Barriers to Financing Bifacial PV Projects

Bifacial Conference 2018

Jenya Meydbray

VP, Solar Technology

Introduction

Founded in 2014, Cypress Creek Renewables is focused on

- Solar Development
- Finance
- EPC
- O&M

- Completed over **250 projects**
- EPC has built **> 1.6 GWs**
- O&M Operates **> 2 GWs**
- Finance has raised **> $2.5 billion**
- Development pipeline of **> 5 GWs**

Project Finance

- Solar projects are cash generating black boxes
- Future cash flows can be financed just like a pool of car leases
- In order to sell future cash flows they need to be well understood by all parties
- There are many technical requirements in understanding future energy yield

Project Stakeholders

Developers and EPCs

- Purchase Equipment: modules, inverters, trackers/racking, cabling, monitoring system, transformers, substations, etc.
- Prepare the site and perform installation

Banks

- Provide Debt to the project
- Covers 40-50% of project cost and is sized based on future cash flows
- Typically 4-6% at up to 25 years, can be 5 years beyond PPA term

Tax Equity Investors

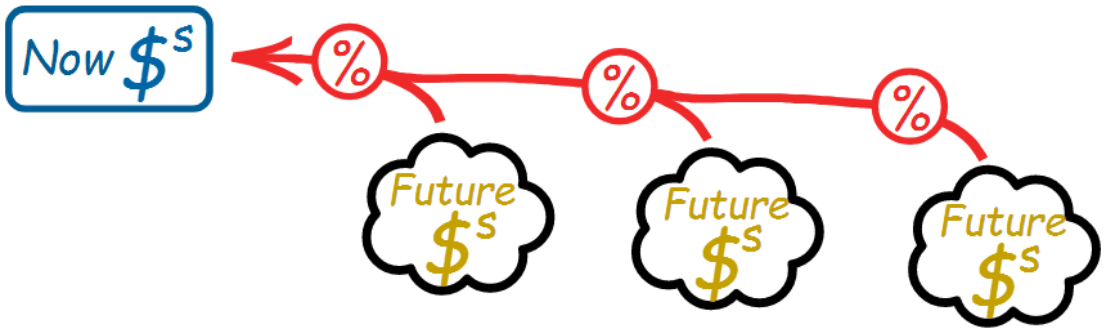
- Covers 45-50% and is based on several factors
- Take the tax credits and invest in some equity portion of the project
- After tax IRRs of 10-20% depending on structure

Independent Engineering Firms

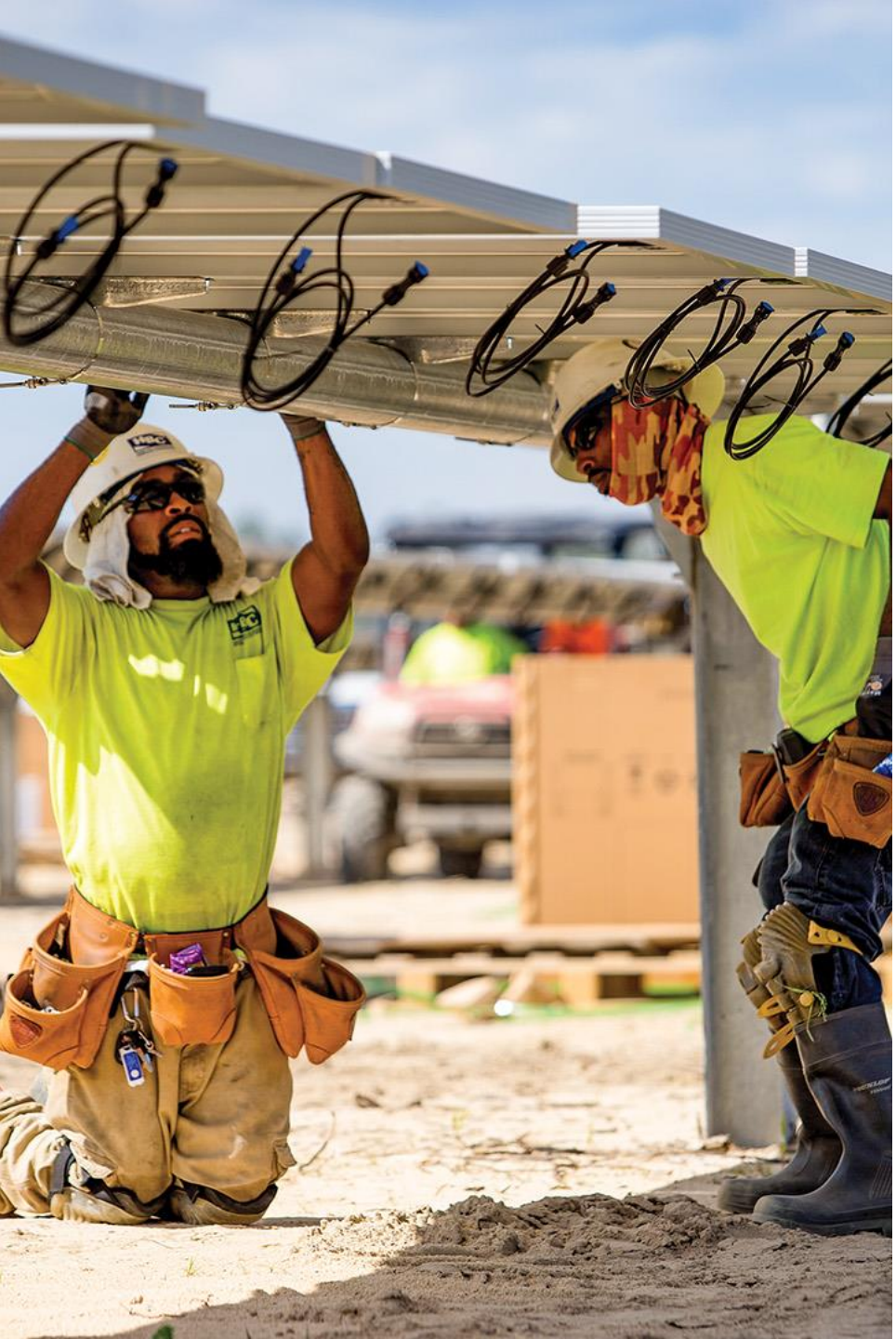
- Advise the lenders and investors on technical assumptions
- Black & Veatch, DNV GL, Enertis, Leidos, Luminalt, AWS Truepower (UL), ICF International

How Projects are Valued

- Most developers try to optimize projects for Net Present Value (NPV)
  - This includes up-front costs
  - Future revenues
  - Cost of capital
  - Operations Costs



Source: mathsisfun.com



How Bifacial Impacts NPV

Up-front costs (CapEx)

- Modules
- Trackers / racking
- combiner boxes + wire management + fuses + mounting + other (?)

Future revenues

- 3-30% yield boost ?

Cost of capital

- Probably not impacted directly but may be fewer sources of capital

Operations Costs

- Probably not impacted
- Reduced in snow ?

Future revenues i.e. yield

- Well accepted methodology for Energy Modeling is the biggest hurdle with bifacial systems
  - Albedo
  - Spectrum on back side
  - Back side IAM
  - Obstructions
  - View factor
  - Mismatch
  - Portrait vs. landscape
  - Snow Shedding
  - Tracking Algorithms
  - Module to module and row to row spacing impacts
  - Tilt angle for fixed tilt
  - Torque Tube shape and size
  - Etc.

Energy Modeling History

Several years ago over-performing solar projects were common. Today +/-1% of PVSyst simulation is widely expected. How can we not repeat this in Bifacial?

2009: Kyocera Solar Modules Exceed Performance at San Diego's Alvarado Plant

- Kyocera solar modules at the Alvarado Water Treatment Facility have performed at 115 percent of expected output since their installation

2011 system on REC factory rooftop in Singapore

- Monitored by 3rd party (SERIS), Average over performance by 5.4%

2016: Solar power does work – and a lot better than we thought, Renew Economy

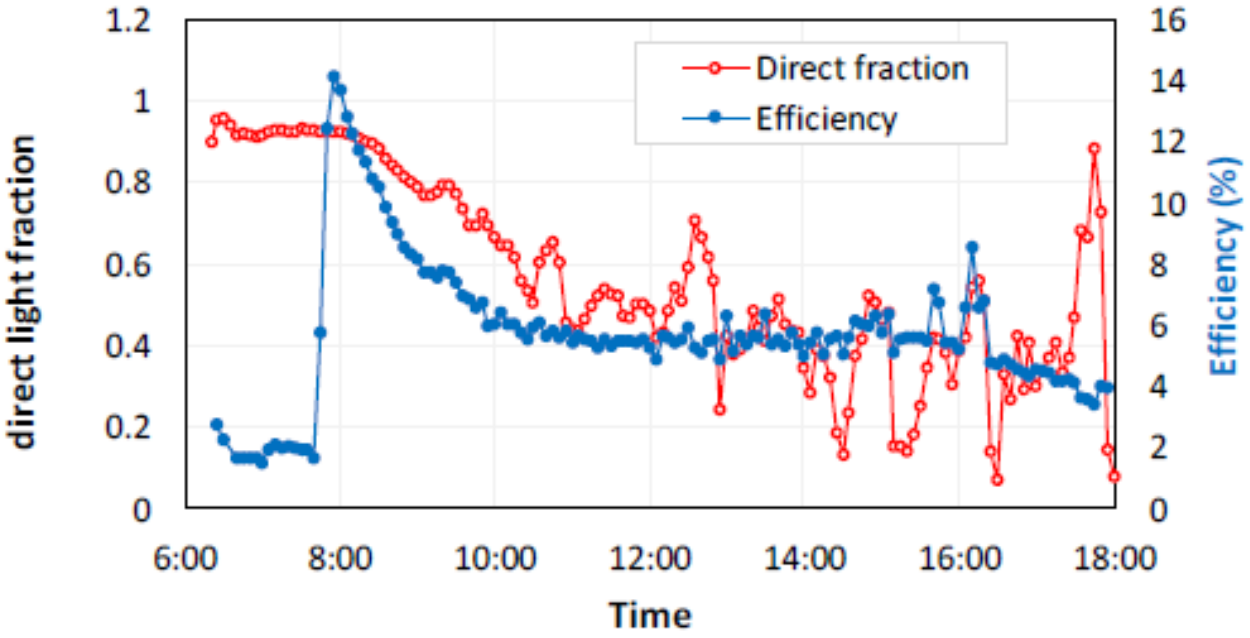
- plants using First Solar thin-film PV modules are performing above expectations by an average of 3.2 per cent

2017: Solar projects beat forecasts while wind falls short, Solar Power World

- production data from Fitch-rated projects against the initial P50 forecasts, data gathered since 2011
- We found 70% of annual observations were at or above the original P50 levels, and only 3% were significantly (more than 10%) below the initial forecasts

Computer Modeling

- Cypress Creek has been working on modeling bifacial system performance variables with a firm called PV Lighthouse
  - Modeled for single day in Golden, CO in March
  - Mostly direct light in bright morning, clouds roll in and lots of diffuse in late afternoon



Mismatch

- Effect of cell to cell mismatch on this day in March in Golden, CO
- 1 high in portrait, 1.2 meter torque tube height, standard backtracking

8 am	10 am	Noon	2 pm	4 pm
• Lots of direct light • Minimal impact of back-side non-uniformity	• More cloud cover / diffuse fraction • Mismatch starting to have impact • Slight **impact from** torque tube	• Staying quite consistent from 10 am	• Increasing cloud cover and diffuse fraction • Tracker at a steeper angle causing top to bottom mismatch	• Substantial cell to cell mismatch and • torque tube shading and • Difference in total irradiance from top to bottom of module

0.2%	-0.4%	0.9%	0.3%	0.6%	-0.5%
0.1%	0.3%	-0.4%	-0.1%	0.8%	0.2%
-0.7%	-0.1%	-0.2%	0.2%	0.1%	-0.1%
-0.1%	-0.4%	0.8%	0.1%	1.0%	0.9%
-0.4%	0.0%	-0.3%	-0.8%	-0.3%	0.3%
-0.4%	-0.7%	-0.4%	-0.2%	-0.1%	0.7%
0.1%	0.0%	0.1%	-0.2%	0.4%	0.0%
-0.2%	0.5%	-0.5%	-0.1%	-0.1%	0.5%
0.6%	-0.2%	0.1%	0.4%	-0.4%	0.0%
-0.3%	-0.7%	-0.4%	0.1%	-0.5%	0.0%

2.1%	1.3%	2.3%	1.1%	1.3%	1.4%
1.0%	1.1%	0.6%	1.4%	1.4%	0.6%
0.3%	0.4%	1.3%	0.1%	0.2%	0.8%
0.0%	-0.4%	-0.2%	-1.3%	-0.6%	-0.4%
-1.2%	-0.8%	-0.8%	-1.7%	-1.4%	-0.3%
-2.7%	-2.1%	-2.7%	-2.7%	-2.4%	-2.5%
-1.1%	-1.1%	-1.2%	-0.4%	-0.7%	-0.7%
0.0%	0.2%	-0.4%	0.3%	0.1%	0.3%
0.5%	0.5%	0.3%	0.3%	0.0%	1.1%
1.4%	1.2%	1.0%	1.3%	2.1%	0.5%

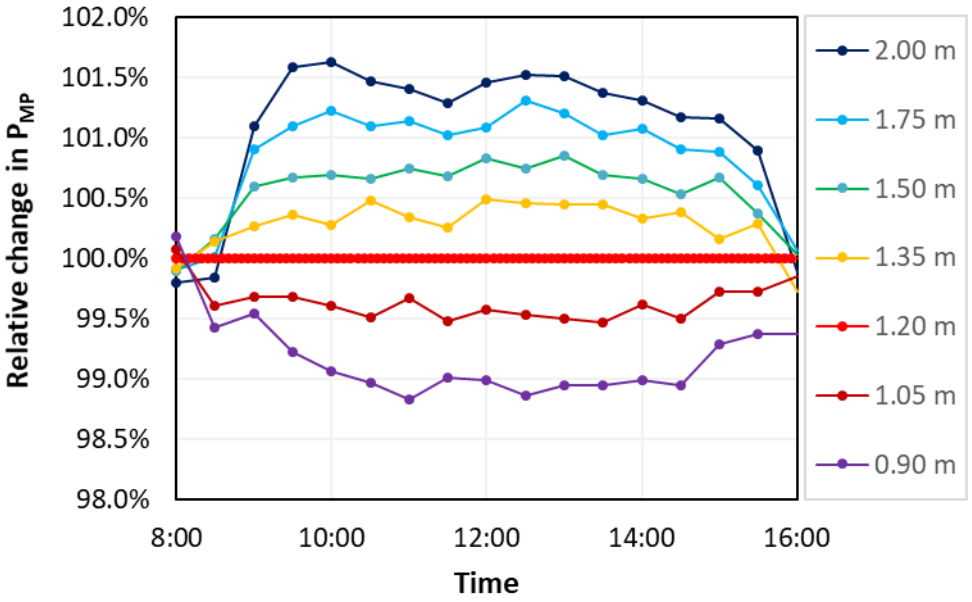
2.6%	1.7%	2.1%	2.5%	2.2%	1.4%
1.0%	0.6%	1.8%	1.1%	0.8%	1.6%
0.2%	0.7%	0.7%	0.7%	0.8%	0.4%
-1.3%	-0.1%	-1.5%	-1.2%	-1.2%	-1.5%
-2.8%	-2.4%	-2.4%	-2.5%	-1.7%	-1.3%
-2.9%	-2.8%	-2.8%	-2.7%	-1.9%	-2.9%
-1.1%	-1.4%	-1.8%	-1.5%	-1.6%	-1.2%
0.1%	0.2%	0.7%	0.5%	0.3%	-0.3%
1.3%	1.4%	1.6%	1.1%	1.2%	1.5%
1.7%	1.1%	2.8%	2.2%	2.2%	1.9%

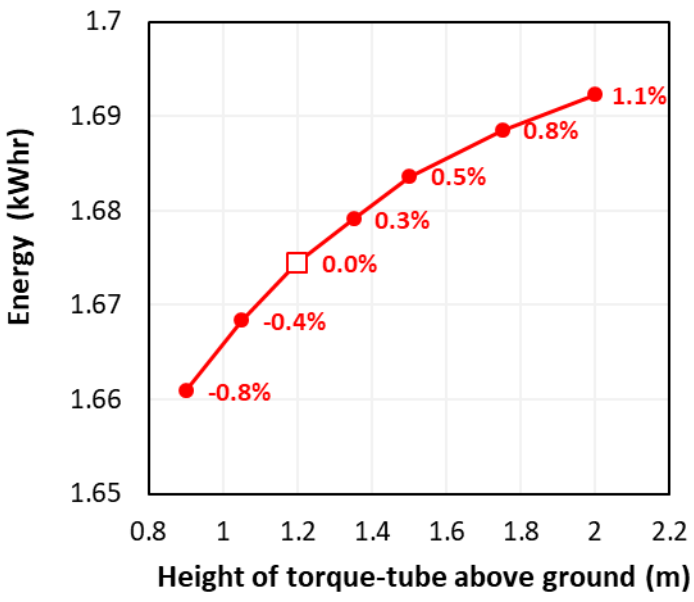
3.3%	2.6%	4.5%	3.4%	5.0%	4.1%
3.7%	3.8%	2.7%	3.8%	3.6%	3.6%
2.2%	1.8%	4.1%	1.5%	3.2%	2.8%
1.0%	1.4%	0.3%	0.8%	1.5%	1.3%
-0.6%	-1.1%	-1.0%	-2.0%	-1.4%	-1.6%
-3.9%	-3.0%	-3.6%	-4.6%	-3.3%	-3.7%
-2.0%	-1.8%	-2.1%	-2.0%	-2.7%	-1.6%
-1.8%	-1.8%	-0.7%	-1.0%	-1.8%	-0.9%
-1.1%	-1.7%	-1.3%	-1.2%	-1.0%	-0.7%
-1.7%	-0.9%	-1.2%	-1.9%	-1.9%	-1.4%

8.3%	9.0%	7.6%	8.1%	9.3%	8.8%
7.6%	7.6%	6.7%	6.7%	6.3%	7.1%
5.8%	6.2%	6.4%	6.6%	4.8%	6.3%
3.5%	3.2%	3.6%	3.2%	3.7%	3.4%
0.3%	0.6%	-1.6%	-0.7%	-1.3%	-1.4%
-7.2%	-6.2%	-6.5%	-6.3%	-5.6%	-6.2%
-6.4%	-6.4%	-5.9%	-7.0%	-6.6%	-7.4%
-3.9%	-3.4%	-2.8%	-3.1%	-2.2%	-3.2%
-4.2%	-4.2%	-3.2%	-3.7%	-3.2%	-3.4%
-4.8%	-4.2%	-4.6%	-4.4%	-4.6%	-4.8%

Torque Tube Height

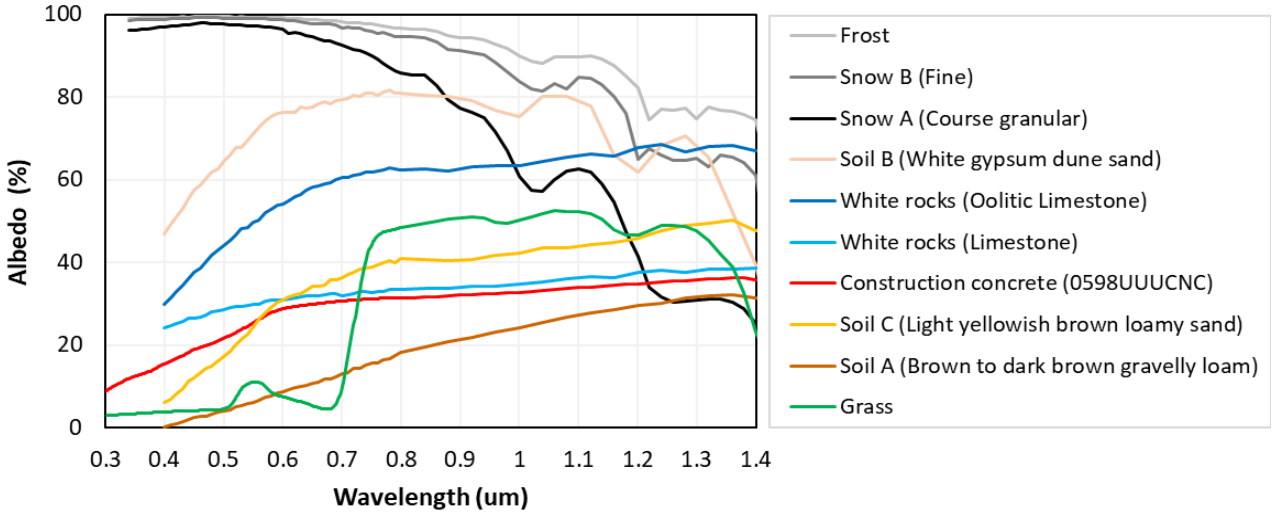
- Roughly 2% absolute yield difference for this one day by increasing torque tube height by roughly 1.1 meters
- Like many other factors with bifacial, will be different results for different system designs, irradiance conditions, and environmental conditions

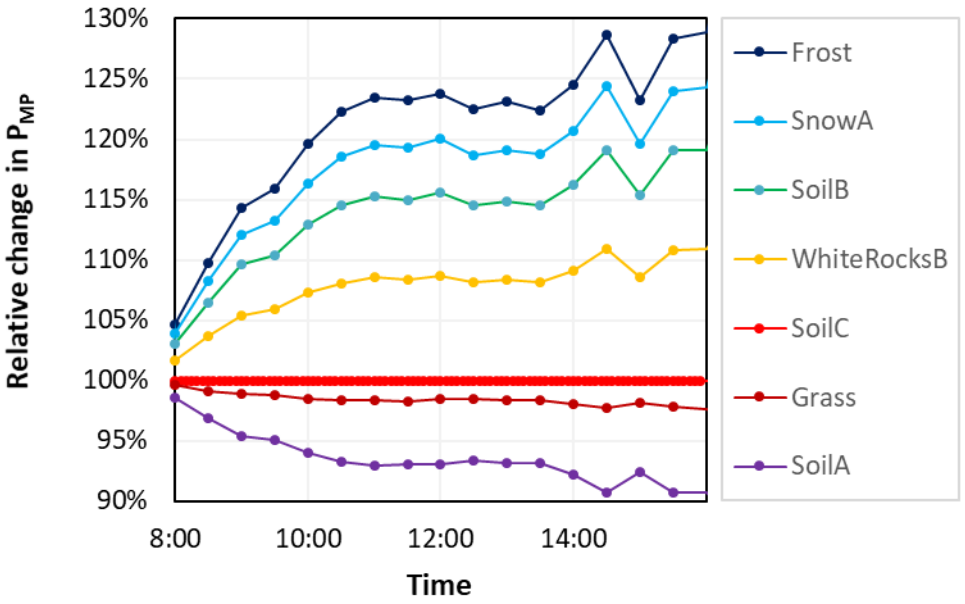


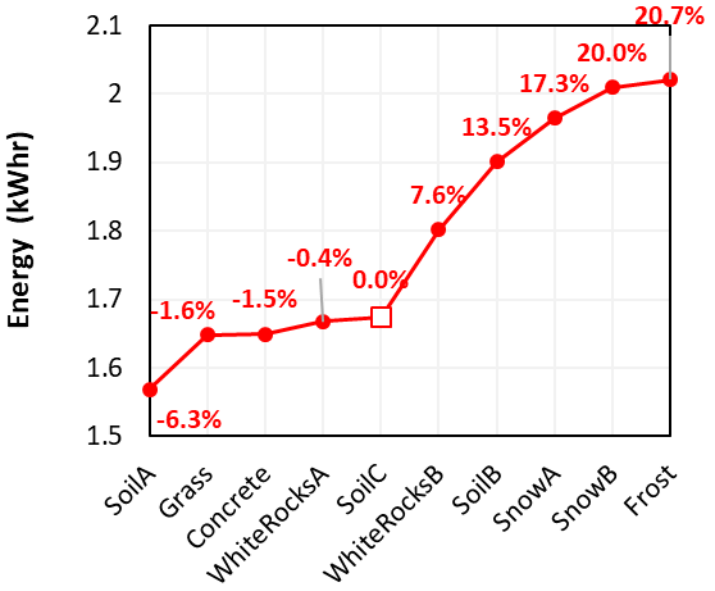


Albedo

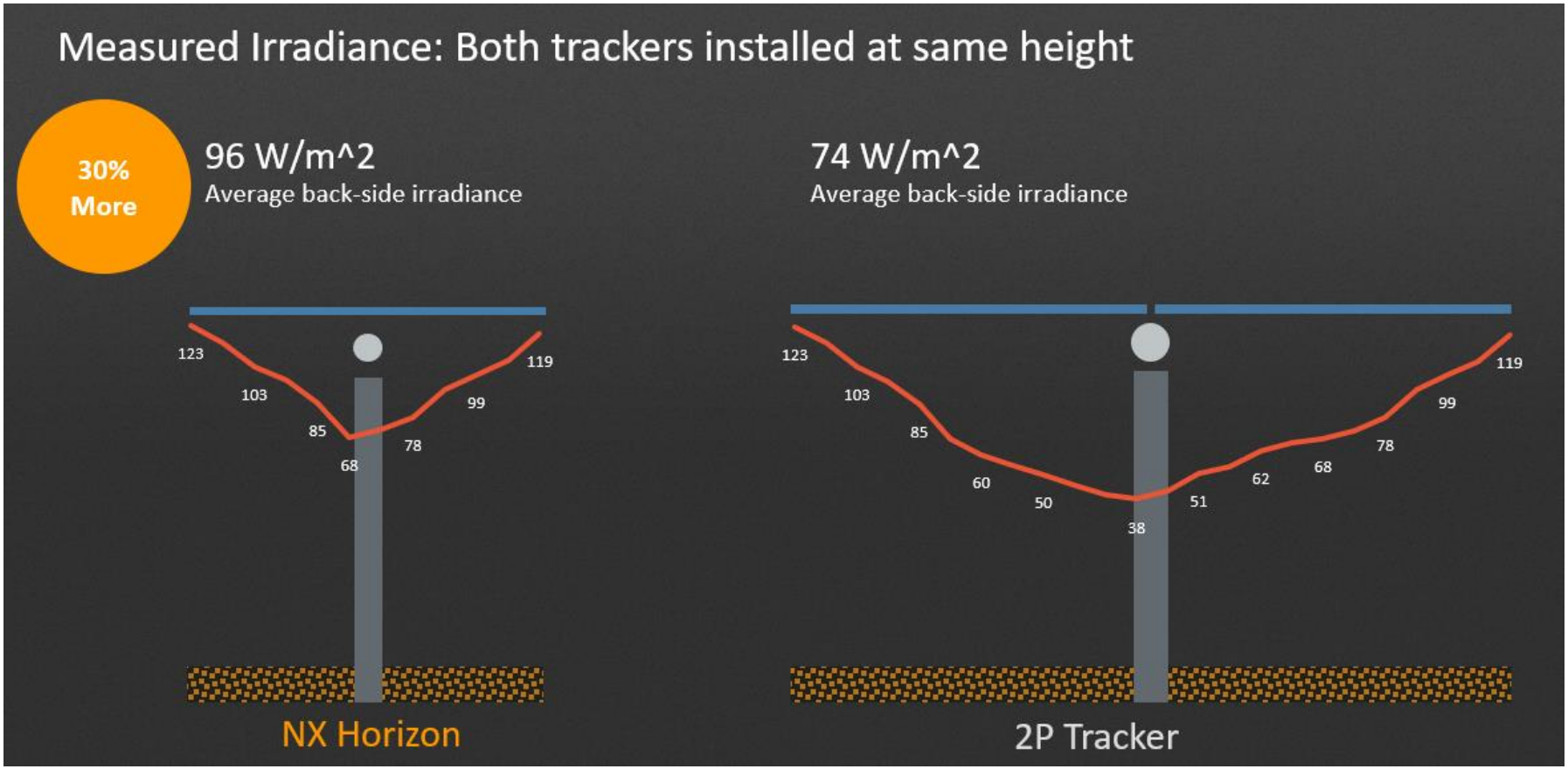
- Albedo obviously has largest impact (26% swing in yield)
- Increasing impact later in day with more back side irradiance contribution







View Factor



Source: from NEXTracker A Flex Company

Bifacial Opportunity and Hurdles

- Bifacial Modules represent the largest step function improvement in project economics for minimal technology risk since the introduction of trackers
- We all need to:
  - Share learnings about build cost and Operations
  - Share real experience with yield and design assumptions
  - Get realistic about module pricing
  - Continue educating the Independent Engineering firms
  - And start building systems!

Thank you!

Jenya.Meydbray@ccrenew.com