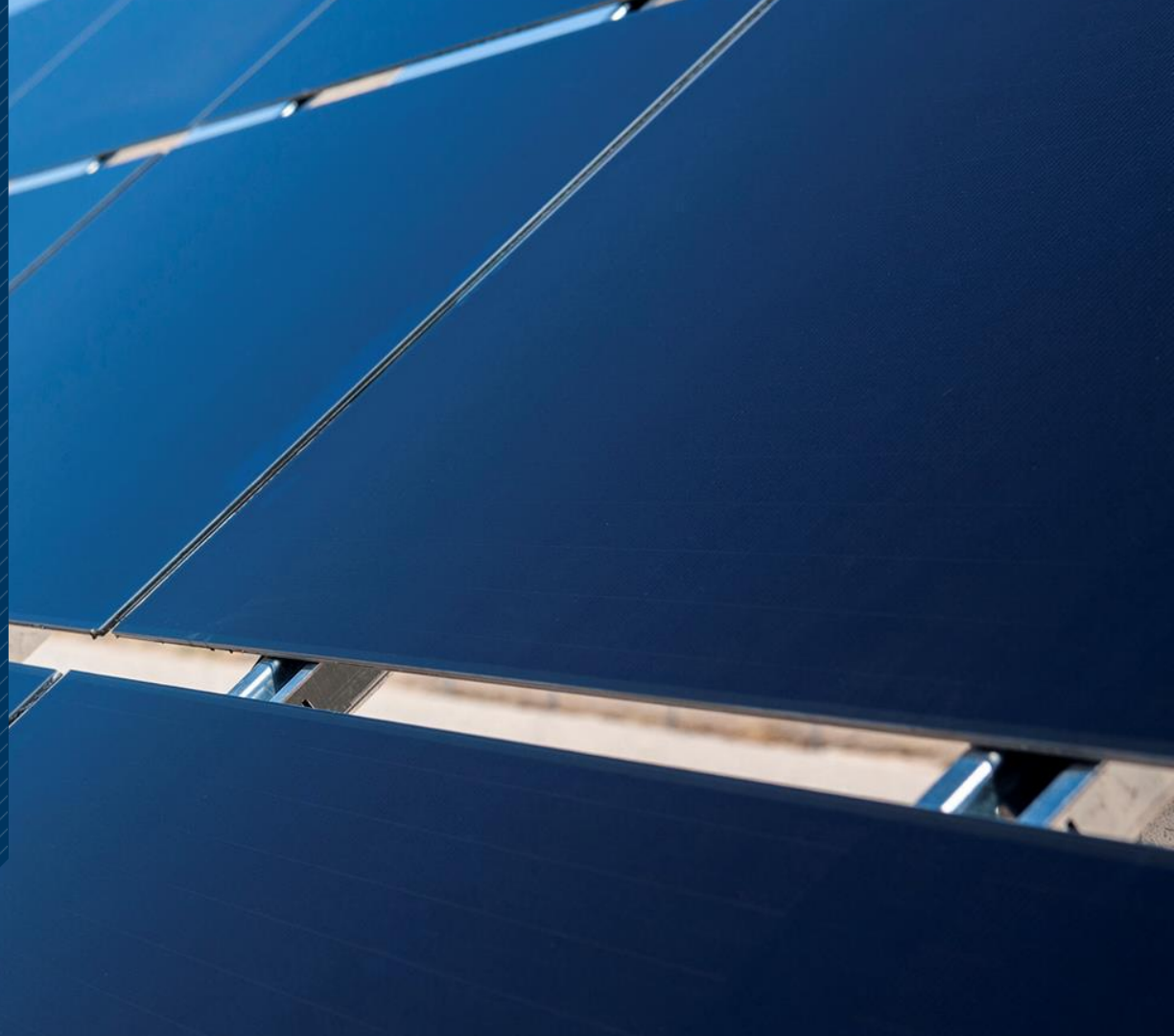
TECHNICAL SEMINAR

TECHNOLOGY UPDATE FS4V3, INTRODUCTION TO
- FS6
- **P**LANT**P**REDICT

Karim Asali
Technical Director

First Solar®

Istanbul, February, 7th, 2018



AGENDA

Start: 10:00 – End: 13:30 (incl. coffee break)

1. PART 1
- Short update on First Solar
- Overview on the key differentiators
- Technology and Manufacturing

2. PART 2
- FS 4V3 Solar Module

COFFEE BREAK

Continue PART 2
- FS 6 Solar Module
- Quality & Reliability

3. PART 3
- Introduction to PlantPredict
- Summary & Conclusion
- Open Discussion

PART 1:
- ABOUT FIRST SOLAR
- OVERVIEW OF KEY DIFFERENTIATORS
- TECHNOLOGY AND MANUFACTURING

FIRST SOLAR AT A GLANCE

Over **17GW** sold worldwide and over **$14.5B** in project financing facilitated

Partner of choice for leading utilities and global power buyers since 1999

Solar energy that is **economically competitive with fossil fuel**

Strongest **financial stability** & **bankability** in the industry

FIRST SOLAR AT A GLANCE

History of solar innovation with **world record efficiency**

High-efficiency technology with a **proven energy advantage**

Lowest environmental impacts
generating clean electricity with
NO carbon emissions or air pollutants

GLOBAL OFFICES & MANUFACTURING

~5,400
Associates

~40,000
Global Supply Chain Jobs

TRUSTED AND BANKABLE PARTNER

CORPORATE RENEWABLES

UTILITY-SCALE

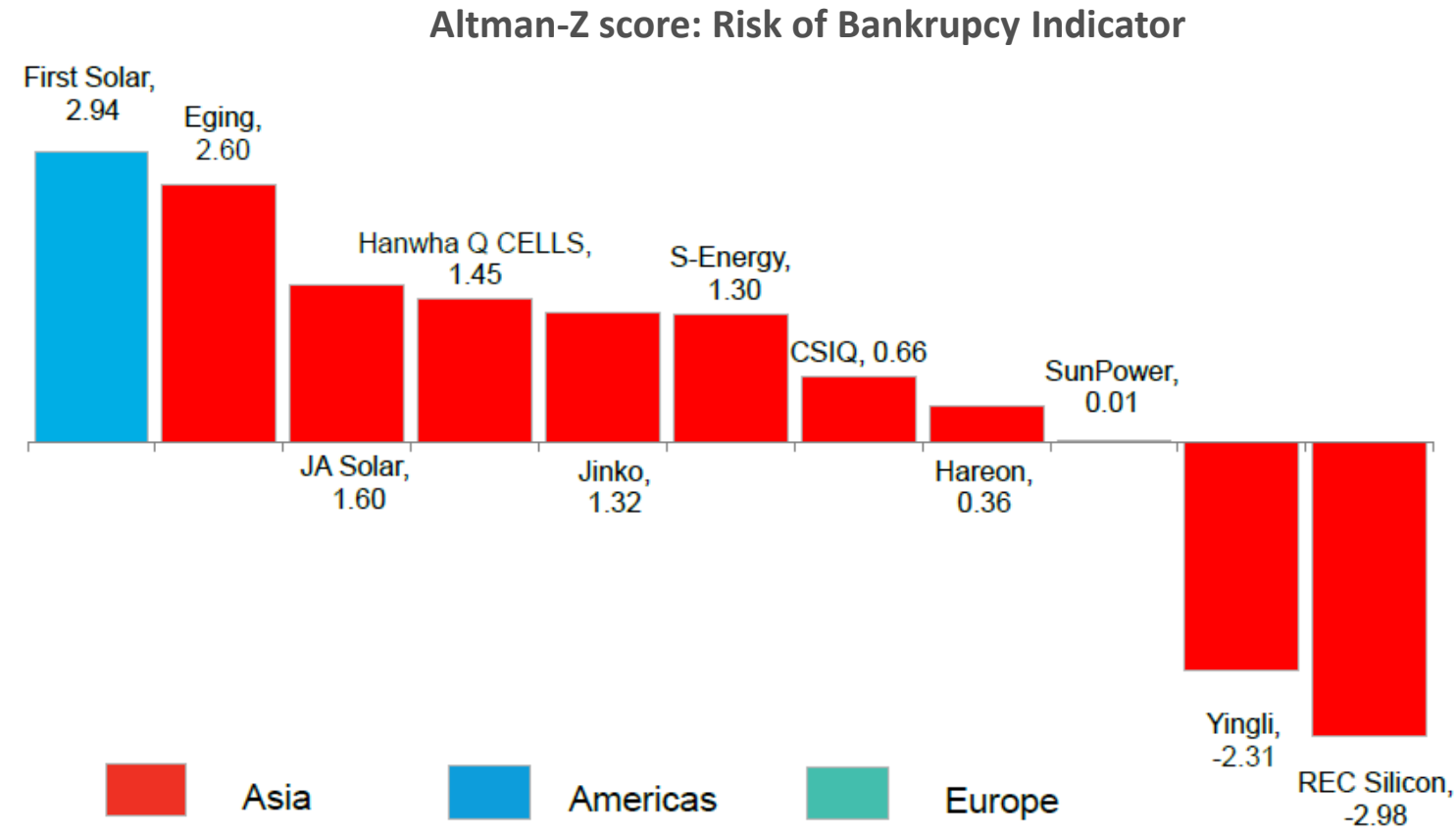
DEVELOPERS & EPC

O&M

"We create **enduring value for our customers** by powering their worlds through clean and affordable energy."

— Mark Widmar
First Solar CEO

BANKABILITY: ALTMAN-Z SCORE OF QUOTED PURE-PLAY SOLAR MANUFACTURER



Safe Zone
Z > 2.6

Gray Zone
1.1 < Z < 2.6

Risk of Bankruptcy
Z < 1.1

Bloomberg New Energy Finance Q1/Q2 2017, company filings

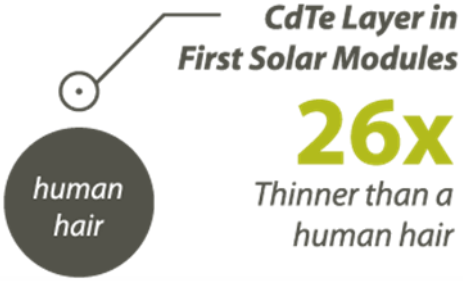
KEY DIFFERENTIATORS AND ADVANTAGES AT A GLANCE

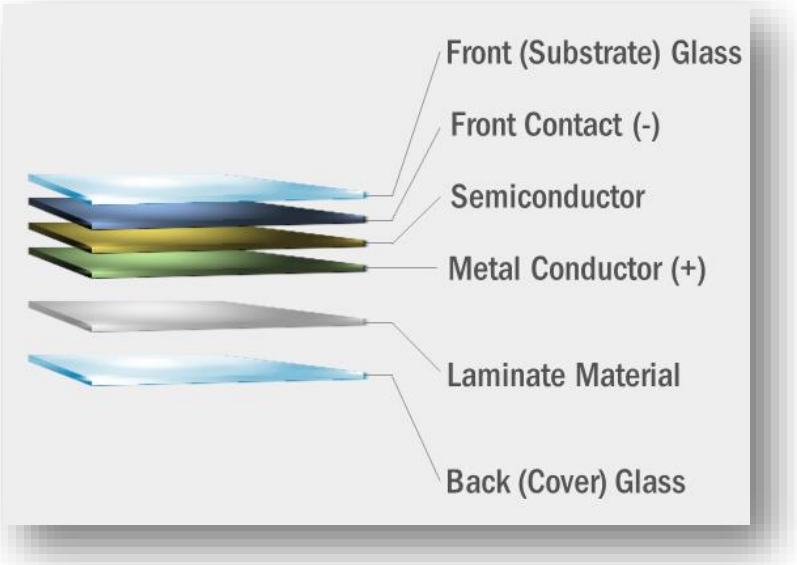
Technology: Propriety Thin Film Technology	**Efficiency:** Unprecedented Improvements	**Energy Yield:** Performance Advantage	**R&D:** World Record Cell Efficiency
Bankability: Strong Cash Position	**Sustainability:** Best Eco-Efficiency Technology	**Track Record:** 17+ GW Global Sales	**Reliability:** Extended Reliability Tests

First Solar®

TECHNOLOGY & MANUFACTURING

COMPOSITION OF FIRST SOLAR MODULES

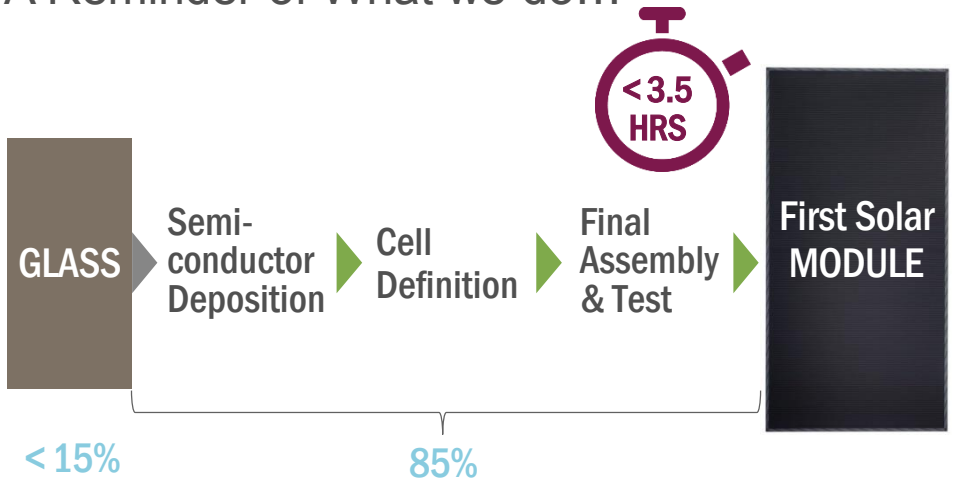




- Each module contains less than 14 grams CdTe
  - 1/26th the thickness of a human hair
- CdTe semiconductor layer is encapsulated between two protective sheets of glass
  - Remains encapsulated when breakage or melting occurs
  - Glass is the most robust and durable backsheet material
- Frameless laminate is robust, cost-effective, and easily recyclable

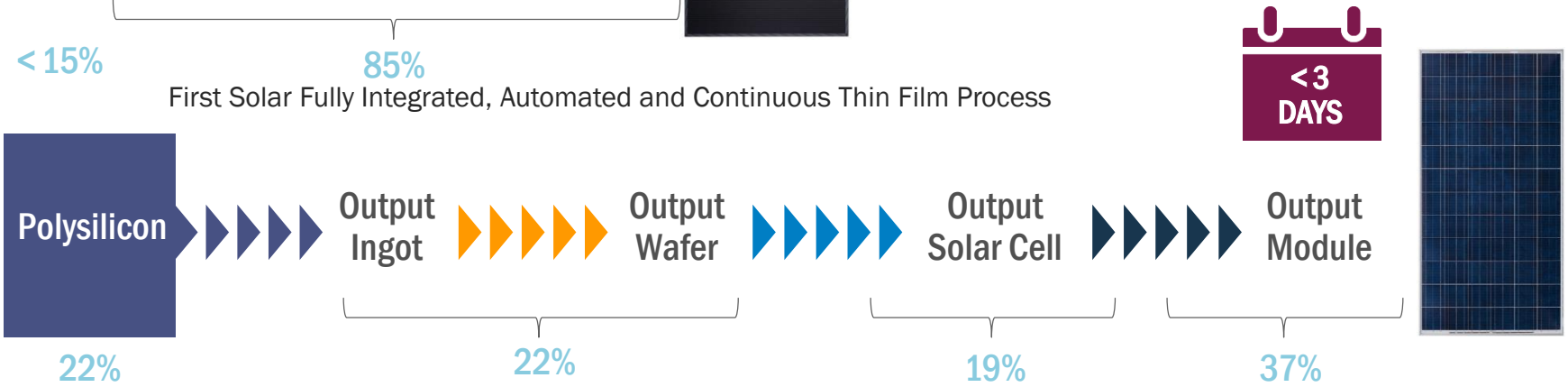
MANUFACTURING PROCESS | COMPARISON MULTI C-SI MODULES

A Reminder of What we do…



- Large glass substrate vs. individual Si wafers
- Fully integrated, continuous process
- Lowest energy and water use
- 1-2% of the semiconductor material vs Si
- Enables lowest carbon footprint and fastest energy payback time

First Solar Fully Integrated, Automated and Continuous Thin Film Process



Si value add data from BNEF "The Relentless Fall in Chinese PV Costs" (October 2014)

MODULE MANUFACTURING PROCESS OVERVIEW

Step 1:
Semiconductor Deposition

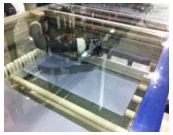
Glass Load, Grind & Clean

Laser Marking

Semi-Conductor Coating

Activation Oven

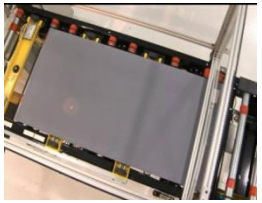
Etch & Clean



Back Contact Formation

Step 2:
Cell Definition

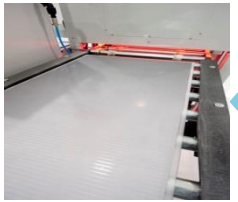
Laser Scribe



Wet-line

Metal Deposition

Edge Delete



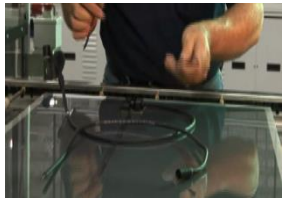
Post-Metal Heat Treat

Step 3:
Final Assembly & Test

Bussing

Cover Glass & Lamination

Cord Plate



Test, Label & Boxing

SERIES 6 MANUFACTURING PROCESS

Serles 6 ManufacturIng Process

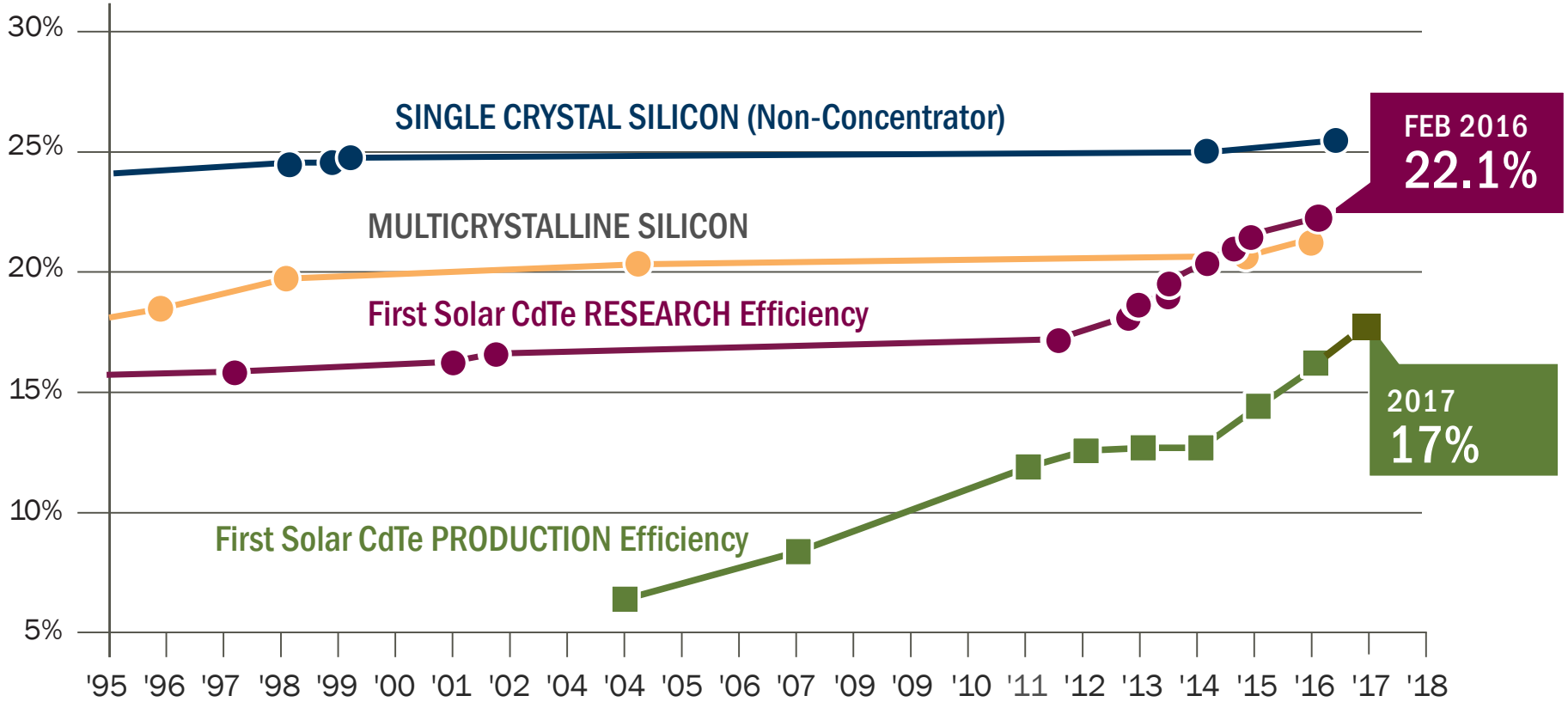
https://vImeo.com/245803424

EFFICIENCY IMPROVEMENTS & ENERGY YIELD ADVANTAGE

METRICS (REVISITED)

Standard Test Conditions	Real Operating Conditions	Value
Efficiency (η)	Capacity Factor	LCOE ($/kWh)
Module Power (W_p)	Energy Density (kW–hr/m²)	$\frac{BOS+Mod+OM+Dev+Fin}{Energy \text{ yield (kWh/kWp.a)}}$
Plant Capacity (MW_p)		NPV

RESEARCH CELL EFFICIENCY: FASTEST INNOVATION RATE IN THE INDUSTRY



WE'VE COME A LONG WAY!

1995

Solar Cells, Inc. FS50

- 50 Watt
- 6.9% Efficiency

2006

FS Series 2

- 75 Watt
- 10.4% Efficiency
- Edge seal improved durability

2013

FS Series 3 Black Plus

- 95 Watt
- 13.2% Efficiency
- Lower degradation
- Thresher, Long Term Sequential Harsh Climate Reliability

2015/16

FS Series 4V2/V3

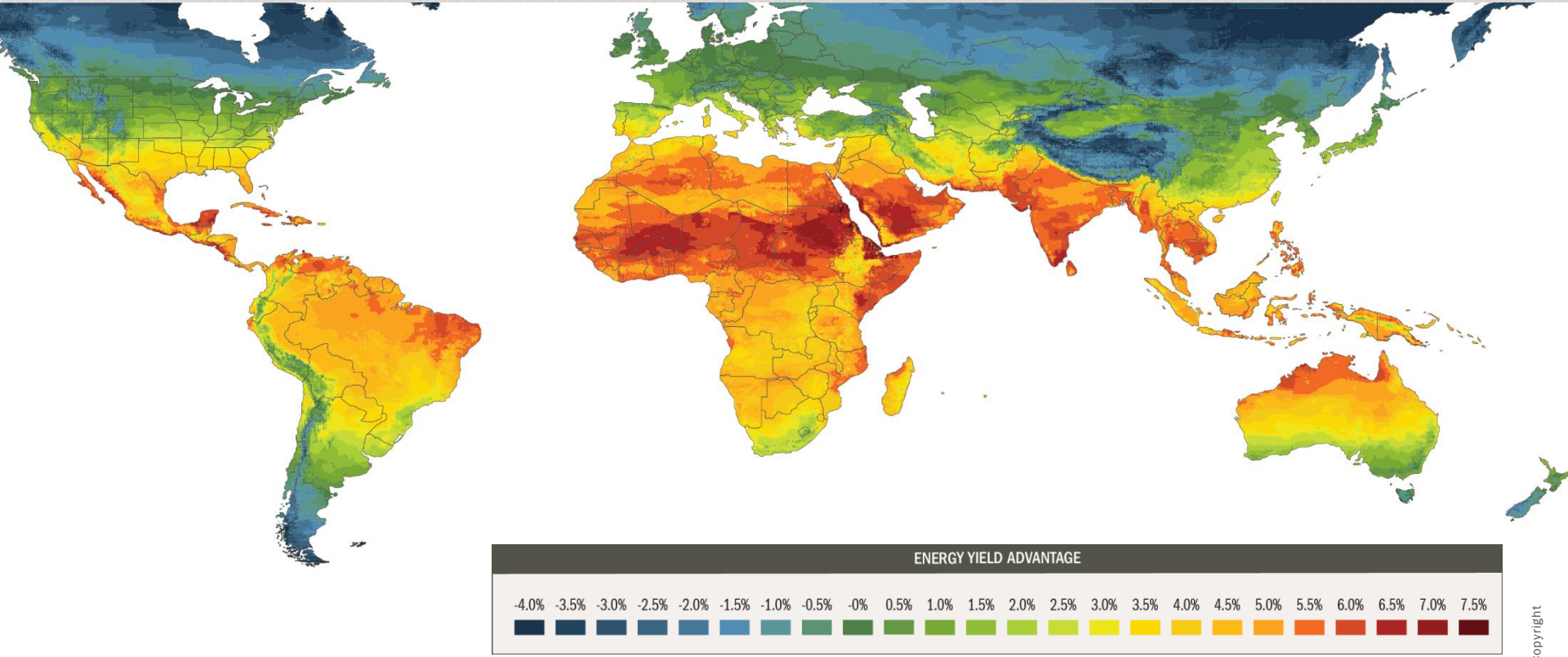
- 117.5 Watt
- 16.3% Efficiency
- Designed for 1500V systems

20…

WORLD RECORD Module

- 132.5Watt
- 18.6% Efficiency
- Highest efficiency thin-film module in the world

ENERGY YIELD ADVANTAGE VS. C-SI

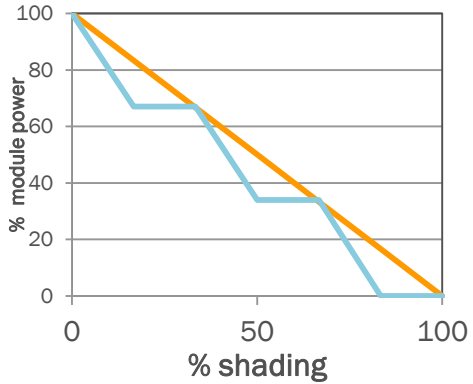


Powered by:

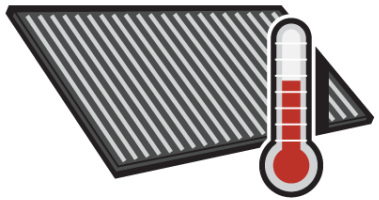
PLANTPREDICT

Up to 7.5% Specific Annual Energy Yield Advantage

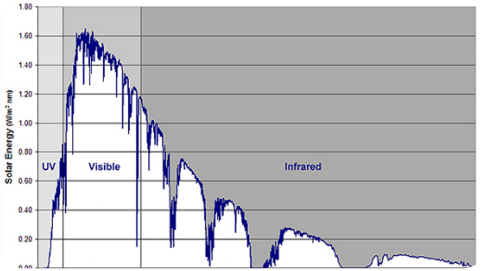
PV CONVERSİON SIMPLIFIED ➡ SUPERIOR ENERGY YIELD



25°C



G173 Reference



Shading 0.5-1%

Shading %=-x . Perf.

Temperature 2-4%

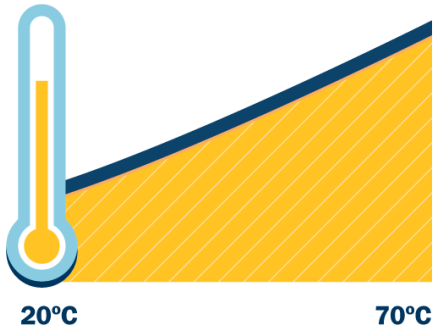
$$\alpha_{Pmp}(T_{cell} - 25\ C)$$

Spectrum 2-5%

$$\frac{\int E \cdot SR\, d\lambda}{\int E\, d\lambda} \frac{\int E_{G173}\, d\lambda}{\int E_{G173} \cdot SR\, d\lambda}$$

SPECIFIC ANNUAL ENERGY YIELD ADVANTAGE
(RELATIVE TO FRAMED BSF AND PERC, MULTI AND MONO)

SUPERIOR TEMPERATURE **COEFFICIENT**

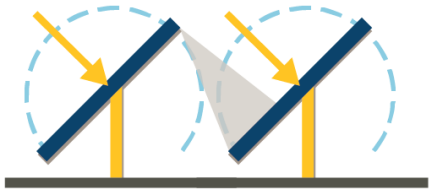


UP TO 3%
MORE THAN C-Si
IN HOT CLIMATES

BETTER SPECTRAL **RESPONSE**

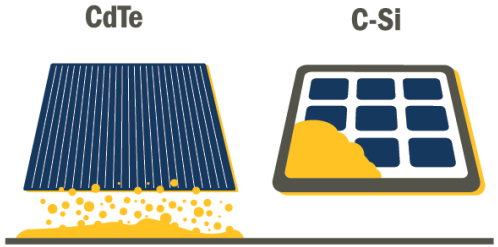
UP TO 4%
MORE THAN C-Si
IN HUMID CONDITIONS

TRUE-TRACKING **ADVANCTAGE**



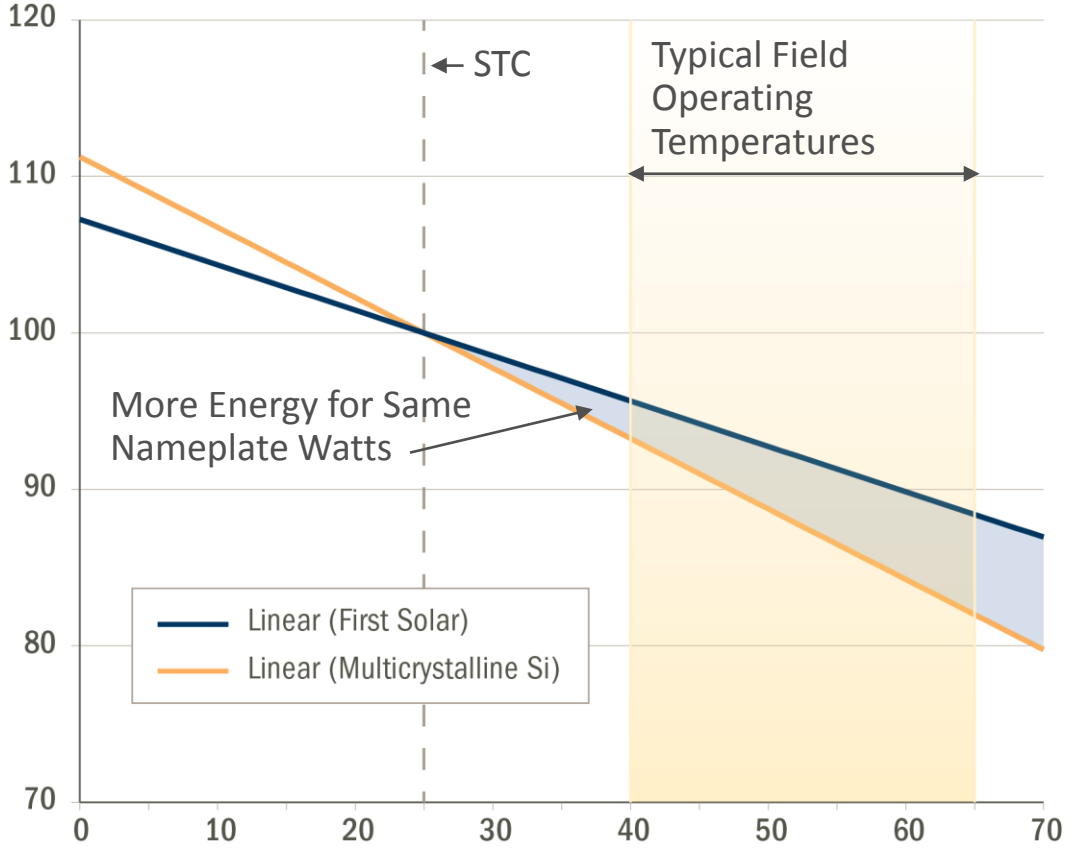
1%
MORE THAN C-Si
ON TRACKERS

REDUCED SOILING & BETTER SNOW-SHEDDING



BETTER
PERFORMANCE
THAN C-Si

PROVEN REAL WORLD ENERGY YIELD ADVANTAGE VS. C-SI: TEMPERATURE RESPONSE



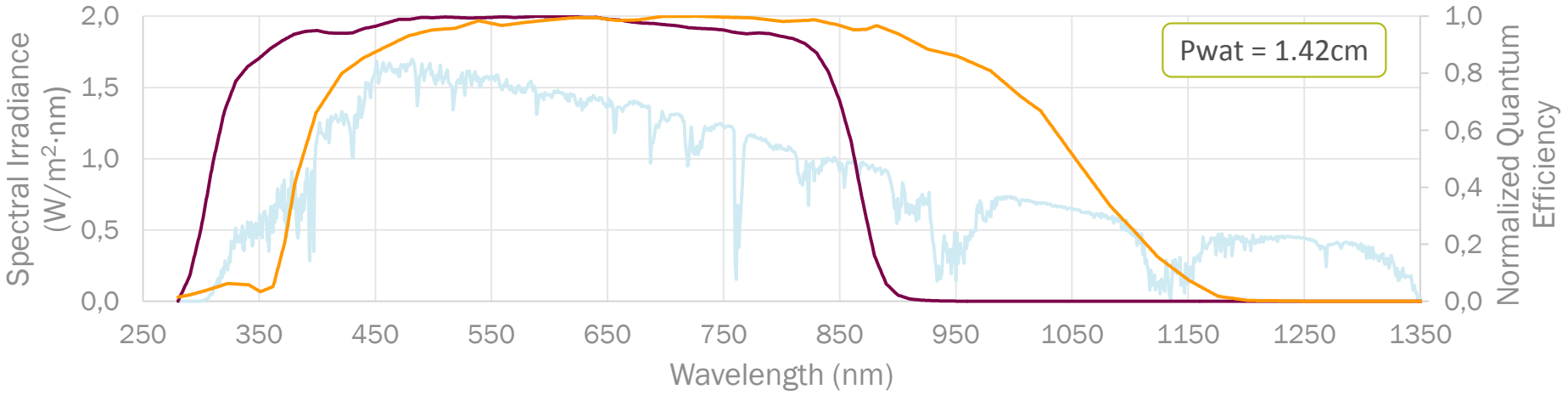
T > 25°C

>90% of Generation when
First Solar has yield advantage

T > 45°C

>60% of Generation when
First Solar has >5% Yield Advantage

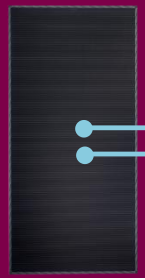
SIMULATED PERFORMANCE AT G173*



Broadband Pyranometer

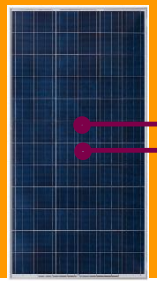
1000 W/m²

CdTe Module



100.0 W

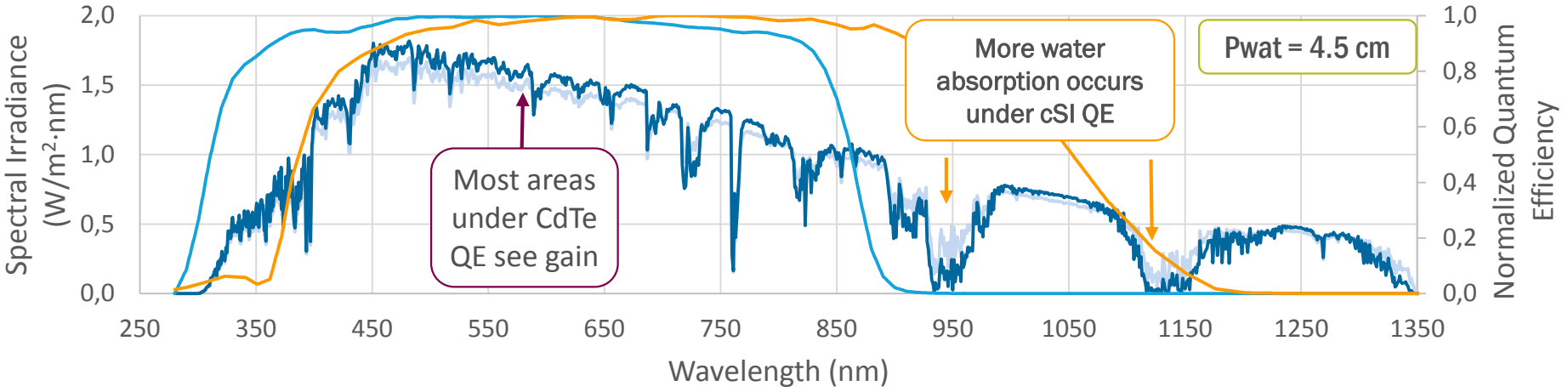
c-Si Module



100.0 W

* The ASTM G173 spectra represent terrestrial solar spectral irradiance on a surface of specified orientation under one and only one set of specifed atmospheric conditions.

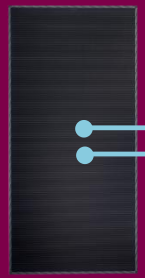
SIMULATED PERFORMANCE AT HIGH PWAT



Broadband Pyranometer

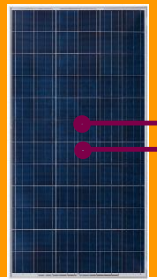
1000 W/m²

CdTe Module



104.7 W

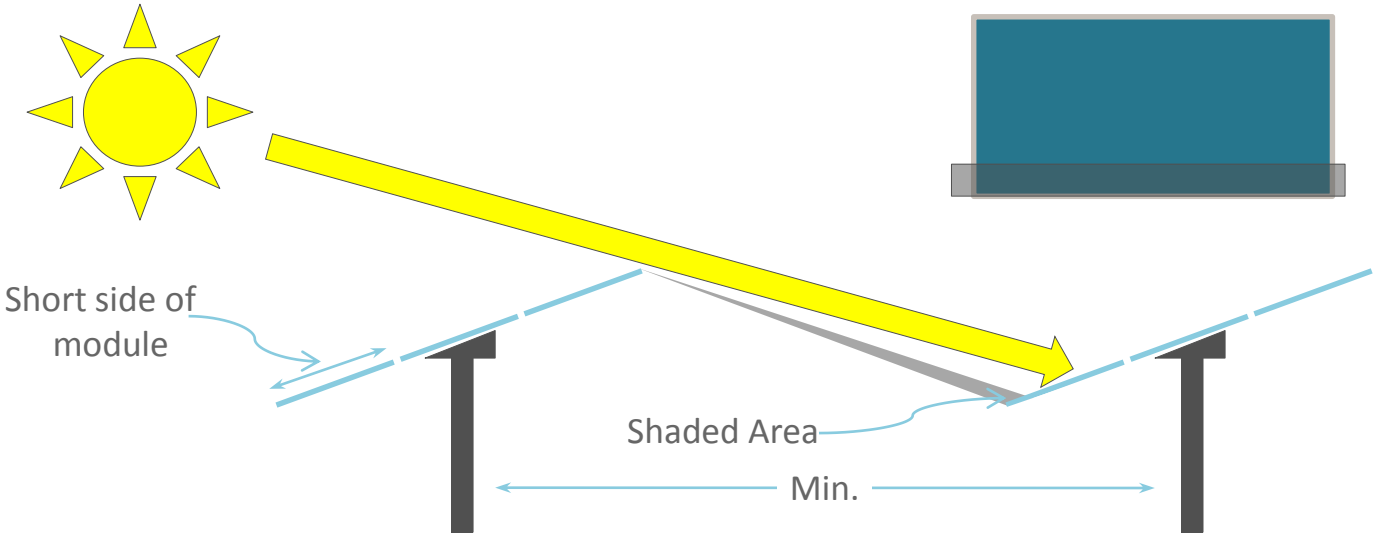
c-Si Module



101.2 W

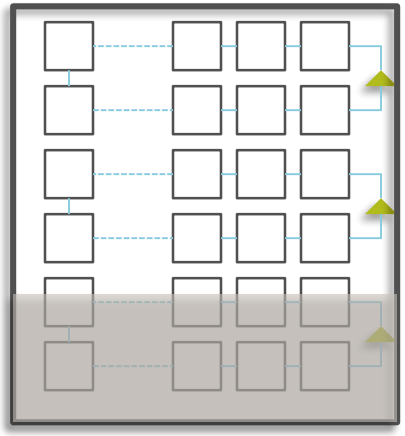
MODULE PERFORMANCE – COMPARISON TO C-SI (FIXED TILT SCENARIO)

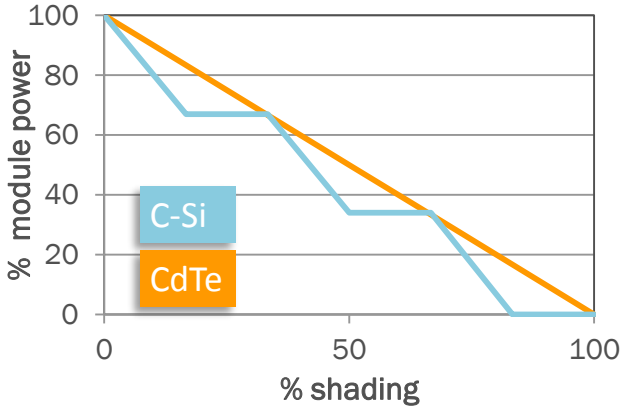
- Robust against shading in landscape orientation (perpendicular to cells)
  - FSLR Power loss is ~proportional to shading: 10% shading = ~10% output power loss
  - Typical c-Si Power loss: 10% shading = ~30% output power loss[1]
  - Minimizes early morning and late evening energy loss while allowing row spacing (array footprint) to be minimized

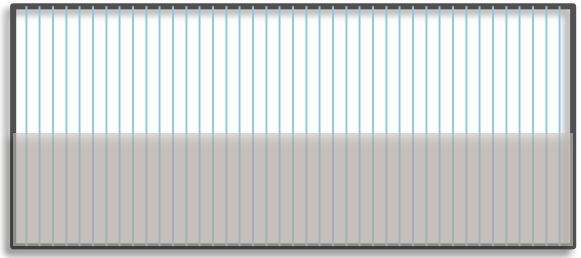


[1]*Partially Shaded Operation of a Grid-Tied PV System,* Chris Deline, National Renewable Energy Laboratory (@ >800W/m²)

SHADING CDTE VS. C-SI





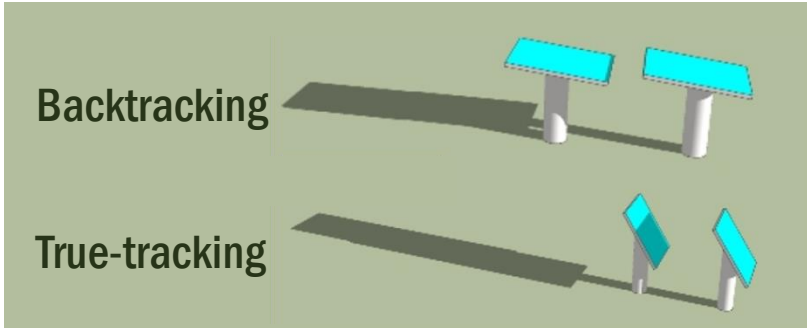


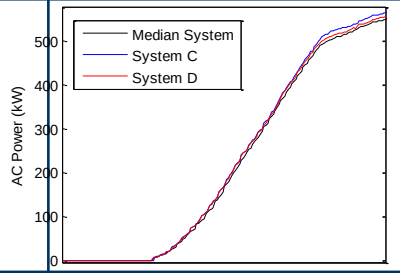
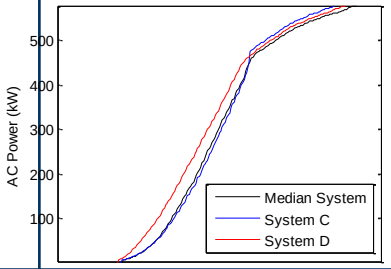
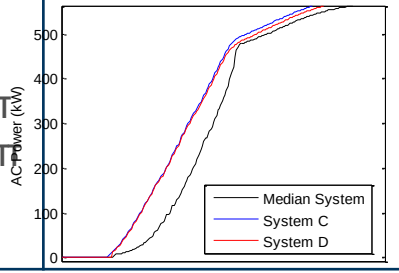
- Effect of shading is dependent on the electrical connections within the module.
  - Some Si modules have multiple rows of series connected which results in non-uniform shading loss
- This result extends to array –level performance
  - Power will drop to zero when voltage of array drops below inverter limit

[1]*Partially Shaded Operation of a Grid-Tied PV System,* Chris Deline, National Renewable Energy Laboratory (@ >800W/m^2)

IMPROVED ENERGY YIELD WITH TRUE TRACKING

- First Solar modules have nearly linear shading response
- By tracking the sun, even in the presence of shadows, True-tracking improves yield over conventional Back-tracking
- True-tracking is now standard FSLR offering



Observation	Condition	Power Profile – Morning Only
August 28, 2012	All Systems BT	
September 9, 2012	Median System & System C BT System D TT	
September 20, 2012	Median System BT Systems C and D TT	

First Solar®

PART 2:
- FS 4V3 SOLAR MODULE
- FS 6 SOLAR MODULE
- QUALITY & RELIABILITY

PRODUCT FEATURES: SERIES 4V3

FIRST SOLAR MODULES FS4V3

- Frameless glass-glass laminate (60 x 120 cm, 12.0 kg) is durable and recyclable
- Power increments of 2.5W (-0/+5W rating tolerance) up to 120W per module
- High energy yield in real operating conditions (PR>80%)
  - Largest advantages in hot, humid climates
  - Low temperature coefficient (-0.28%/°C)
  - High spectral gain in high humidity
- Robust against shading in landscape orientation (perpendicular to cells)
- Certified reliability and safety according to IEC 61646 and IEC 61730 @1500VDC;
  - UL Listed; Extended Harsh Climate Reliability: Thresher, Long Term Sequential, Atlas 25+
- 25-year Linear Power Output Warranty for 80% of nominal power subject to warranty terms and conditions
- Manufacturing certified to ISO 9001:2008 (quality), ISO 14001:2004 (environmental) and OHSAS 18001:2007 (occupational, health & safety) standards
- Collection and Recycling EOL Program

FIRST SOLAR FS SERIES 4V3 AND 4AV3 MODULE SPECS

MODULE NUMBERS AND RATINGS AT STANDARD TEST CONDITIONS (1000W/m², AM 1.5, 25°C)[5]							
NOMINAL VALUES		FS-4110-3 FS-4110A-3	FS-4112-3 FS-4112A-3	FS-4115-3 FS-4115A-3	FS-4117-3 FS-4117A-3	FS-4120-3 FS-4120A-3	FS-4122-3 FS-4122A-3
Nominal Power[6] (-0/+5W)	P_{MPP} (W)	110.0	112.5	115.0	117.5	120.0	122.5
Voltage at P_{MAX}	V_{MPP} (V)	67.8	68.5	69.3	70.1	70.8	71.5
Current at P_{MAX}	I_{MPP} (A)	1.62	1.64	1.66	1.68	1.70	1.71
Open Circuit Voltage	V_{OC} (V)	86.4	87.0	87.6	88.1	88.7	88.7
Short Circuit Current	I_{SC} (A)	1.82	1.83	1.83	1.83	1.84	1.85
Module Efficiency	%	15.3	15.6	16.0	16.3	16.7	17.0
Maximum System Voltage	V_{SYS} (V)	1500 [7,8]					
Limiting Reverse Current	I_R (A)	4.0					
Maximum Series Fuse	I_{CF} (A)	4.0					

Tk mpp = -0.28%/°C
Tk Voc = -0.28%/°C
Connector = MC4 or MC4 EVO2
IEC 1000V Class A/ 1500V Class B with MC4 or Class A with MC4 EVO2

FS-4XXA includes Anti-Reflective Coating

FIRST SOLAR THIN FILM TECHNOLOGY

FIRST SOLAR S4v3

	First Solar	Multi c-Si	Advantage
Higher Module Efficiency	Up to 17%	Up to 16.2%	+0.7%
Superior Temperature Coefficient	-0.28%/°C	-0.40%/°C	+0.12%/°C
Better Spectral Response	Up to 6%	0%	+6%
Tracker Shading Gain	Up to 1%	0%	+1%
Better Shading Response *Typical power loss with 10% shading*	10%	30%	+20%
Improved Energy Density *up to 11.7% in 2016*	<=11.7%	0%	+11.7%

Multi c-Si

Source: Data from First Solar and competitor data sheets.

COFFEE BREAK
(30 MİN)

DEEP DIVE FS SERIES 6

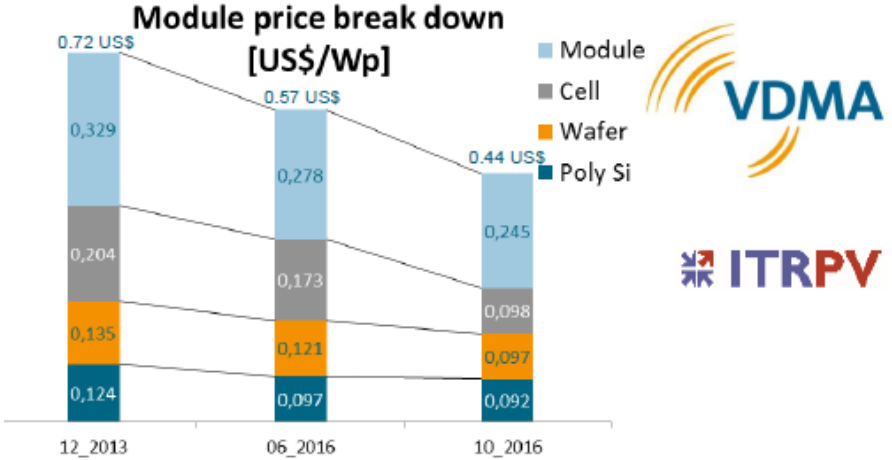
MOTIVATION TO INTRODUCE FS SERIES 6

- PV market has seen a massive price errosion in H2/2016
- Further lowering LCOE:
  PV market is moving from a past driven by cost reduction to a future driven by efficiency
- Mono PERC will drive this transition

  - mono PERC requires new equipment

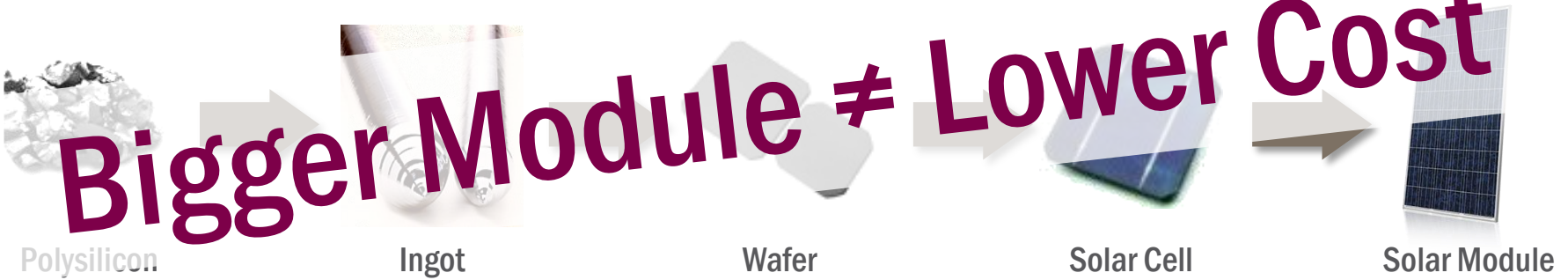
  - LID (Light Induced Degradation) & LeTID (Light and elevated Temperature Induced Degradation)

  - Bifacial, hard to predict performance gain
- Likely to see in 2018 and beyond low eff. Poly-BSF product dumped in market
- SERIES 6 ALLOWS TO REDUCE COSTS ON MANUFACTURING AS WELL AS SYSTEM LEVEL



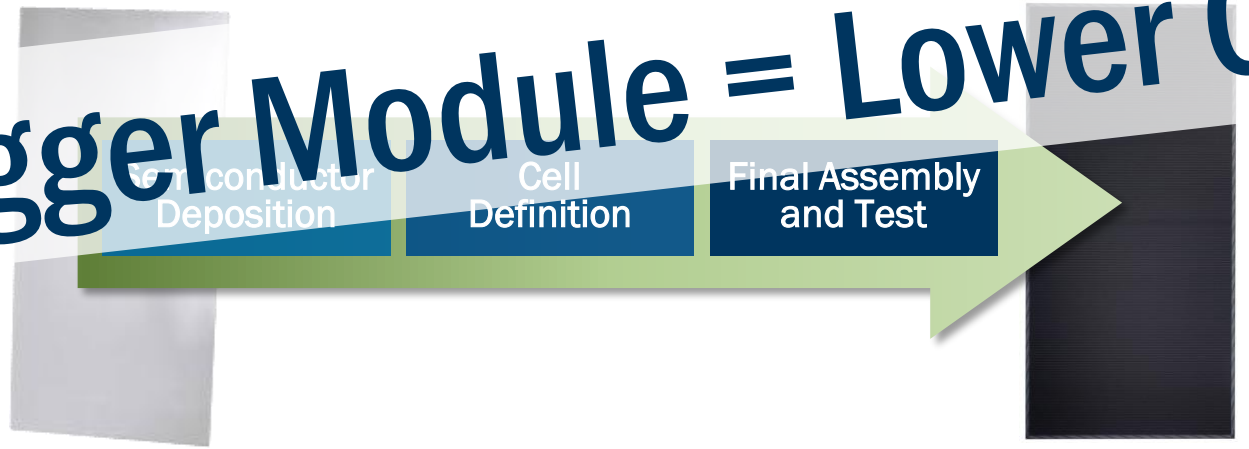
Source of ggraphic: edition 7 of ITRPV, Oct. 16

Crystalline Silicon Batch Technology, **Unit of process is the Wafer**



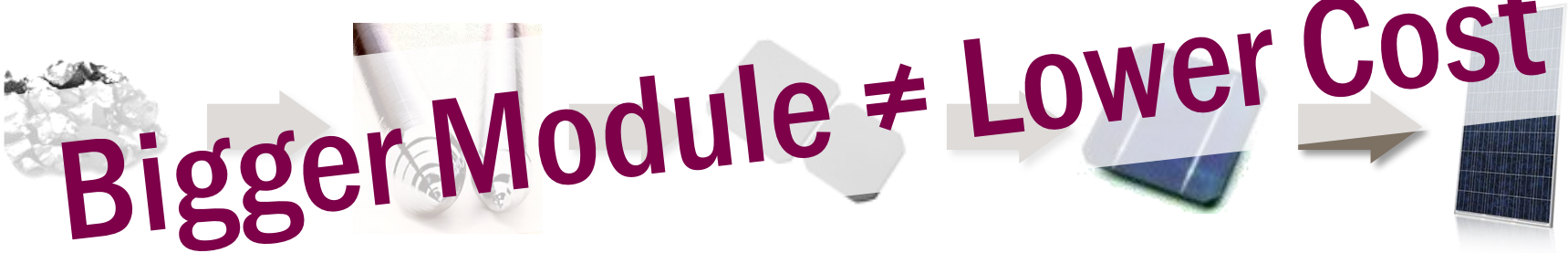
Bigger Module ≠ Lower Cost

Thin Film Continuous Flow, **Unit of process is the Glass**



Bigger Module = Lower Cost

Crystalline Silicon Batch Technology, **Unit of process is the Wafer**



Bigger Module ≠ Lower Cost


42”
1764 in2
HITACHI
5 years
60”
3600 in2
SAMSUNG

S6 KEY COMMERCIAL ADVANTAGES

High Performance

HIGHEST POWER UTILITY-SCALE MODULE

- 17.0-18.2% efficiency
- Maintains energy yield advantages (3-7% more energy/watt)
- Maintains market leading reliability

Large Format

MORE WATTS PER INSTALL OPERATION

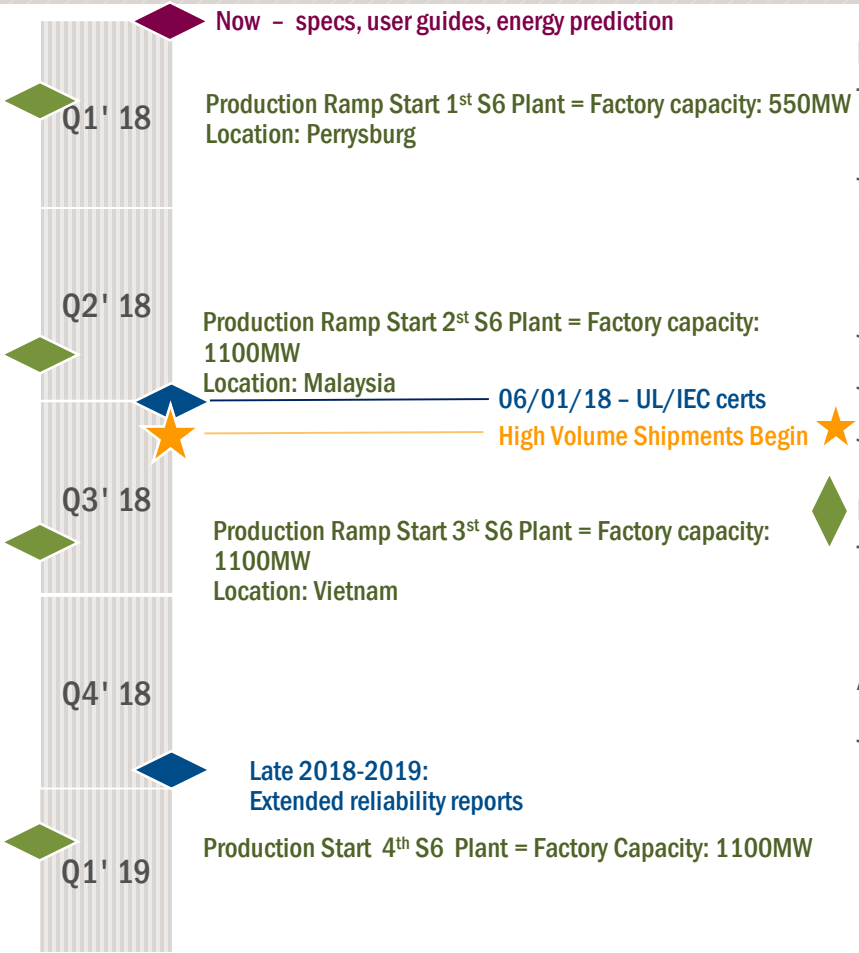
- Same height as c-Si allows common structures platforms

Framed

SIMPLIFIED MOUNTING TO COMMON INDUSTRY STRUCTURES

- Undermount Frame extended past all perimeter edges for protection
- Compatibility with ~drop in replacement into common mounting systems

S6 SCHEDULE OVERVIEW



KEY PRODUCT COMMERCIAL DATES

Now	S6 prelim datasheet & Energy Prediction available
Jul 2017	Many Ecosystem Partners/EPCs Quoting S6 Structures
Nov 2017	P90 S6 specs, User Guide, Key app notes
Dec 2017	S6 Factory testing/Field Trials begin
Jun 2018	Initial UL/IEC certifications received; 6 months field data
Jul 2018	IE Bankability report issued
Jul 2018	High volume shipments begin

KEY PRODUCTION START DATES

Feb 2018	0.55GW	Ohio
May 2018	1.10GW	Malaysia
Aug 2018	1.10GW	Vietnam
Jan 2019	1.10GW	TBD

Mitigating schedule risk by prioritizing FS-EPC fulfilled projects in 2018

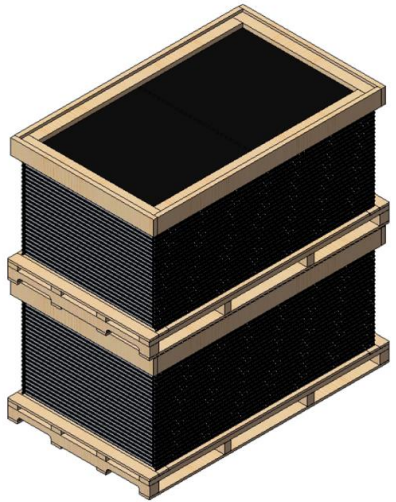
Maintaining some S4 production for the foreseeable future

S6 MECHANİCAL AND MOUNTİNG

MECHANICAL OVERVIEW

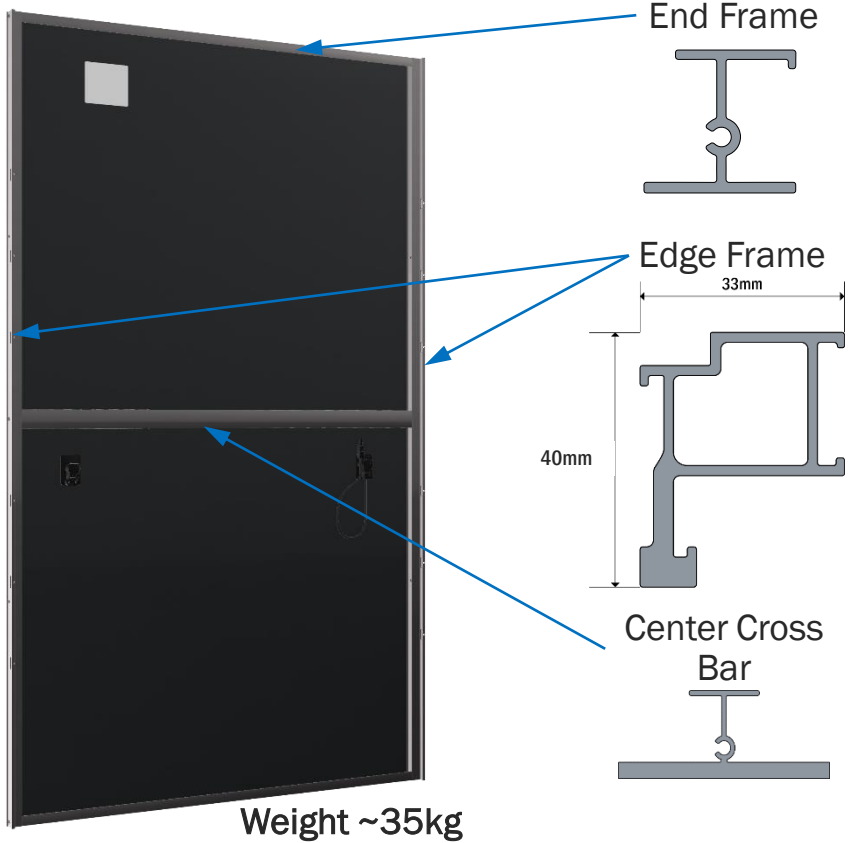
MECHANICAL DESCRIPTION	
Length	2009 mm
Width	1230 mm
Laminate Thickness	5.4 mm
Area	2.47 m²
Module Weight	35 kg
Frame Material	Anodized Aluminum
Front Glass	• 2.8 mm heat strength • Series 6A™ includes anti-reflective coating
Back Glass	2.2 mm heat strength
Encapsulation	Laminate material with edge seal
Frame to Glass Adhesive	Silicone
Load Rating	2400 Pa (IEC61215)

Packaging Information	
Modules per Pallet	26
Pallet Weight	955 kg
Pallet Dimensions (L x W x H)	2200 x 1300 x 1150 mm (86 x 51 x 45 in)
Pallets per 40' Container	18

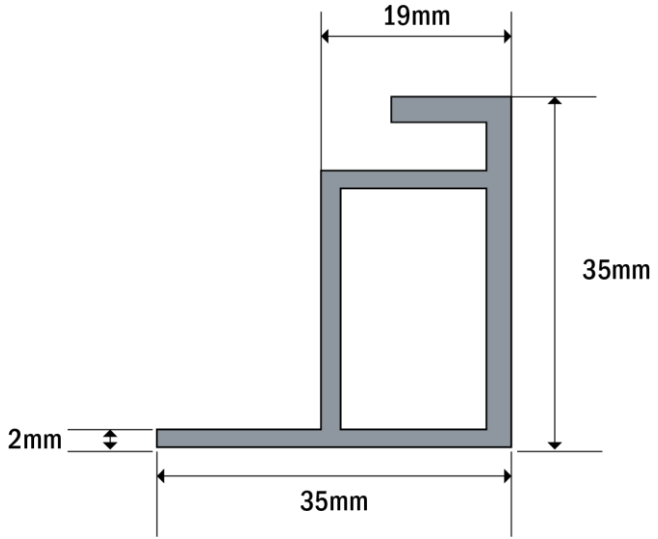


SERIES 6 – FRAME DESIGN

Series 6

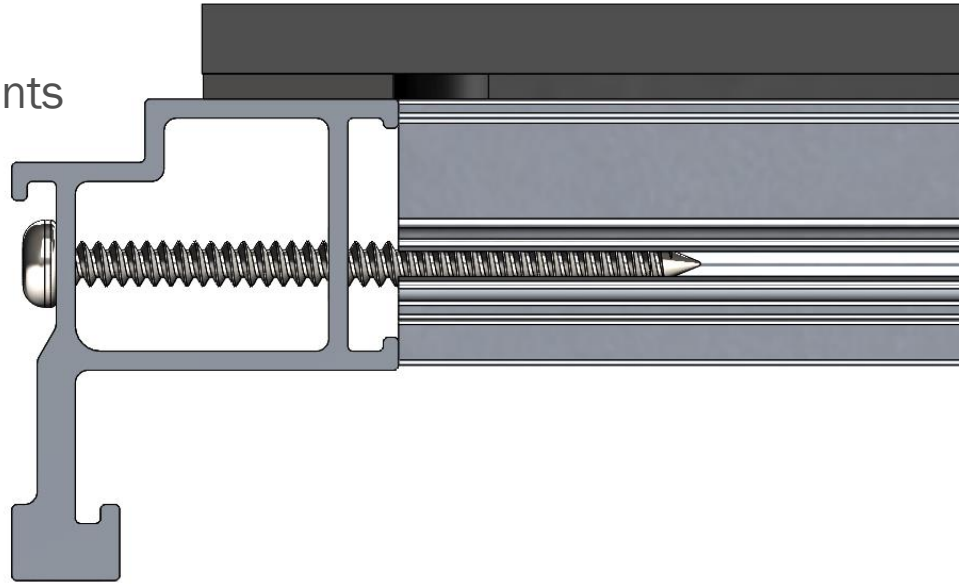


Silicon 35mm Standard



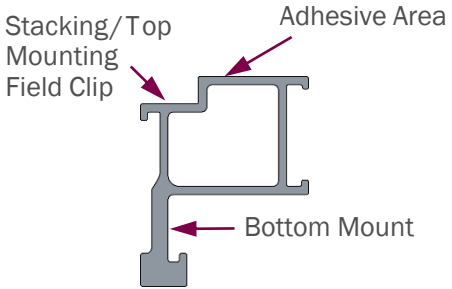
FRAME ATTACHMENT AND ASSEMBLY

- Frame factory assembled
- Anodized aluminum with Stainless Steel Screws
- Fully adhered on all frame components using ~2mm Silicone epoxy (robotic dispensed)

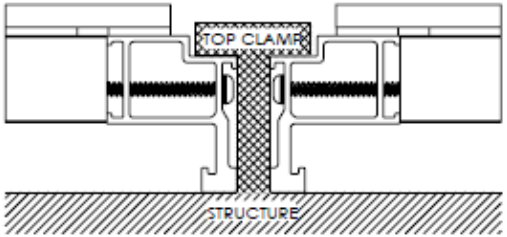


FRAME FEATURES AND STRUCTURE PARTNERS

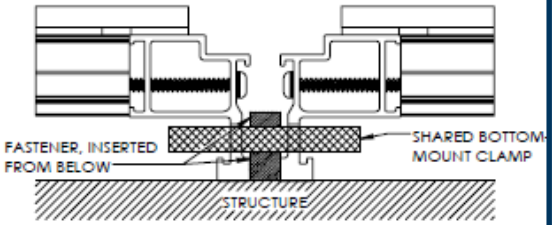
FEATURE DEFINITION



Top Mounting



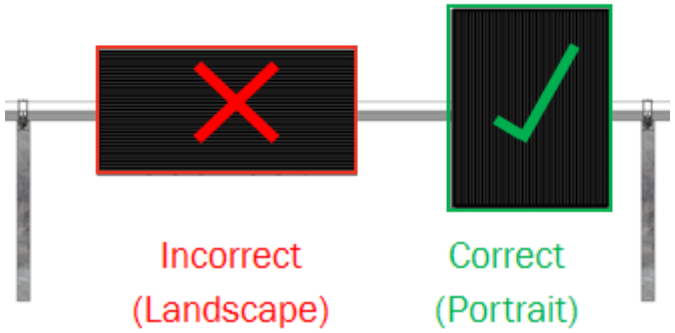
Bottom Mounting



ARRAY TECHNOLOGIES
exosun FOCUS ON SOLAR SOLUTIONS
CLAVIJO european leading technologies
panelclaw
SCHLETTER
Soltec
GAMECHANGE SOLAR REPOWERING THE PLANET
shoals technologies group
SOLAR FLEXRACK A Division of Northern States Metals
mounting systems
TRACKING & MOUNTING SYSTEMS IDEEMATEC DEUTSCHLAND GMBH
NEXTracker Unleashing Solar Profits

S6 MOUNTING: PORTRAIT VS LANDSCAPE

S6 Mounting



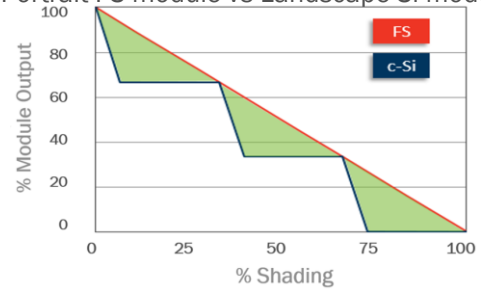
First Solar Series 6 modules are not designed for mounting in landscape. Portrait orientation is suitable for all applications and provides a clear energy yield benefit.

Organization of the cells in a FS module allows for a linear shading response

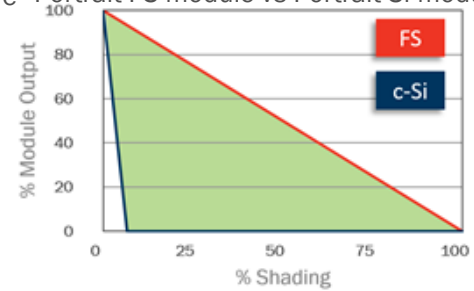
- i.e. if 10% of the module is shaded only 10% of the energy is lost

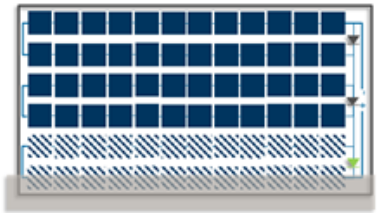
Shading Response

Portrait FS module vs Landscape Si module



Portrait FS module vs Portrait Si module

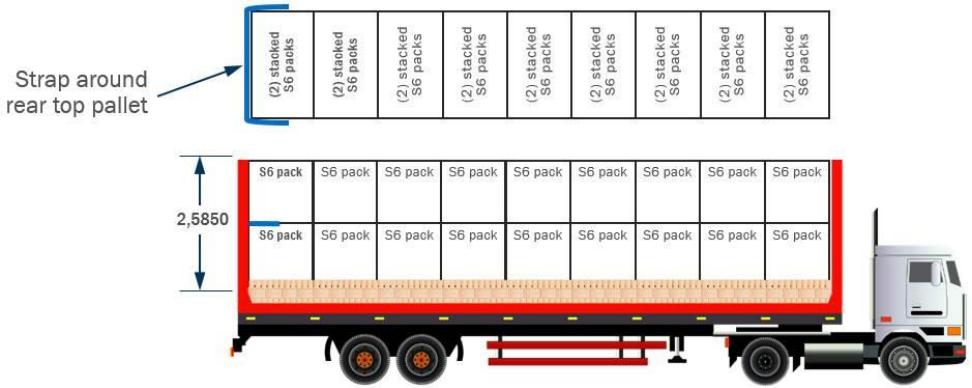




c-Si modules have multiple rows of cells connected in series. Partial shading of any cell in a row will result in that row and the next row being bypassed to prevent hotspots and power reduction of the entire module.

1*Partially Shaded Operation of a Grid-Tied PV System,* Chris Deline, National Renewable Energy Laboratory (@ >800W/m2)

SERIES 6 – PACKAGING DESIGN



S6 Packaging

- Wood Pallet, Banding
- (26) S6 per pack
- ISTA 3E & IEC 62759-1 compliant
- Less Waste

Shipping Container

- (18) packs per Hi-cube container
- 200+kW per container
- ~18,450kg [~40,600lbs] per container

PACKAGING COMPARISON

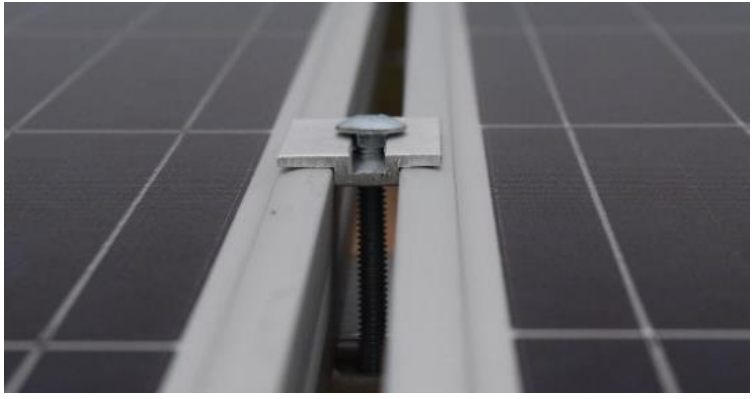
First Solar S6 — 26 per Pallet

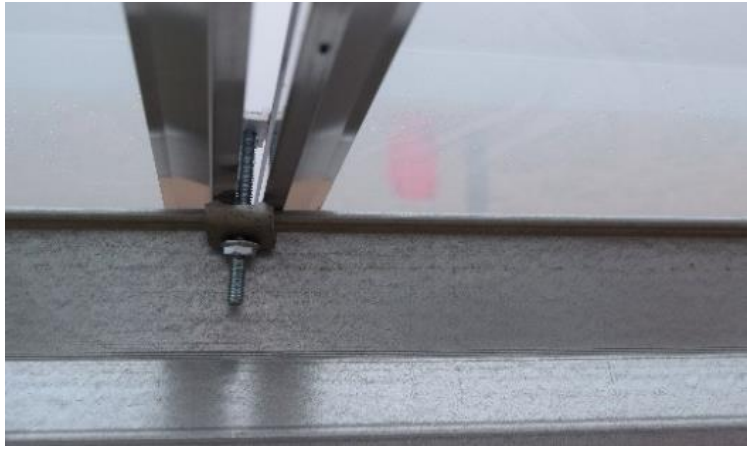
Canadian Solar — 26 per Pallet

STRUCTURE PARTNERS: TOP ATTACHMENT METHODS

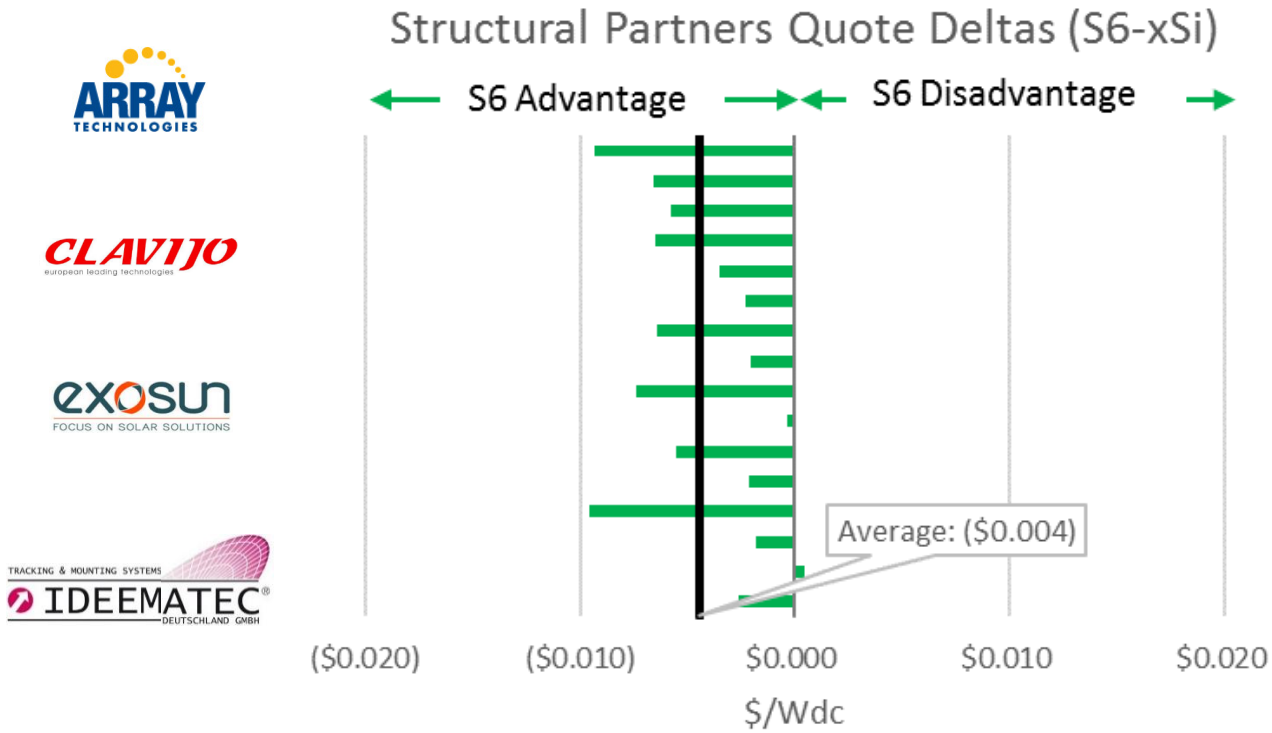
ATI – Module Ear Clamp

Exosun – Module Clips xSi





STRUCTURAL PARTNERS PRICE DELTAS (SERIES 6 – XSI; 430W – 340W)

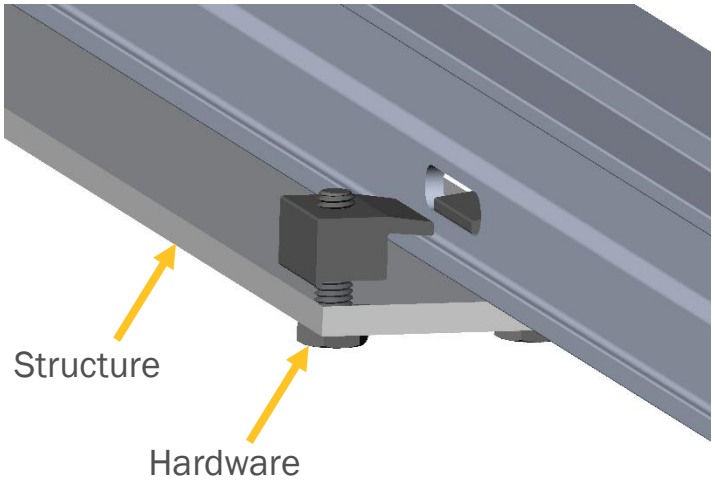


Leading structural partners show *advantage* for Series 6

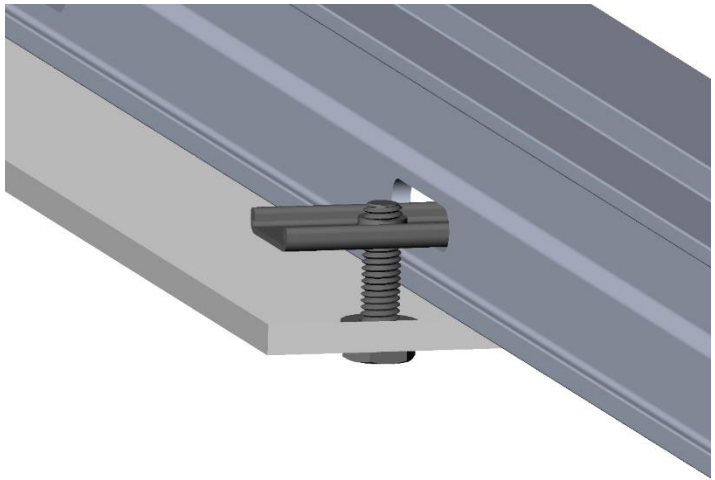
Series 6 – xSi; 430W – 340w; Fixed Tilt (Avg: 0.002 advantage), Single Axis Tracker (Avg: 0.006 advantage).

BOTTOM MOUNTING: CONCEPTS

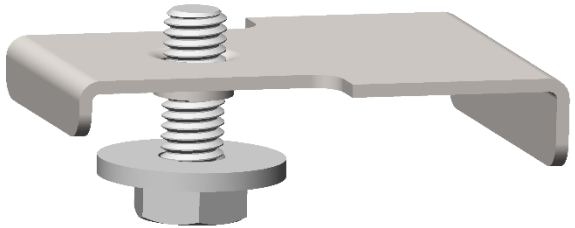
Inboard Clamp



Shared Clamp

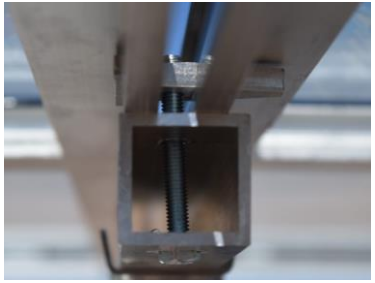


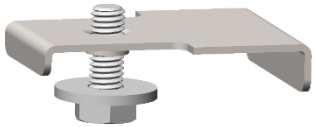
Shared Clamp

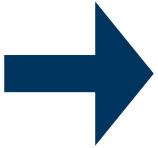


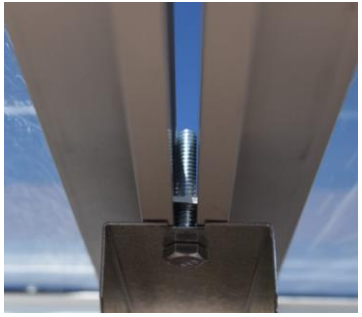
Left frame not shown, isometric view of mounting hardware, structure depicted as lower bar

SPEEDSLOT MOUNTING CLAMPS: IN FIELD TESTING









MOUNTING LOCATIONS & LOAD RATINGS

Test loads per IEC 61215:

2400 Pa (Positive and Negative)

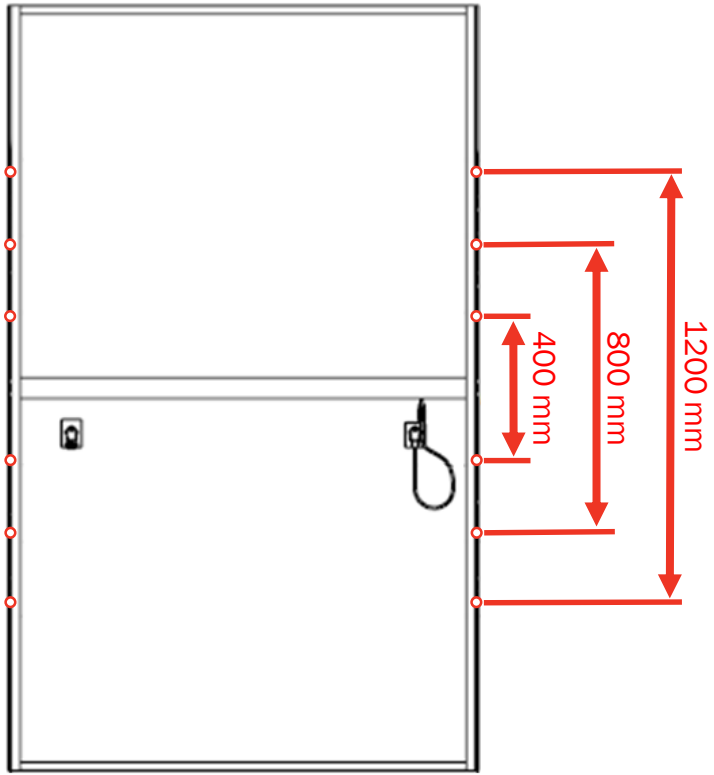
- 400 to 1200 mm top-clamp spacing
- 400, 800, or 1200 mm bottom-mount locations

3600 Pa (Positive)

- 800 to 1200 mm top-clamp spacing
- 800 or 1200 mm bottom-mount locations

5400 Pa (Positive)

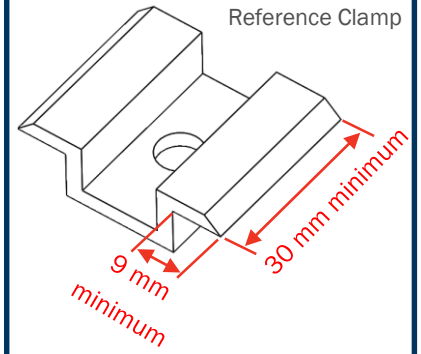
Will require multiple fastening locations. See installation guide.



Fastener Locations

Use minimum of four symmetrically-located top-clamps or bottom-mount fasteners.

Clamp Dimensions

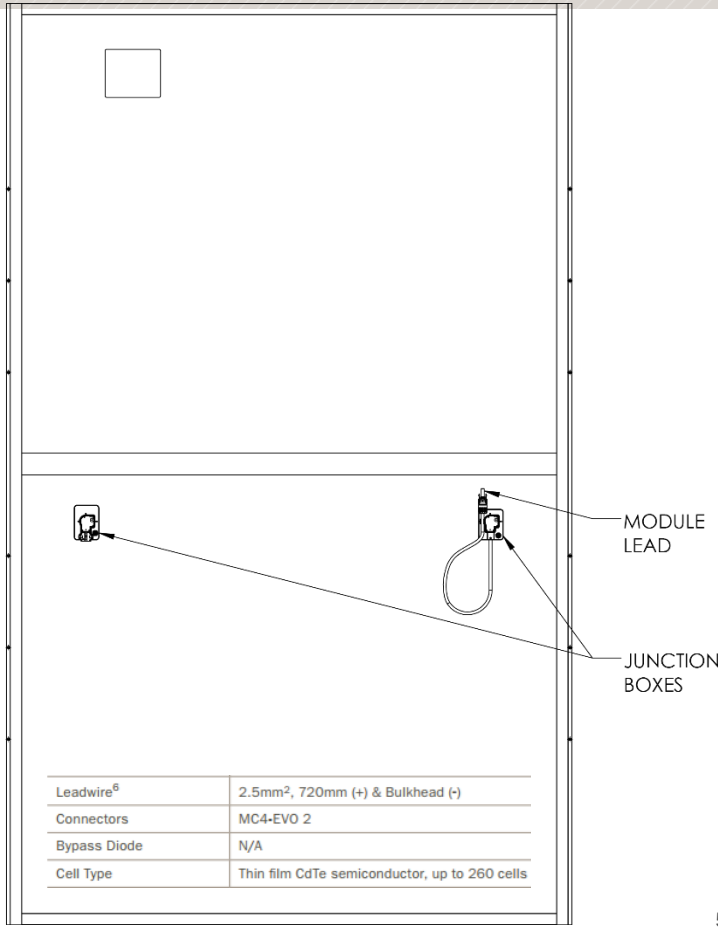


S6 ELECTRICAL AND WIRING

ELECTRICAL OVERVIEW

MODEL TYPES AND RATINGS AT STANDARD TEST CONDITIONS (1000W/m², AM 1.5, 25°C)[3]							
NOMINAL VALUES		FS-6420 FS-6420A	FS-6425 FS-6425A	FS-6430 FS-6430A	FS-6435 FS-6435A	FS-6440 FS-6440A	FS-6445 FS-6445A
Nominal Power[4] (-0/+5%)	P_{MPP} (W)	420.0	425.0	430.0	435.0	440.0	445.0
Efficiency (%)	%	≥17.0	≥17.2	≥17.4	≥17.6	≥17.8	≥18.0
Voltage at P_{MAX}	V_{MPP} (V)	178.5	179.4	180.3	181.2	182.0	182.8
Current at P_{MAX}	I_{MPP} (A)	2.35	2.37	2.38	2.40	2.42	2.43
Open Circuit Voltage	V_{OC} (V)	214.6	215.0	215.3	215.7	216.1	216.5
Short Circuit Current	I_{SC} (A)	2.62	2.63	2.63	2.64	2.65	2.65
Maximum System Voltage	V_{SYS} (V)	1500[5,6]					
Limiting Reverse Current	I_R (A)	6.0					
Maximum Series Fuse	I_{CF} (A)	6.0					

TEMPERATURE CHARACTERISTICS		
Module Operating Temperature Range	(°C)	-40 to +85
Temperature Coefficient of P_{MPP}	T_K (P_{MPP})	-0.32%/°C [Temperature Range: 25°C to 75°C]
Temperature Coefficient of V_{OC}	T_K (V_{OC})	-0.28%/°C
Temperature Coefficient of I_{SC}	T_K (I_{SC})	+0.04%/°C



Leadwire[6]	2.5mm², 720mm (+) & Bulkhead (-)
Connectors	MC4-EVO 2
Bypass Diode	N/A
Cell Type	Thin film CdTe semiconductor, up to 260 cells

6 Leadwire length from junction box exit to connector mating surface

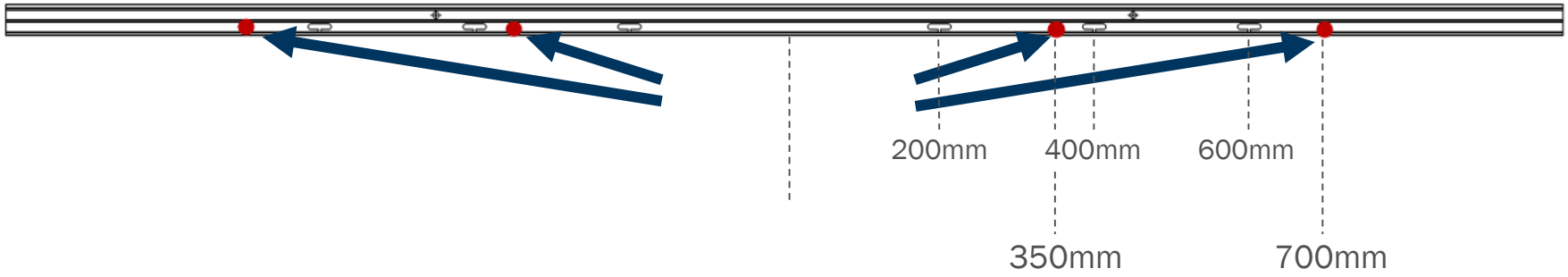
PRELIMINARY S6 DUAL JUNCTION BOX DESIGN

S6 Dual Junction Box Benefits

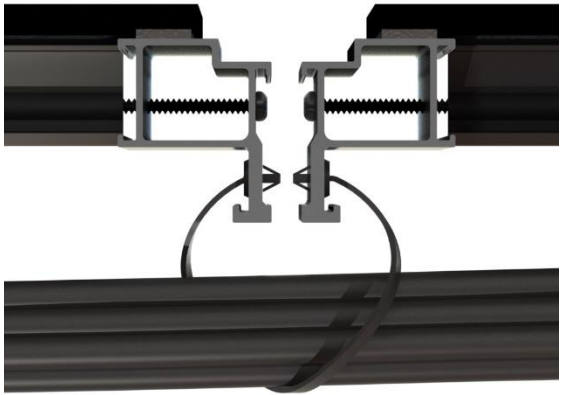
- Simplified installation process
  - — No confusion over positive and negative wires
  - — Only one lead wire
- No wire management needed at module level [1]
- Now an independently certified Junction Box

1. NEC 334.30, at intervals not exceeding 1.4m [4.5ft] and within 300mm [12in] of every cable entry into enclosures such as junction boxes."

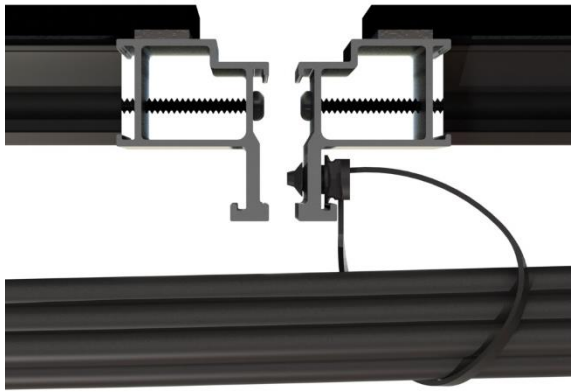
S6 WIRE MANAGEMENT



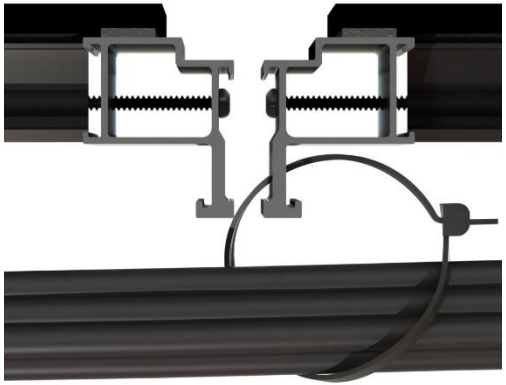
Wire Management and/or grounding holes (Ø5.6mm)



Sling Strap



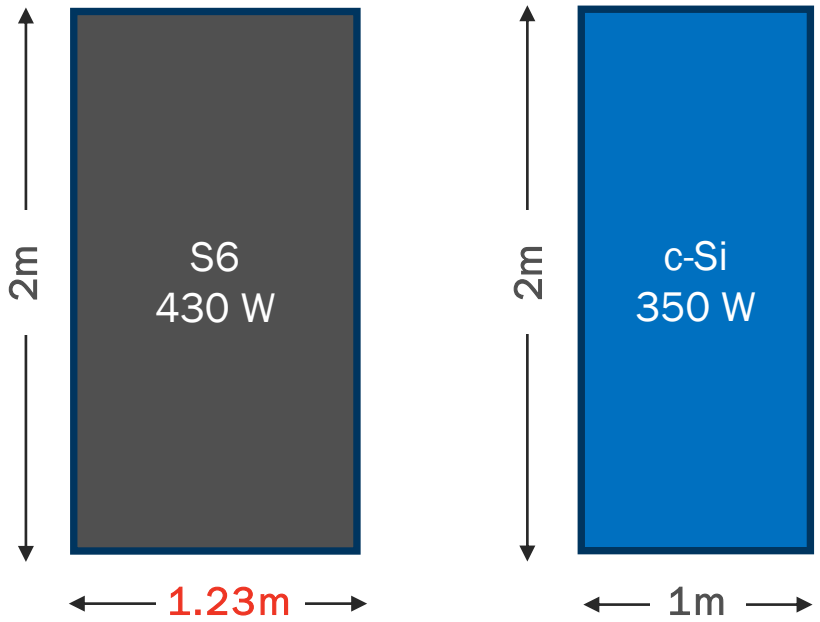
Fir Tree

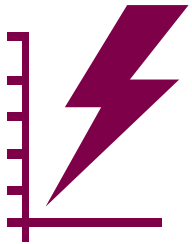


Cable Tie

MODULE VOLTAGE – KEY DRIVER FOR SMALL DC BOS PENALTY

Physical Dimensions Equal Efficiency

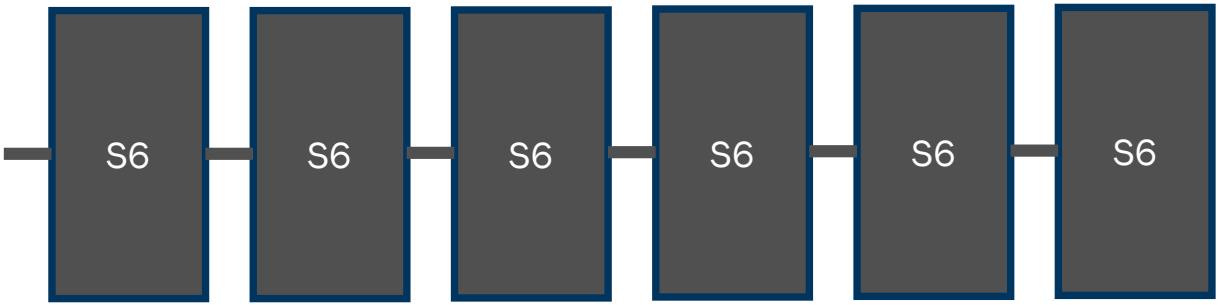


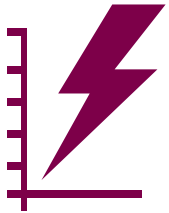


~5X

Module Voltage

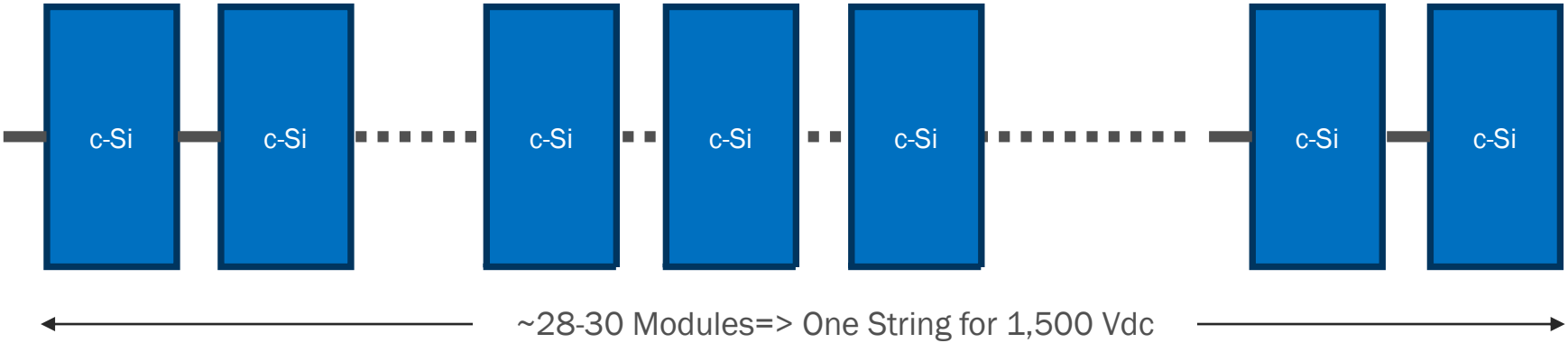
MAKING A STRING IS DIFFERENT … SERIES 6 HAS HIGHER VOLTAGE





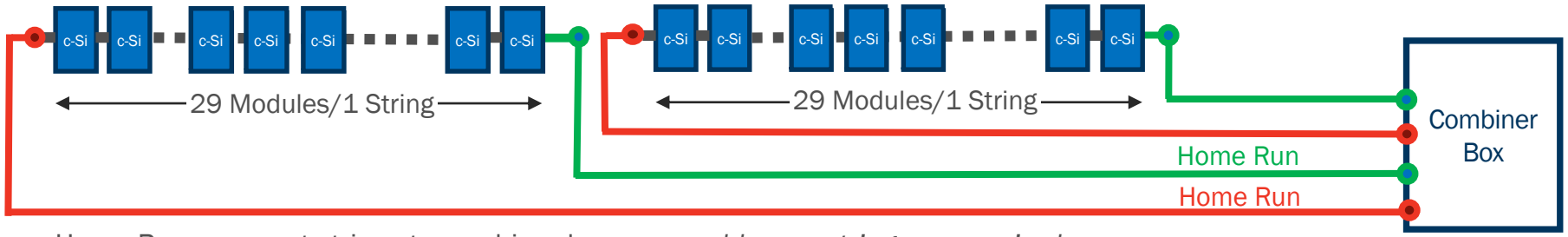
~5X

Module Voltage



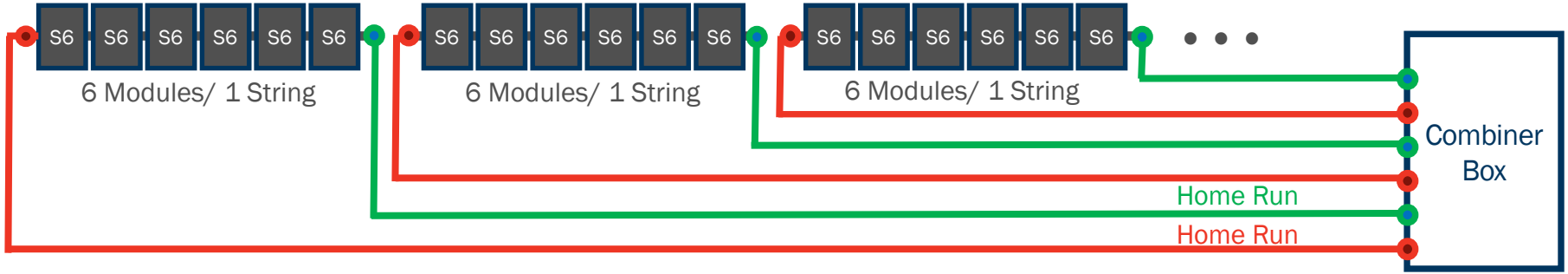
MAKING A ROW OUT OF STRING OF MODULES

Typical c-Si String Configuration



Home Runs connect strings to combiner box… *can add more strings as required*

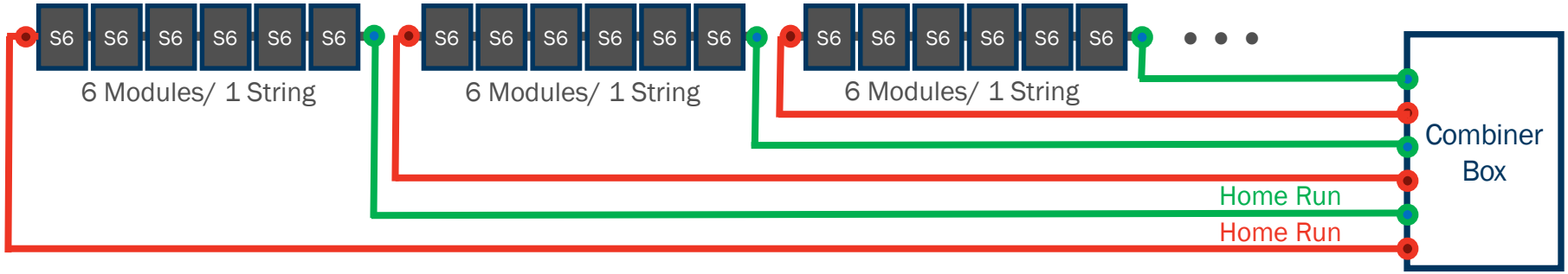
Similar Approach Leads to Increased DC Wiring Cost



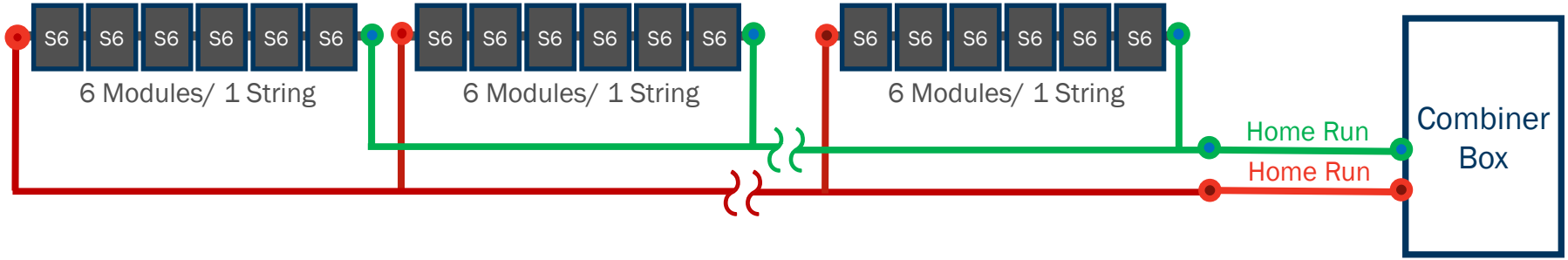
~5X DC Wiring… not a good approach

BETTER DC WIRING APPROACH SAVES BOS COST FOR SERIES 6

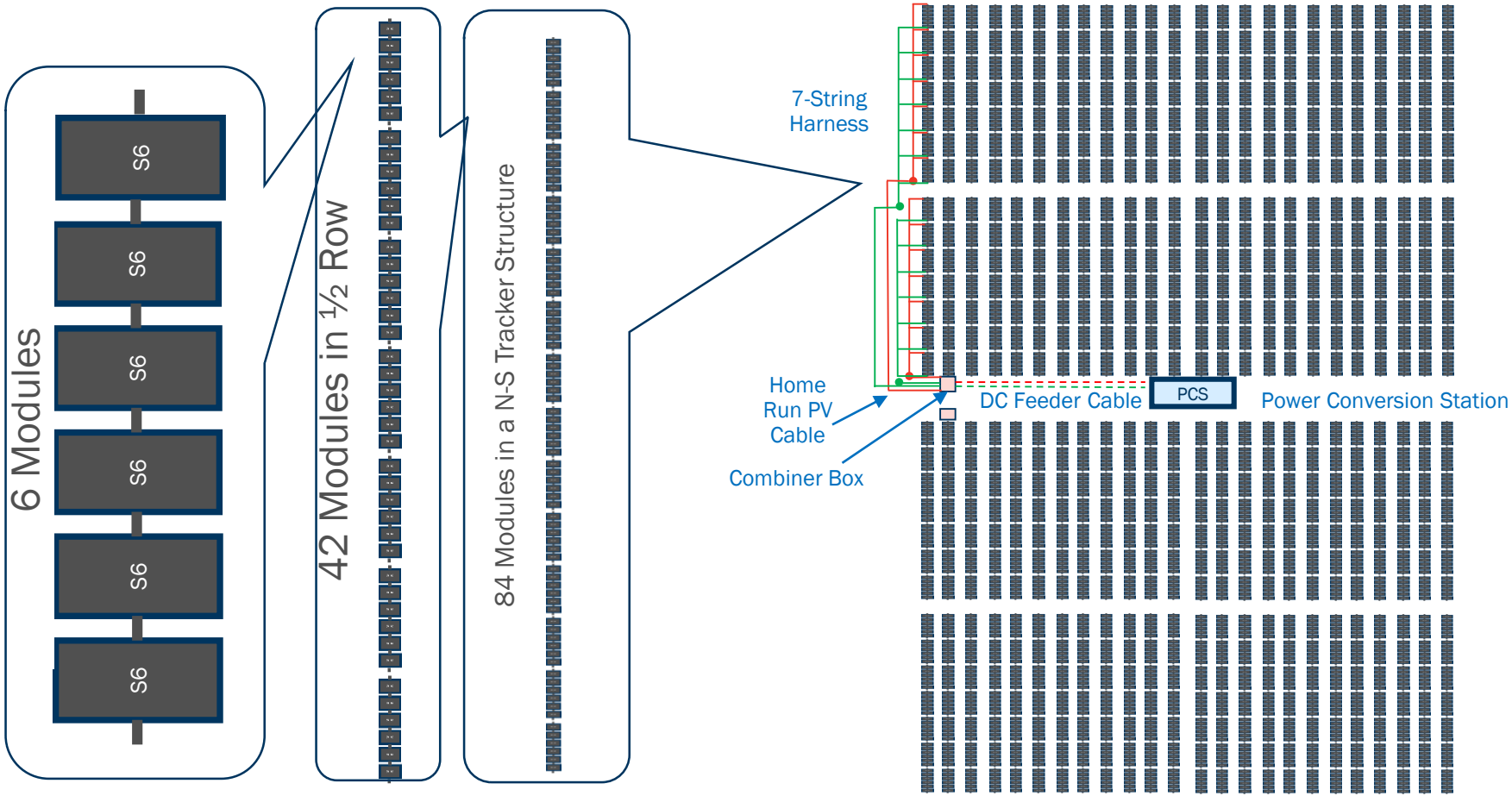
c-Si Approach Leads to Increased DC Wiring Cost



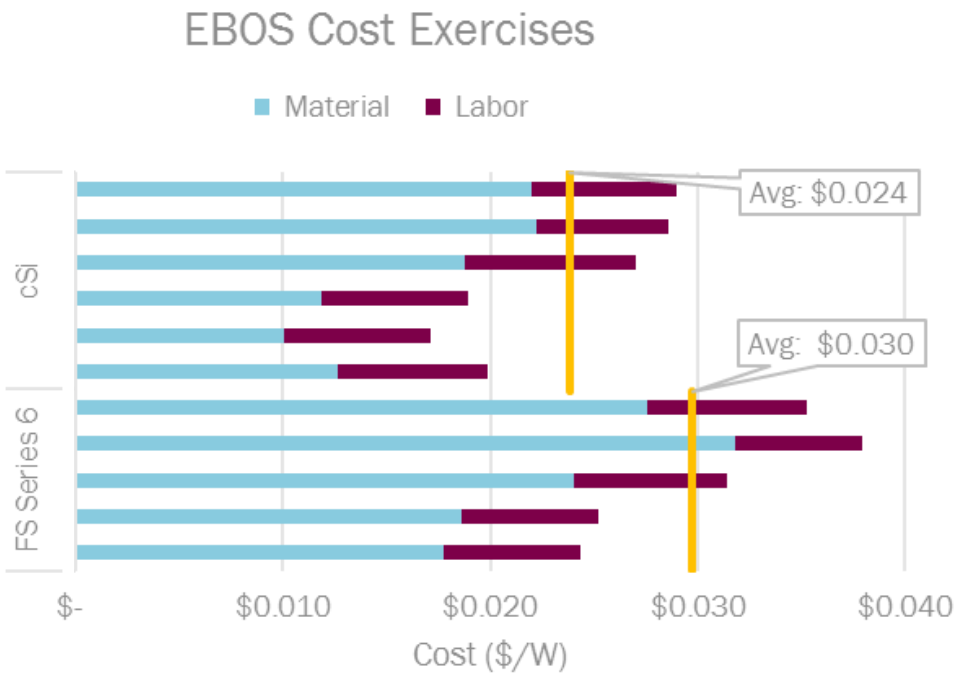
Multi-string Harness Reduced BOS Cost



A TYPICAL TRACKER ARRAY



EBOS INDEPENDENT ANALYSIS



sgurr energy
A Wood Group Business

BURNS McDONNELL

350W cSi, 430W S6, regional labor rates, United States, Europe, India reports available

FIRST SOLAR SERIES 6

FIrst Solar Serles

https://vImeo.com/245805769

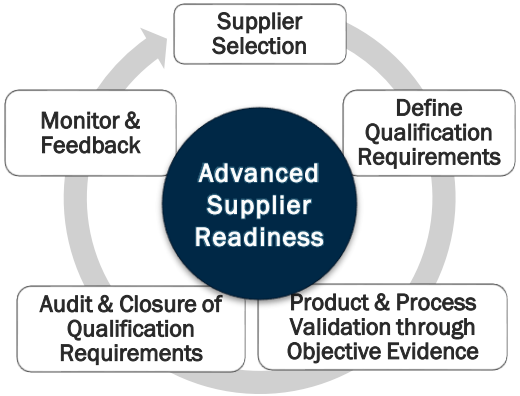
QUALITY & RELIABILITY

RAPID INNOVATION WITH LOW RISK | QUALITY SYSTEMS I/ II

Competitive Advantage

We have **100% of our product supply base fully integrated** into our manufacturing systems

- **Single global spec** for all components for reduced variation
- **1 Bill of Material** for all manufacturing locations
- Our customers do not need to spend time and $$ ensuring product is consistent and correct.



ISSUES REDUCED — VOLUME

150

On-site supplier audits conducted since 2012

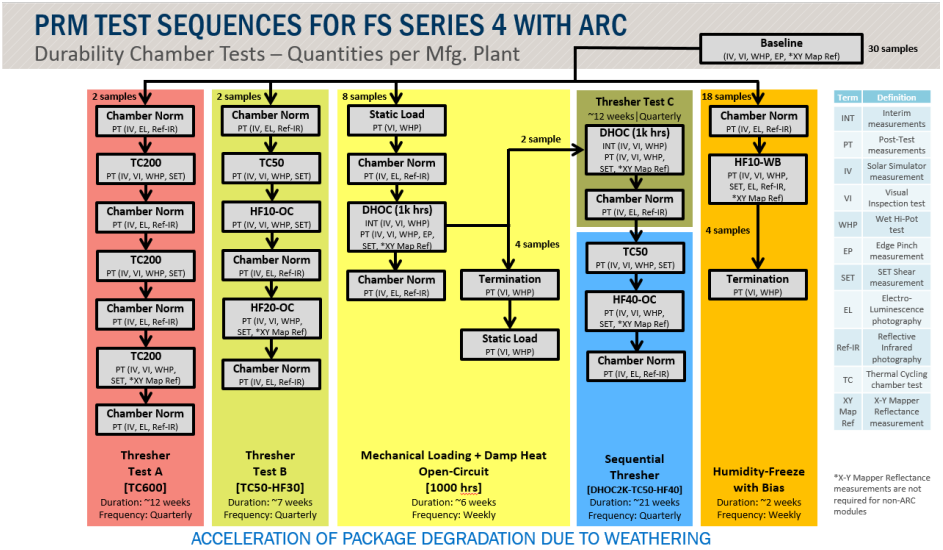
Key Elements Reviewed as part of Supplier Quality Audits

- Quality Management System
- Material Management System
- Production Management System
- Environmental Health & Safety

RAPID INNOVATION WITH LOW RISK | QUALITY SYSTEMS II/ II

Competitive Advantage

We provide the innovative process control and testing with transparency giving our customers confidence to avoid the extra cost and time of their own testing.



- On-site audit & witness testing
- Continuous Production Reliability Monitoring (PRM)
- Third Party Quality & Reliability Certifications

Available to customers:

- Module Factory Power data Report
- Representative Reliability Test Data for Shipped Product (PRM data as Proxy)
- Manufacturing and Reliability Lab Visit/Audit

First Solar Goes Well Beyond 'Standard Testing' To Qualify Products

QUALITY AND RELIABILITY LEADER | HIGH CONFIDENCE RELIABILITY

	First Solar	SunPower	Yingli	Trina	Canadian Solar	Solar Frontier	Panasonic	Hanwha	SolarWorld	Jinko Solar	JA Solar	REC	LG	Commodity Competitor
IEC61701 Salt Mist Corrosion	X	X	X		X	X				X	X			X
Ammonia Resistance	X	X			X	X				X				X
IEC Damp Heat 85C/85%RH 1000 hrs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Damp Heat 85C/85%RH 2000 hrs	X	X					X	X			X			
IEC Temp Cycle -40 to +85C 200 Cycles	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Temp Cycle -40 to +85C 600 Cycles	X	X					X	X			X			
IEC Humidity Freeze 10 cycles	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Humidity Freeze 40 cycles	X						X	X			X			
Chemical Exposure, FSLR-ALT, etc.	X													
Independent Thresher Test Certification	X										X			
PID Free (negative grounded)	X	X	X	X	X				X	X	X	X		X
TUV Sequential Test Certification	X						X	X						
IEC 60068 Desert Sand Resistance	X		X							X				
JETPVm Certification	X		X			X				X				
Atlas 25+	X	X												
Fraunhofer - PVDI Rating	X	X												
TUV PV+ Rating								good	very good					
1500V IEC	X										X			

*Based on availability of publicly disclosed information. Companies completing but not disclosing results are not included. References and citations available.

INDUSTRY-LEADING QUALITY, SAFETY, RELIABILITY AND BANKABILITY

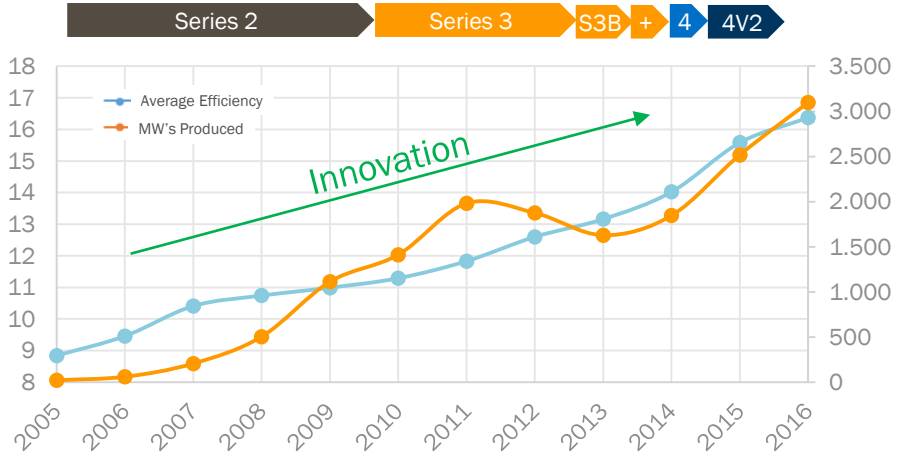
Test	Description	Results
IEC 61646/IEC 61730 Certification	Basic industry market entry certifications	**PASS** *1500V certification level*
Thresher Test	Multiplies basic IEC 61730/61646 test cycles and durations 2X to 4X	**PASS** *<5% Power Output drop*
Long-Term Sequential Test	6-month accelerated protocol to evaluate long-term harsh climate durability	**PASS** *1st thin film module, and one of only 5 modules in the world to pass.*
Atlas 25+ Certification	12-month weathering-intensive certification through projected 25+ year harsh climate field lifetimes	**PASS** *One of only 4 modules in the world to pass.*
IEC 62804 PID-Resistant Certification	Demonstrates high resistance to potential induced degradation at extreme ± 1500V voltages at most extreme 192hr 85C/85% RH test levels, enabling confident floating and grounded applications	**PASS** *1500V*
IEC 60068 Certification Desert Sand Resistance	Demonstrates minimal power loss and package integrity resistant to wind-blown particulates	**PASS**
Fraunhofer PV Durability Initiative	Durability benchmarking program rates modules according to their likelihood of performing reliably over their expected service life based on accelerated stress testing and long-term outdoor exposure	**PASS** *Best-in-class long term durability*

Certified to world-class quality, safety, reliability and durability standards.

RAPID INNOVATION WITH LOW RISK: SUMMARY

We have 10 years of demonstrated innovation, reducing cost, while improving Quality & Reliability bringing more competitive product to the market faster than others making us an ideal long term technology partner

Rapid Innovation



+

Improved Quality & Reliability

Industry-leading portfolio of independently evaluated extended reliability and durability results

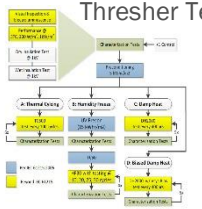
ATLAS 25+ Comprehensive PV Durability Testing

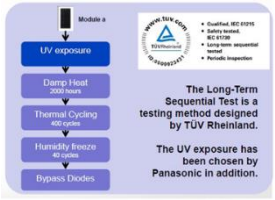
Fraunhofer USA

Photovoltaic Technologies: The PV Module Durability Initiative (PVDI)

Fraunhofer Center for Sustainable Energy Systems

Thresher Test

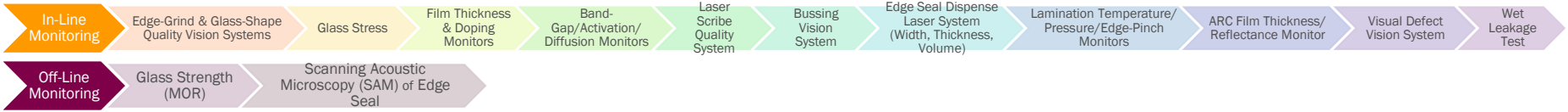


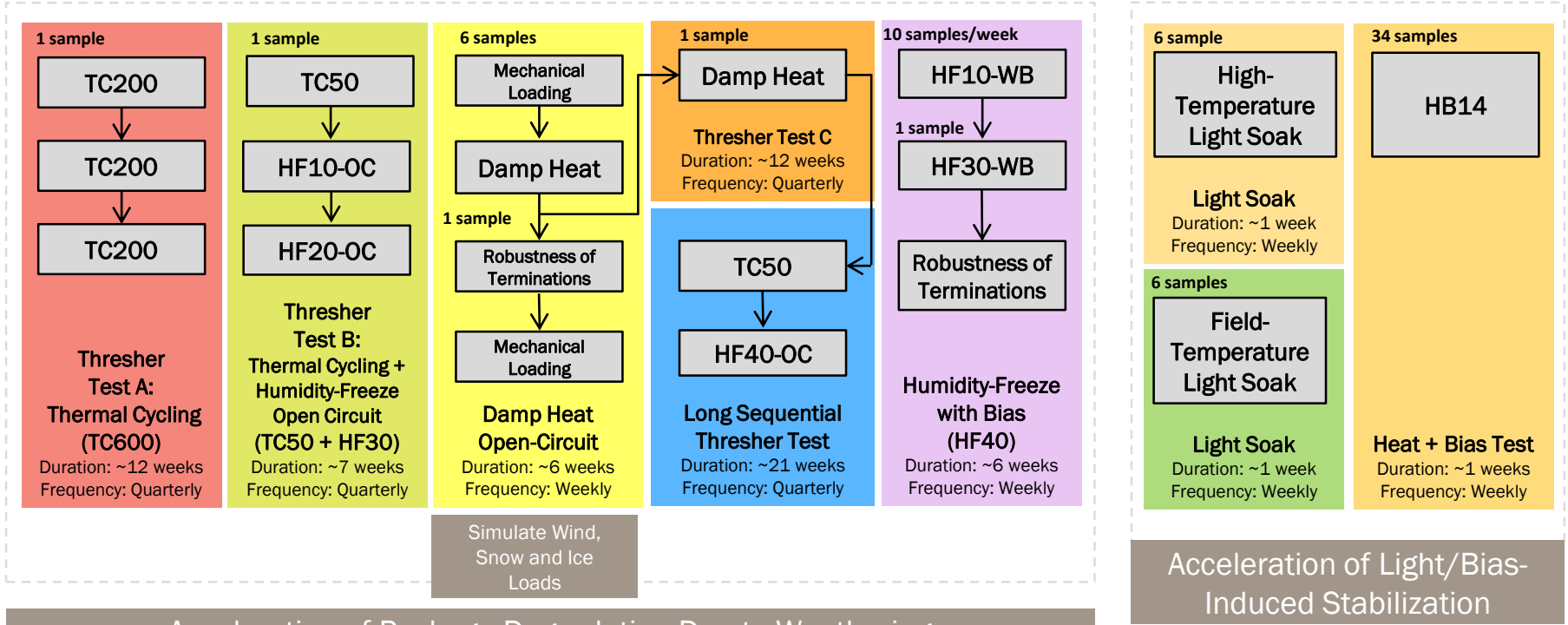


Ideal Long Term Technology Partner

PRODUCT RELIABILITY MONITORING FOR FS SERIES 6

In-Line Metrology & Weekly Production Monitoring Testing Per Plant





First Solar®

SUSTAINABILITY

PROVIDING THE LEADING ECO-EFFICIENT PV TECHNOLOGY

proven energy advantage

economically competitive with fossil fuel

lowest environmental impacts

- Validated by 3rd party research and global peer reviews
- Higher energy yields at a competitive cost
- Fastest energy payback time < 1 year
- Smallest carbon footprint and air pollutants
- Lowest life cycle water use
- Industry leading PV recycling program

Creating MORE VALUE with LESS ENVIRONMENTAL IMPACT.

Seitz et al., Eco-Efficiency Analysis of Photovoltaic Modules, Bavarian State Ministry of Environment and Health, 2013.

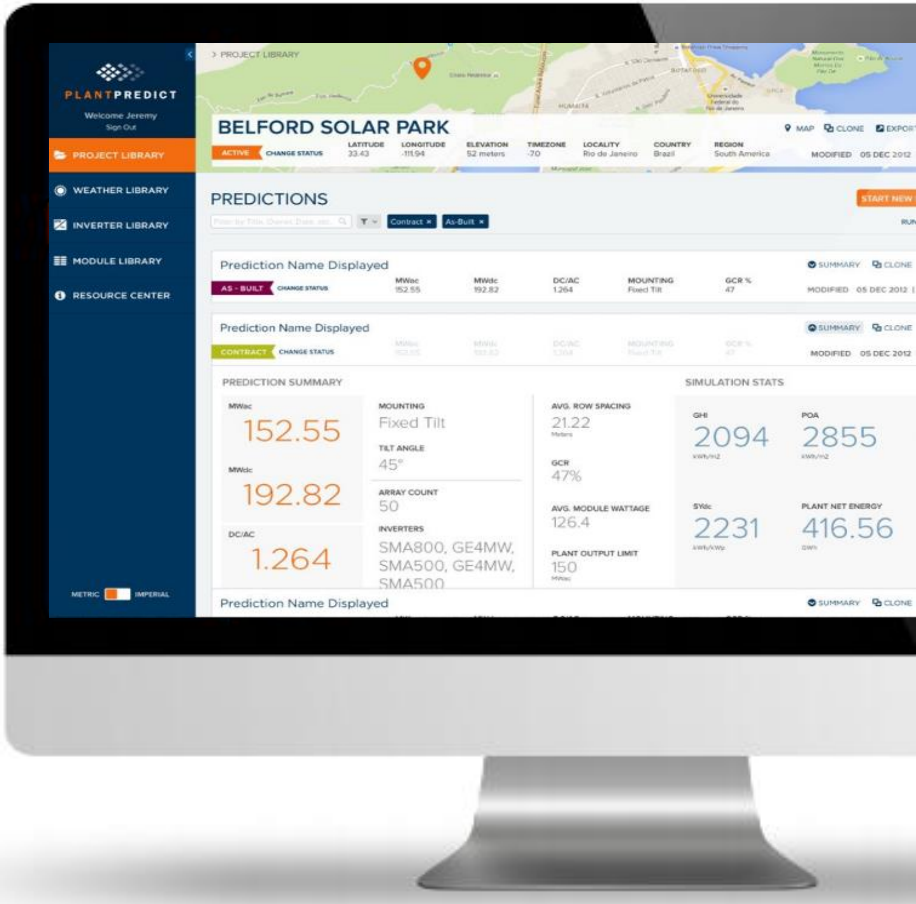
First Solar®

INTRODUCING PLANT PREDICT

PLANT PREDICT

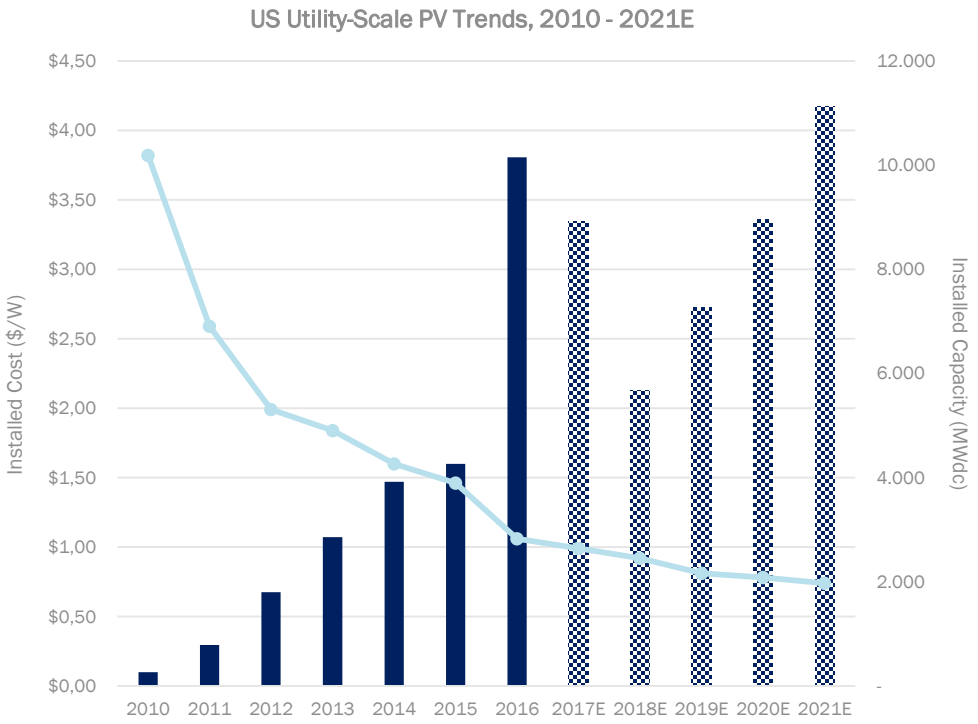
PlantPredict:

Solar Performance Modeling Made Simple



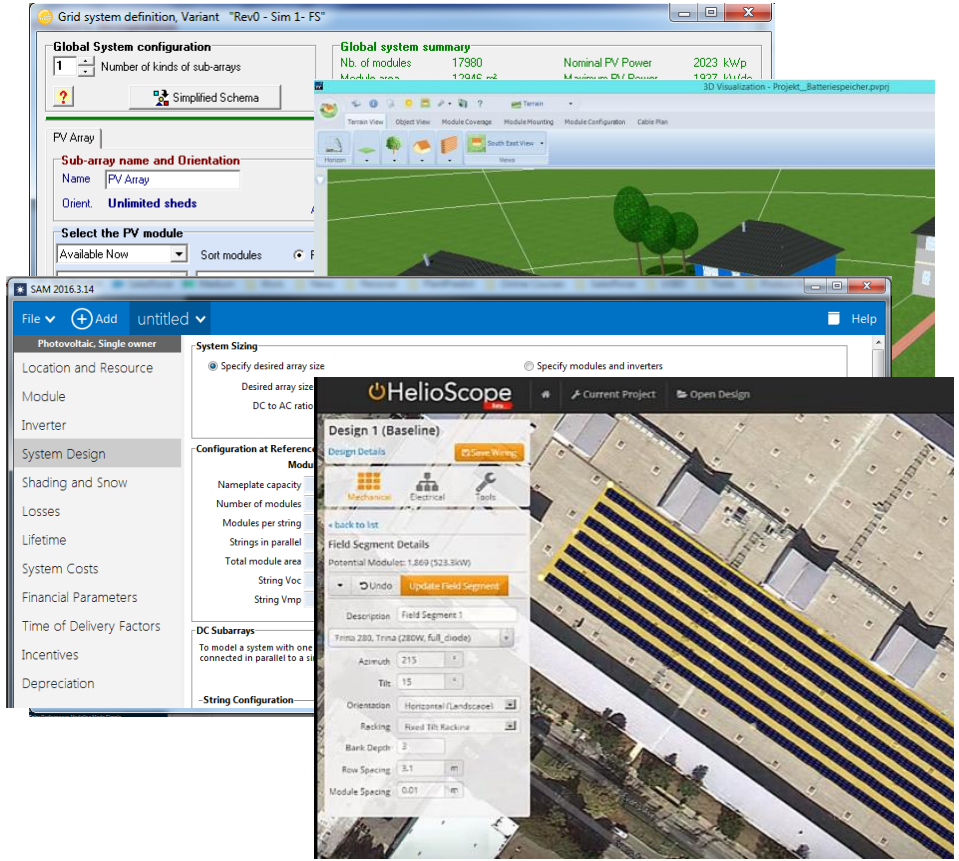
BACKGROUND

- Solar PV has been exploding in the US and around the world!
  - — Costs have dropped by over 75%
  - — Installations have gone up 15x
- Solar made up 40% of all new energy capacity in the US in 2016
- Global clean energy industry is worth over $1TR!
  - — More than commercial airlines and fashion



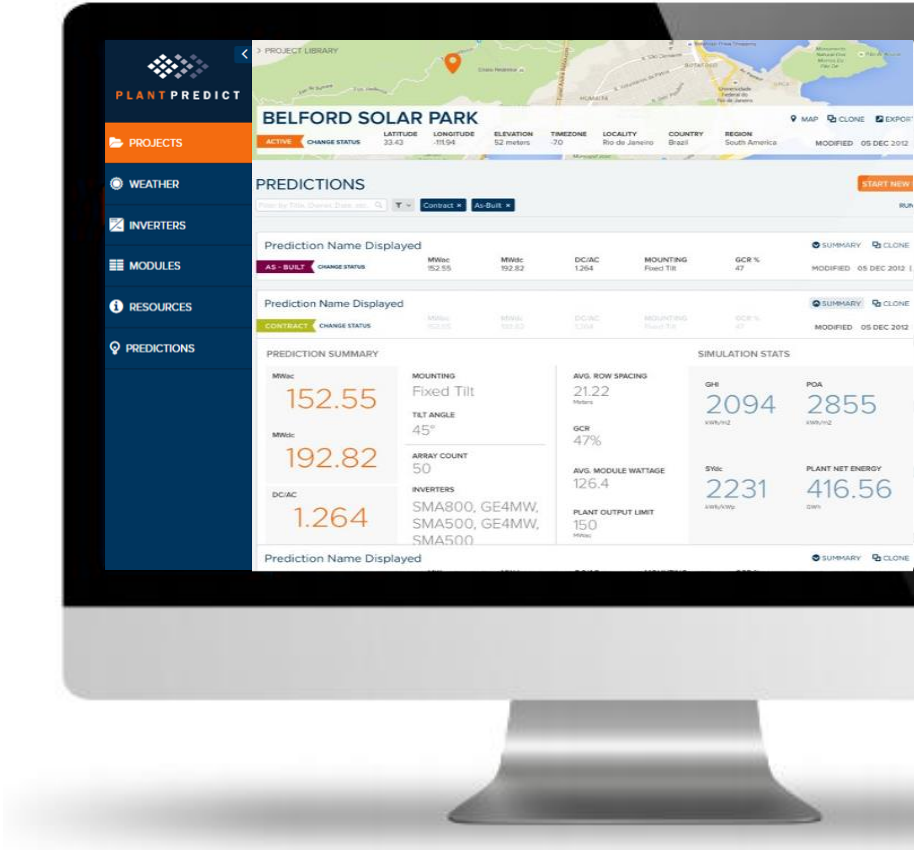
TIMELINE OF PV TOOLS

- 1992 – PVSyst begins development in University of Geneva
  - 1999 – Version 3.0
  - 2006 – Version 4.0
  - 2009 – Version 5.0
    - In V 5.5, product separates from University of Geneva into independent company, PVsyst SA
  - 2013 – Version 6.0
- 1998 – Valentin launches PV*SOL
- 2007 – NREL launches SAM
- 2014 – Folsom Labs launches Helioscope
- 2016 – PlantPredict publicly launched
  - 2009 – Began as Farm Simulation Tool (FST) in Optisolar
  - 2010 – Evolved into ISIS at FS for internal use
  - 2015 – Name changed to PlantPredict for political reasons…



PLANTPREDICT: SOLAR PERFORMANCE MODELING MADE SIMPLE

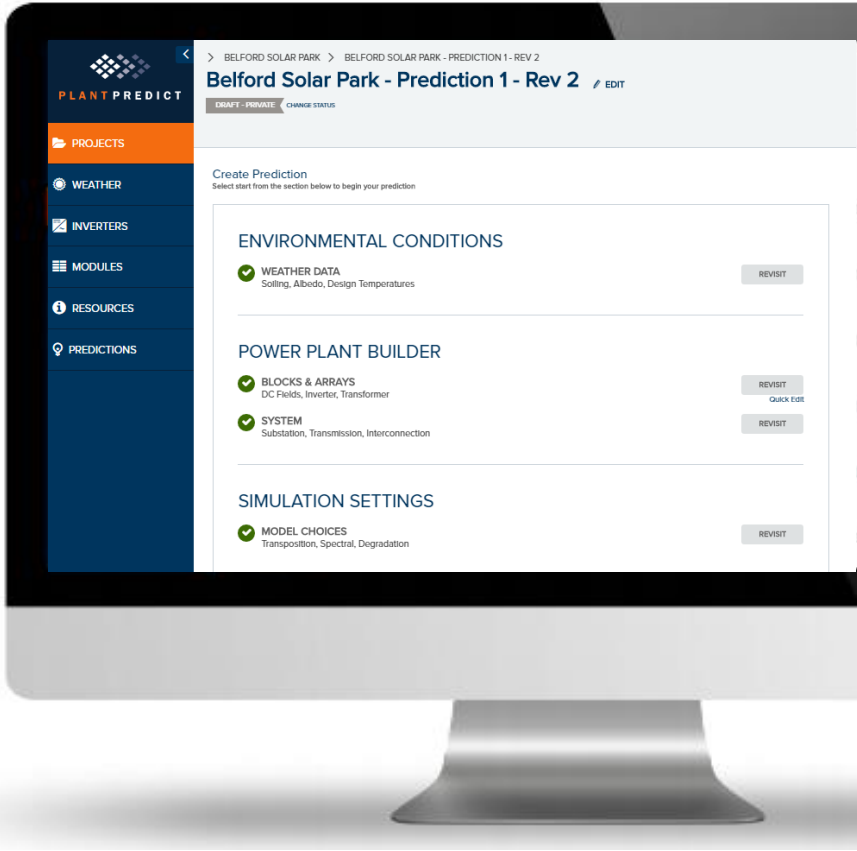
- Generate *quick, contract-grade predictions* via a streamlined user interface
- Designed specifically for *utility-scale solar*
  - Sub-hourly and multi-year predictions
  - Direct weather download
  - Built-in spectral correction
  - Cloud-based application
- *Independently reviewed and benchmarked* against more than 1 GW of operating facilities



Reviewed by: DNV·GL, RV, leidos, ICF

THE BENEFITS OF PLANTPREDICT

- Reduce prediction time by *up to 75%*
  - — Easy to learn, short learning curve
- End-to-end utility-scale modeling
  - — Built-in MV and HV transformers, Tx lines
  - — Built-in availability and LGIA losses
  - — *No need for pre- or post-processing*
- Pre-loaded with industry standard weather, module, and inverter files
- Optimize your design with “Clone” and “Quick Edit”
- Cloud-hosted for ease of sharing and data security



PLANTPREDICT VS COMPARABLE SOFTWARE

Features	PVSyst	NREL SAM	HelioScope	PlantPredict
Utility-scale PV prediction	✓*	✓		✓
Direct Weather Download		✓**		✓
Spectral Modeling			✓	✓
Sub-hourly Weather Data				✓
Multi-Year Predictions		✓		✓
DC Degradation				✓
Non-Linear Temperature Coefficient				✓
Cloud Sharing				✓
Free				✓
Advanced Shading Model	✓	✓	✓	Coming Soon
Layout Capability			✓	Coming Soon

*Requires extensive workarounds and post-processing, **Only NREL weather download capability

PLANTPREDICT MAIN CALCULATION METHODS

IRRADIANCE MODELING	Solar position: NREL's Solar Position Algorithm Decomposition Model: Erbs, Reindl, or DIRINT Transposition Model: Hay or Perez
EFFECTİVE İRRADİANCE	Incidence Angle Modifier: ASHRAE, Sandia, or user tabular Spectral Correction: 1 and 2 Parameter (Pwat, AM), Sandia, or user monthly input Shading: 2D trigonometric
DC SYSTEM	Module Temperature: Heat Balance or Sandia PV Module IV Curve: 1-diode model Degradation Model: Linear DC option
AC SYSTEM	Transformer and AC Losses: Up to 6 transmission lines or transformers Availability, LGIA Limit, and Auxiliary Losses: Included Degradation Model: Stepped AC or Linear AC

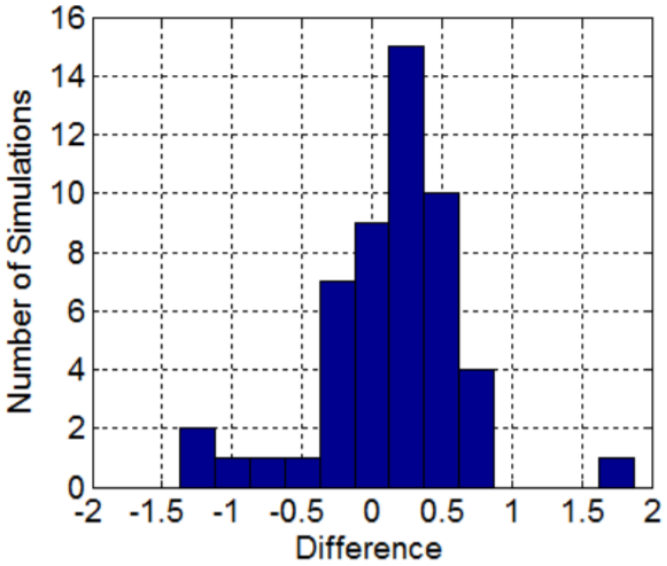
All algorithms are published. See Resource Center for more details

BENCHMARKING PLANTPREDICT

Site	DC MW range	Commission Year	Mounting Type	Climate	Region	Duration (yr)
1	20-30	2009	Fixed Tilt	Hot	USA	5.1
2	30-40	2010	Fixed Tilt	Hot	USA	4.1
3	30-40	2012	Fixed Tilt	Hot	USA	2.7
4	60-70	2012	Fixed Tilt	Hot	USA	2.7
5	30-40	2012	Fixed Tilt	Hot	USA	2.5
6	10-20	2012	Fixed Tilt	Hot	Australia	2.3
7	30-40	2012	Horizontal Tracker	Hot	USA	2.0
8	20-30	2013	Fixed Tilt	Hot	USA	1.9
9	80-90	2013	Fixed Tilt	Hot	USA	1.6
10	30-40	2013	Fixed Tilt	Hot	USA	1.5
11	200-300	2013	Fixed Tilt	Hot	USA	1.2
12	10-20	2013	Fixed Tilt	Hot	Middle East	1.2
13	50-60	2013	Fixed Tilt	Hot	USA	1.0
14	30-40	2014	Fixed Tilt	Hot	USA	0.8
15	20-30	2014	Horizontal Tracker	Hot	USA	0.5
16	60-70	2014	Horizontal Tracker	Hot	USA	0.6
17	30-40	2014	Fixed Tilt	Hot	USA	0.3
18	70-80	2010	Fixed Tilt	Temperate	Canada	4.3
19	20-30	2012	Fixed Tilt	Temperate	Canada	2.9
20	20-30	2013	Fixed Tilt	Temperate	Canada	1.9

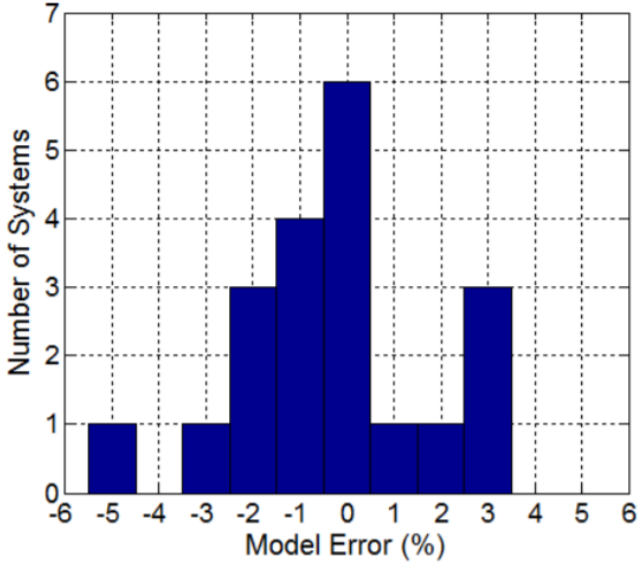
BENCHMARKING PLANTPREDICT

PlantPredict vs. PVsyst:
Comparison of 51 Simulations



Mean energy yield difference of 0.13% ± 0.52%

PlantPredict vs. Measured Data:
Comparison of 20 Plants



Average energy meter error of 0.41% ± 2.01%

K. Passow, L. Ngan, B. Littmann, M. Lee, and A. Panchula, "Accuracy of Energy Assessments in Utility Scale PV Power Plant using PlantPredict," *42nd IEEE Photovoltaic Specialists Conference* (2015).

INDEPENDENT REVIEWS

leidos

Review of user interface and structure, algorithms used, and case studies (including independent modeling of c-Si)

"PlantPredict appears to be well-constructed for the use of simulations and energy production estimates of utility-scale PV plants, and appears to be able to provide a modeling accuracy equivalent to other commonly used industry software tools for utility-scale projects; in certain cases where spectral correction is required, the modeling accuracy of PlantPredict may surpass other tools."

BLACK & VEATCH

Review of algorithms used, comparison of PlantPredict vs. PVsyst for three cases, and review of internal validation work

"PlantPredict should be able to model the fundamental aspects of solar PV energy production. [...] The algorithms selected for implementation in PlantPredict are used across the industry and offer spectral modeling capability that may result in more accurate energy prediction than those of PVsyst."

ICF

DNV·GL

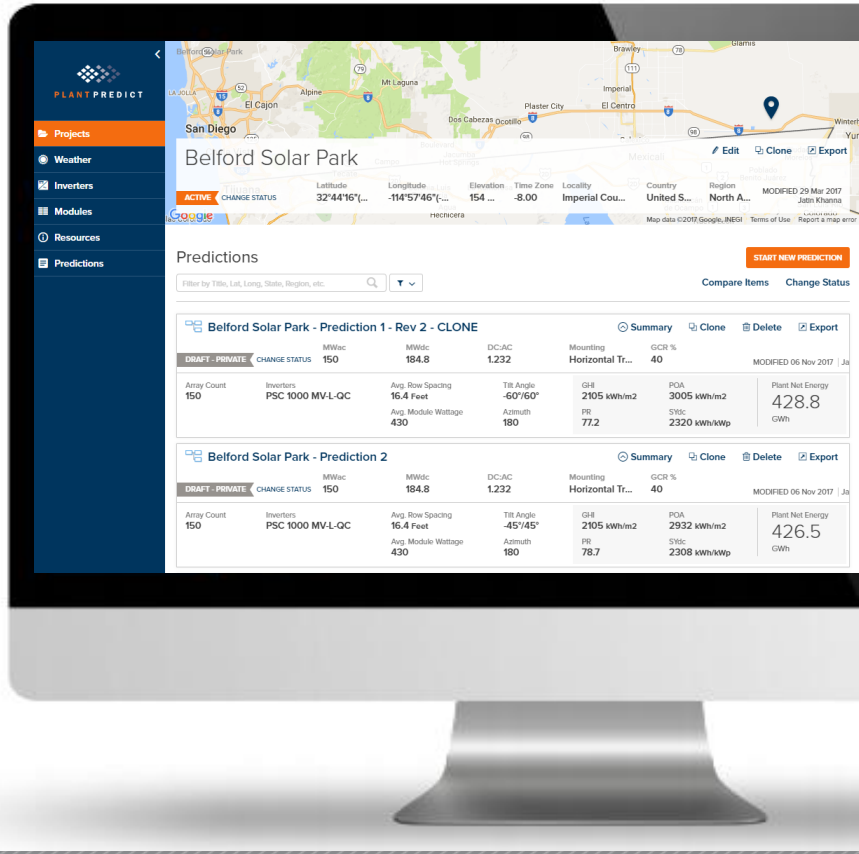
PlantPredict offers certain logistical and technical advantages.


First Solar®

PLANT PREDICT

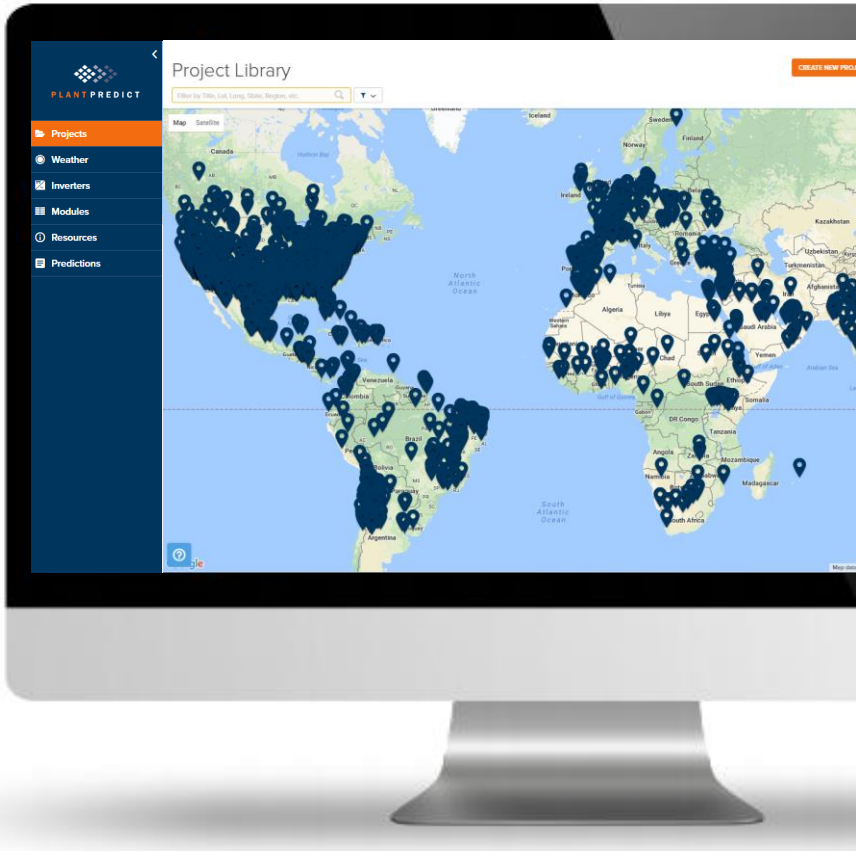
PlantPredict:

Solar Performance Modeling Made Simple



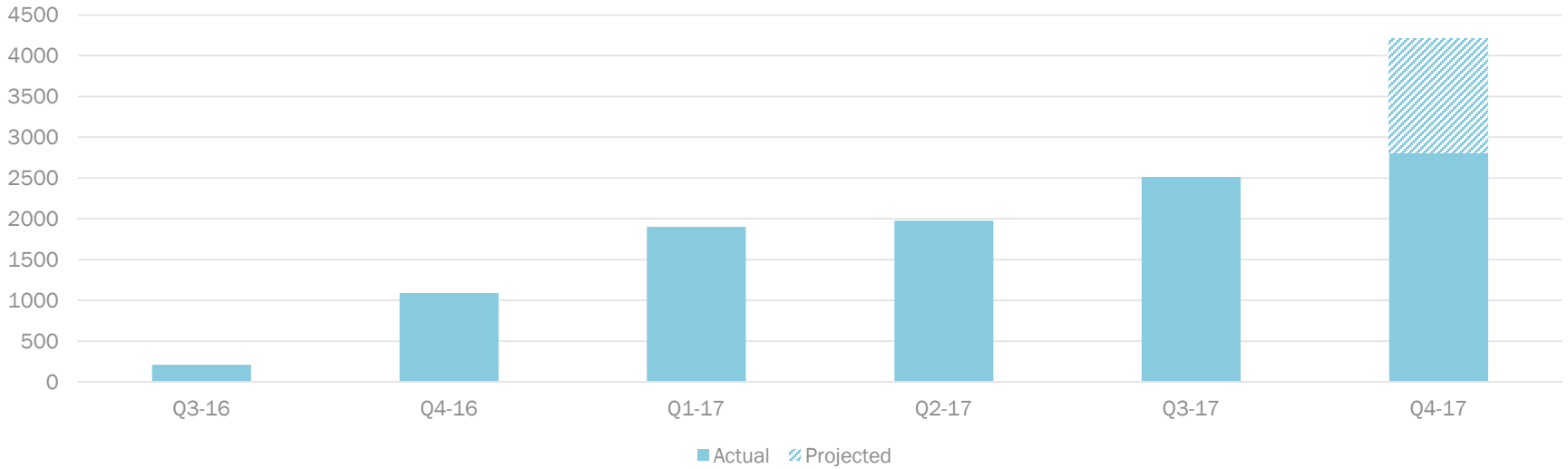
INTRODUCING PLANTPREDICT

- Generate *quick, contract-grade predictions* via a streamlined user interface
- Designed *specifically for utility-scale solar*
  - Sub-hourly and multi-year predictions
  - One-click weather download
  - Built-in spectral correction
  - Cloud-based application
- *Independently reviewed and benchmarked* against more than 1 GW of operating facilities



Reviewed by: DNV·GL, RV, leidos, ICF

PLANTPREDICT'S GROWTH STORY



- Over 7,000 predictions run in first year since launch
- Current user base: 130+ active users, 60+ companies, across all five continents
- PlantPredict was used in the sale of *350+ MW of utility-scale PV projects*
  - "A review of PlantPredict's capabilities by independent engineering firm Leidos found that the application provided modeling accuracy equivalent to other energy prediction modeling tools currently used in the industry."

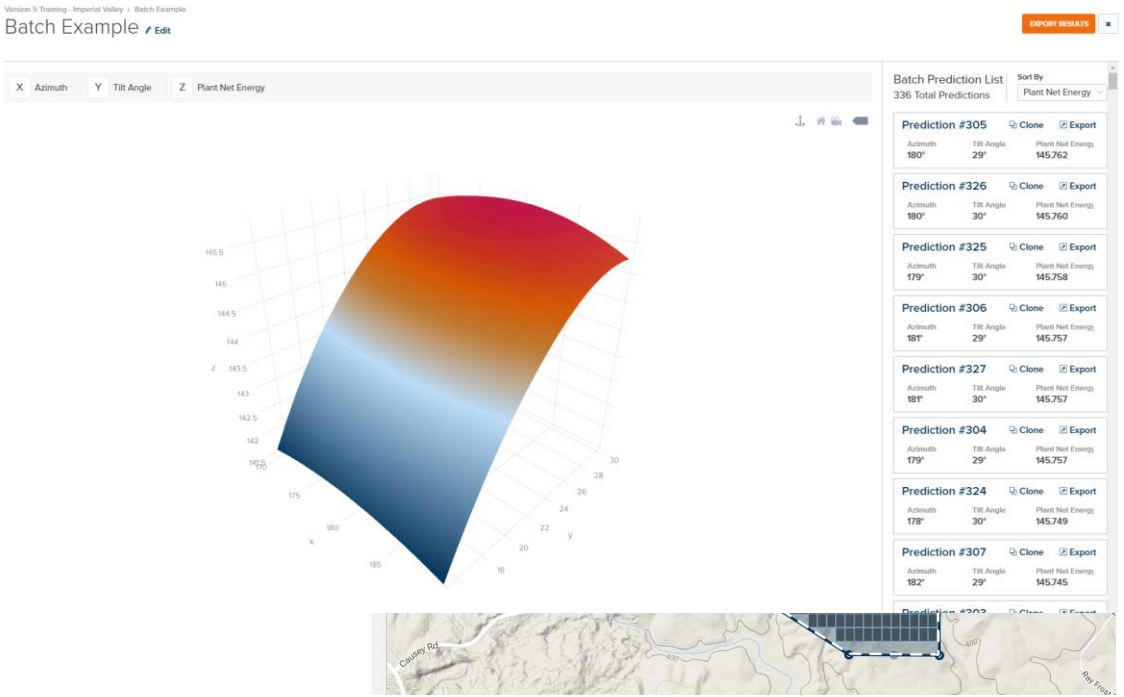
MODERN FEATURES TO MOVE UTILITY-SCALE PV FORWARD

Current

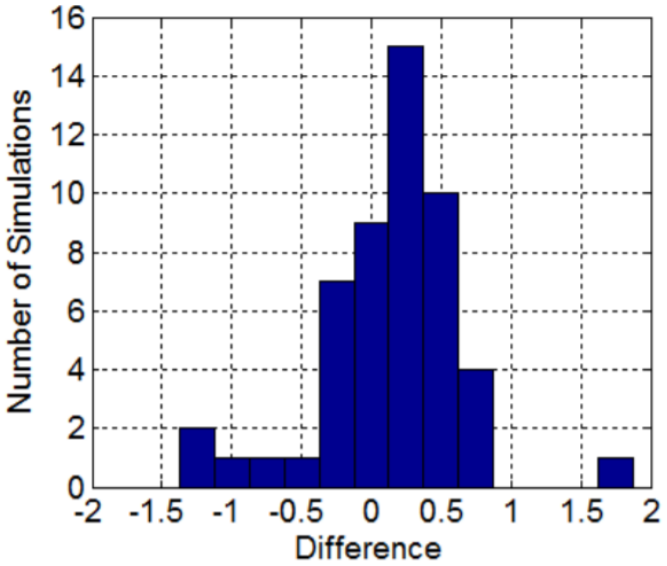
- Slope Shading
  - Model uneven terrain
- POAI Import
  - Reduce prediction uncertainty with measured POA
- Map Builder
  - Understand site capacity in an instant
- Batch Processing
  - Optimize your site for maximum returns

Upcoming

- *Developer Portal for API*
- *PV + Storage Modeling*
- *Bifacial Modeling*

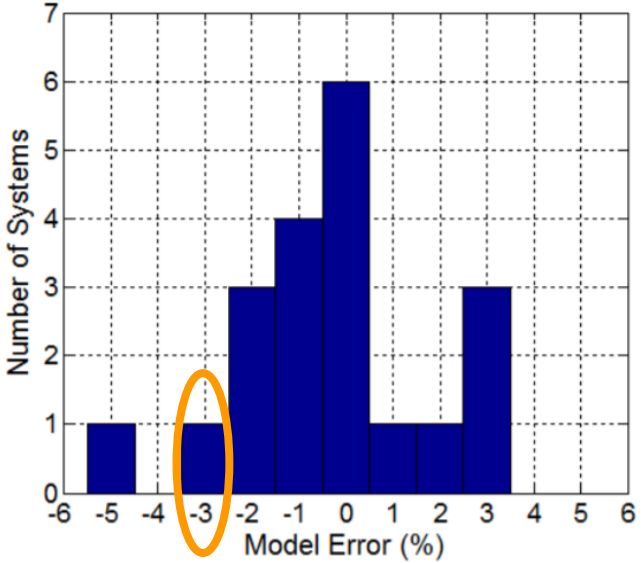


PlantPredict vs. PVsyst: Comparison of 51 Simulations



Mean energy yield difference of 0.13%*

PlantPredict vs. Measured Data: Comparison of 20 Plants

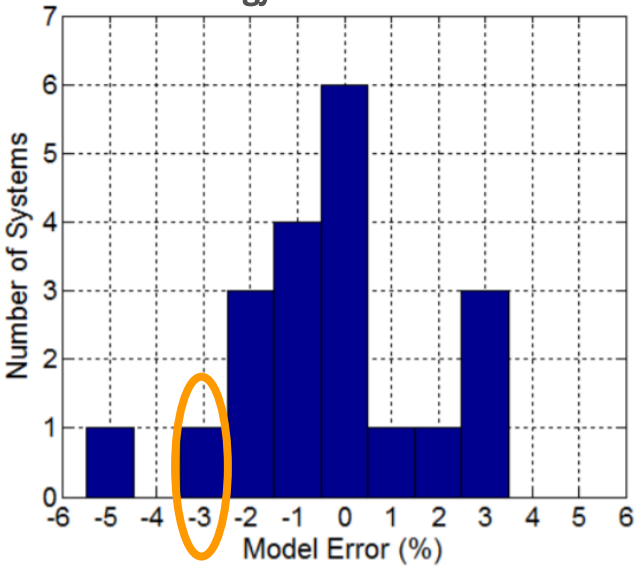


Average energy meter error of -0.41%**

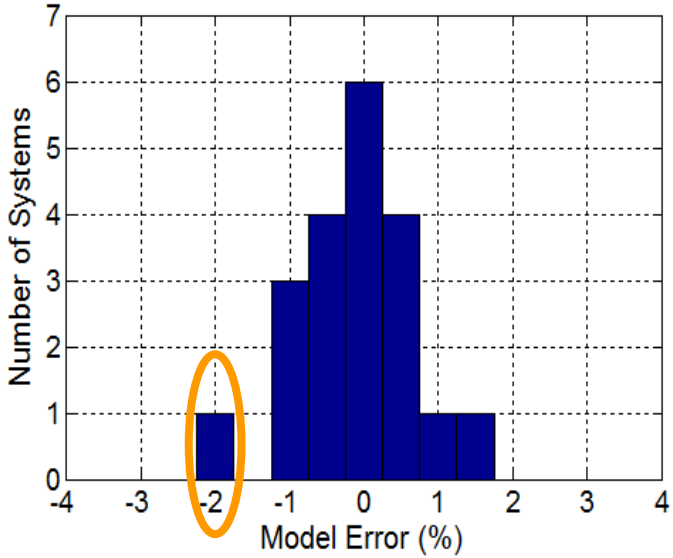
*Measurement error of ± 0.52% ** Measurement error of ± 2.01%

K. Passow, L. Ngan, B. Littmann, M. Lee, and A. Panchula, "Accuracy of Energy Assessments in Utility Scale PV Power Plant using PlantPredict," *42nd IEEE Photovoltaic Specialists Conference* (2015).

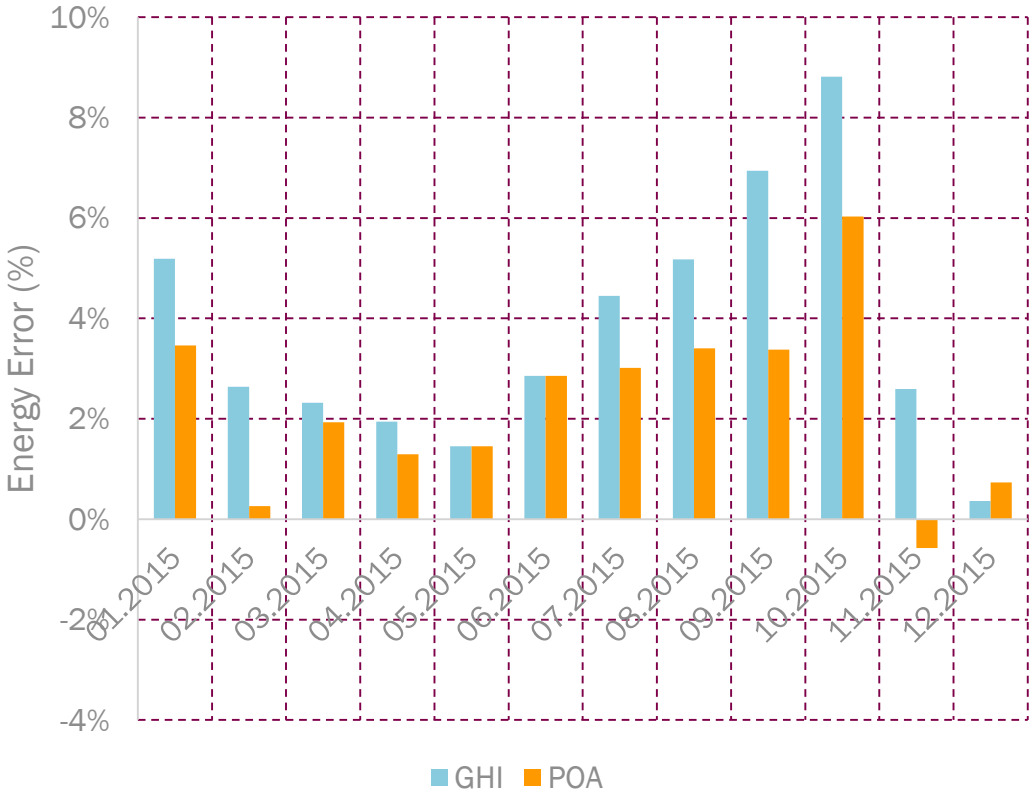
PlantPredict vs. Measured Data: Energy Meter Error



PlantPredict vs. Measured Data: POA Error



Energy meter error appears to be correlated with POA error at this site



Energy Error

GHI import (Hay/Erbs): -3.40%

POA import (GTI DIRINT): -2.13%

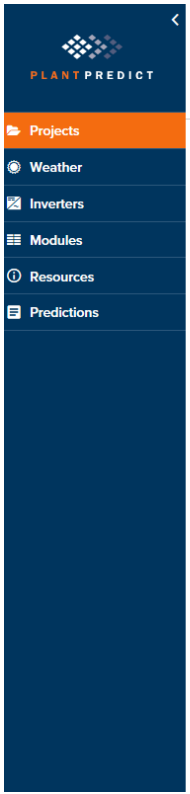
Location: Weihai, China

Target AC Capacity: 10 MW

DC:AC Ratio: 1.2

Tilt Angle: ?

GCR: ?



Weihai China PVPM › Weihai China Reference Prediction

Weihai China Reference Prediction Edit

DRAFT - PRIVATE CHANGE STATUS

SAVE + CLOSE PREDICTION

Delete

MODIFIED 30 Nov 2017 | Kendra Passow

Environmental Conditions

Weather Data — REVISIT
Soiling, Albedo, Design Temperatures

Power Plant Builder

Blocks & Arrays — REVISIT (Quick Edit)
DC Fields, Inverter, Transformer

System — REVISIT
Substation, Transmission, Interconnection

Simulation Settings

Model Choices — REVISIT
Transposition, Spectral, Degradation

Run Your Prediction — RUN PREDICTION
All required information has been added and you can now run your prediction.

Prediction Logic: Version 5

Environmental Conditions
Weather Details

Weather File Name
SolarGIS - 37.513N - 122.12E

GHI	DHI	Soiling
1,460.47 kWh/m²	768.43 kWh/m²	2.00%

Power Plant Builder
Power Plant Data

BLOCK	ARRAYS	ROW (m)	MODULE (W)	MWac	MWdc	DC:AC
1	10	8.08	430	10	12	1.2
			TOTAL SYSTEM CAPACITY	10	12	1.2

Simulation Settings
Simulation Model

Model Choices

Transposition	Spectral	Degradation
PEREZ	2-PARAM PWAT AND AM	NONE

Weihai China PVPM › Batch Quick

Batch Quick Edit

DRAFT - PRIVATE CHANGE STATUS

VIEW RESULTS RUN PREDICTION

MODIFIED 30 Nov 2017 | Kendra Passow

Set Batch Constants

Base Settings

PlantPredict Default Values Edit Clear Selection

Copied: 29 Nov 2017 At 4:04PM

Weather

SolarGIS - 37.513N - 122.12E Change

GLOBAL

GHI 1460.47 kWh/m²

DHI 768.43 kWh/m²

Inverter

GE ProSolar 1 MW Change

ACTIVE

Manufacturer GE

Rated PWR 1000 kW

Module

FS-6430A CdTe Aug2017 Change

GLOBAL

Manufacturer FIRST SOLAR

Rated Power 430 W

Maximum Desired MWdc	Mounting Type
12 MWdc	Fixed Tilt
DC:AC Ratio	**Tilt Angle**
1.2	Varied °
GCR	**Azimuth**
Varied %	180

Choose up to 2 Variables to Iterate

Variable	Start	Stop	Step	Total Steps
DC:AC Ratio				
GCR %	30	60	5	7
Azimuth				
Tilt Angle	20	50	5	7

Prediction Queue

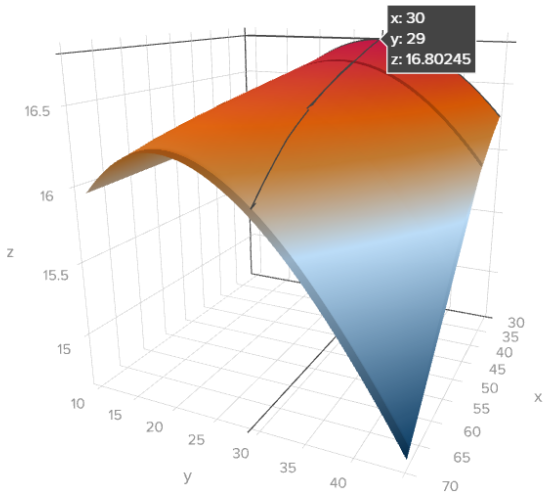
View Prediction Variation Queue

Available	Ready
301	49

Batch Test 2 Edit

EXPORT RESULTS

X GCR % Y Tilt Angle Z Plant Net Energy



Batch Prediction List

324 Total Predictions

Sort By: Plant Net Energy

Prediction #20 Clone Export
GCR % 30 | Tilt Angle 29° | Plant Net Energy 16.802

Prediction #21 Clone Export
GCR % 30 | Tilt Angle 30° | Plant Net Energy 16.800

Prediction #19 Clone Export
GCR % 30 | Tilt Angle 28° | Plant Net Energy 16.800

Prediction #22 Clone Export
GCR % 30 | Tilt Angle 31° | Plant Net Energy 16.794

Prediction #18 Clone Export
GCR % 30 | Tilt Angle 27° | Plant Net Energy 16.793

Prediction #23 Clone Export
GCR % 30 | Tilt Angle 32° | Plant Net Energy 16.783

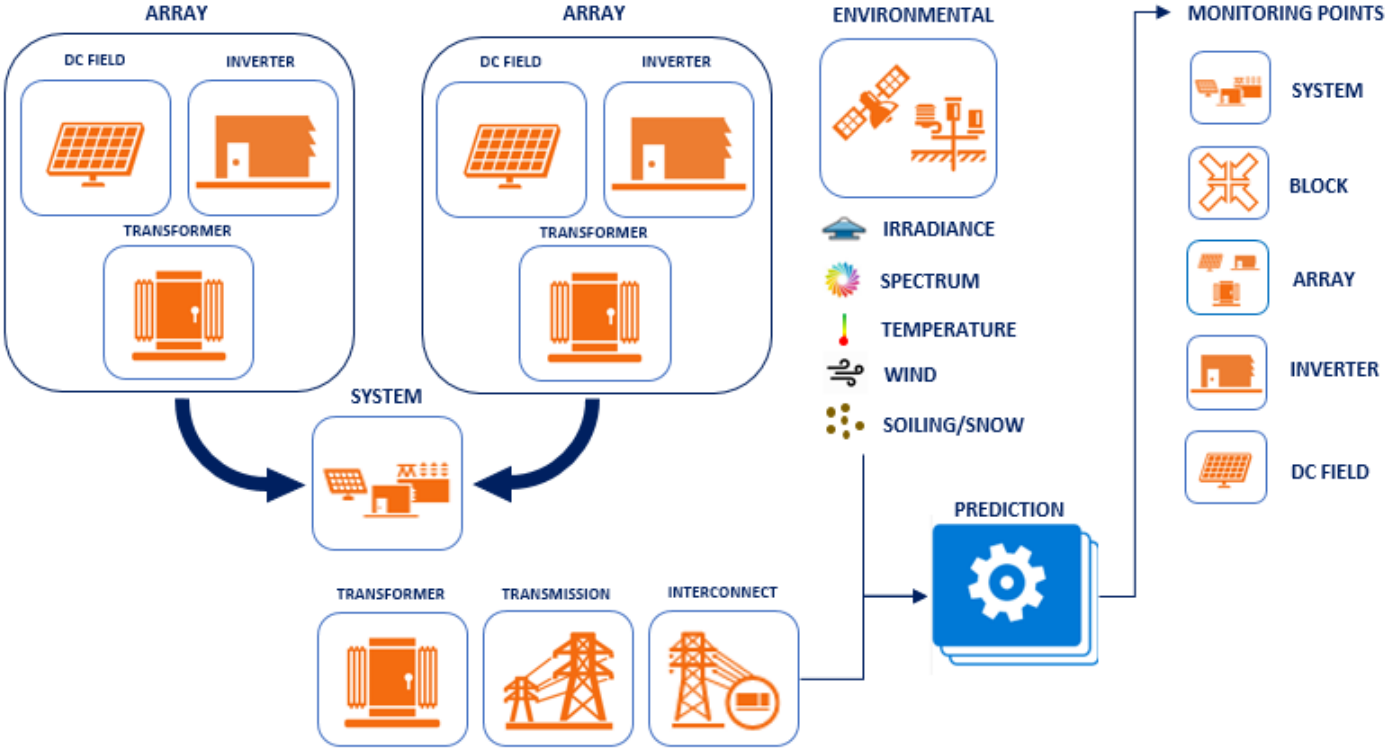
In summary, PlantPredict appears to be well-constructed for the use of simulations and energy production estimates of utility-scale PV plants, and appears to be able to provide a modeling accuracy equivalent to other commonly used industry software tools for utility-scale projects; in certain cases where spectral correction is required, the modeling accuracy of PlantPredict may surpass other tools.

PlantPredict Overview

PlantPredict simulates the electricity production from a photovoltaic power plant. This document outlines the PlantPredict's algorithmic capabilities. The formal software architecture, graphical user interface, and implementation details are not contained in this document.

At a top level, as illustrated in Figure 1, the input to PlantPredict consists of a time series of environmental inputs such as irradiance, temperature, and a static power plant using a nested hierarchy of subassemblies to create a representation of a photovoltaic power plant. A set of model choices, simulation settings, and controls allow the user to combine the weather and power plant model into an executed prediction.

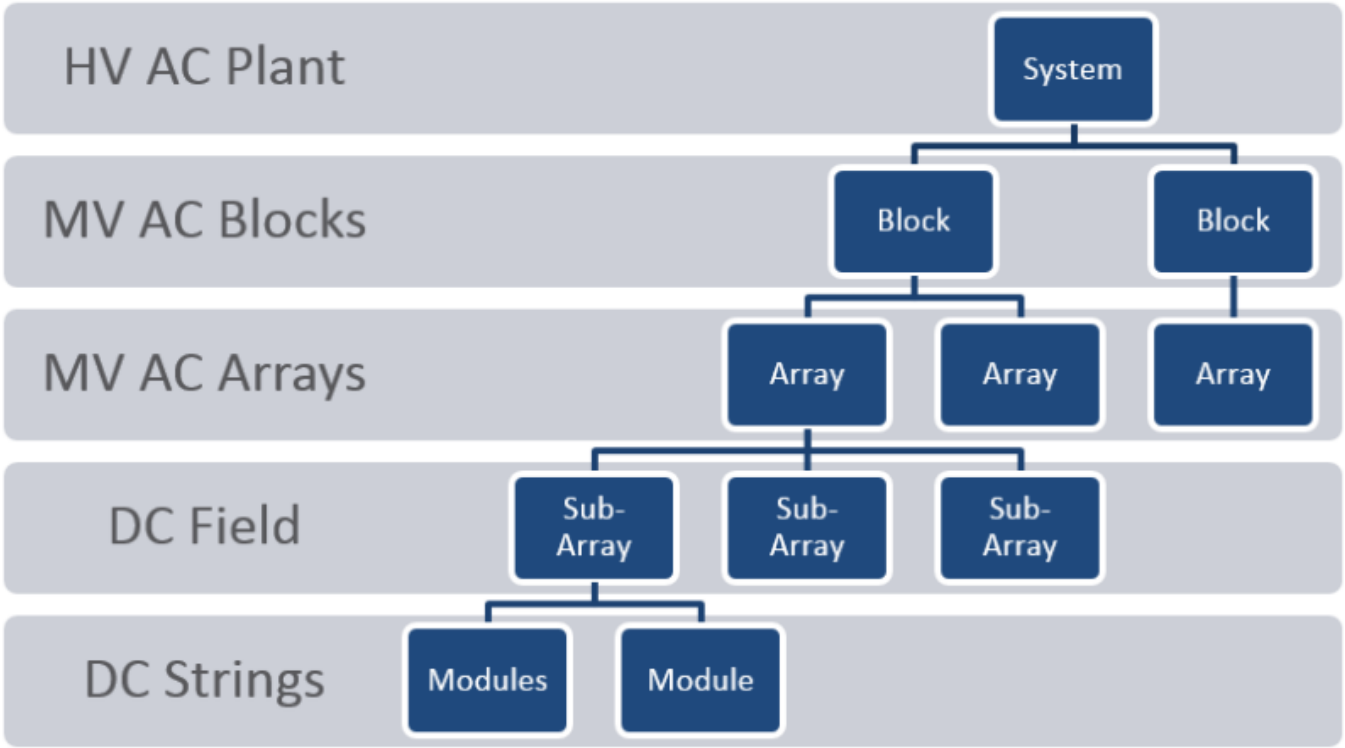
The output of the tool can be compared to the monitoring points in the actual power plant *(irradiance, array current & voltage, power meter)* to benchmark the tool performance against actual generation.



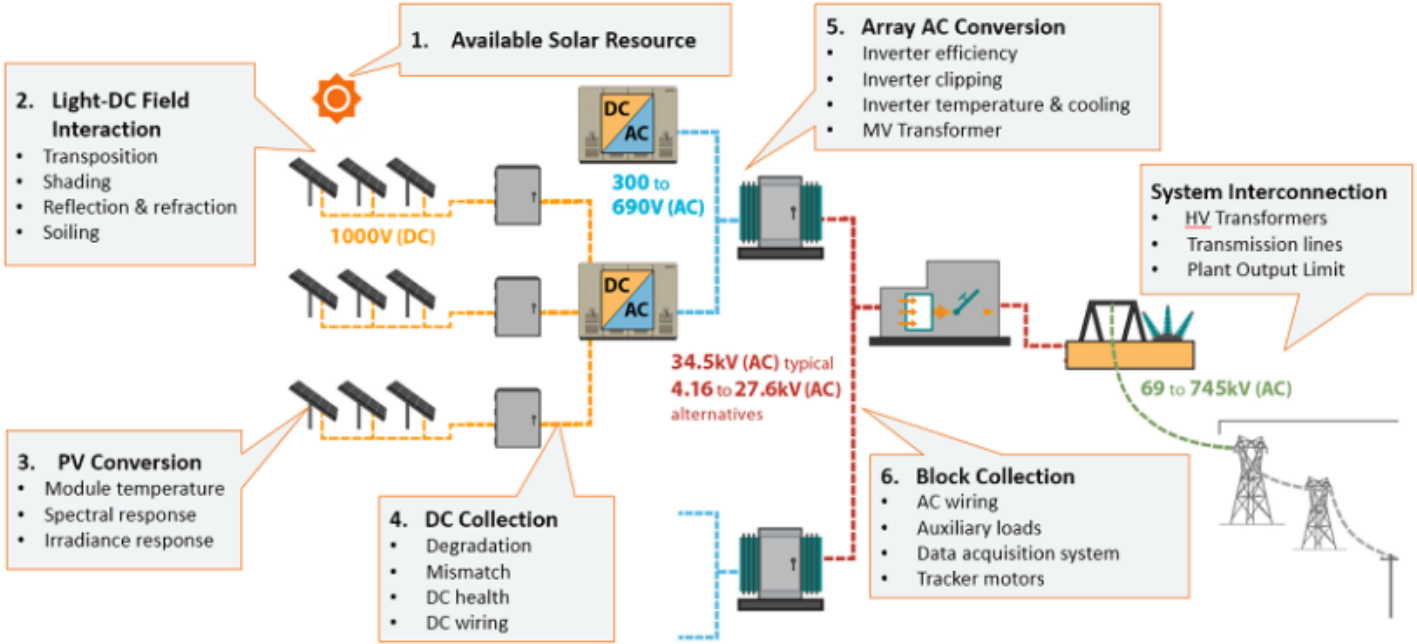
Power Plant Characteristics

From a modeling perspective, a solar power plant is comprised of the following hierarchy of building blocks, as shown in Figure 2. A set of photovoltaic modules is electrically connected in series to obtain the desired DC system voltage. The strings are then connected in parallel through a hierarchy of wire harnesses and combiners to achieve the desired current rating appropriate for the DC input to the inverters.

The parallel aggregation of harnesses into combiner boxes and DC inputs to the inverter terminal will be treated monolithically by the simulation engine; i.e. I(V) curves of the individual modules will be scaled in parallel and series to generate the “effective” I(V) curve seen by the inverter, with allowances made for module mismatch and DC health losses. Physically, the matrix of modules are arranged in tables and rows into DC Fields surrounding a Power Conversion Station housing one or more inverters, collectively referred to as an Array.



POWER PLANT ENERGY CONVERSION PROCESS



S6 FIELD TRIALS

INSTALLATION TRIALS – SERIES 6 & c-SI COMPARISON

INSTALLATION TRIALS

(26) S6 modules / pallet
Horizontal Orientation

(26) c-Si modules / pallet
Vertical Orientation

INSTALLATION TRIALS: INDEPENDENT LABOR STUDIES

STRUCTURAL INSTALL COMPARISON

		Sec/Mod	MH/Mod	$/Wdc
EXOSUN				
Series 6		22.6	0.038	0.0052
c-Si		24.8	0.041	0.0073
	Delta	-10%	-10%	-39%
ATI				
Series 6		31.0	0.034	0.0048
c-Si		30.4	0.034	0.0060
	Delta	2%	2%	-24%

INSTALLATION TRIALS: CONCLUSIONS

- Installation velocities are similar to c-Si
- Less man*hrs/watt (~20-30% *l*ess labor cost)
- Installation practices are the same
- Weight: *"Honestly I don't think there is too much of a difference because those 'c-Si' are a lot lighter, yes we throw more but when you are throwing fewer of the heavier ones , I guess it kind of balances out"*

S6 install on ATI Structure

c-Si install on Exosun Structure

INSTALLATION TRIALS: IE TIME STUDY (INSTALLATION STEPS SIMILAR TO c-SI)

1 Pick up from pallet

2 Walk module to structure

3 Lift onto structure

4 Position into bracket “T”

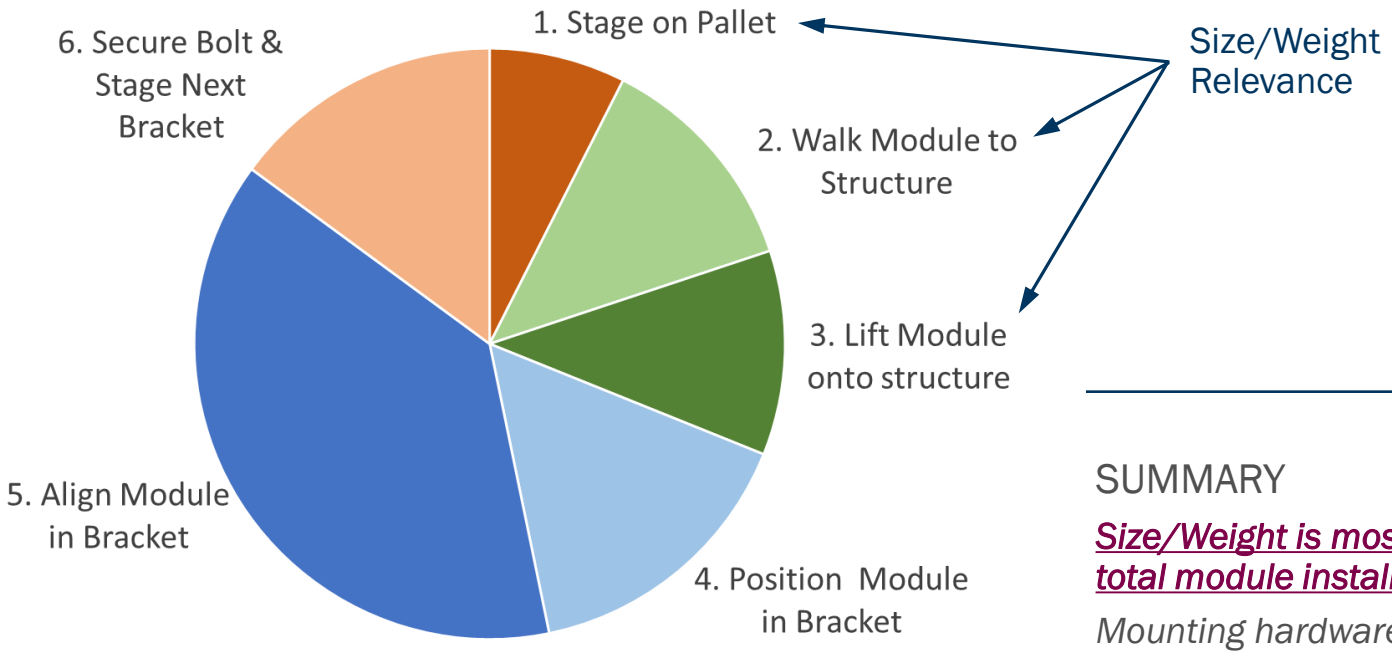
5 Align in the bracket “T”

6 Secure bracket bolt

INSTALLATION TRIALS: SERIES 6 ON ATI STRUCTURE (VIDEO)

INSTALLATION TRIALS: IE STUDY – TOTAL INSTALL TIME

S6 on ATI — 3 Man + Operator



SUMMARY

Size/Weight is most relevant in ~30% of total module install time.

Mounting hardware design and installation aids can improve install times

*Time in seconds, percentage of time spent on work element per module

UNCHARTED TERRITORY? NOT REALLY.

- The module will **retain its superior temperature coefficient and spectral response behavior**.
- In the factory, the >3x larger form factor **lowers the cost-per-watt**.
- In the field, the larger form factor **reverses any 'Balance of Systems Penalty'**, while **offering installation velocity gains**.
- Time to market backed by **supply chain that is well vetted and understood**.
- Transfer of S5 **ecosystem knowledge** to S6 product.


First Solar®