

Maximizing PV System Performance with Single-Axis Trackers

Presented By:



6/21/2018

Speakers:

Dan Shugar, Founder & CEO, NEXTracker

Venkata Abbaraju, Senior Director of Product Development, NEXTracker

Dustin Shively, Director of Engineering, Clenera, LLC

Moderator:

Scott Moskowitz, Senior Analyst, Solar, GTM Research

gtm: WEBINAR



Scott Moskowitz
Senior Analyst, Solar,
GTM Research



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Speaker Bios

Today's Speakers



Dan Shugar

Founder & CEO,
NEXTracker



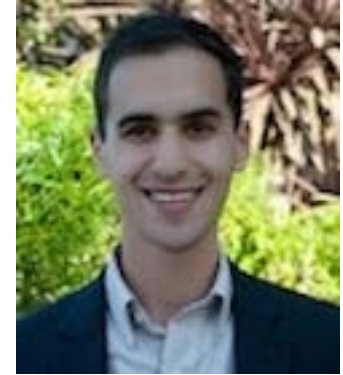
Venkata Abbaraju

Senior Director of
Product Development,
NEXTracker



Dustin Shively

Director of Engineering,
Clenera, LLC

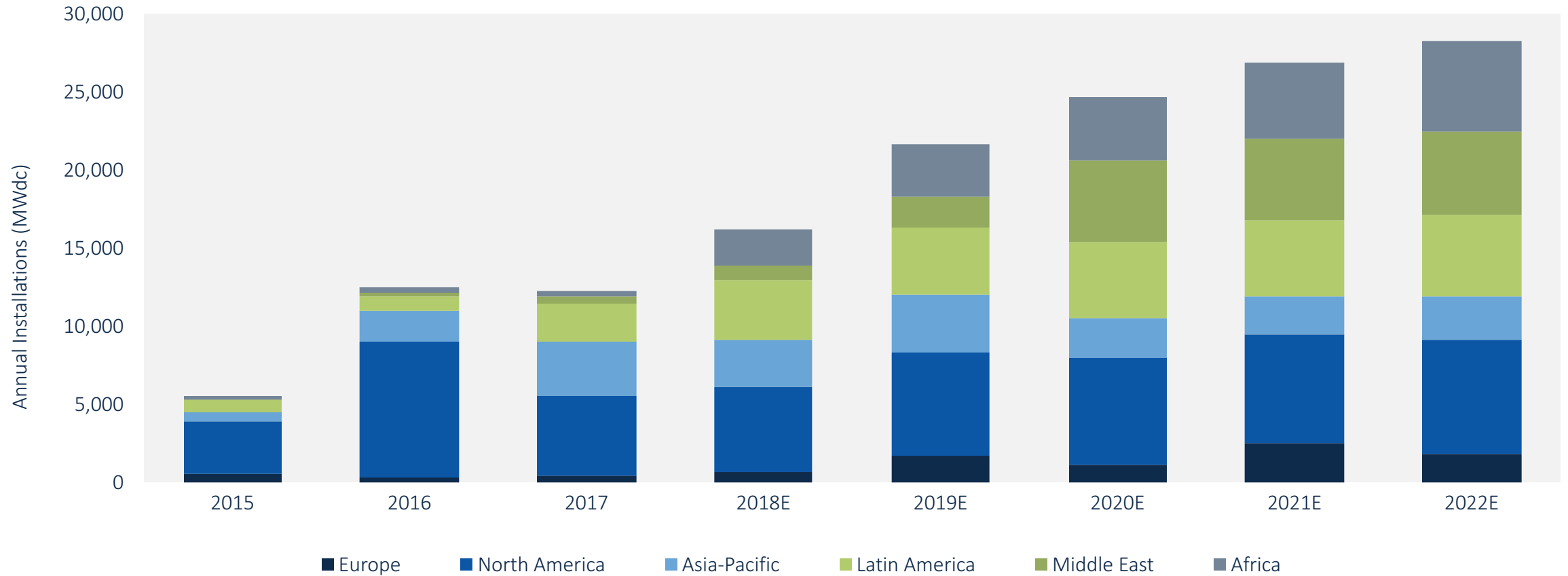


Scott Moskowitz

Senior Analyst, Solar
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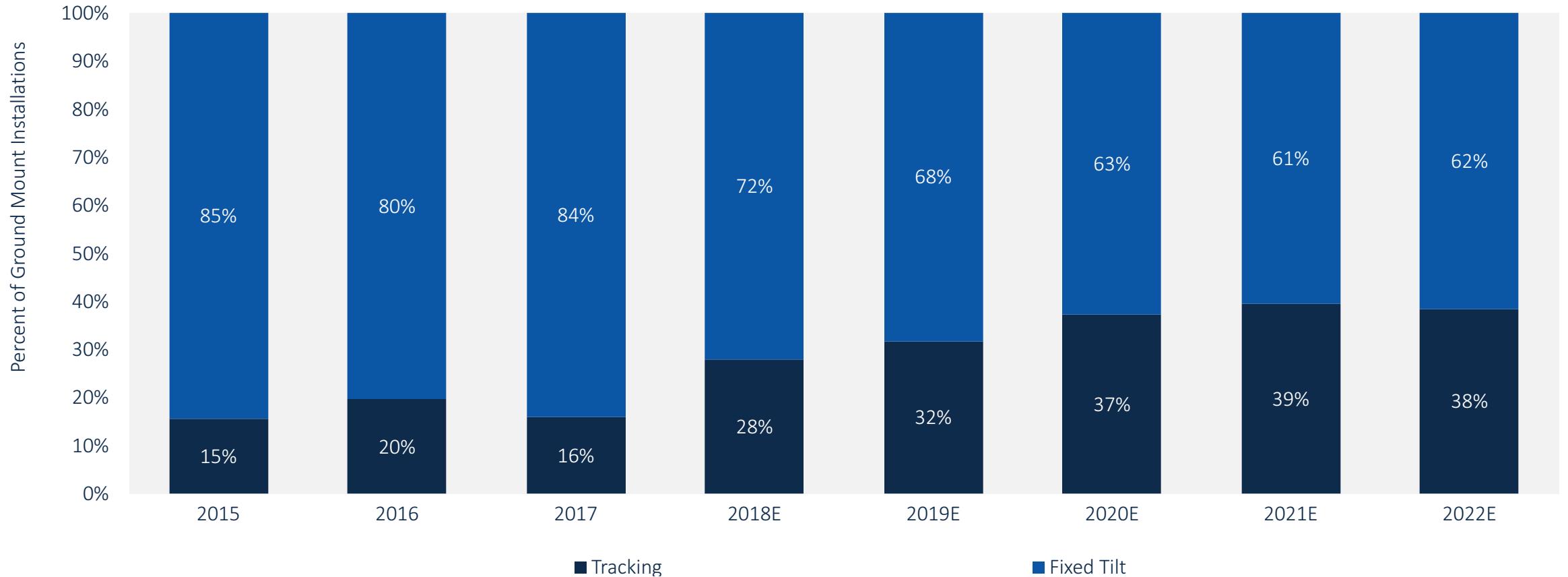
Solar Tracker Demand Continues to Grow and Diversify

Global Solar Tracker Project Installations 2015 to 2022E, MWdc



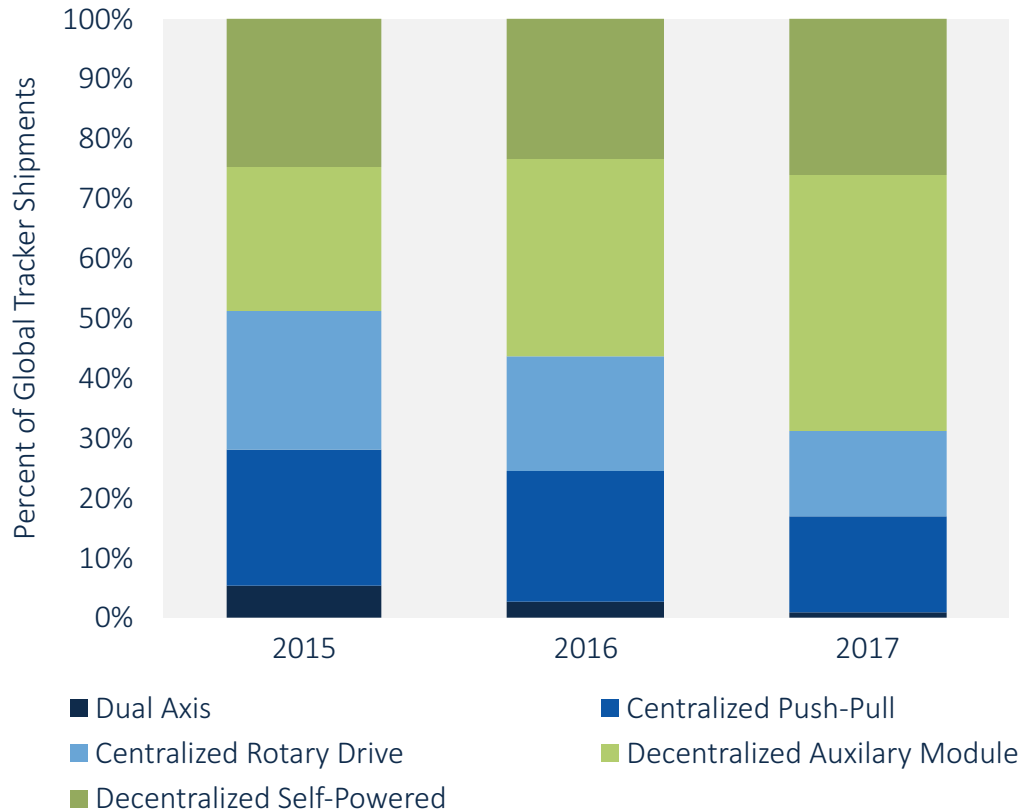
Trackers Will Also Continue to Gain Share Relative to Fixed Tilt Racking

Ratio of Fixed Tilt to Trackers Used in Ground Mount Projects Globally, 2015 to 2022E

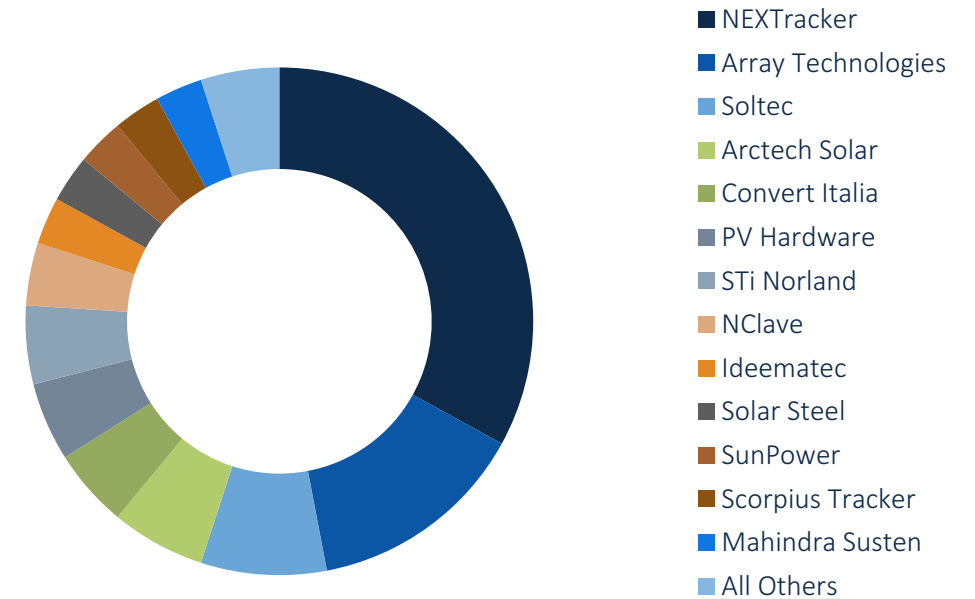


Tracker Shipments Jumped 32 Percent in 2013 to 14.6 GW, NEXTracker Leads the Market

Global PV Tracker Shipments by Technology Type 2015-2017



Global PV Tracker Market Shares by Shipments for Full-Year 2017 (MWdc)



Take 15 Percent Off GTM's Upcoming Events with Code WEBINAR



November 13 - 14 | Austin, TX

**power &
renewables
summit
2018**



December 11 - 12 | San Francisco, CA

**energy
storage
summit
2018**



MAXIMIZING PV SYSTEM PERFORMANCE

Driving LCOE reduction through bifacial and smart system control

Scott Moskovitz, GTM

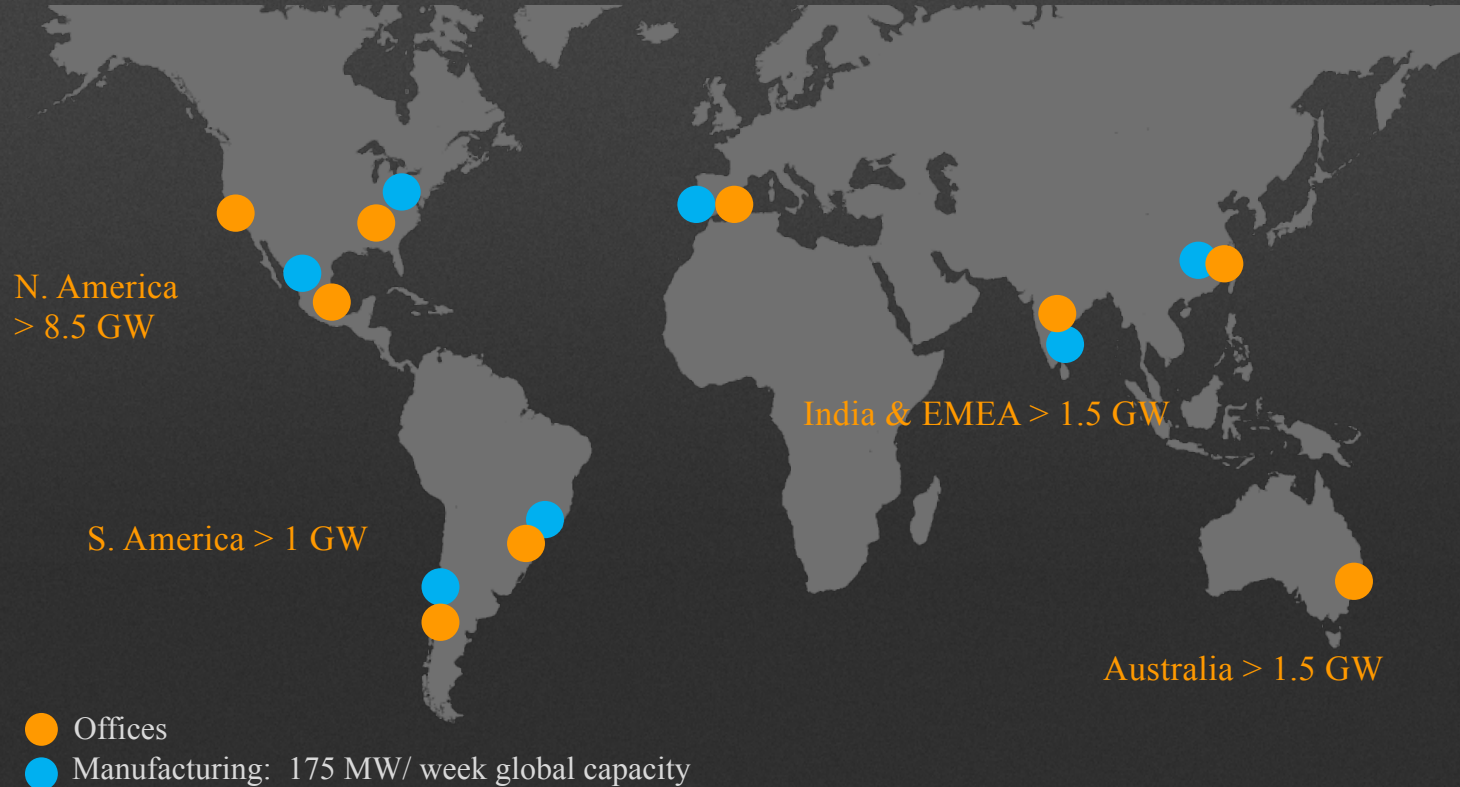
Dustin Shively, Clenera

Venkata Abbaraju & Dan Shugar, NEXTracker

Greentech Media Webinar

June 21st, 2018

NEXTRACKER, A FLEX COMPANY



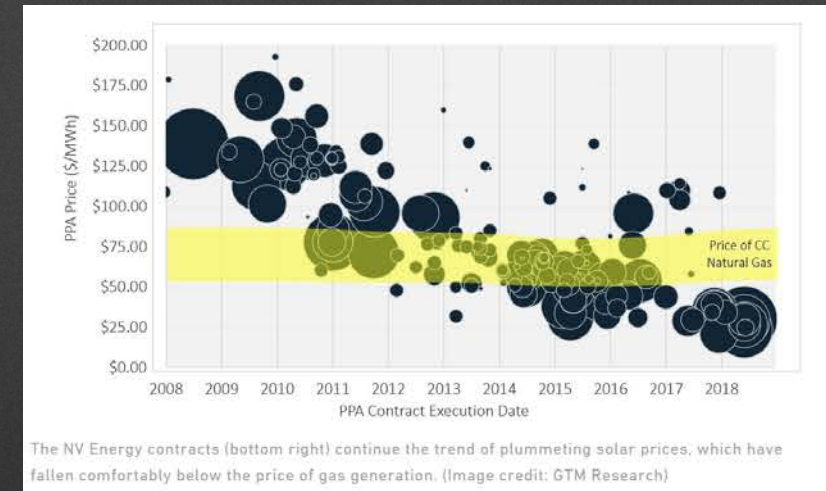
An investment grade company

- \$25B revenue
- \$13B balance sheet
- > \$400M free cash flow

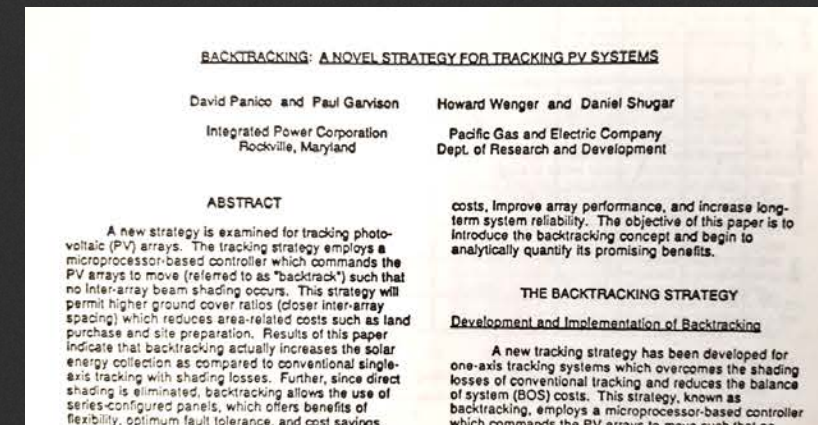
13 GW trackers delivered globally
10 GW of Gen2 NX Horizon, zero wind events

THE IMPERATIVE FOR ONGOING YIELD GAIN

- Scaling has driven PV CapEx ferociously, but much of industry at unsustainably low margins
- Competitive LCOE most important driver in utility scale sector
- Trackers , especially 1 axis horizontal, most optimal for lowest LCOE
- Backtracking algorithms first introduced in 1991
- NX acquired machine learning company in 2016 to accelerate next gen control strategy across its platforms



8minutenergy 300 MW Eagle Shadow: \$23.76/MWh fixed



“Backtracking: A Novel Strategy for Tracking PV Systems”,
Panico, Garvison, Wenger, Shugar, IEEE PVSC 1991

CREATING VALUE THRU INNOVATION & CONNECTIVITY

TrueCapture builds on prior NX technology including independent rows, self-powered smart tracker, and data connectivity with NERC-CIP Compliance



**Independent Rows
Balanced Tracker**

Up to 93 modules, 1500V,
120° tracking range,
15% N-S slope tolerance, &
torsional limiter each pier



**Self Grounded
Tracker**

Certified to UL 2703 & 3703
standard, no need for
additional grounding
components and labor



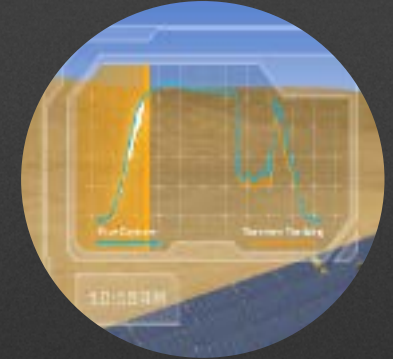
**Self Powered &
Smart Tracker**

Eliminates AC power;
integrated UPS, inclinometer,
motor current monitoring, &
wireless communications,
smart module



**Predictive Analytics &
Digital O&M™**

Auto-commissioning,
remote monitoring &
control of
system health;
NERC-CIP compliant



**TrueCapture™ Smart
Control System**

Using AI, machine learning
and weather data,
TrueCapture enhances
energy yield on solar plant
and storage + solar
applications

REAL WORLD CONDITIONS CAN LIMIT PRODUCTION

Row-to-Row Height Variances

The World is Not Flat

- Terrain undulations
- As-Built construction variances
- Nearby geographic features



Diffuse Irradiance

- Overcast/ clouds
- Fog
- Heavy haze or pollution



SHADING UNDER TRADITIONAL BACKTRACKING

Site w/ Variable Slope



Morning and Afternoon Shading

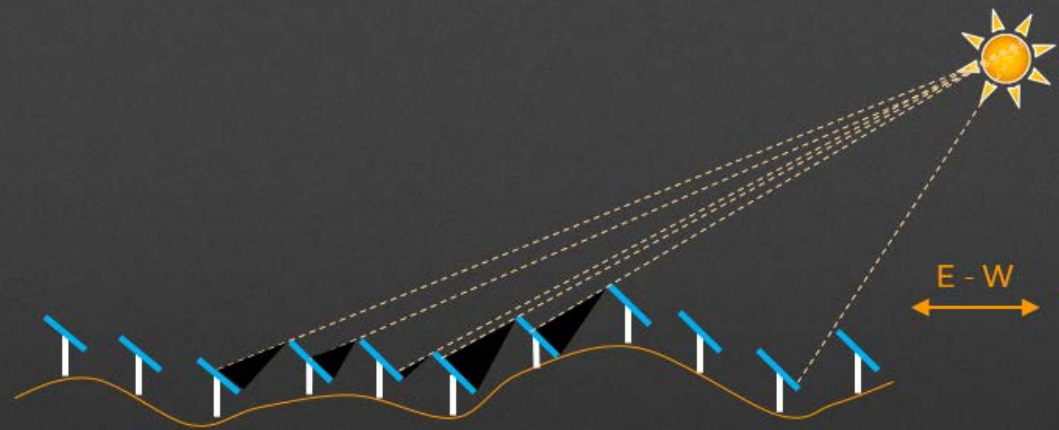


ROW-TO-ROW HEIGHT VARIATIONS (undulation or construction tolerance)

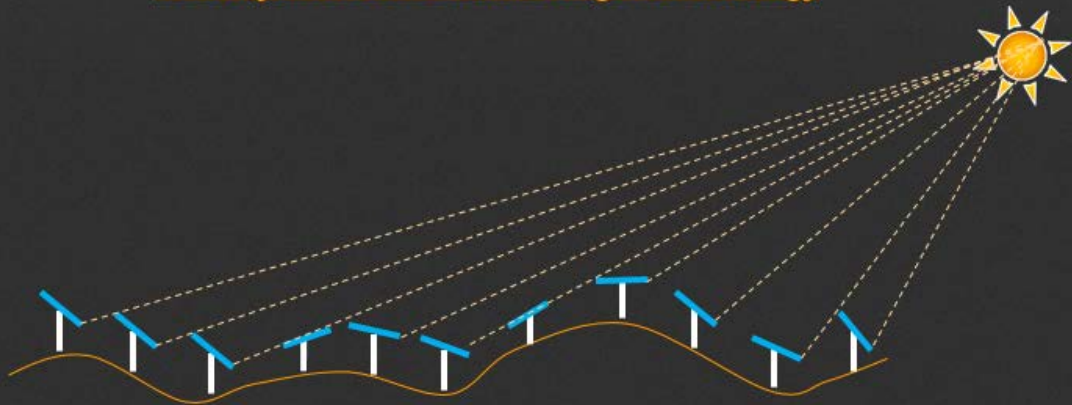


TRUECAPTURE CONTROL SYSTEM

ROW-TO-ROW TRACKING

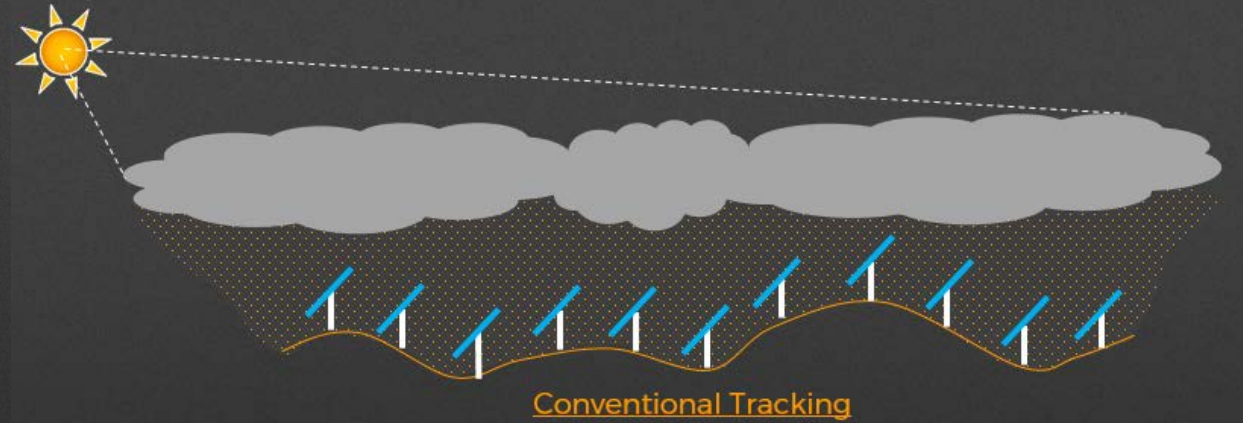


Industry standard backtracking methodology

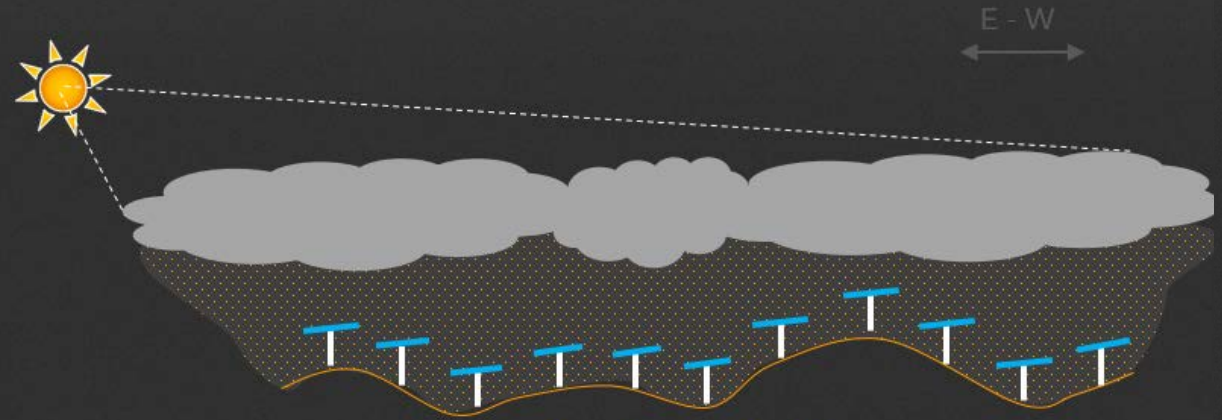


TrueCapture eliminates shading losses

DIFFUSE TRACKING

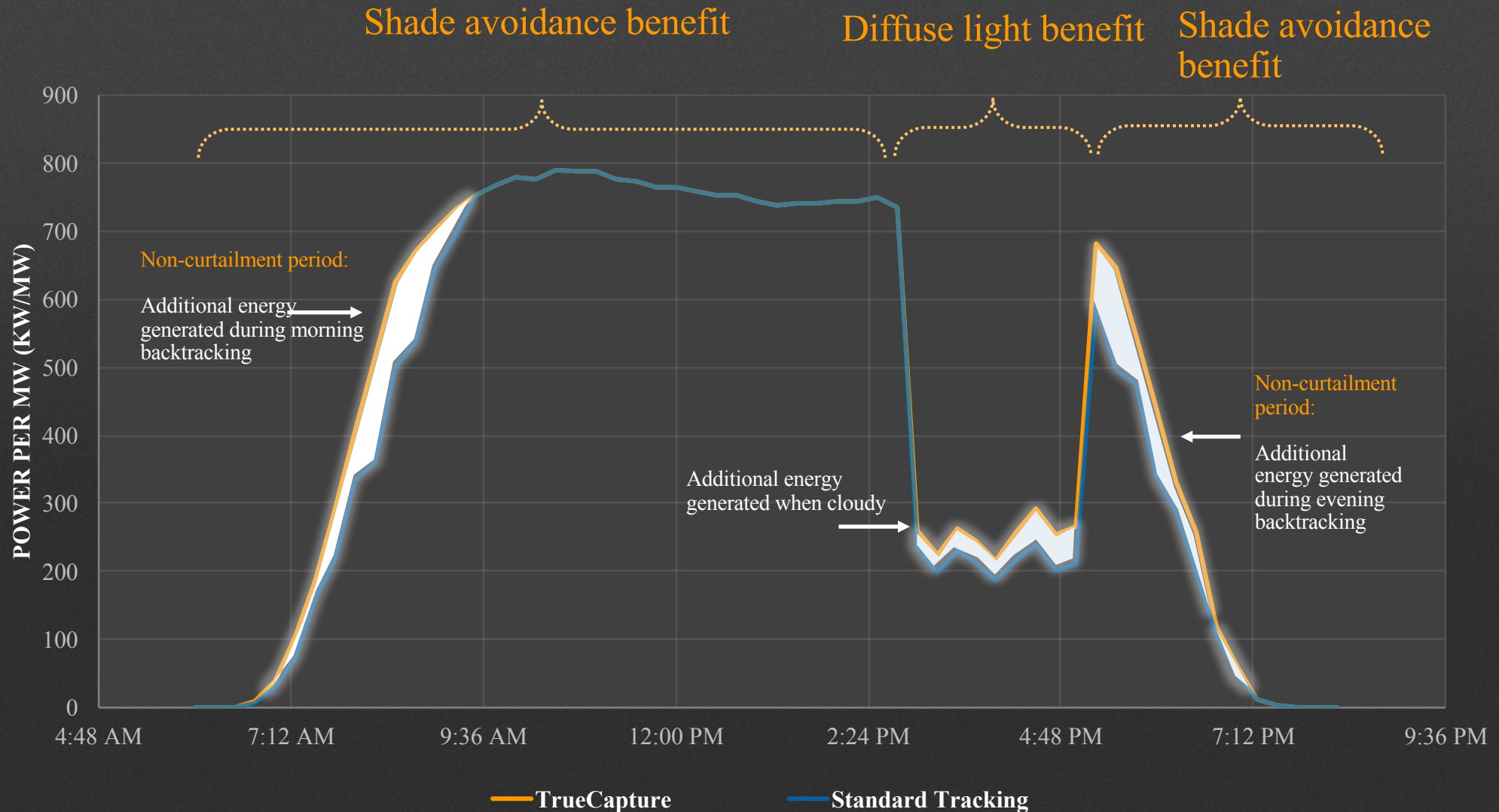


Conventional Tracking



True Capture Tracking

TRUECAPTURE ENERGY YIELD BENEFIT



Simulated example – one typical day on 1 MW site

TrueCapture Case Study: Perspective of a Developer, Owner, and Operator

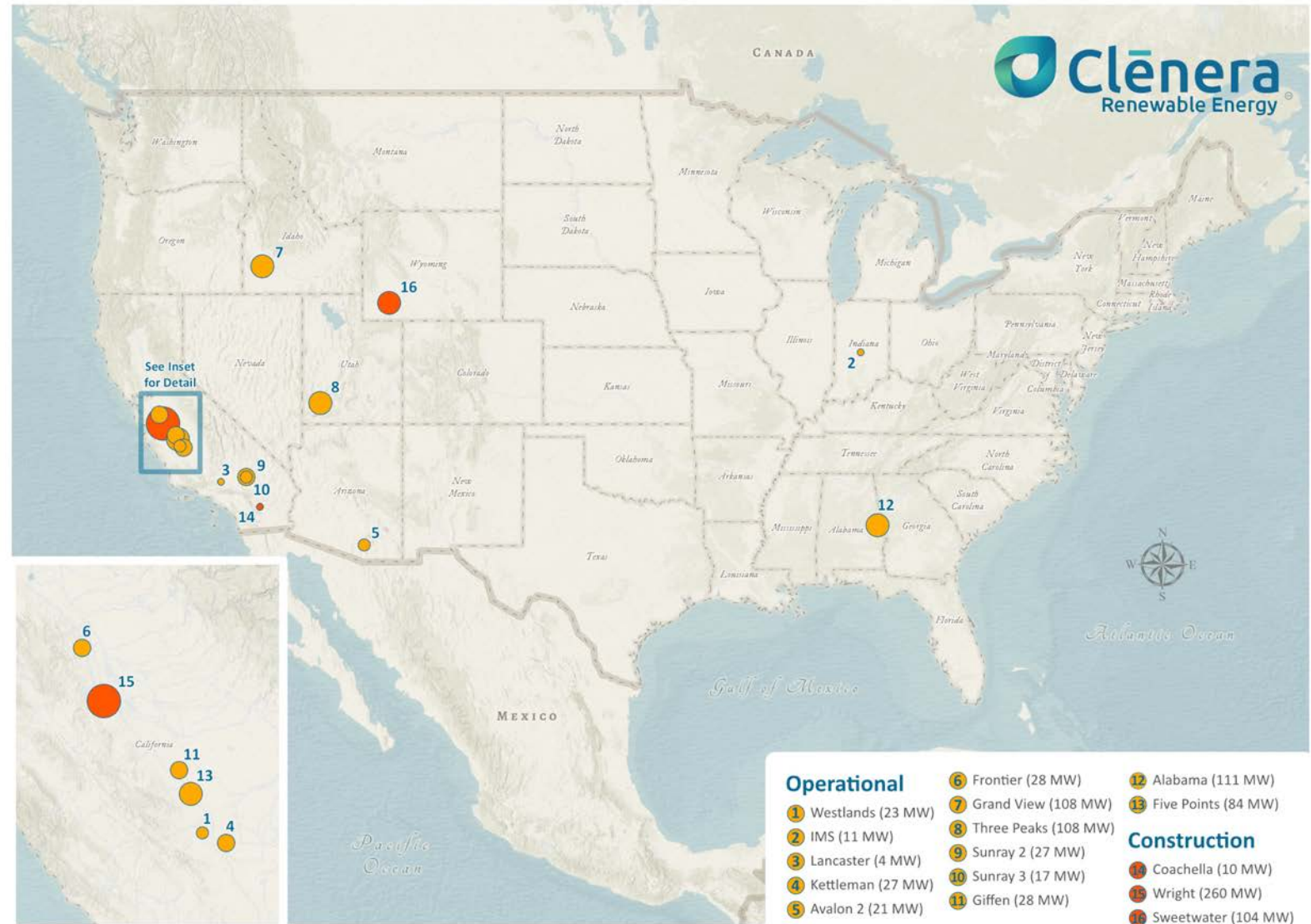
Dustin Shively, Director of Engineering
Clenera Renewable Energy



Clēnera Growing Across America

Cost, efficiency, and team driving explosive growth

- Acquisitions & Greenfield Development
- Asset Manager & Operations
- 630 MW-DC Installed Capacity
- 18 plants operating and in construction
- Over 1,500 MW-DC planned construction for 2018 & 2019
- 5 GW in development for 2019-2022



California Central Valley Inset

Solar continues to grow in the SE

AL Solar A

- 111 MW-DC
- 1,100 acres
- Energy produced is equivalent to approx. 20,000 homes
- Energy solar to Alabama Power
- Connects to 115kV transmission



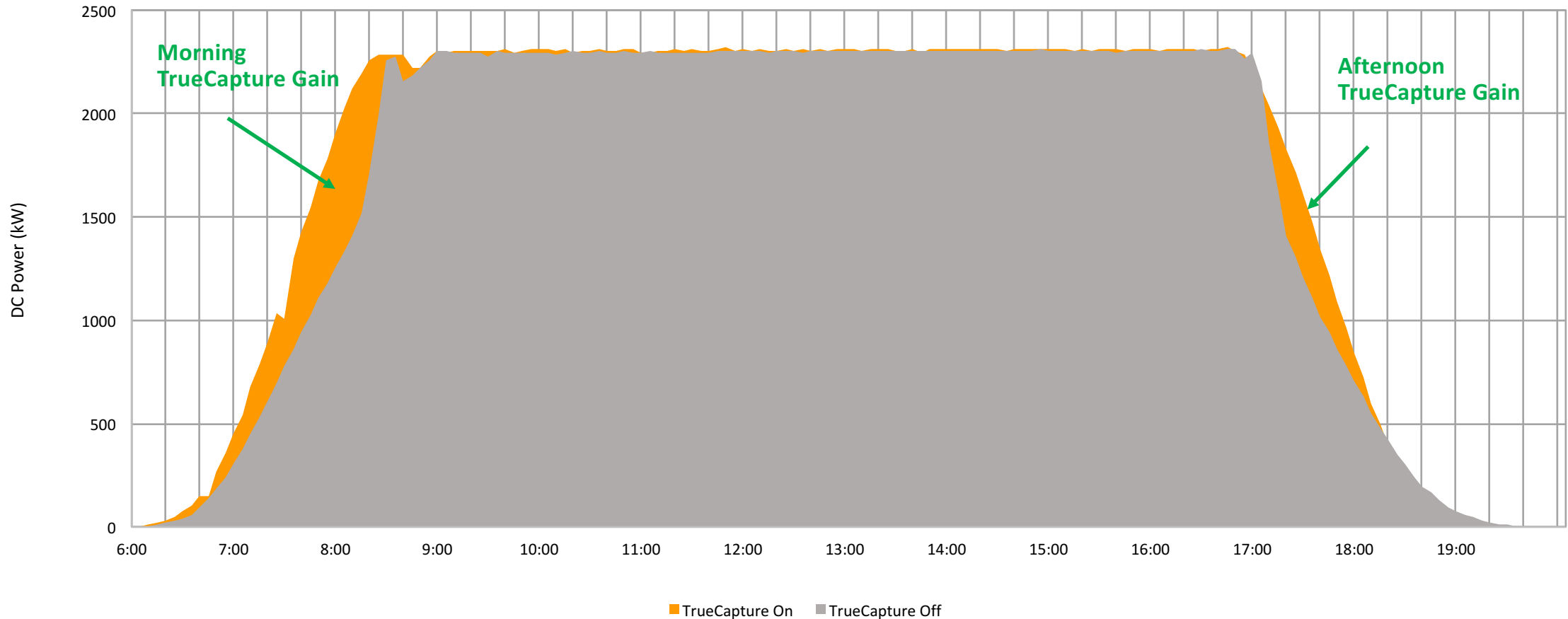
Due to terrain, some parts of the plant experience row-to-row shading at certain times of the day.

LAFAYETTE, ALABAMA – 115 MW



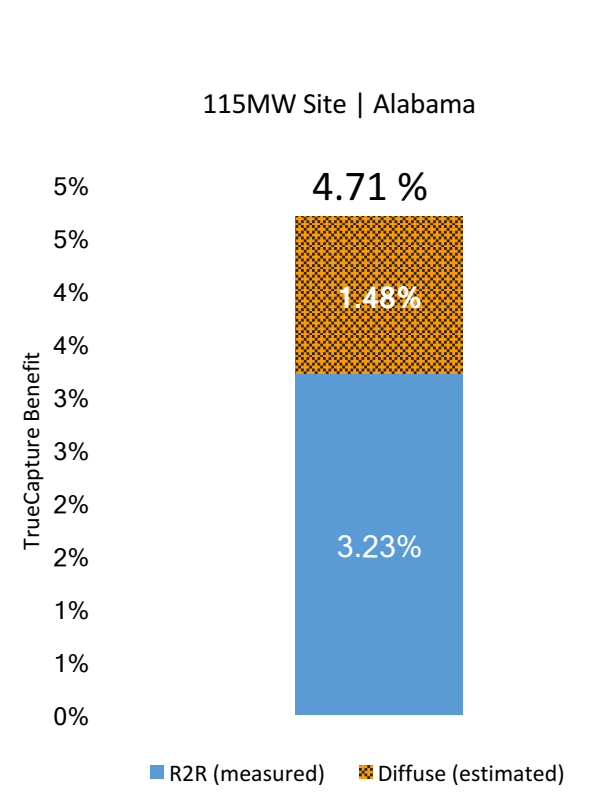
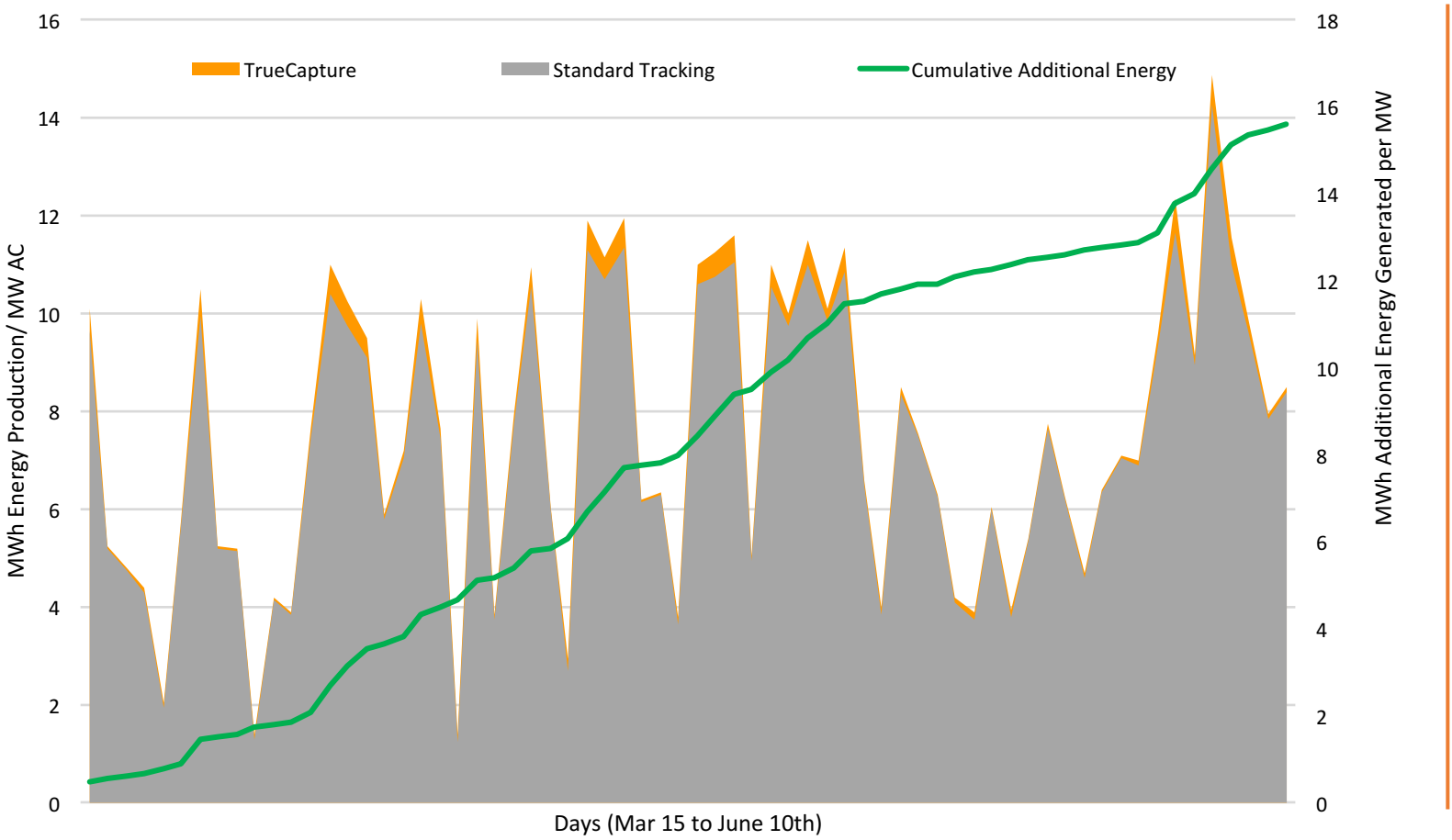
Alabama 115MW DC Site: Representative Clear Sunny Day: TrueCapture Generated 4.3% More Energy Production (R2R Only)

Lafayette Alabama Inverter Block 304
2.2MW AC Inverter | DC:AC = 1.45



Alabama 115MW DC Site 3-Month Period

TrueCapture Generated 3.23% more energy Production Overall (R2R Only)





TrueCapture Additional Case Studies & Benefits

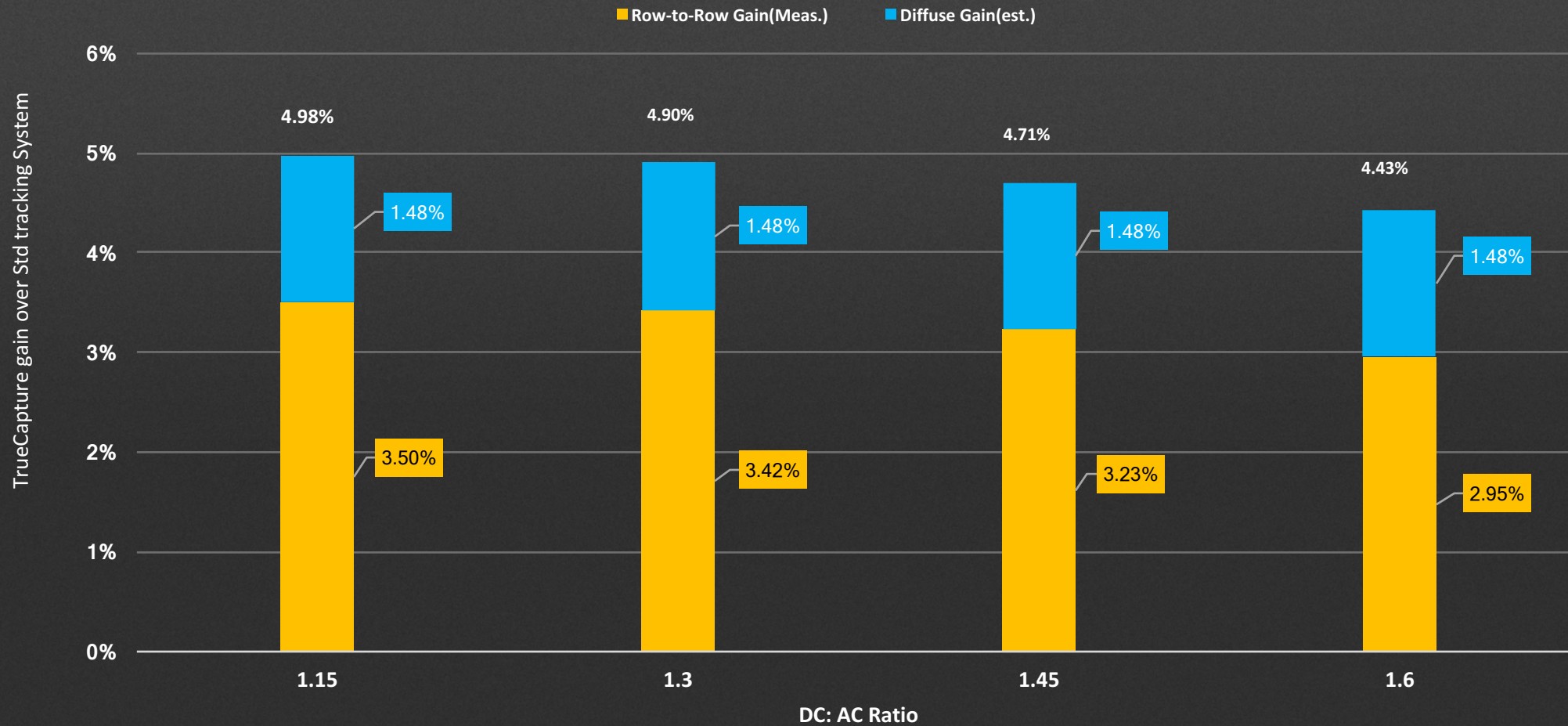
Dan Shugar & Venkata Abbaraju

NEXTracker

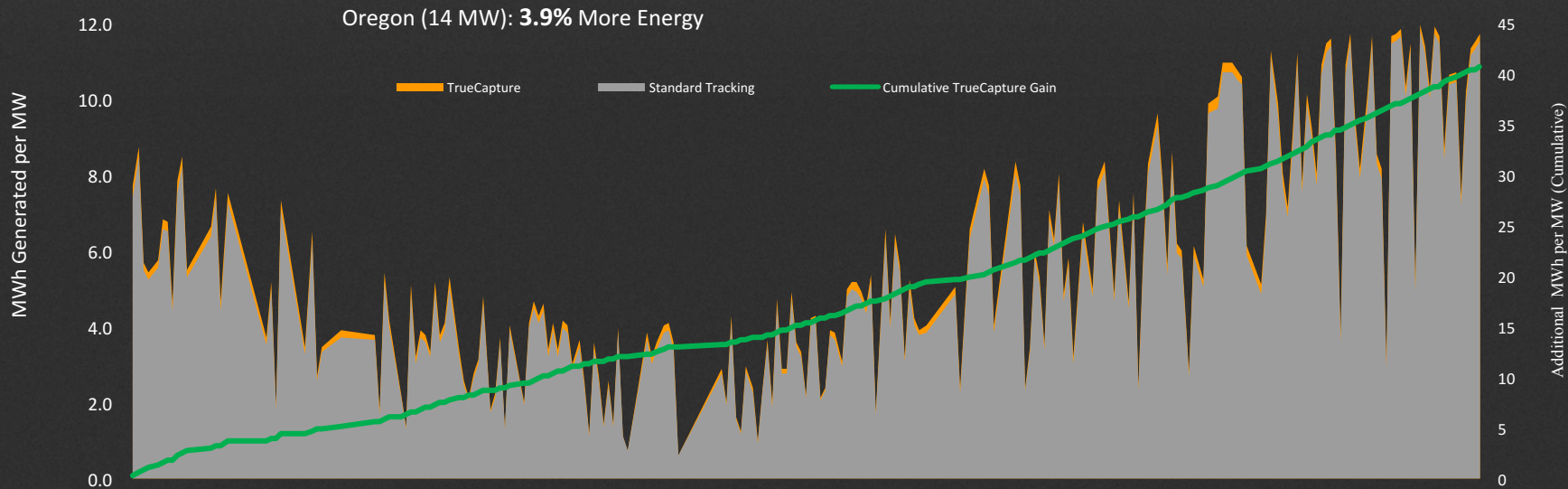
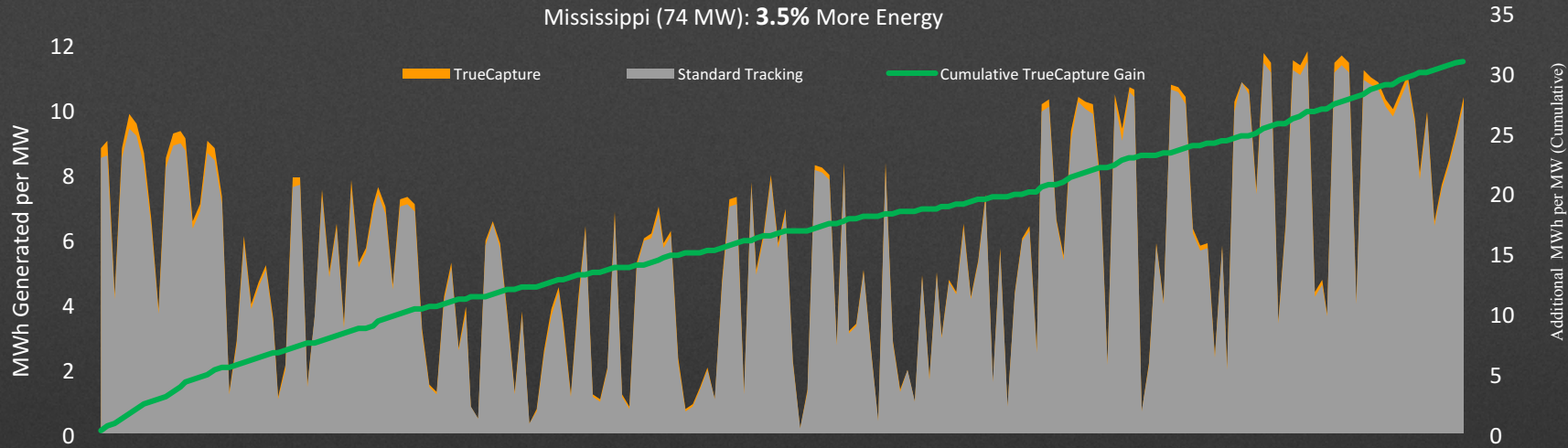
CLIPPING VS. DC/AC RATIO TO TRUETCAPTURE:

Clipping has almost no effect

Almost all TrueCapture gain occurs during off-peak time (during backtracking and cloudy conditions):



TRUECAPTURE BENEFIT: OTHER CASE STUDIES



D.E. Shaw Renewable Investments
 Bryan Martin, CEO
Bloomberg New Energy Finance Summit,
 April 2018 Presentation:

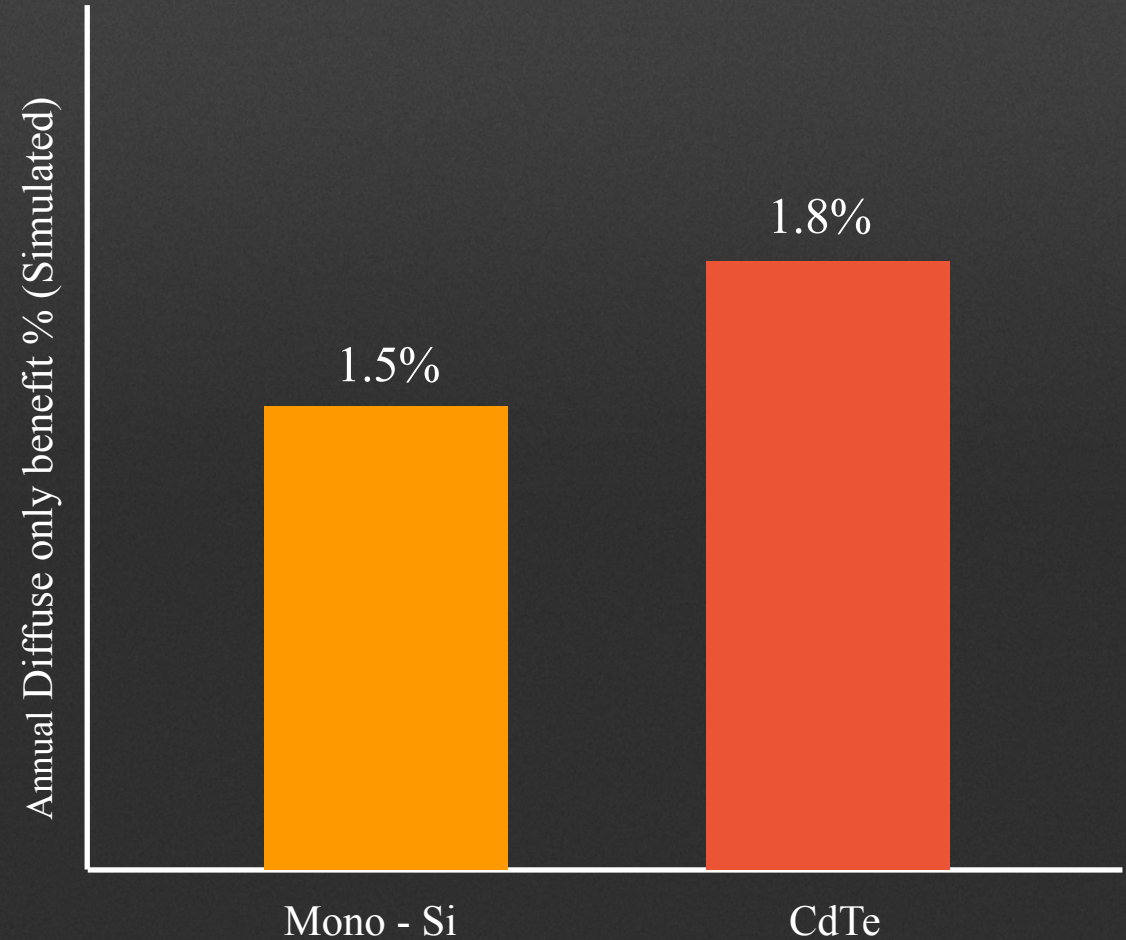
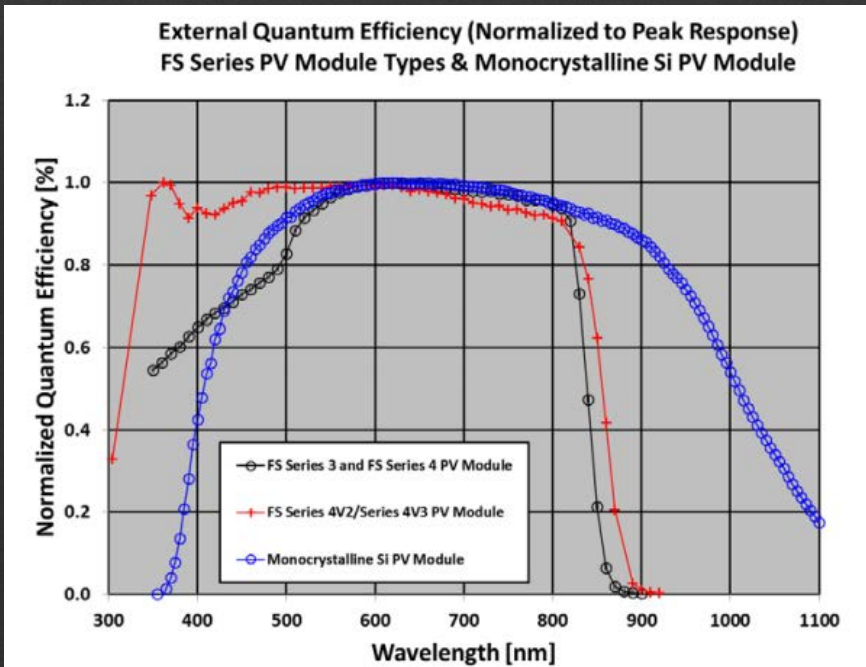
<https://www.youtube.com/watch?v=G4czdUqBbRM>

Additional Validations:

- TrueCapture I.E. Report: 90% Complete
- Multiple New Projects Financed with TrueCapture

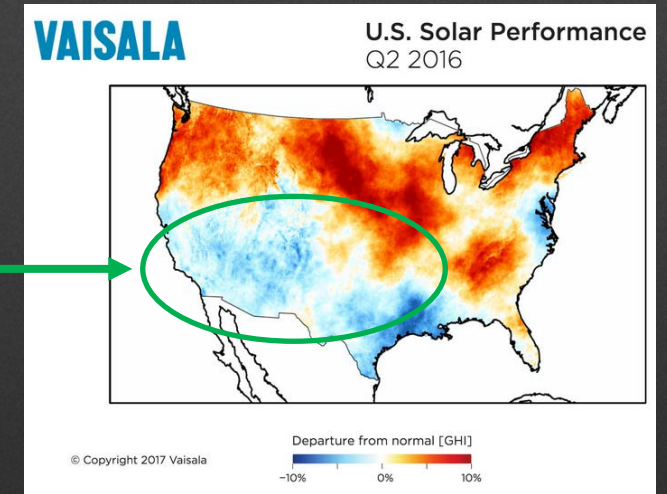
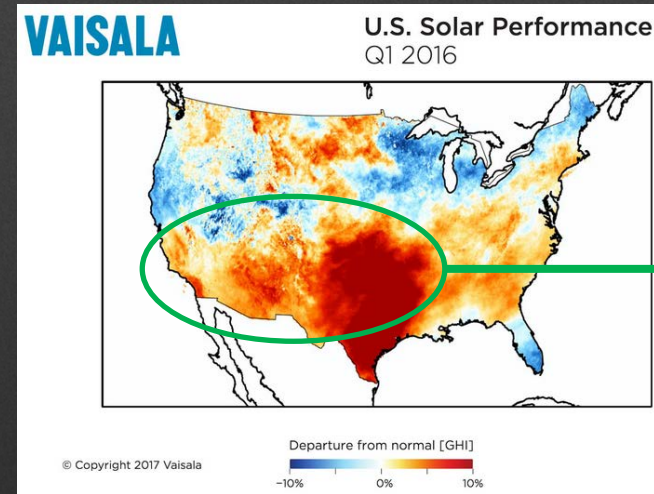
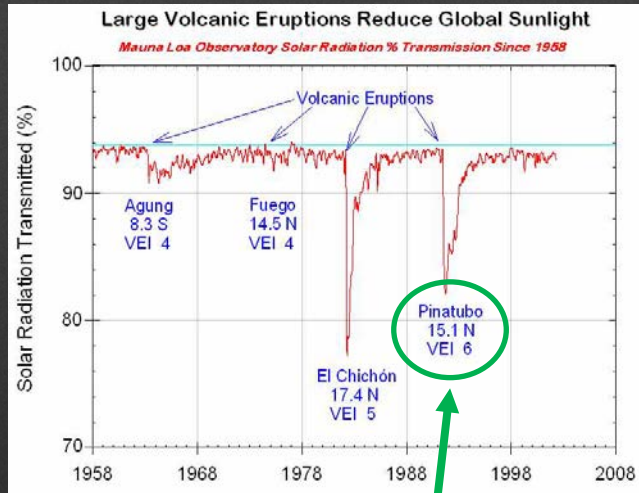
TRUECAPTURE BENEFIT WITH CdTe PV MODULES - TENNESSEE SITE

- Row-to-Row benefit currently not used with CdTe technology
- CdTe technology yields more diffuse benefit due to superior spectral response

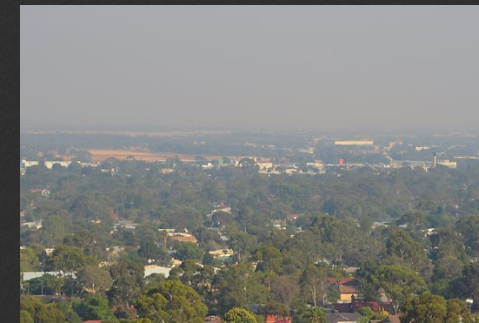


RESILIENCY FOR UNEXPECTED ATMOSPHERIC DISTURBANCES

TrueCapture can reduce production impacts attributable to volcanic eruptions, fires, dust storms and El Nino conditions by dynamically operating the PV plant

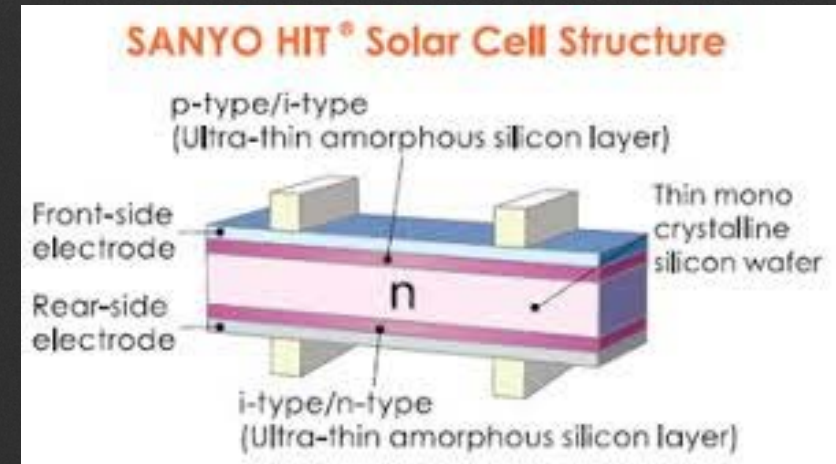


Wild fire impacts on PV energy production. Source: GTM



BIFACIAL HISTORY HIGHLIGHTS

- Japanese researcher H. Mori proposed bifacial in 1960
- 20 kW Solarex beta bifacial array at PVUSA in 1990
- Sanyo commercialized HIT for PowerLight in 2006
- PowerLight designed bifacial optimized trackers in 2007



2007: 14 MW NELLIS AIRBASE PV, LAS VEGAS, NV

- Largest PV in USA at time
- Included 2 MW Sanyo bifacial
- Used PowerLight T-20 Tracker with 2P design, tilt
- Measured good bifacial gains of 12%+ due to low GCR and high albedo
- Visited by Pres. Obama 2009



SPRINGS PRESERVE BIFACIAL PROJECT, 2008

- Site is a Las Vegas area water history museum; open to public
- PowerLight EPC & tracker manufacturer
- Horizontal tracker over tube with tilted PV
- White reflective fabric doubling as shade for cars
- Up to 17% measured bifacial gains

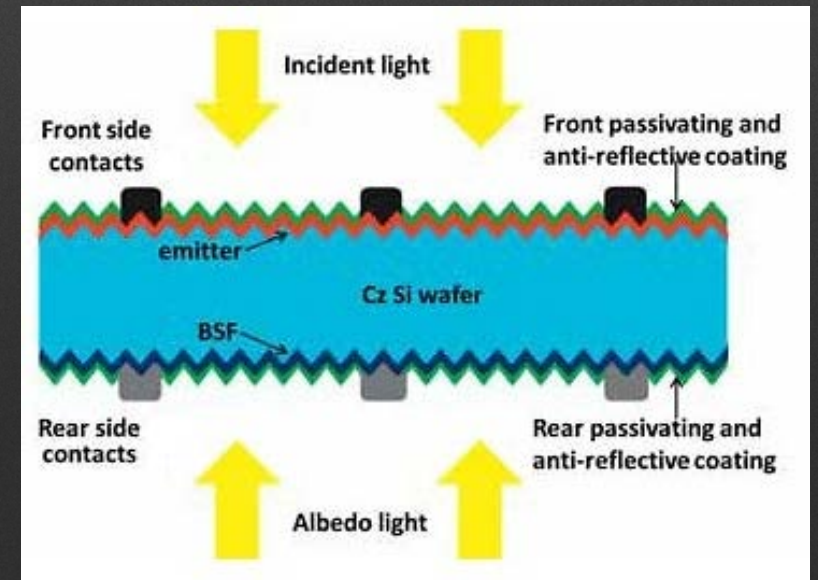


PowerLight tilted 1 axis tracker over reflective fabric with Sanyo HIT. Springs Preserve 2008

BIFACIAL CELL AND MODULE TECHNOLOGY TODAY

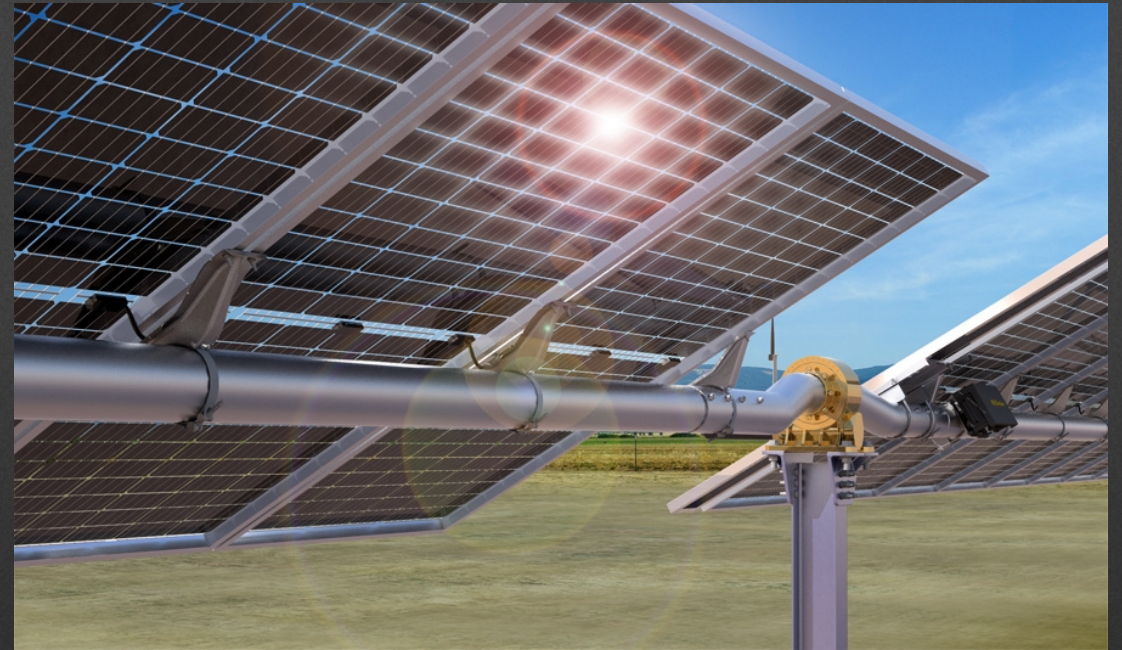
Industry Finally Moving Toward Bifacial at Scale

- Bifacial cells increasingly available & efficient
- Many PV manufacturers moving from Al-BSF to high quantum efficiency designs with HIT, PERC, IBC.
- Cell enablers: high quality Mono, better quality multi casting, thinner wafers, backside passivation and texturing
- Module enabler: availability of 2 mm and 2.5 mm high quality, durable low iron glass

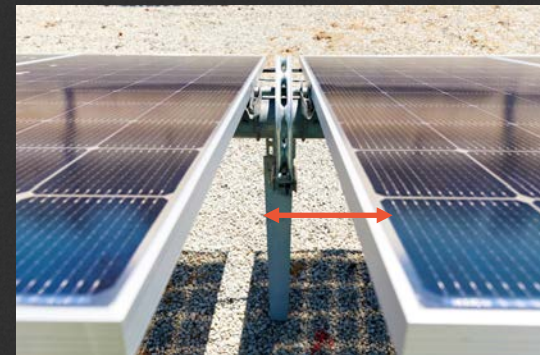


NX HORIZON: *CONCEPTUALIZED* AS A BIFACIAL TRACKER

- One portrait design for maximum albedo capture
- Modules suspended between Piers and bearings
- Rails: Tall, short, and tapered away from module, which is held OFF the tube
- Tube is round, 5" diameter, reflective



Testing rear tube effect at Center for Solar Excellence



NEXTracker's NX Horizon single-axis tracker

NX CENTER FOR SOLAR EXCELLENCE: ESTABLISHED IN 2013

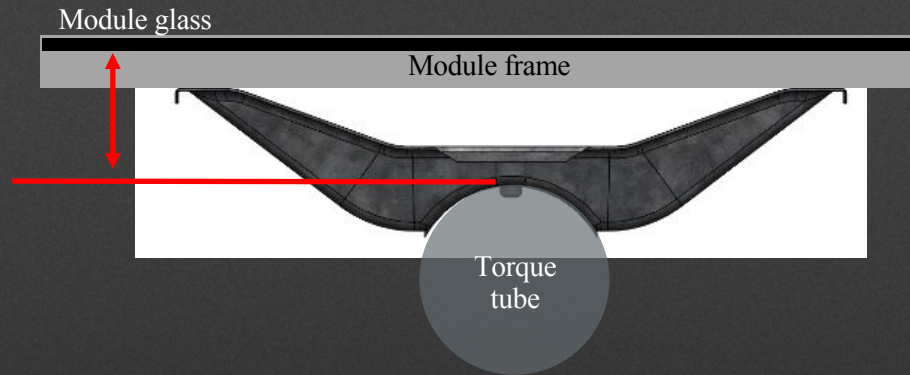
- **Technology showcase and R&D center**
64 PV and inverter and battery technologies in field, four different tracker manufacturers, 5 inverters, 4 battery types
- **Testing facility**
Extended lifecycle reliability, multiple storage technologies, bifacial, thin film, linked & independent rows, fixed tilt.
- **Training**
NABCEP accredited installer training, PowerworX Academy for customers and EPCs
- **Bifacial**
First tested in 2014



TORQUE TUBE IMPACT ON ENERGY YIELD

For Standard Bifacial Modules

- 6.5% rear shade factor used in PVSyst modeling



- Optimized tube and mountain rail configuration
- Negligible back-side energy impact from tube due to round profile, distance from module, and reflective surface
- Measured annual effective $\sim 0.5\%$ energy yield loss due to tube at NX test facility

NX HORIZON BIFACIAL GAIN UP TO 14%

4 years of field testing at Center for Solar Excellence, Fremont, CA (NX HQ)



NX Horizon with Framed Bifacial Modules
Center for Solar Excellence, Fremont CA

Month	Module A Bifacial gain (90% bifacial)	Module B Bifacial gain (70% bifacial)
January '17		5.99%
February '17		7.29%
March '17	13.8%	7.34%
April '17	14.0%	5.34%
May '17	14.4%	4.99%
June '17	13.1%	
	+13.8%	+6.2%

- Comparison of bifacial gain for same cell technology from each module manufacturer
- GCR 42%, albedo measured @ 18%
- Huawei 25kW inverters

Each MPPT was connected to a string of PV modules with different technologies

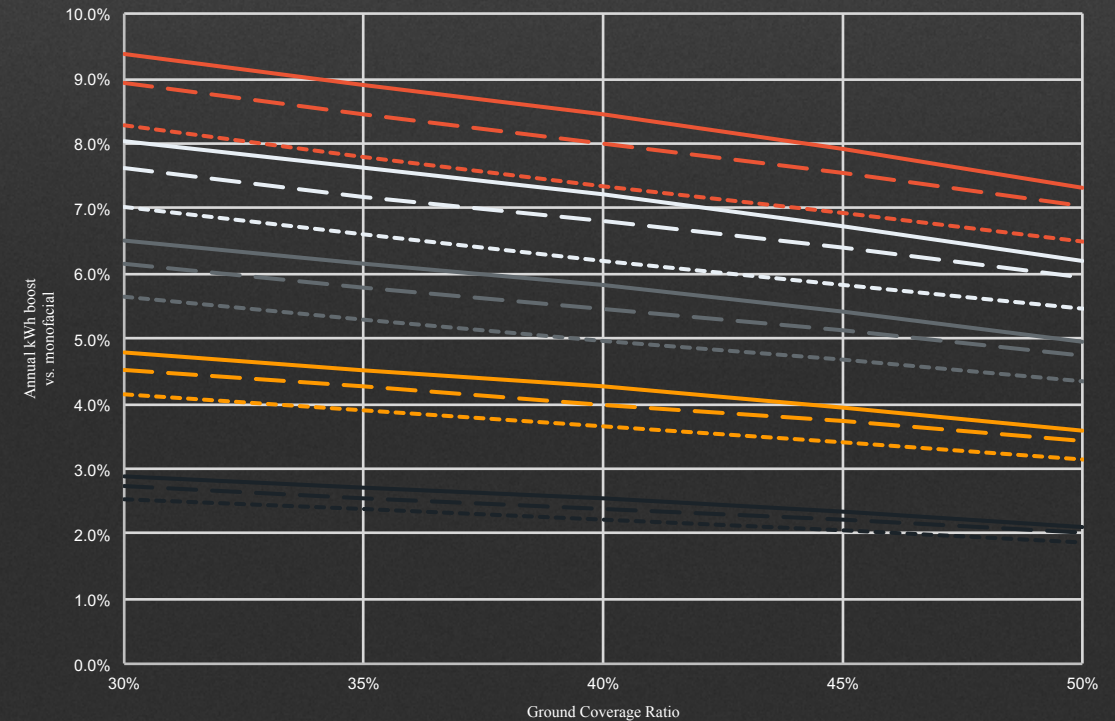
PVSYST NOW MODELS BIFACIAL + TRACKER

Factors influencing Bifacial yield:



- Albedo ↑
- View Factor ↑
- GCR (yield vs. land) ↓
- Array Height (yield vs. structure cost) ↑
- PV array height-to-width ratio ↑
- PV Bifaciality ↑
- System DC / AC ↓

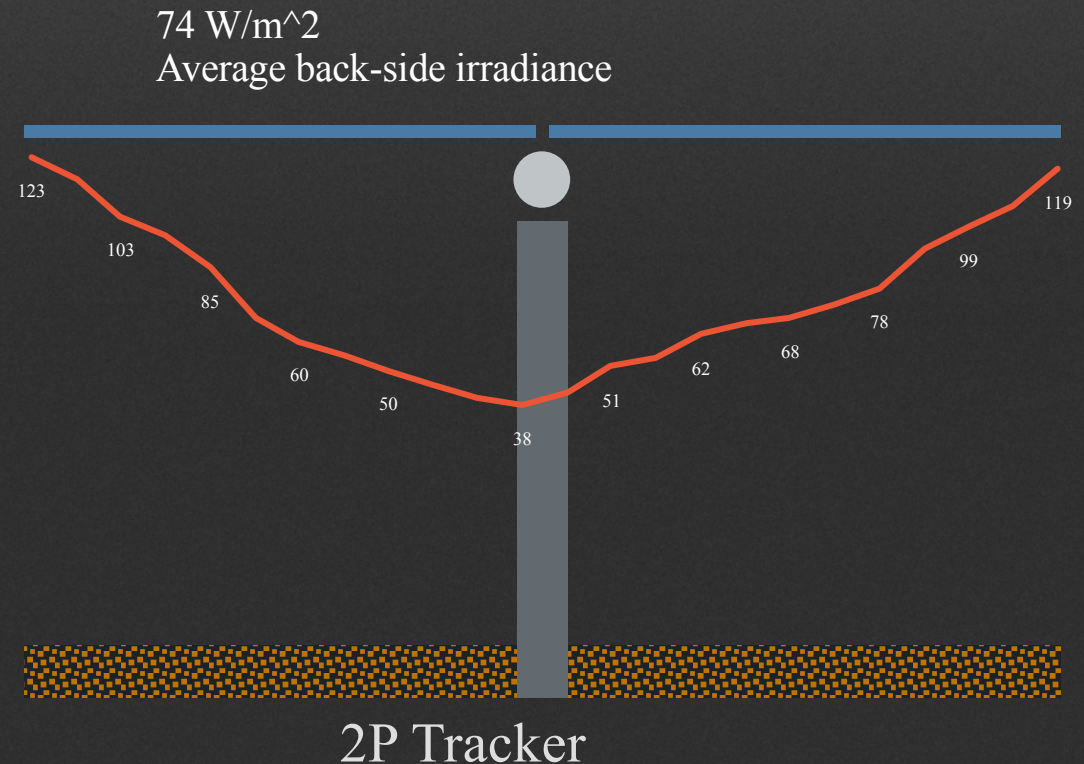
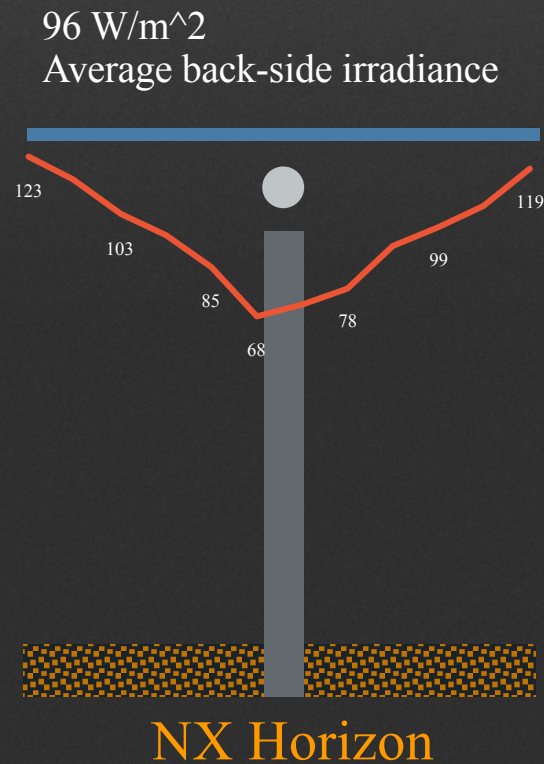
Bifacial Gain on NX Horizon



1 x PORTRAIT TRACKERS COLLECT MORE BACK-SIDE IRRADIANCE

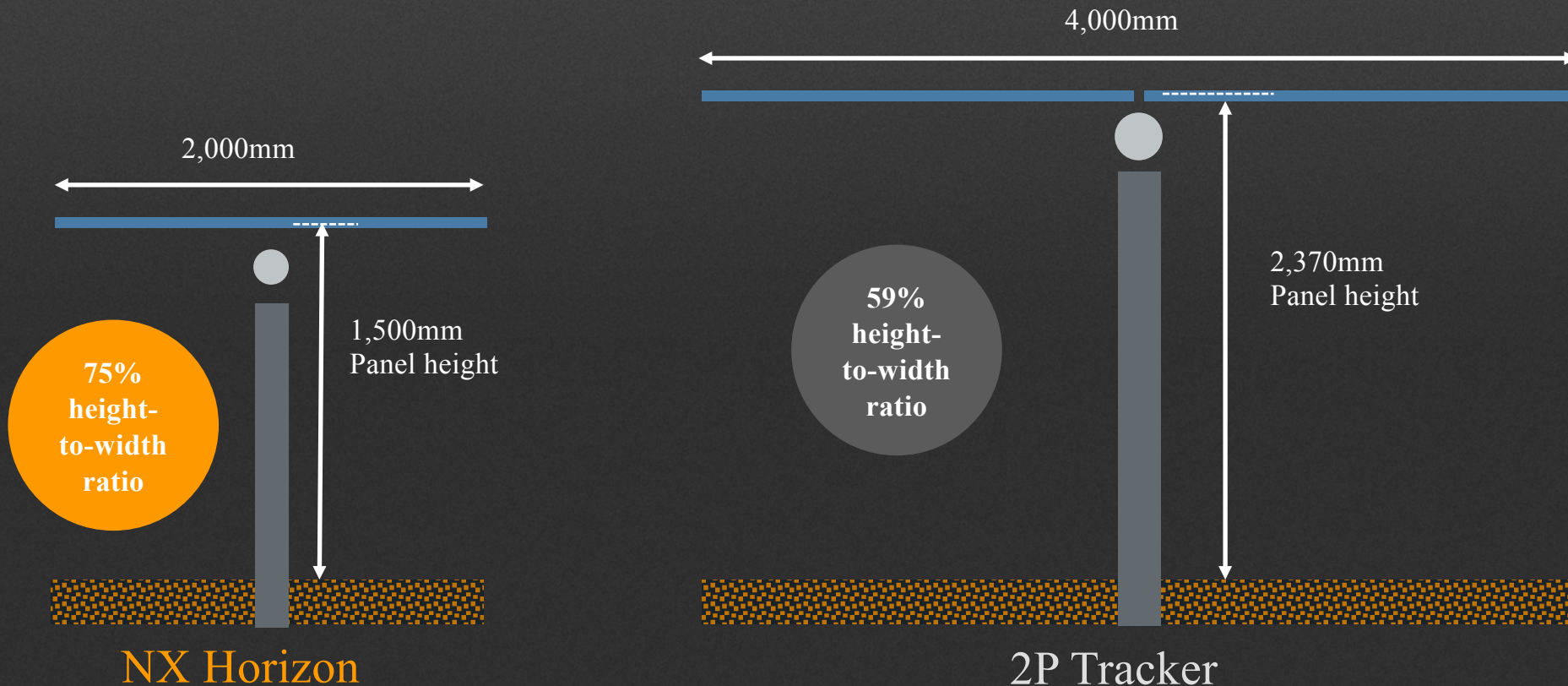
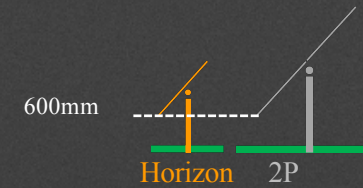
Hypothetical Scenario: Both trackers installed at same height

- Back-side irradiance function of tracker height/width ratio



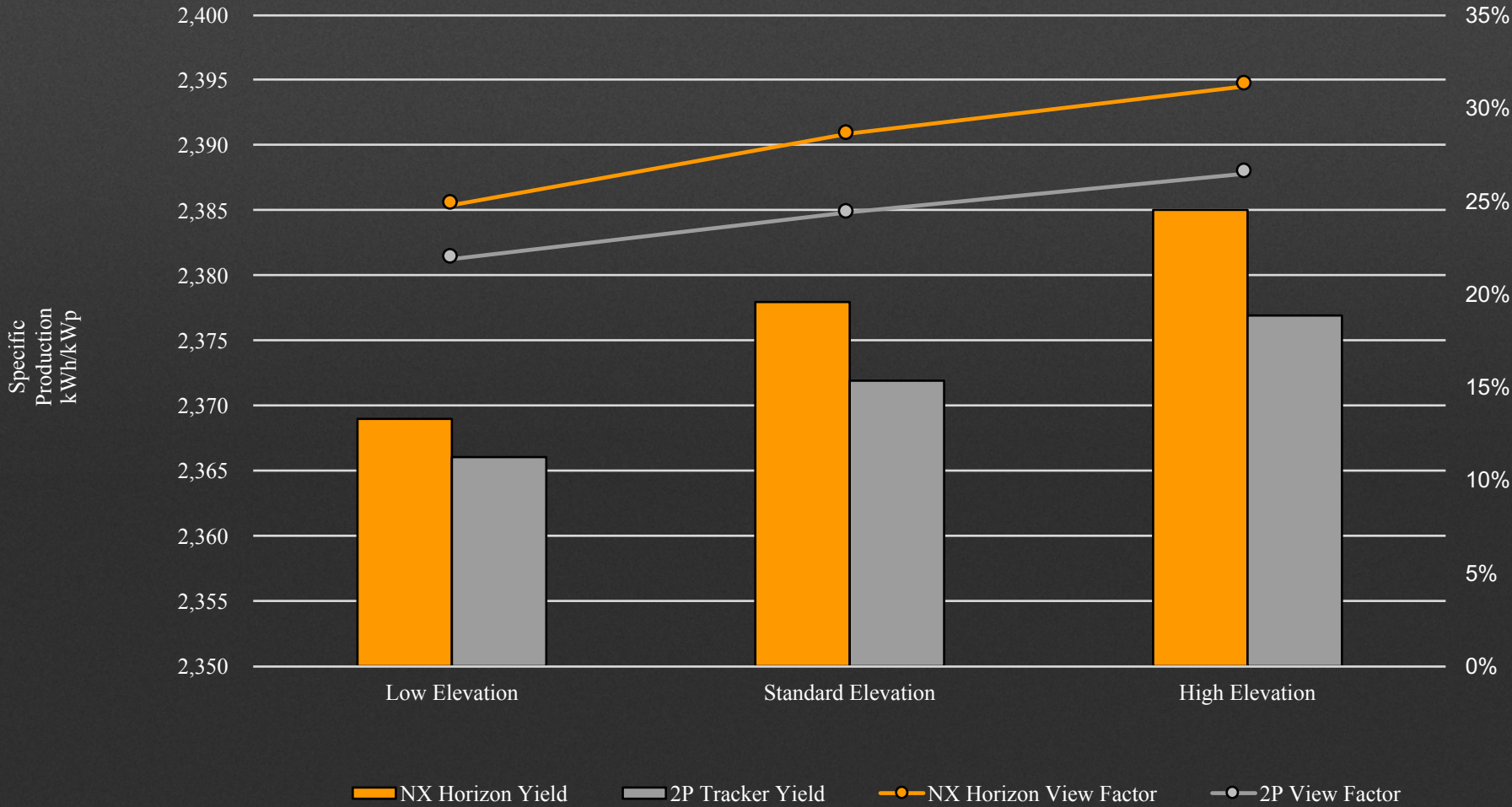
1 x PORTRAIT TRACKERS COLLECT MORE BACK-SIDE IRRADIANCE

Real World: Designed to clearance height



PVSYST ANALYSIS: NX HORIZON vs. 2P TRACKER

Energy Production w/ Bifacial Panels
NX Horizon vs. 2P Tracker



0.3% More Energy vs. 2P

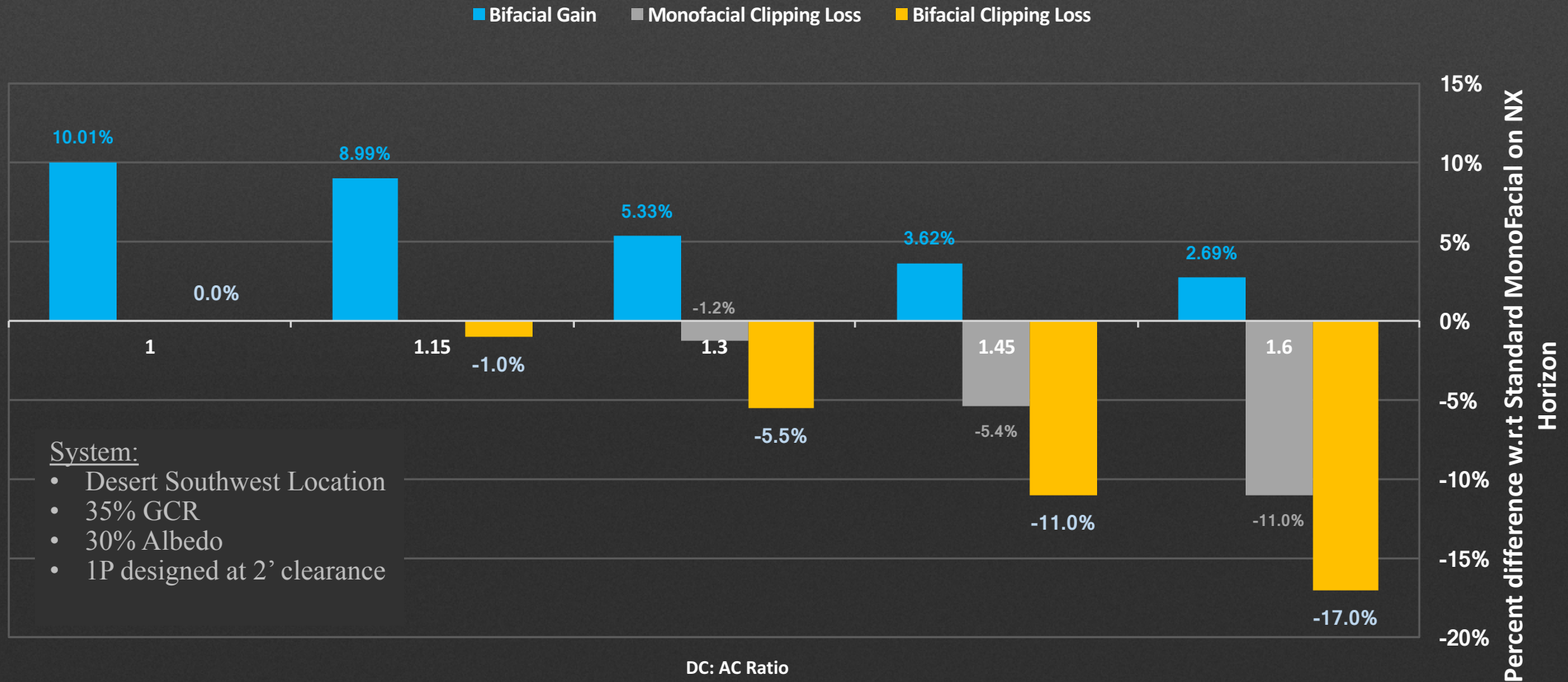


Modeled with PV Syst v6.72

- Blythe CA
- TMY3 weather data
- “Horizontal unlimited trackers” simulation method
- 90% bifacial PV modules
- 20% ground albedo
- 40% ground cover ratio
- +/- 60° tracking range
- 1.20 DC/AC ratio
- 6.5% back-side shade factor for NX Horizon
- 3.0% back-side shade factor for 2P tracker
- Clearance = module edge to grade @ 60° tilt:
 - Low: 300mm
 - Standard: 600mm
 - High: 900mm

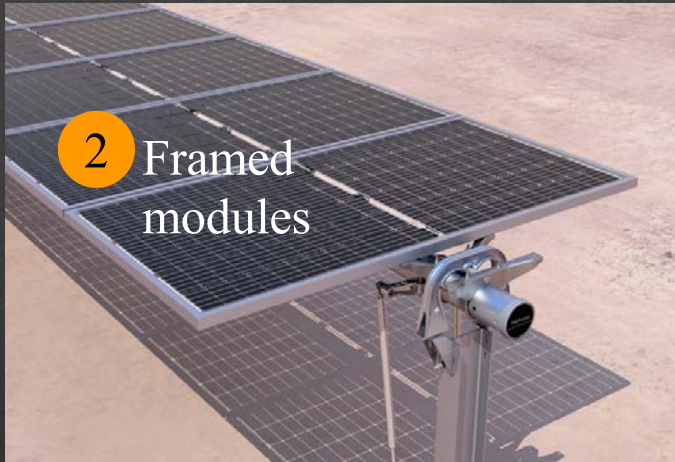
CLIPPING VS DC/AC FOR MONOFACIAL & BIFACIAL

Most of the bifacial yield occurs during mid-day, when inverters reach peak power



NEXTRACKER RECOMMENDATIONS FOR MAXIMUM YIELD

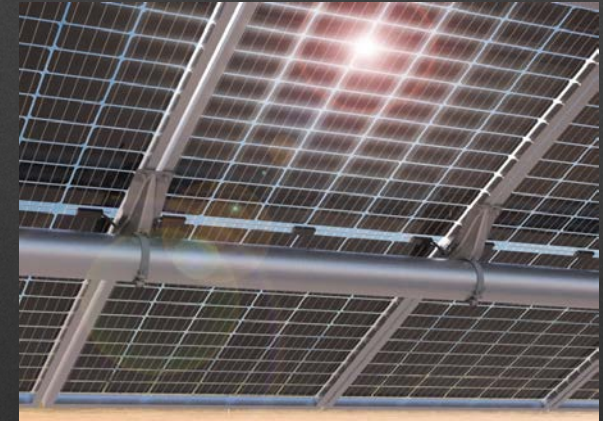
1 1 Module in Portrait Tracker



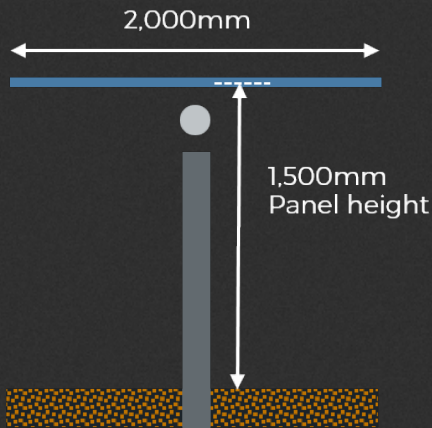
3 30-40% GCR*



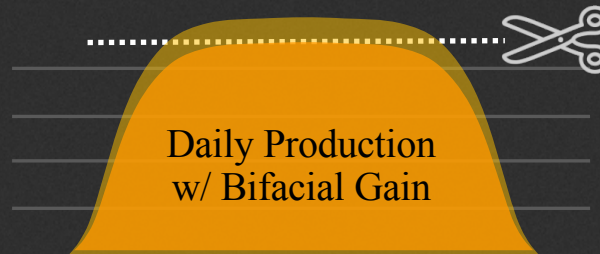
4 Low Profile Rail + Round Tube



5



6 ~1.25 DC/AC Ratio*



7 Consider Storage*



FRAMED MODULES ARE BEST FOR TRACKERS

General Framed Advantages for Trackers:

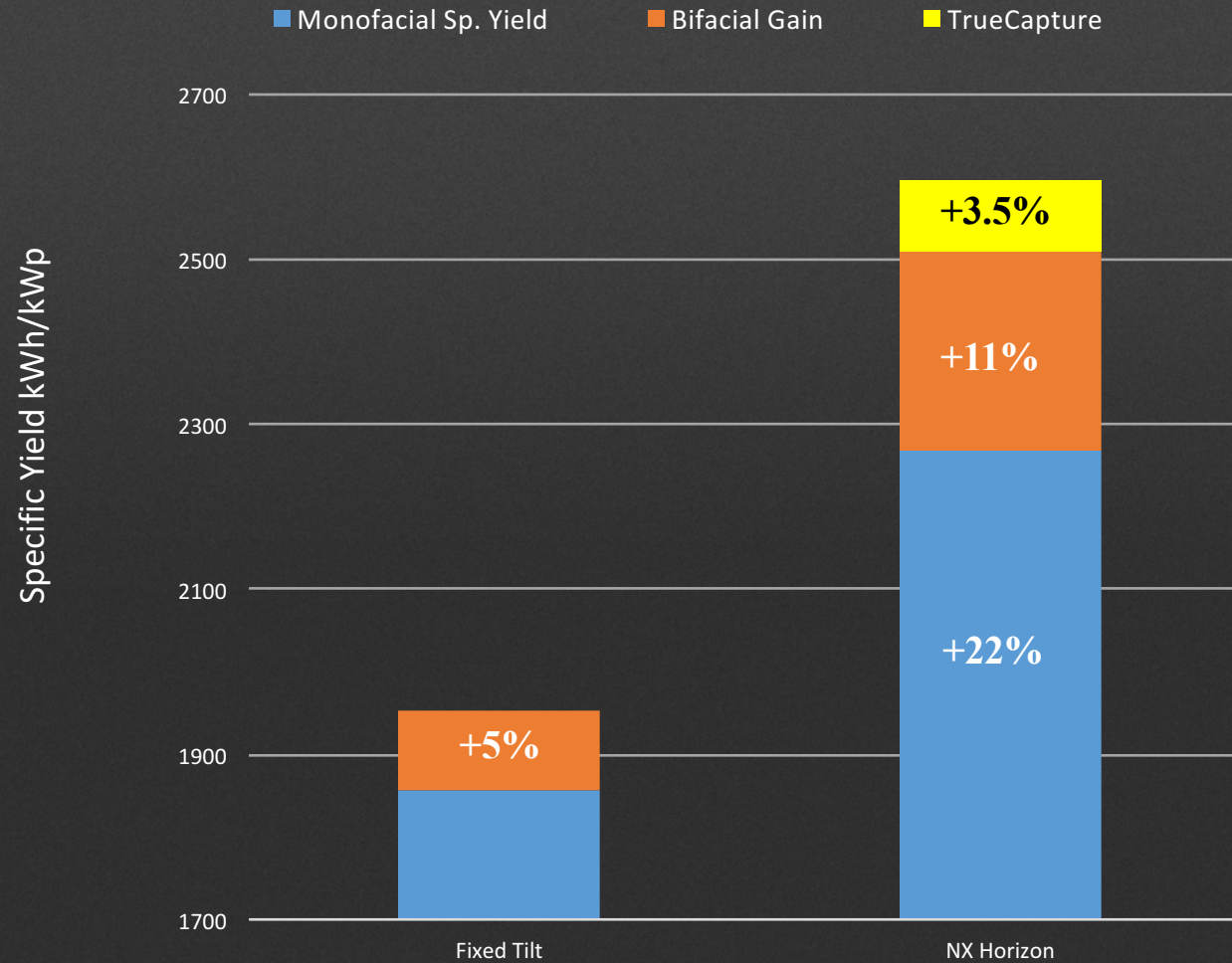
- Faster installation time with less breakage
- Improved module reliability. *Note: UL1703 is a static test, real world has dynamic loads*
- No slippage and less risk of damage in high wind situations
- Thinner glass = less weight
- Long term durability; less breakage with site equipment, animals, ice/snow, sand dunes

Especially for bifacial:

- Enables safe mounting in portrait w/shared rail – no rails behind modules
- Avoid concentrating stresses on weak edges of module glass
- Short (400mm), low profile rail minimizes module edge shading

TRUECAPTURE + BIFACIAL: A WINNING COMBINATION

FIXED VS TRACKER BIFACIAL STUDY



Site Conditions

Location: Desert Southwest
Albedo: 38%

NX Horizon System

GCR: 35%
Bifaciality: 85%

Fixed

Fixed Tilt: 25 degree
GCR: 60%
Bifaciality: 85%

Q & A

754 MW NEXTracker System
Villanueva, Mexico
Client: ENEL Green Power