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Solar Performance Modeling Essentials

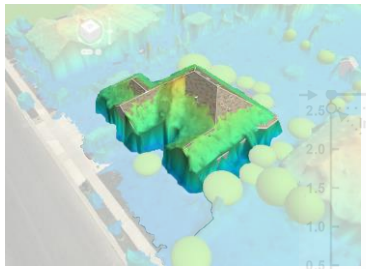
A Note on the Aurora Acquisition

- When the webinar was announced, we were Folsom Labs. Folsom Labs is now part of Aurora Solar.
- No changes to HelioScope (or Aurora for that matter) planned in the near term
- Longer-term, there will almost certainly be changes, but all with the goal of a better customer/user experience

Bankability is a Common Thread Between Aurora and HelioScope

Accuracy is one thing that brought Aurora and Folsom Labs together

- “Bankability” can mean something different depending on the product & market segment
  - LIDAR, ray-tracing
  - Detailed module physics
  - Doesn’t necessarily mean conservative, but does mean accurate

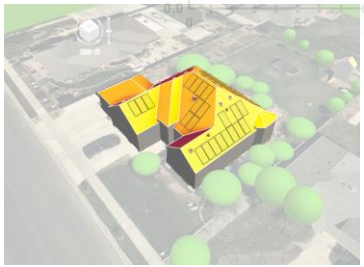


$$I = I_{ph} - I_0\left(e^{\frac{q}{kT}\cdot\frac{1}{\gamma N_{CS}}(V+IR_s)} - 1\right) - \frac{V+IR_s}{R_{sh}}$$

$$I_{PH}(G,T_C) = \left(\frac{G}{G_{ref}}\right)\cdot\left(I_{PHref} + \mu_{Isc}(T_C - T_{Cref})\right)$$

$$I_0(T_C) = I_{0ref}\left(\frac{T_C}{T_{Cref}}\right)^3 \cdot e^{\left(\left(\frac{q\cdot E_{gap}}{\gamma\cdot k}\right)\left(\frac{1}{T_{Cref}} - \frac{1}{T_C}\right)\right)}$$

$$R_{SH}(G) = R_{SH}(G_{ref}) + \left(R_{SH}(0) - R_{SH}(G_{ref})\right)\cdot e^{\left(-\beta\frac{G}{G_{ref}}\right)}$$



Solar Performance Modeling for Non-Physicists

Questions you might be asking yourself:

- Are we **leaving money on the table** with our proposals?
- Should we be **more aggressive or more conservative** in our estimates? How would we even figure that out?
- Are we **losing deals** because our competitors are being more aggressive? What can I do about that?

Today's Webinar Goals / Agenda

What are the things that can move the needle on your next proposal?

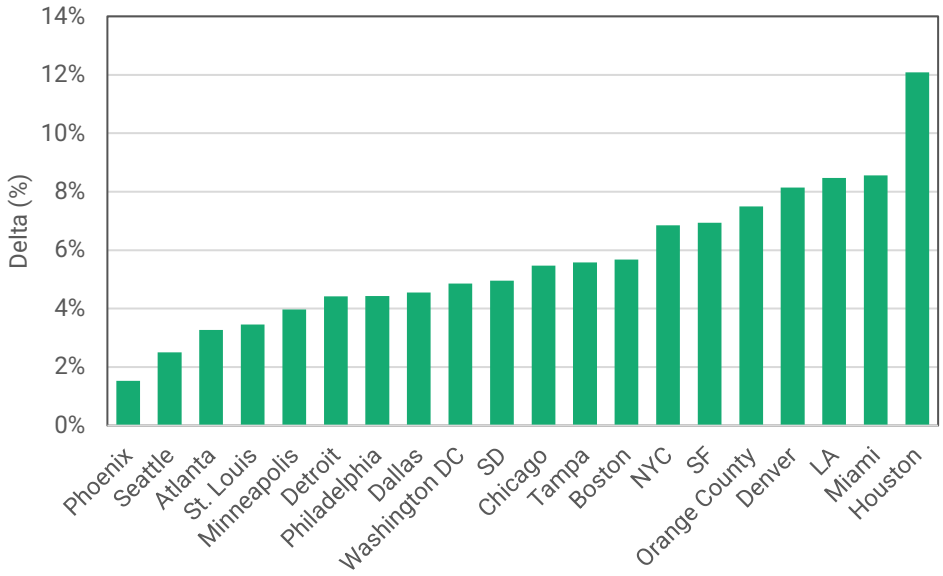
1. Choose your weather file carefully
2. Make sure shading is calculated, not estimated
3. Don't just ballpark mismatch
4. Watch out for undervoltage clipping
5. Know how to sell premium modules

Bonus: How can you knock down an overly aggressive competitive bid?

Choose Your Weather File Carefully

The Difference Between a Conservative and Aggressive Weather File Can Be 6-12%

Difference Between Conservative and Aggressive Weather Files

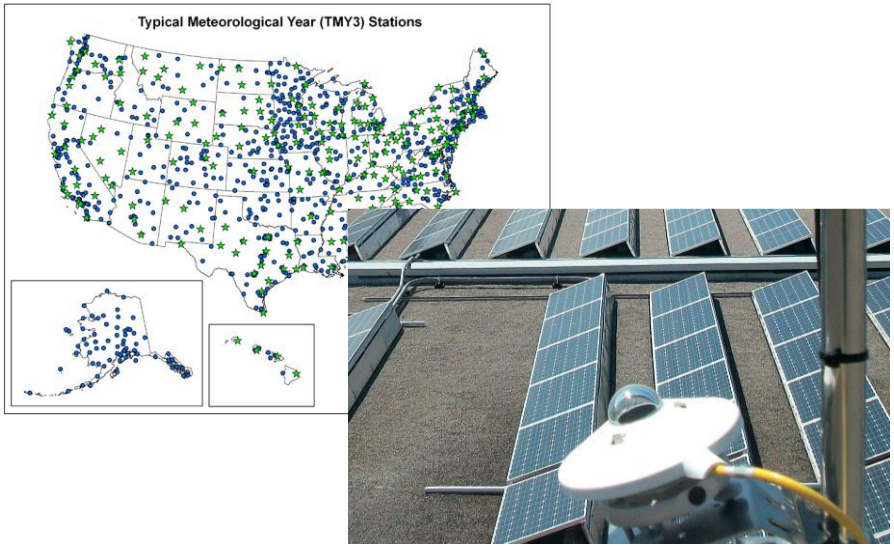


Source: Team analysis; based on TMY3, Prospector, and NREL PSM weather files in the top 20 US Metro Areas.

There Are Two Main Types of Weather Files

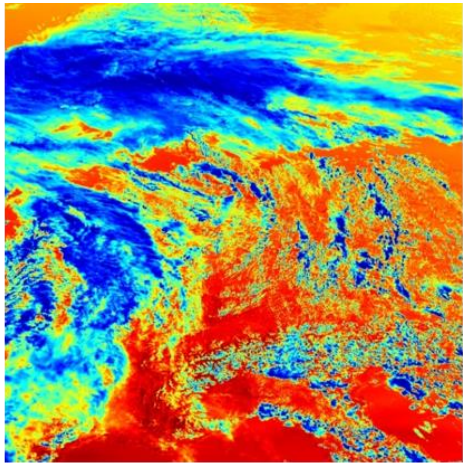
Ground-Based Weather Files

Examples: TMY2, TMY3, EPW



Satellite-Based Weather Files

Examples: NREL PSM, Prospector, Meteonorm

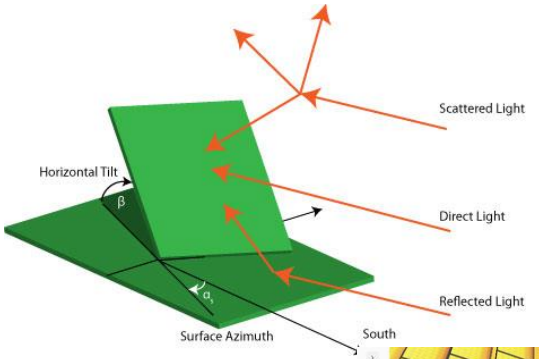


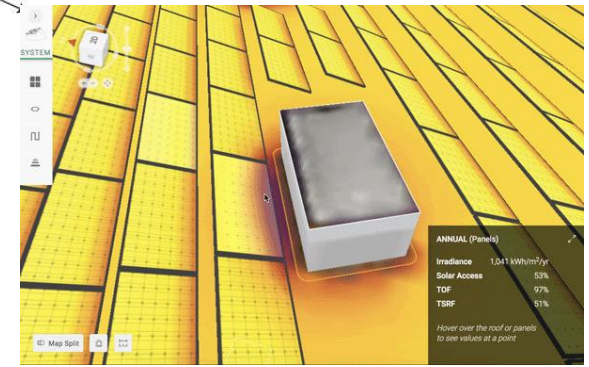
Make Sure Shade Losses are Calculated

Shade Calculations Are Significantly More Accurate Than Auto-Generated Shade Projections

Calculated Shade Includes:

- Effect for both direct & diffuse sunlight
- Full 3D modeling of a scene, including:
  - Things missed by Google 3D
  - Changes in environment (trees growing, trees removed)
- Circuit effects
- Horizon effects

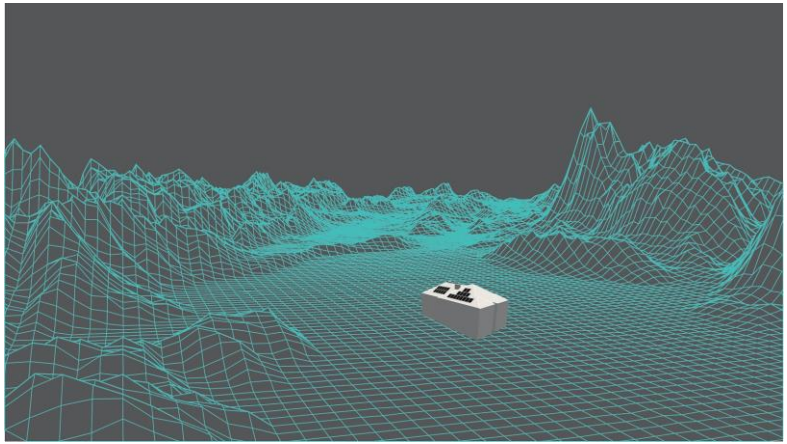




Horizon Is a Powerful Way to Enhance Shading Analysis

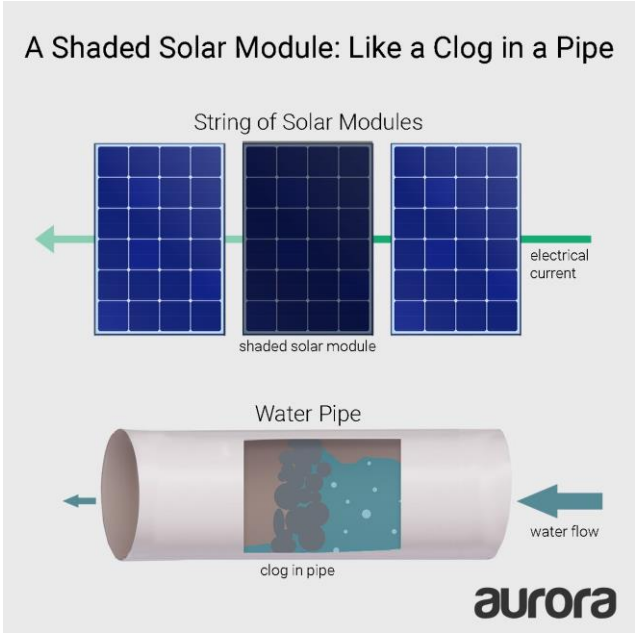
Complementary Horizon Capabilities

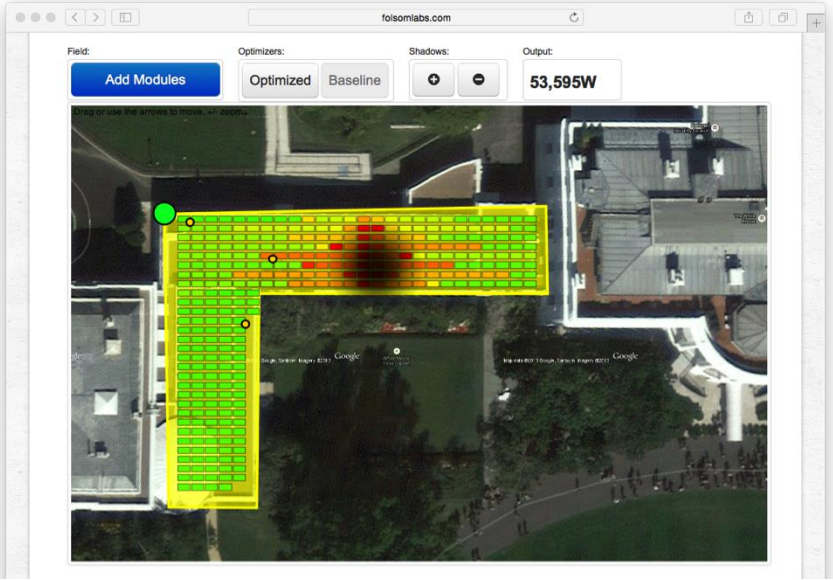
- Aurora: automatic 3D Horizon Projections based on full 3D scene
- HelioScope: uploaded Horizon file based on on-site readings



Don’t Just Ballpark Mismatch

Many Know the Clogged Pipe Analogy, Though the Real World Is Complicated





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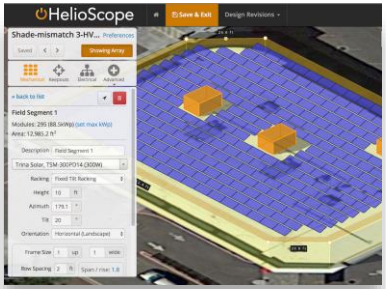
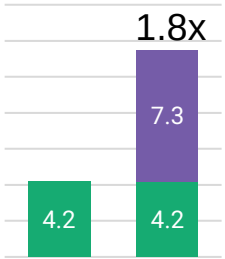
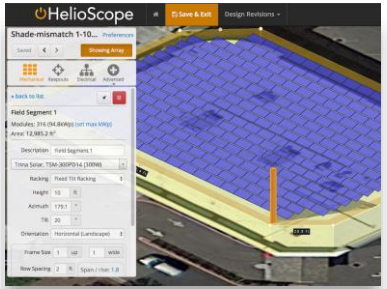
Shade and Mismatch Do Not Always… Match

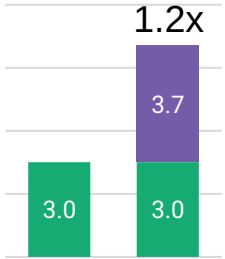
HVAC



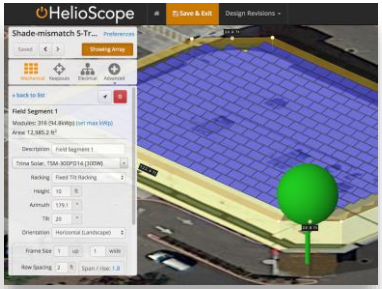


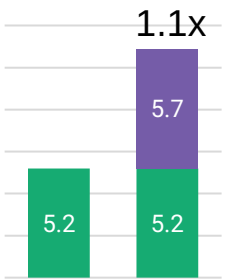
Flagpole



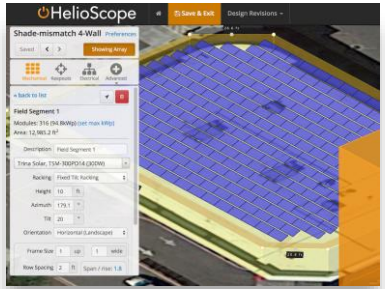


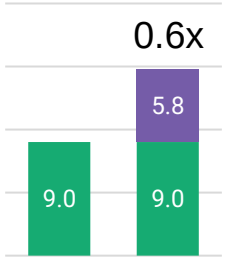
Tree





Wall/Building





Source: Team analysis

Temperature Losses: Larger Than You Think

Just Because PV Watts Doesn't Show Temperature Loss Doesn't Mean That It Isn't There

Temperature Losses Over 10% Are Common

- Depends on location, mounting type, and module
- All math is fairly similar (even non-simulation software). Only difference is reporting.
- Modules with better temperature coefficients can have a material impact on the system energy yield
    - If competitor is using a non-simulation tool, then a good chance they don't realize how much temperature is hurting them

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	2,114.1	
	POA Irradiance	2,362.3	11.7%
	Shaded Irradiance	2,361.8	0.0%
	Irradiance after Reflection	2,293.9	-2.9%
	Irradiance after Soiling	2,248.1	-2.0%
	Total Collector Irradiance	**2,248.1**	**0.0%**
Energy (kWh)	Nameplate	5,483.7	
	Output at Irradiance Levels	5,506.9	0.4%
	Output at Cell Temperature Derate	4,545.7	-17.5%
	Output After Mismatch	4,543.3	-0.1%
	Optimal DC Output	4,543.3	0.0%
	Constrained DC Output	4,541.4	0.0%
	Inverter Output	4,372.4	-3.6%
	Energy to Grid	**4,336.5**	**-0.8%**
Temperature Metrics			
	Avg. Operating Ambient Temp		24.4 °C
	Avg. Operating Cell Temp		49.6 °C

Watch Out for Undervoltage Clipping

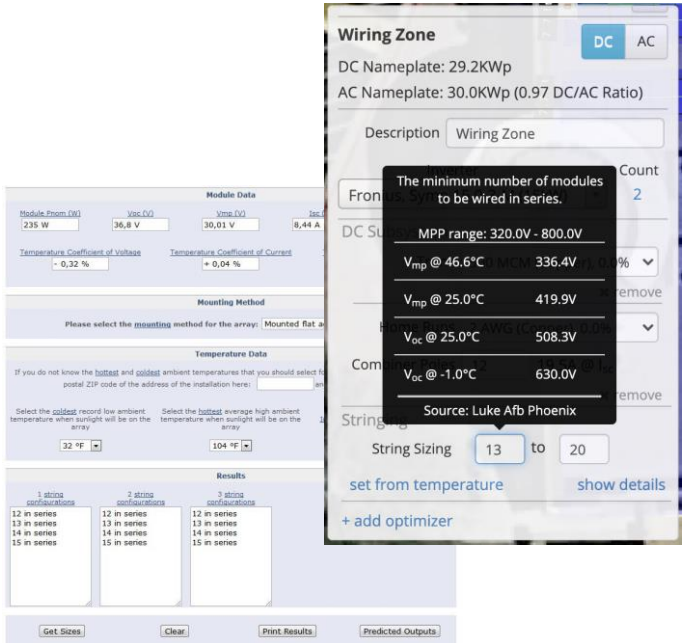
Just Because Things Look Good at Rated Specs Doesn't Mean They Will Perform

The Misconception

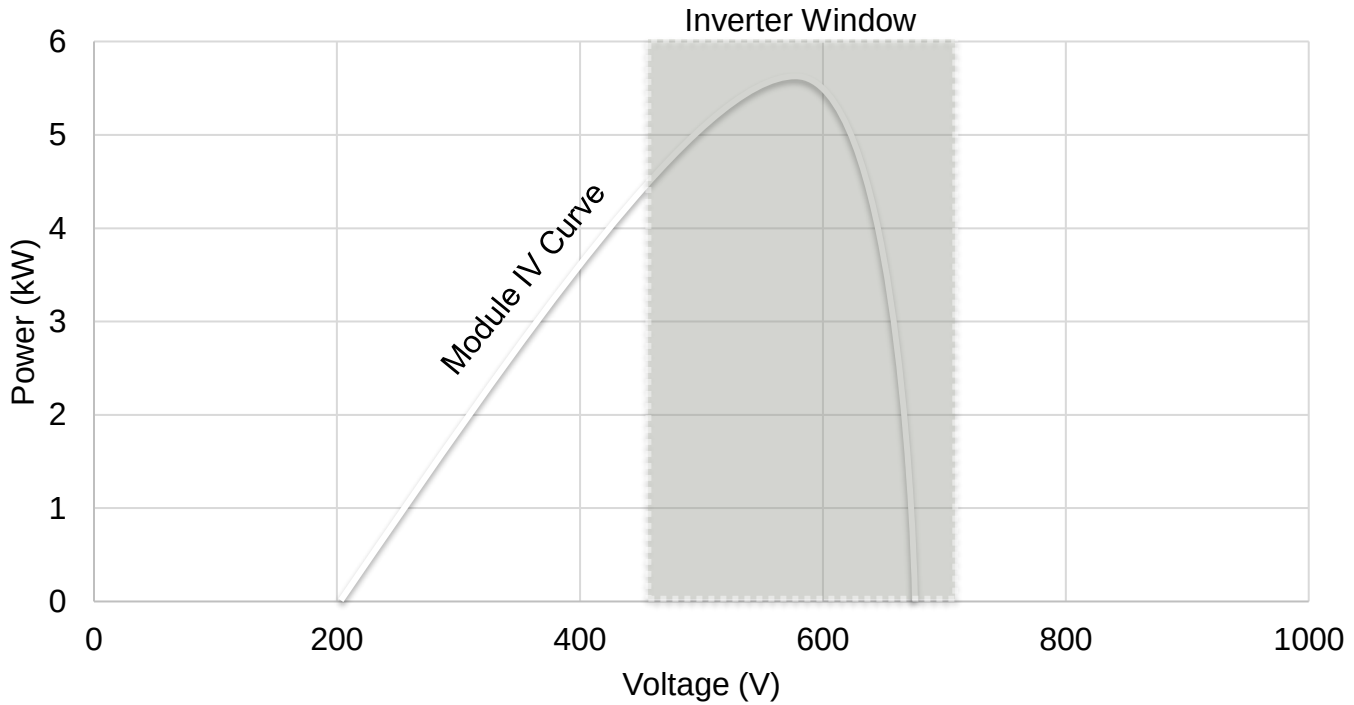
- As long as string is within inverter's voltage range then we're good

The Reality

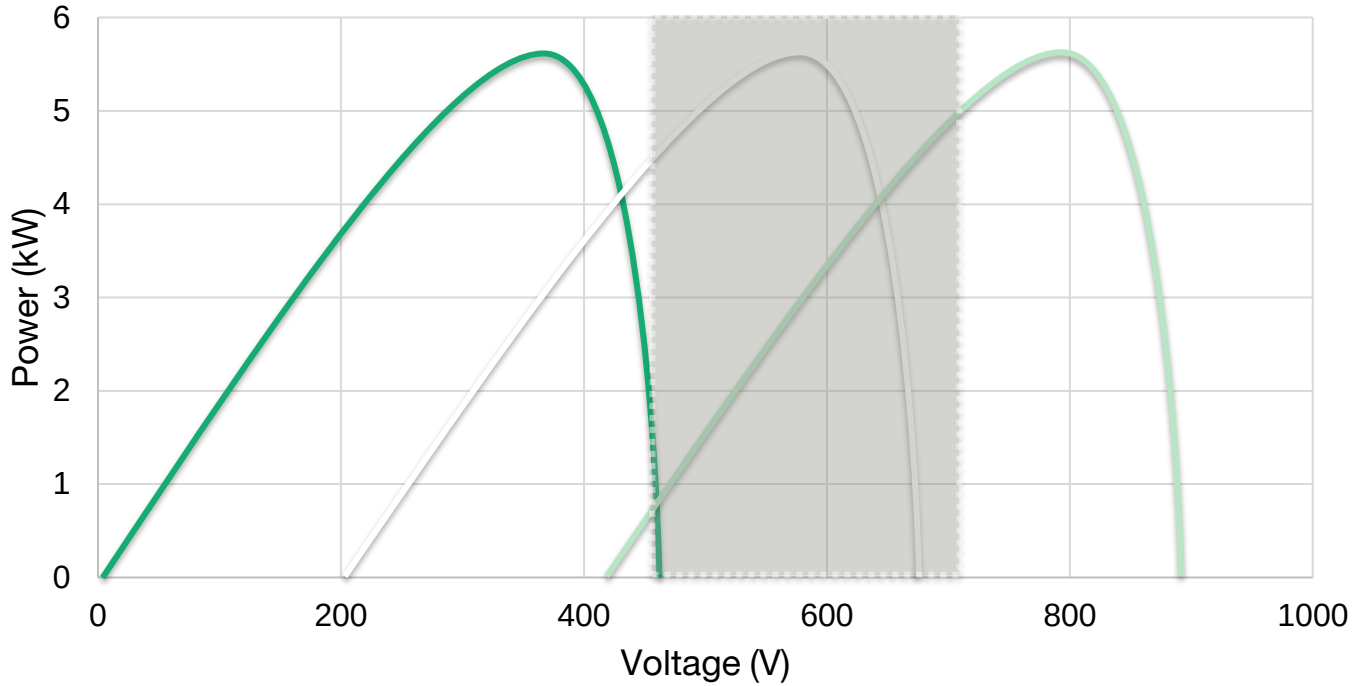
- High-temperature (low-voltage) behavior can be more extreme than the standard calculations, since heat builds. This is not a safety issue.
- Under-voltage clipping hurts way more than power or over-voltage



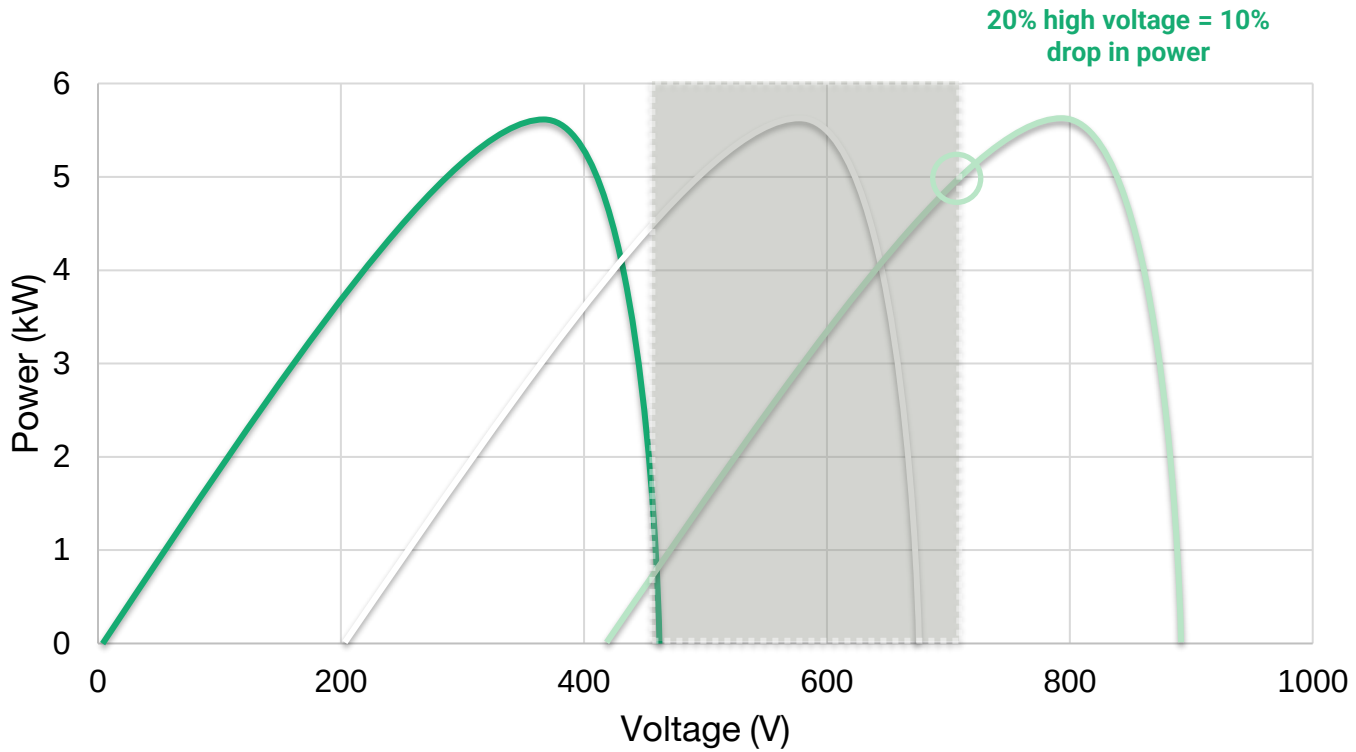
Designers Will Ensure the String Voltage Is Within the Inverter's Range



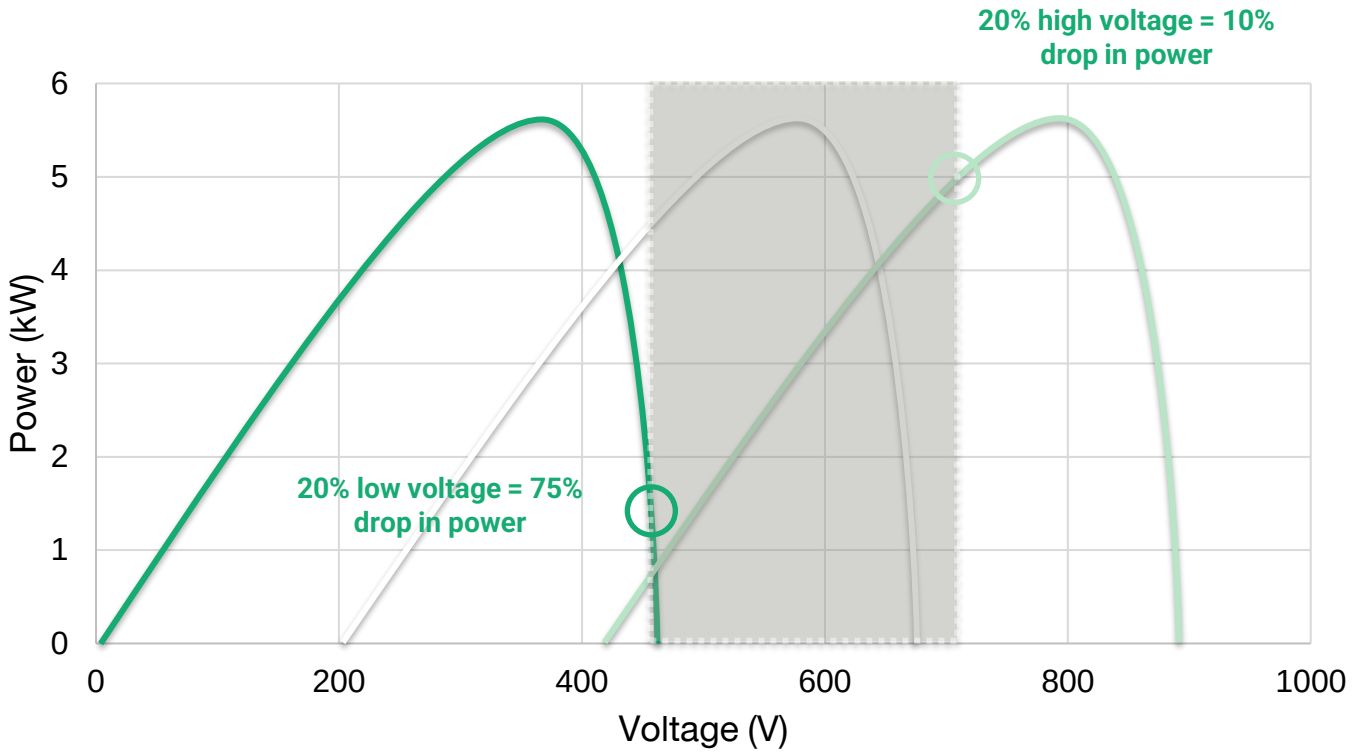
However, the String Voltage Will Rise & Fall with Temperature Changes



…With High Voltage, the String Can be Pulled Off Its Max Power Point



…But the Same Low-Voltage Gap Results in Significantly Greater Clipping Loss



When Selling Premium Modules: How Much of a Boost is Fair?

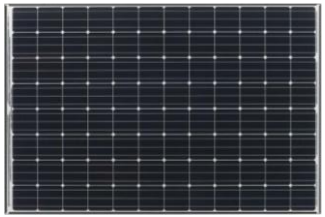
What Does a High Efficiency or Premium Module Get You?

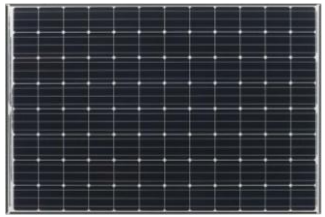
Power Density
More solar capacity (in watts) per unit of area

Reliability
Long-term performance with fewer defects

Bankability
OEM able to back product over 25 years

A Tale of Two Modules: High Efficiency Buys More Watts, Not More kWh/kWp

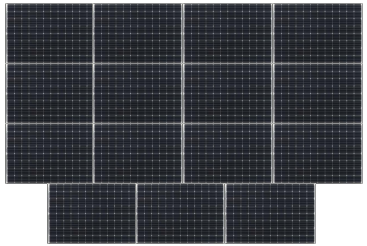




	Standard Efficiency (16%)	High Efficiency (20%)
Power	320W	400W
Annual Energy (controlling for location, system efficiency)	480kW	600kW
kWh/kWp	1,500	1,500

A standard-efficiency 5kW array will produce as much energy as a high-efficiency 5kW array

A Tale of Two Systems: High Efficiency Buys More Watts, Not More kWh/kWp



	Standard Efficiency (16%)	High Efficiency (20%)
Power	4.8kW	4.8kW
Module Quantity	15	12
Annual Energy	7,200 kWh	7,200 kWh

A standard-efficiency 5kW array will produce as much energy as a high-efficiency 5kW array

However, PV Watts Contributes to Confusion Here

GET STARTED
SOLAR RESOURCE DATA
SYSTEM INFO
- System Size (DC kW)
- Module Type
- Array Type
- System Losses
- System Losses Categories
- Tilt
- Azimuth
- DC to AC Size Ratio
- Inverter Efficiency
- Ground Coverage Ratio
- Draw Your System

RESULTS
TECHNICAL REFERENCE
FOR DEVELOPERS
ABOUT
LEGAL DISCLAIMER
FEEDBACK

Module Type

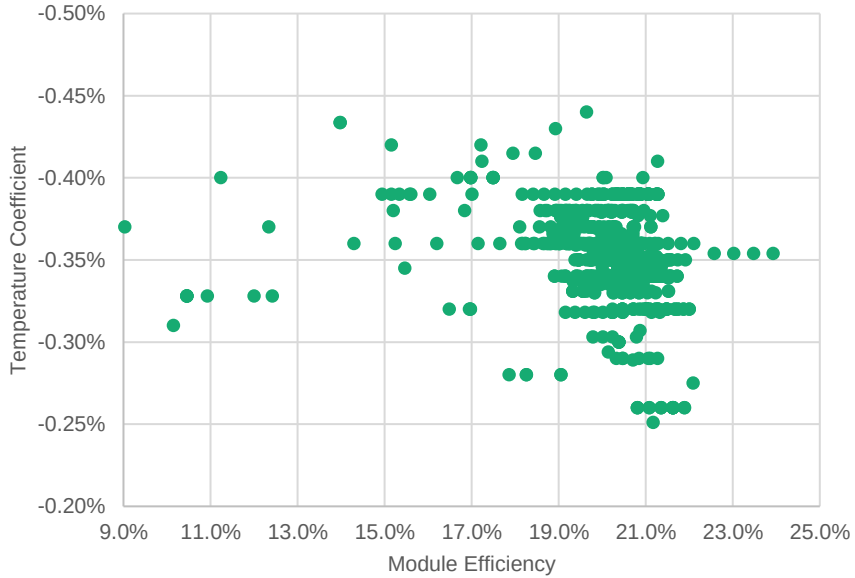
The module type describes the photovoltaic modules in the array. If you do not have information about the modules in the system, use the default Standard module type. Otherwise, you can use information from the module data sheet and the table below to choose the module type.

Module Type Options

PVWatts® Module Type	Cell Material	Approximate Nominal Efficiency	Module Cover	Temperature Coefficient of Power
Standard	Crystalline Silicon	15%	Glass	-0.47 %/°C
Premium	Crystalline Silicon	19%	Glass with anti-reflective coating	-0.35 %/°C
Thin Film	Thin film	10%	Glass	-0.20 %/°C

See the Technical Reference for details about how PVWatts® models the different module types.

High-efficiency modules do not necessarily have better temperature coefficients



Source: HelioScope database, based on most recent 1,000 modules added to database.

Today’s Agenda: Recap

What are the things that can move the needle on your next proposal?

1. Choose your weather file carefully
2. Make sure shading is calculated, not estimated
3. Don’t just ballpark mismatch
4. Watch out for undervoltage clipping
5. Know how to sell premium modules

Bonus: How can you knock down an overly aggressive competitive bid?

How To Knock Down a Competitive Bid

These Same Concepts Give You Some Ammo for a Competitive Bid Conversation

Questions to Ask:

- What weather file are they using?
- Are they projecting a boost from premium modules?
- Is there shading?
- (In a hot environment): Have they confirmed that the system will not suffer from clipping at the hottest temperatures?

Want to Go Deeper?

If you still have these questions:

1. How can I go deeper on the concepts discussed here?
2. Is Aurora or HelioScope right for my needs?

Then follow these links:

1. Search our help centers (both HelioScope and Aurora), or ask our support teams.
2. Sign up for a demo here.

https://www.aurorasolar.com/

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Thank You!

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