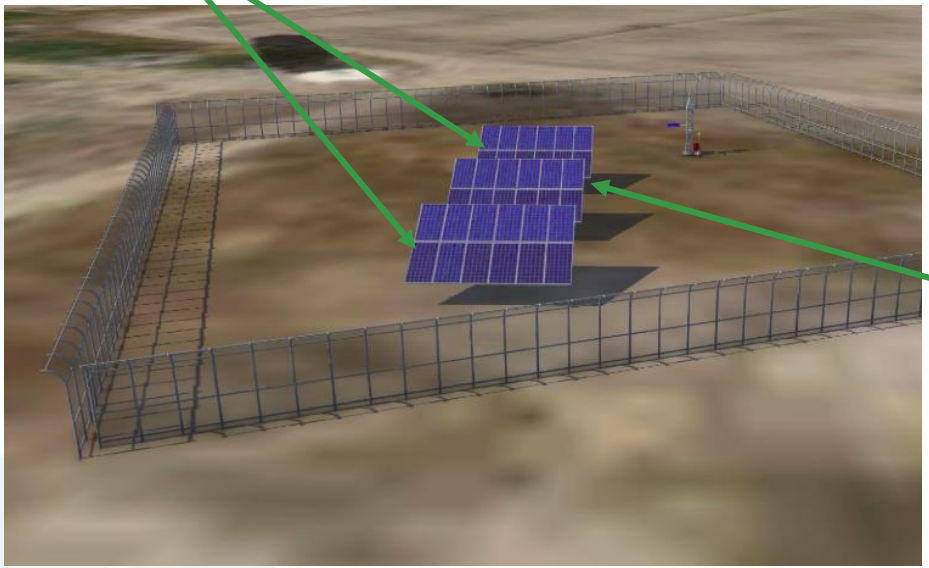
LID / LeTID on front and back	Same??
Infinite row length	Bad assumption but what is the impact?
Albedo	Ok to assume a single number?
Albedo Spectrum	Big enough effect to matter?
Mismatch losses	Larger than monofacial?
Obstructions	Impact of near vs far shading?
Portrait vs. landscape	Does it matter?
Split cell vs. full cell	What's interaction with 1 P vs. 2 P trackers?
Tracker height	Magnitude of impact vs added cost?

Bifacial Test Site Description

Status

- Michigan: snowy and cold, installed early 2019
- Oregon: hot and dry, late 2019
- South Carolina: arid climate, late 2019

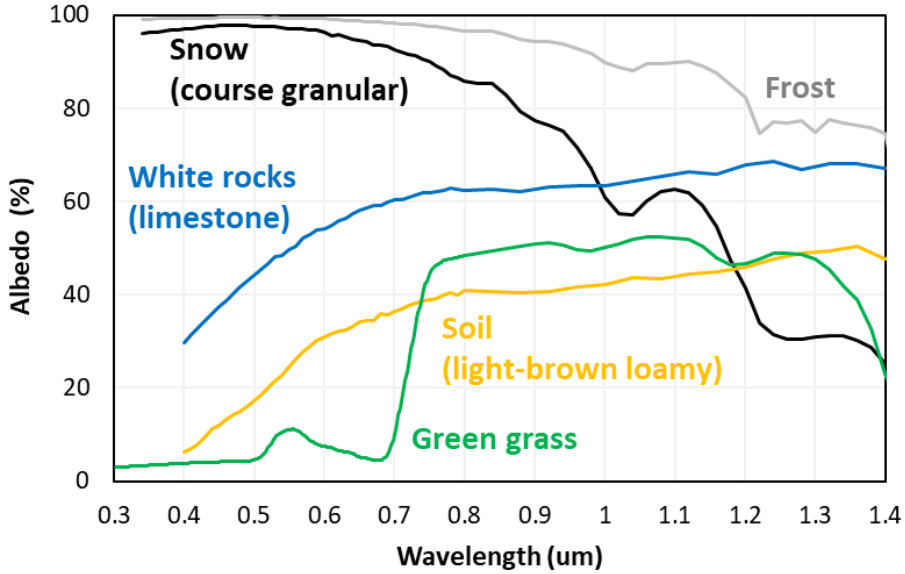
Monofacial
dummy modules



Modules under test

Spectral Measurement

- Does the spectrum of the albedo matter enough to measure it?
- Installing EKO spectroradiometers on all 3 bifacial test sites
  - 300 – 1100 nm
- 2 per site: One facing up and one down
- Installation in late 2019 / early 2020

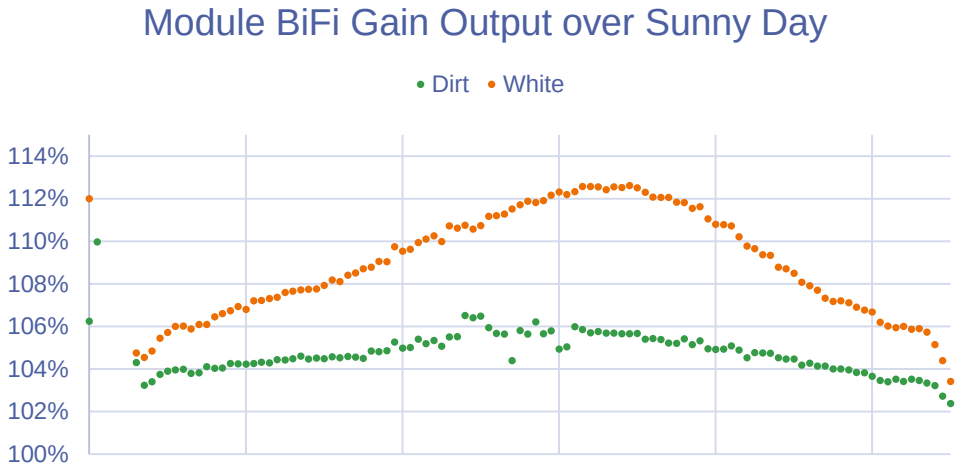


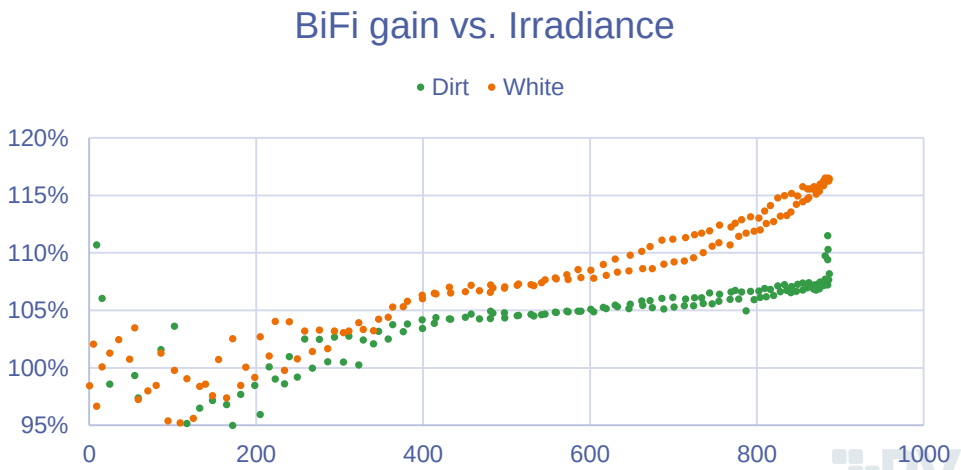
1500V testing in Davis, CA

- 4 manufacturers
- NEXTracker
- 0.35 GCR
- 2 x Albedos
  - Dirt
  - White Sheet
- Monofacial vs. Bifacial
- 1500V strings

Results for Sunny Day

	Avg Flash Test relative to nameplate			
Manufacturer	**Monofacial**	**Bifacial**	**Cell Type**	**Bifaciality**
A	99.3%	102.0%	half-cut	60%
B	101.3%	99.2%	full cell	77%



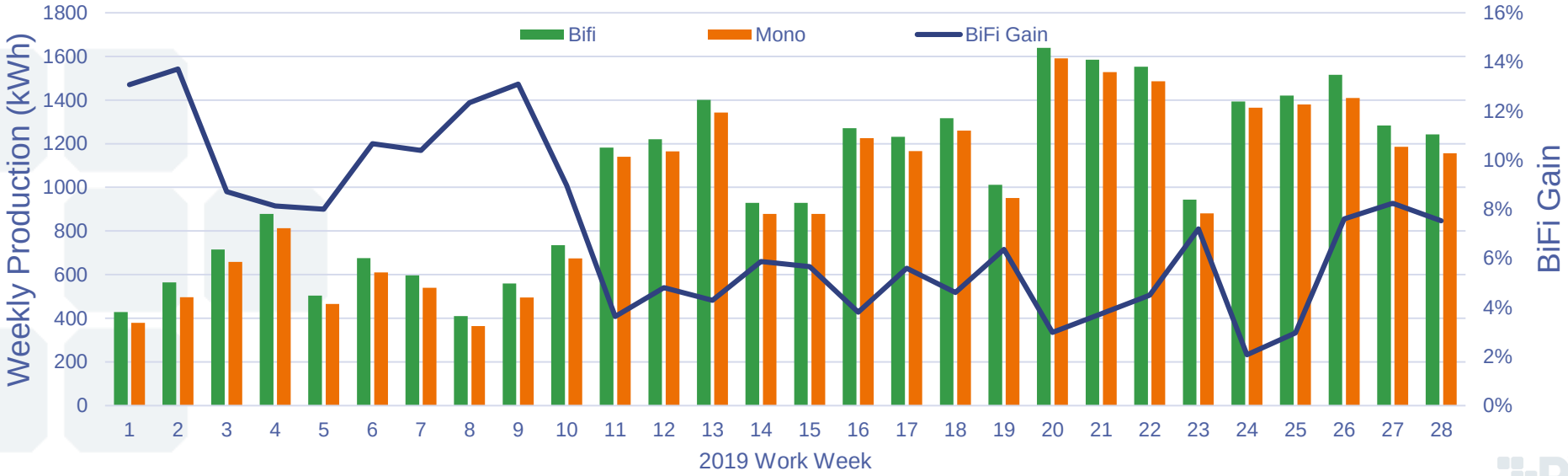


Module to Module Mismatch

- 2 MW bifacial site in North Carolina
- 1 monofacial reference block (25kW)
- Will instrument each module in a string and the string with IV curve tracers to directly measure mismatch losses
- Target Q2 2020

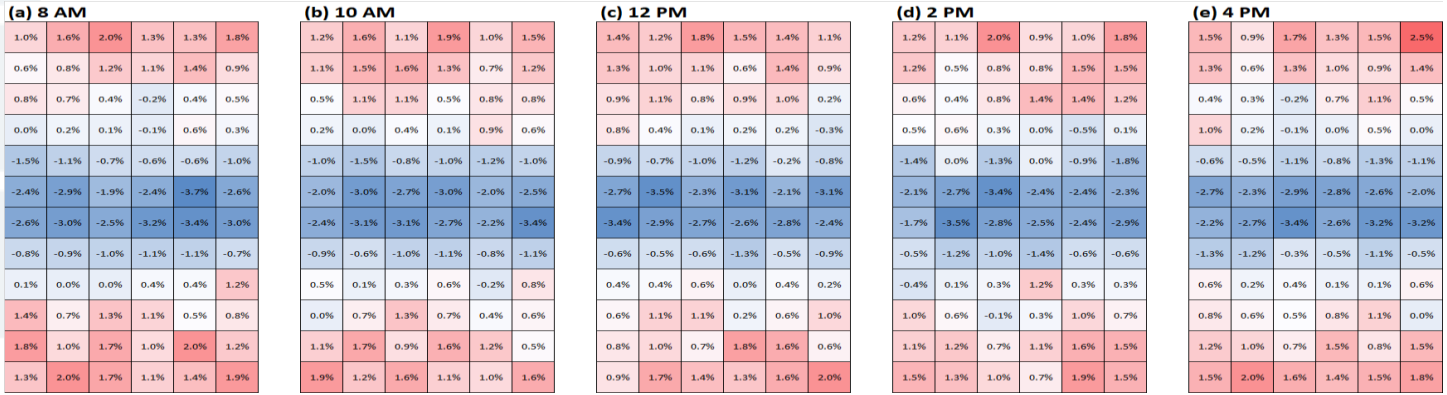
North Carolina Yield Results

- So far ~6% bifacial yield gain year to date
- However, DC / AC ratio is 1.3 so summer sees lots of clipping
- Untreated grass ground, albedo is roughly 15%



Ray Tracing

- Initial modeling process is about to get underway
- PV Lighthouse has completed initial ray tracing models
- Roughly +/- 2% irradiance non-uniformity modeled, next step is to validate
- Once ray tracing model is validated with field data we can run it iteratively across many conditions: racking, backtracking algorithm, ground cover, split vs. full cell, etc.



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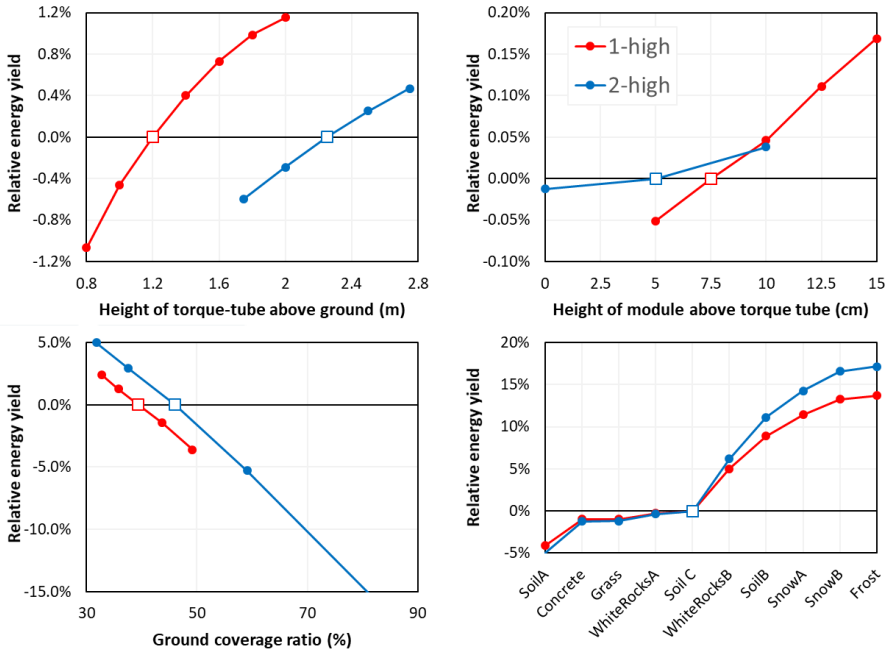

- Initial ray tracing results
- All of these techniques to increase yield have a cost so the returns have to be high enough
- Today likely can't finance full value of these without some field validation


PVEL
MAKE DATA MATTER.
THANK YOU