
Solar Site Evaluation Tips and Techniques

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Shade Measurement Topics

- Site analysis considerations
 - Why measure shade?
 - Terminology
 - Shade measurement strategies
- Using the SunEye
 - Live demo
 - Common problems and solutions
 - State rebate requirements
- Resources, Questions and Answers



Solmetric Corporation

- Founded in 2005
- 20 employees
- Headquarters in Sebastopol, CA
- Mission: to improve the effectiveness of solar systems and those who install them by providing high quality, easy-to-use, accurate tools with embedded technical know-how.



Why measure shade?

- Choose optimum location for panels
- Identify issues early in the process
- Ensure sufficient energy production
- Ensure optimum state rebate



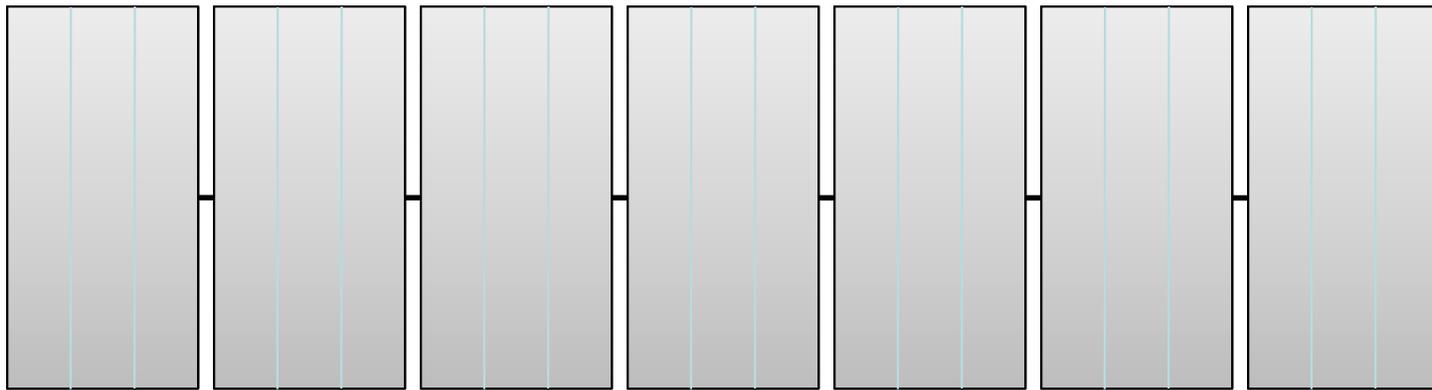
Note: Shading can have disproportionate impact on energy production

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PV String Simulation Model

Sun position, panel tilt/Azimuth

Irradiance, shade, temperature, wind speed



Module bypass diode configuration

Module parameters

Inverter parameters

String wiring

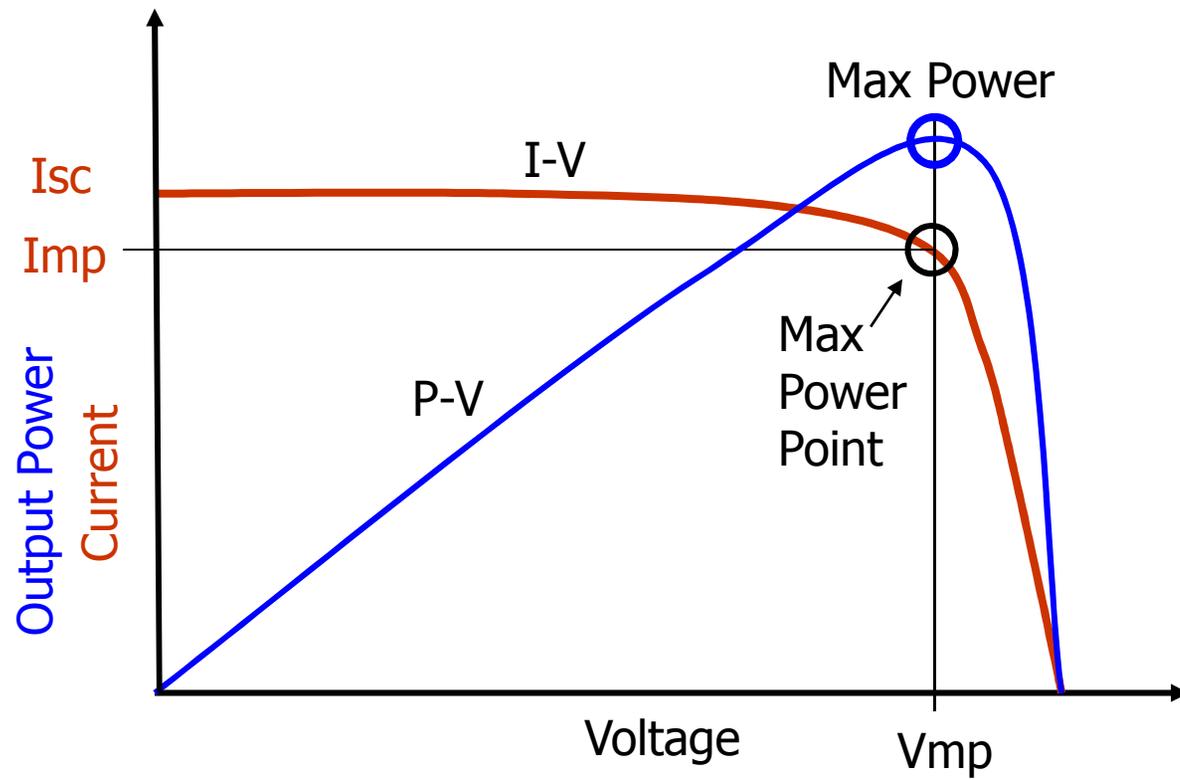


AC KWh



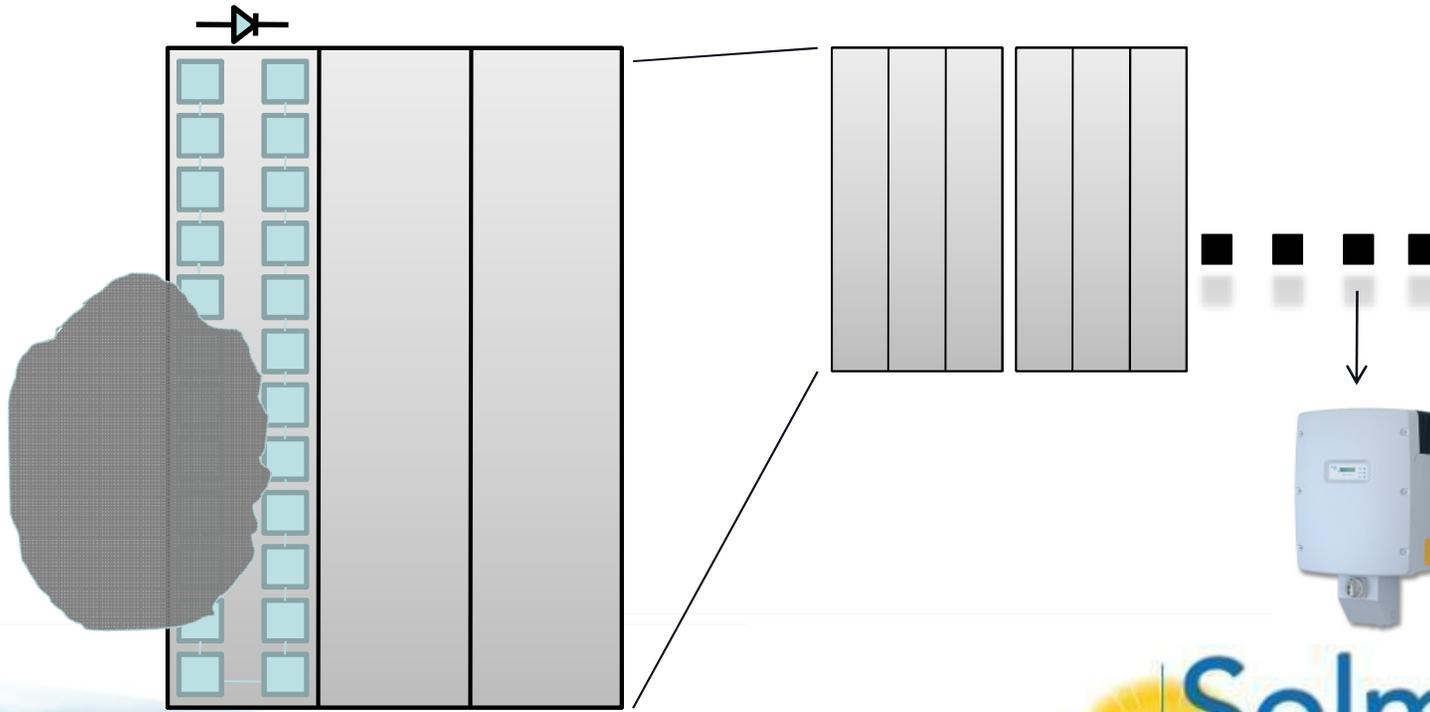
What's Happening Electrically?

I-V and P-V curves



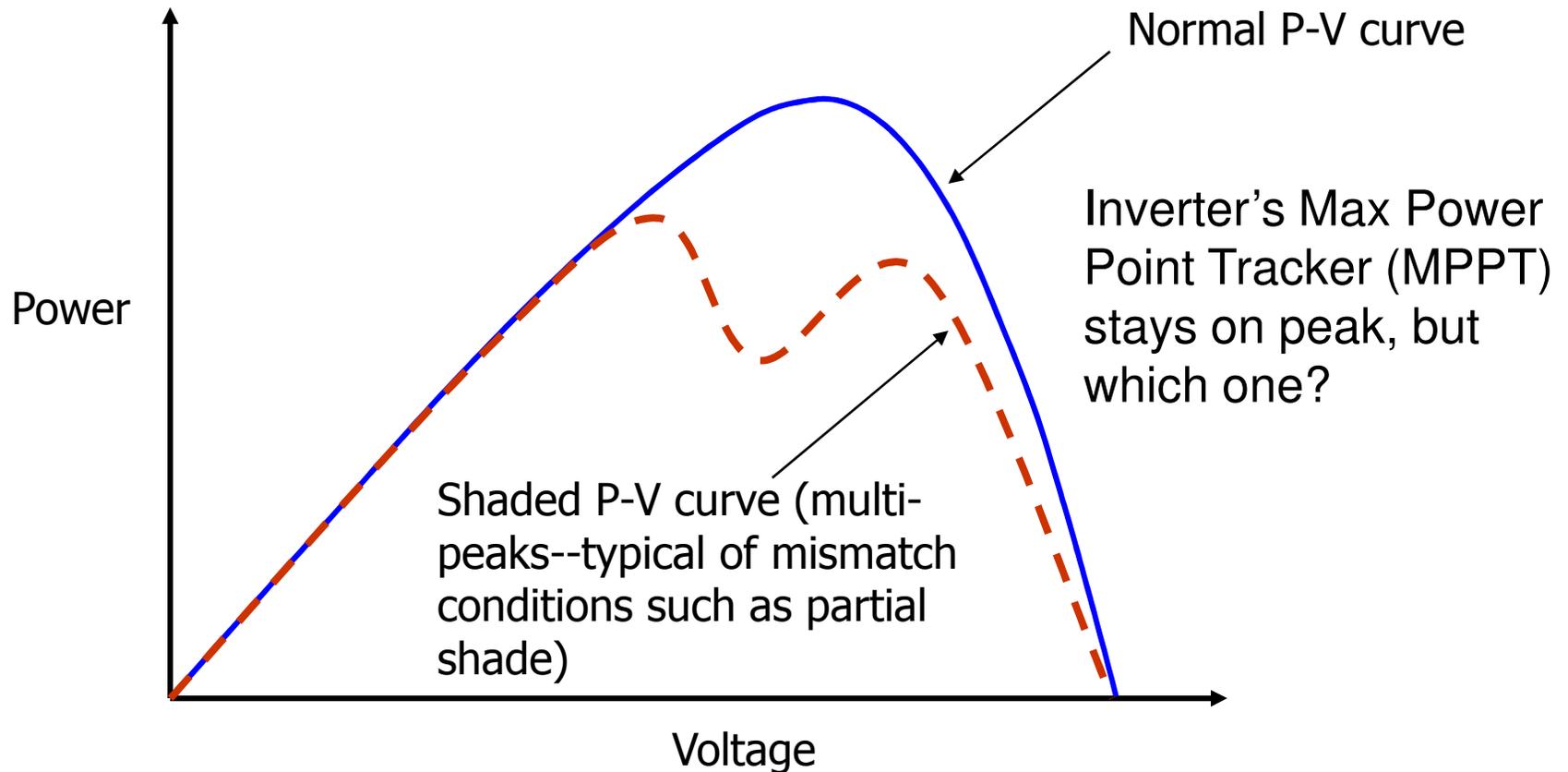
Shade, String Current, and Bypass Diodes

- Partial shading reduces current flow in module **and string**
- Typical module has 24 cells in 3 sub-strings each with a bypass diode
- When bypass diode activated, string current restored, but voltage drops

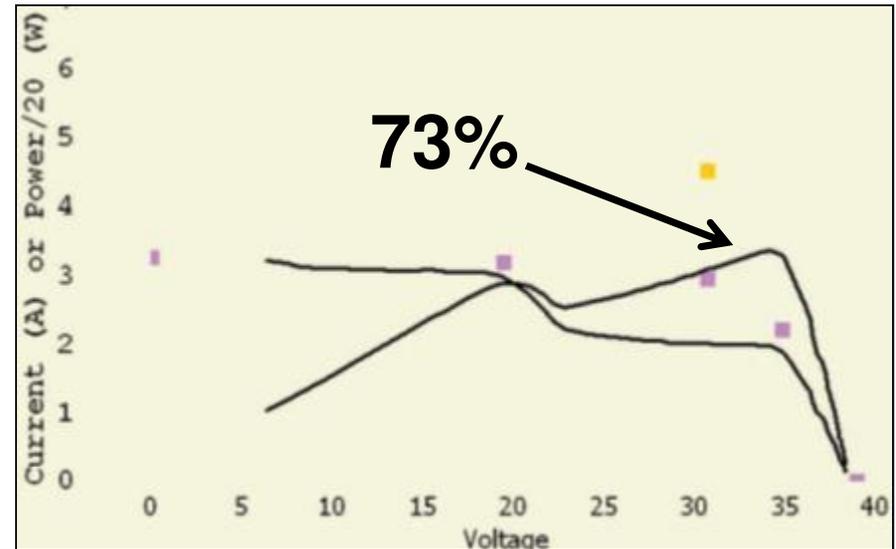
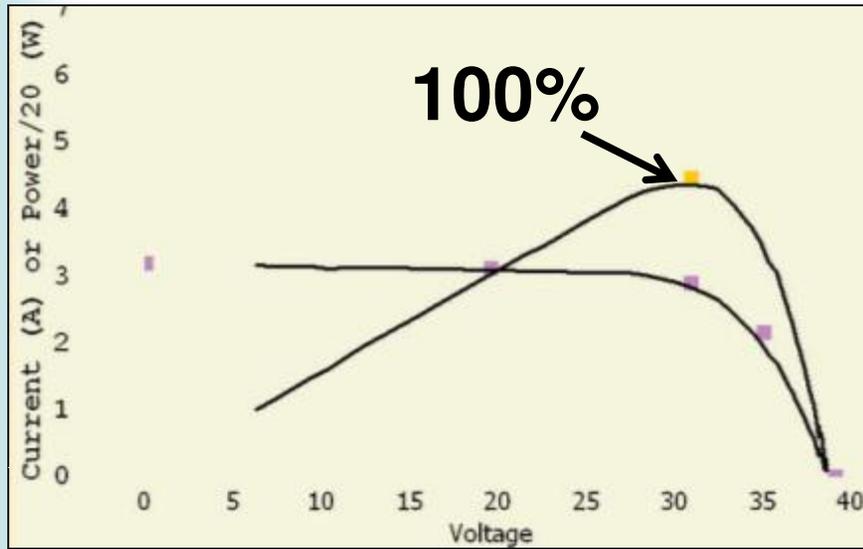


Multiple Peaks Challenging for the Inverter

Impact of Shading on the P-V Curve



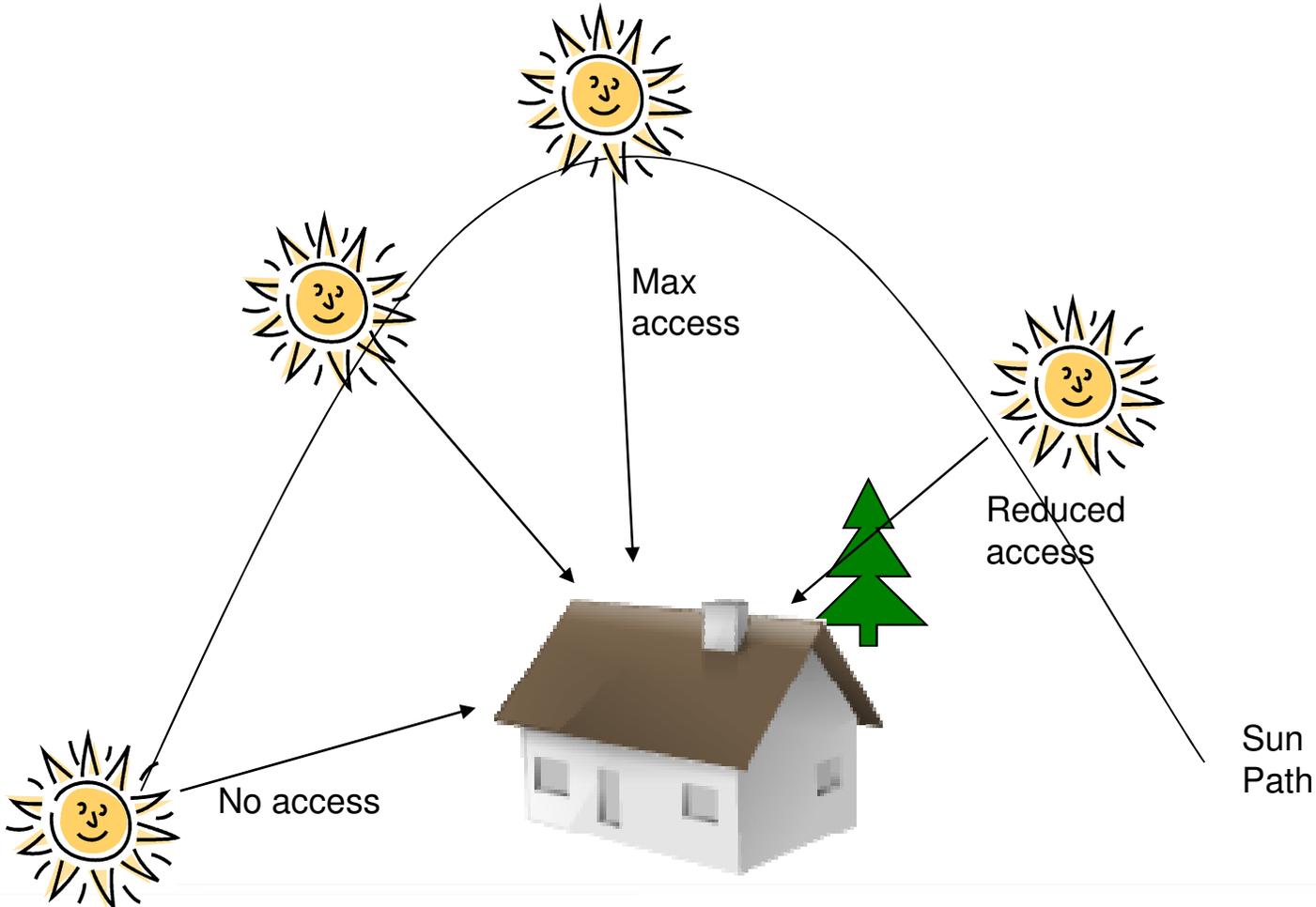
Shading: a little bit goes a long way



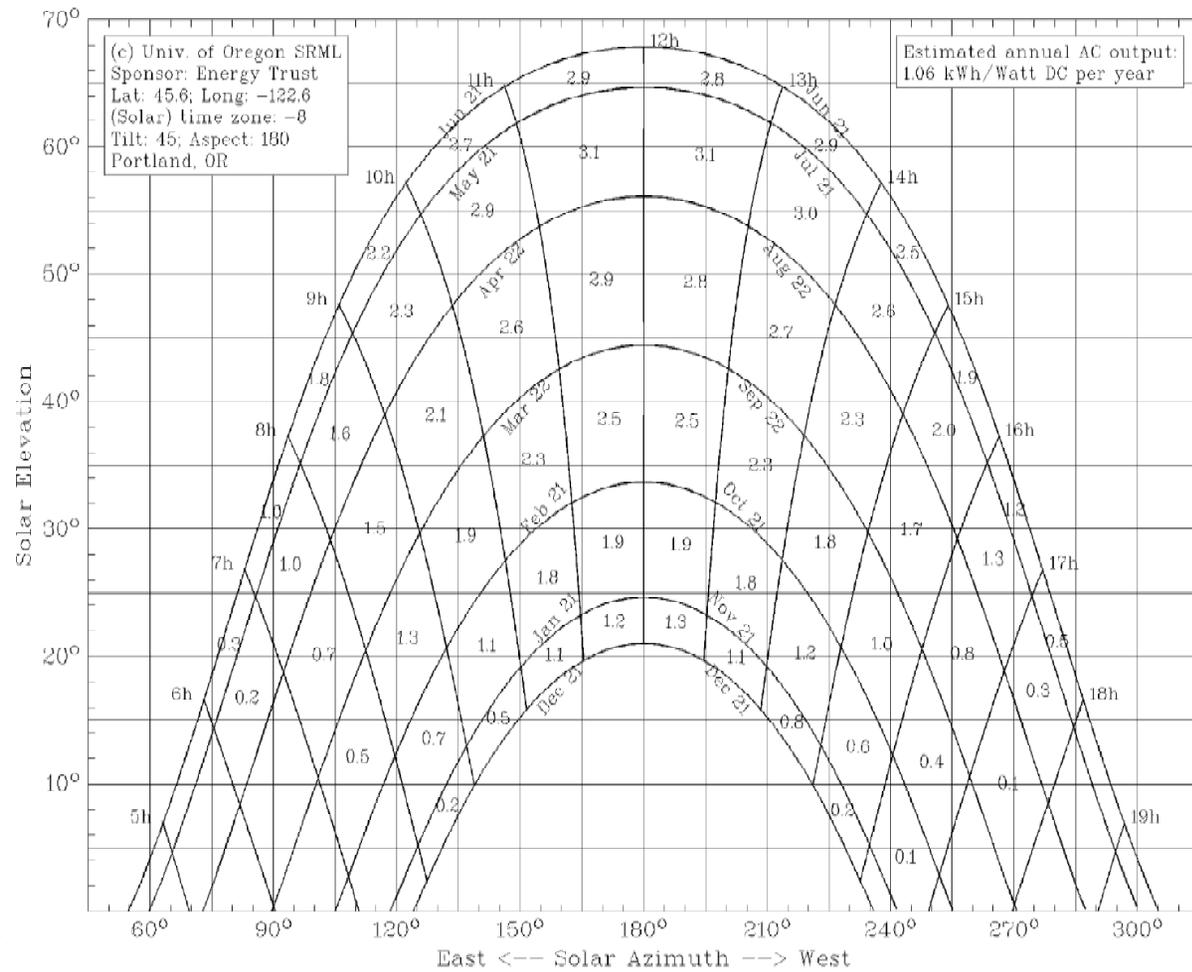
Business Card covering half of one cell



Sun path interaction



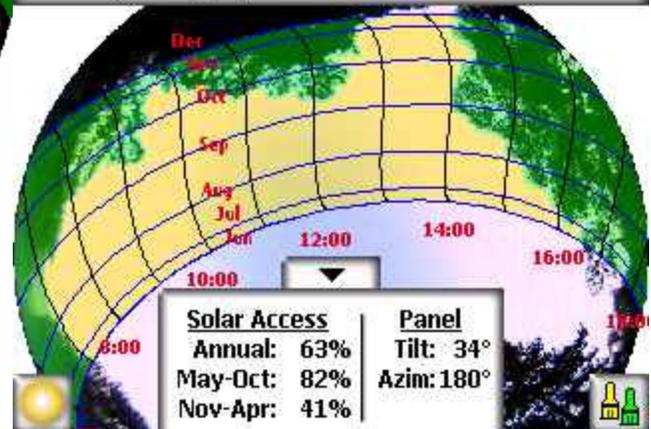
Annual sun path example



Hemisphere view (Skyline)

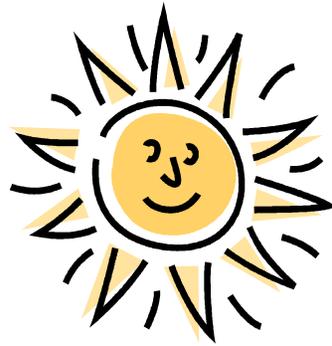


Sky05 -- 10/29/07 17:59 -- Southeast corner of roof



Irradiance

Incident solar radiation (power) per unit area in kW/m^2



Approximately $1 \text{ kW}/\text{m}^2$ at the earth's surface.

Insolation – Solar Energy over Time per unit Area in kWh/m²



1 kW/m² of irradiance for 6 hours
= 1 kW/m² x 6 hr = 6 kWh/m² of insolation.

6 kWh/m² of insolation on a 2 sq-m surface
= 6 kWh/m² * 2 m² = 12 kWh of energy received by the surface.



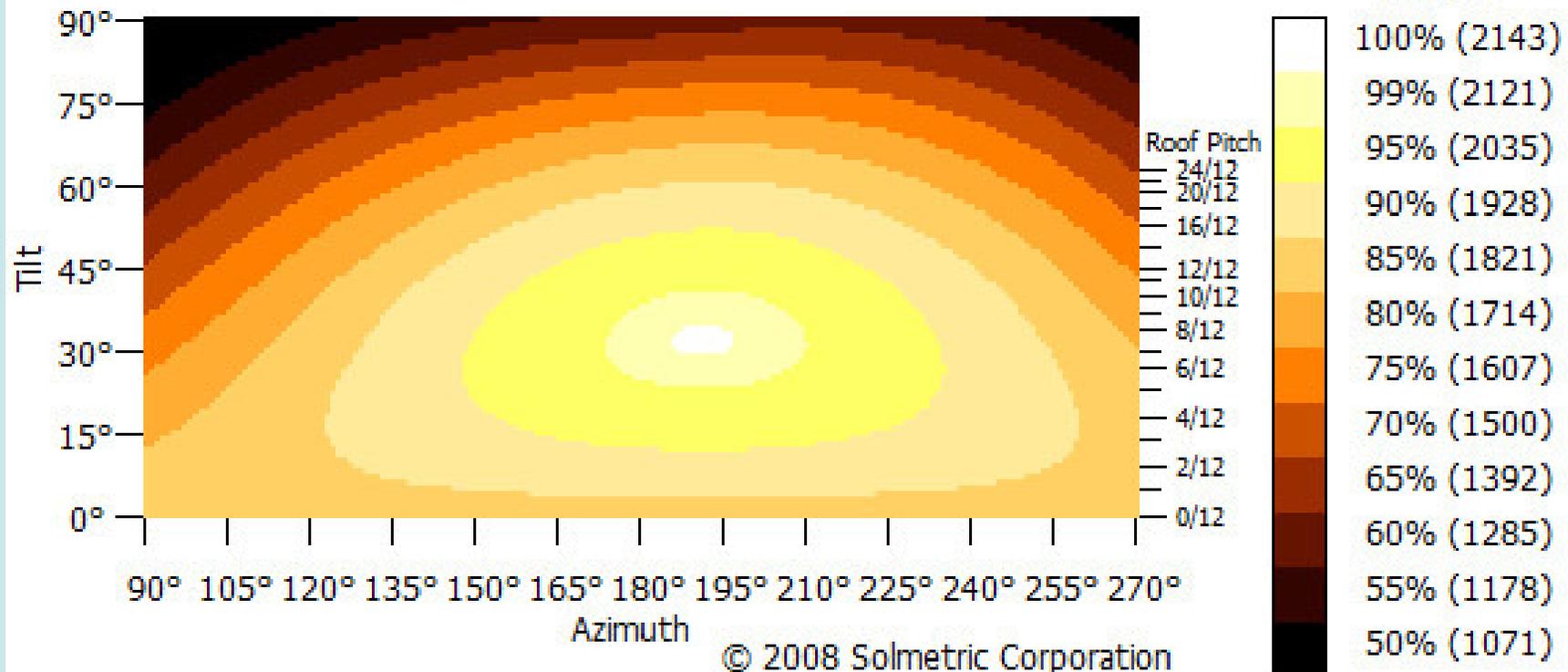
San Diego insolation



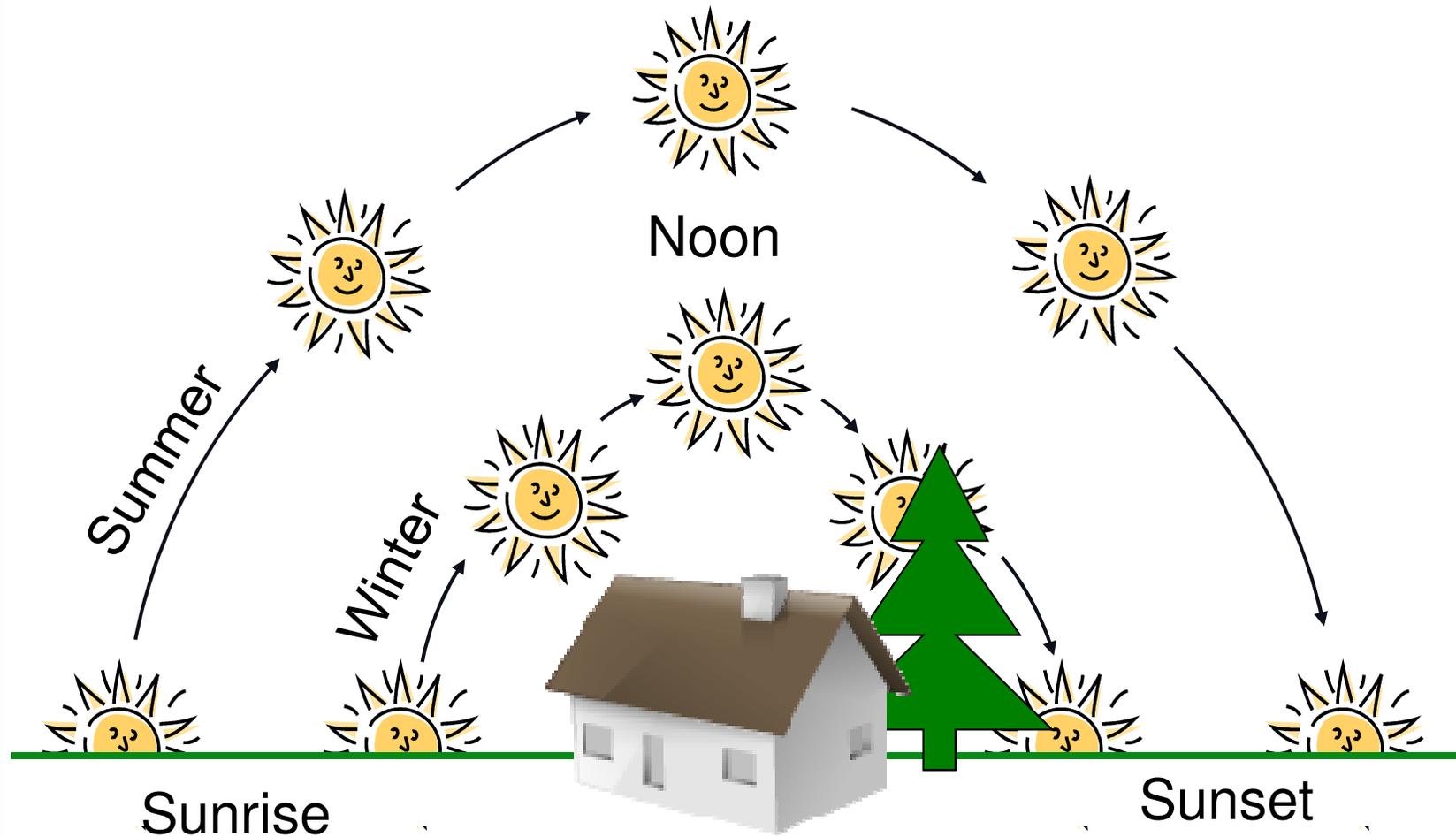
Annual Insolation as a Function of Panel Orientation

Location: SAN DIEGO LINDBERGH FI, CA Optimal Tilt=32°, Azimuth=191°, Insolation=2143 kWh/m²

Station ID: 722900, Latitude: N 32.73, Longitude: W 117.17



Sun Trajectories ("Sunpaths")

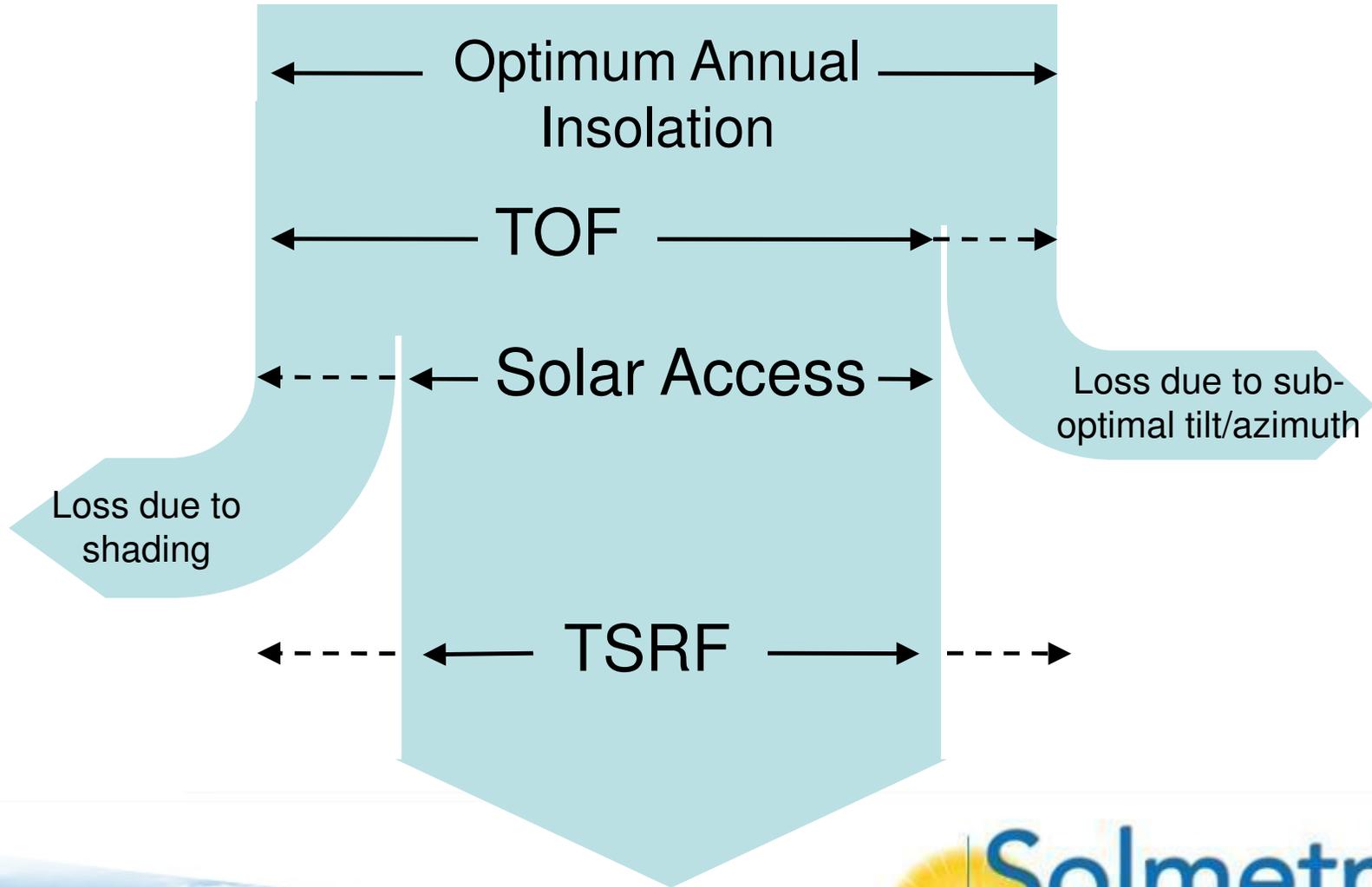


Solar Resource Terms

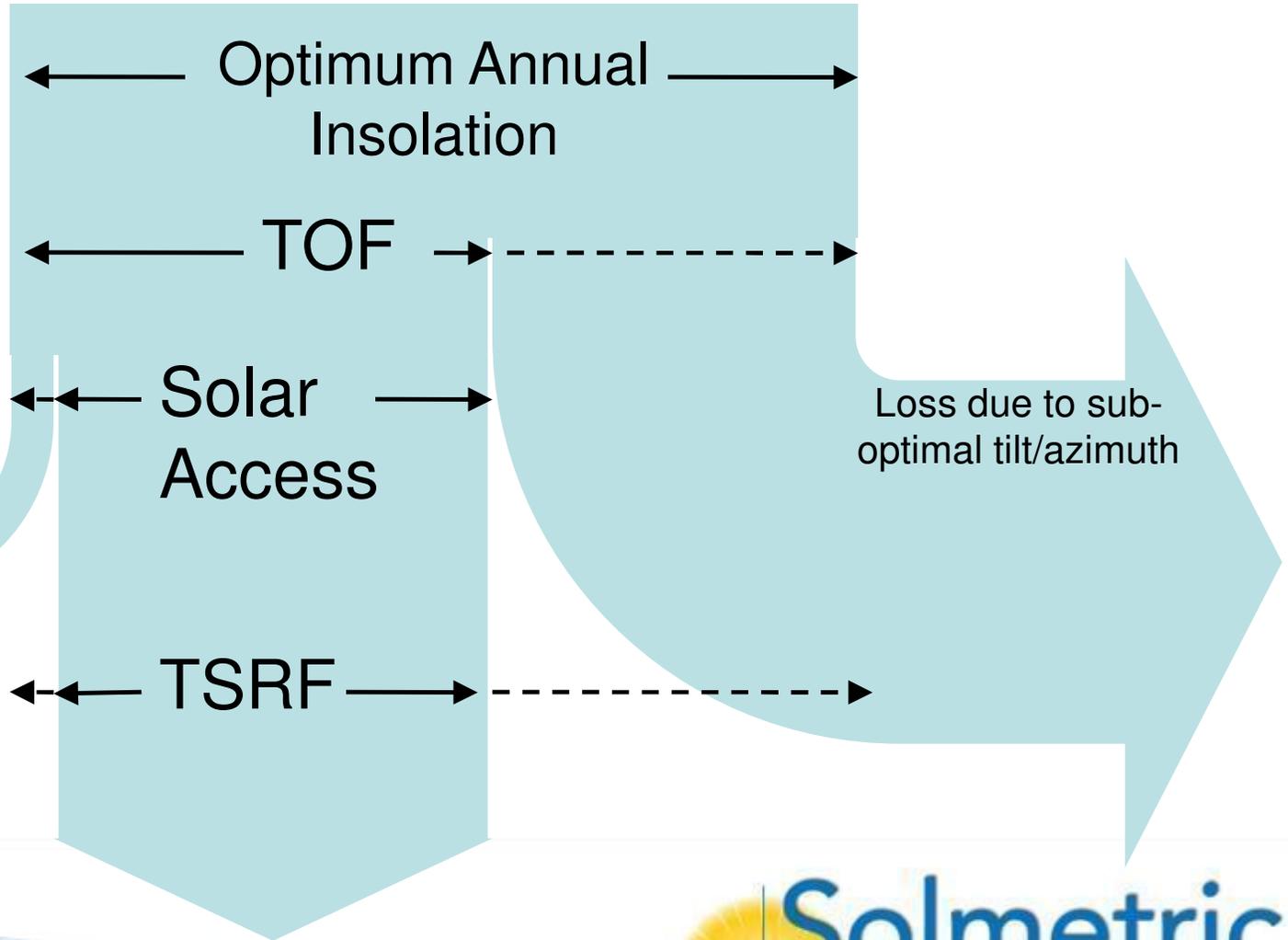
- Insolation. Incident Solar Radiation, kWh/m²
- Solar Access. Insolation compared to no shading, in field of view of the panel.
- Tilt and Orientation Factor (TOF). TOF is the solar insolation at the actual tilt and orientation divided by the insolation at the optimum tilt and orientation, expressed in percent.
- Total Solar Resource Fraction (TSRF). TSRF is the ratio of insolation available accounting for both shading and TOF, compared to the total insolation available at a given location at the optimum tilt and orientation and with no shading. TSRF is also expressed in percent, according to the following equation: $TSRF = \text{Solar Access} * \text{TOF}$.



Solar Resource Terms



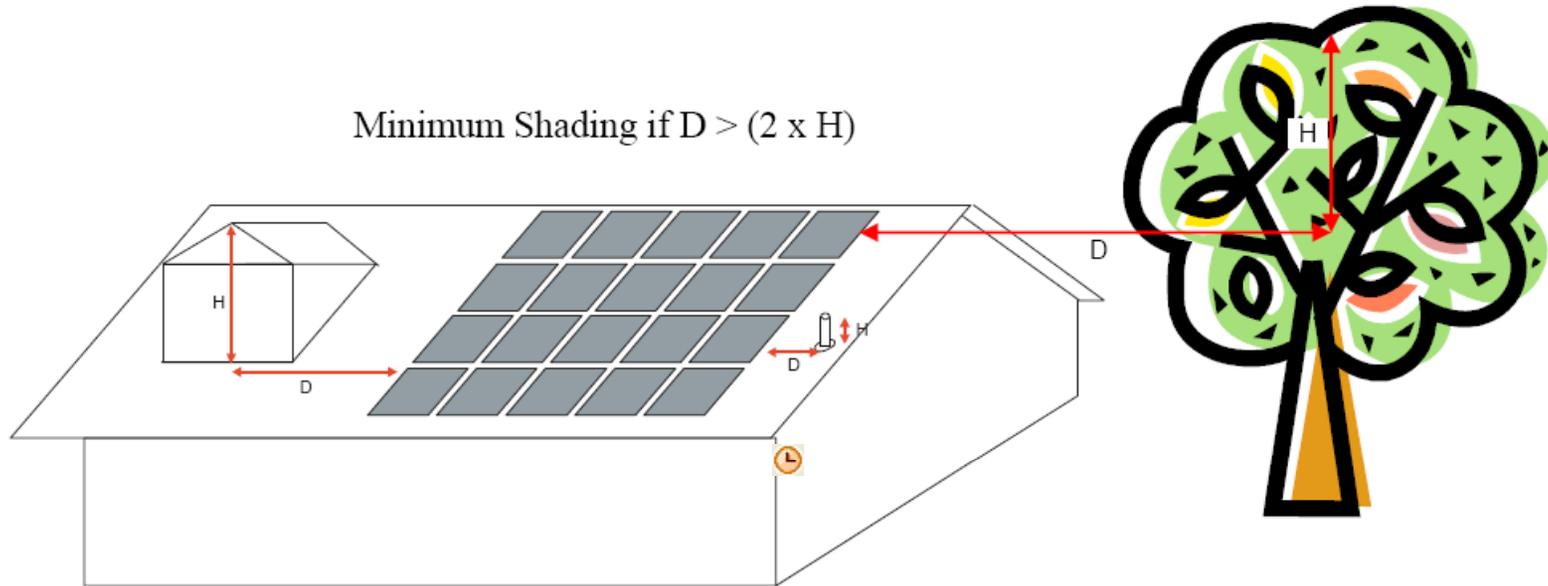
Solar Resource Example



Good Solar Access means little shade, but not necessarily the best solar production.

Obstruction Geometry

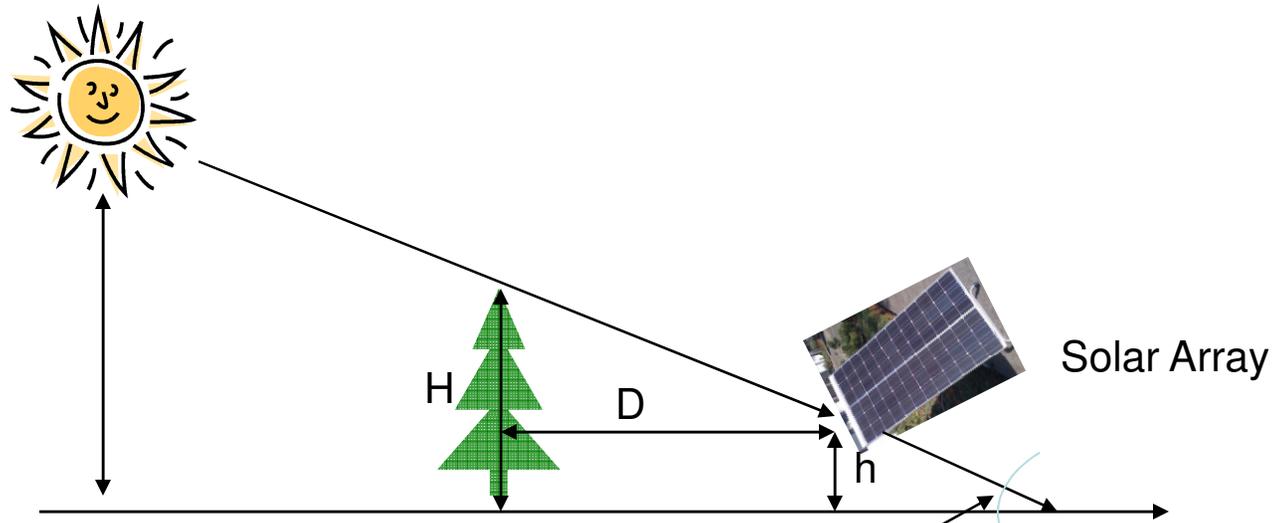
Minimum Shading if $D > (2 \times H)$



- D/H as high as possible
- $D/H > 2$ is California Minimal Shading ~ 26 degrees
- $D/H > 3+$ is "shade free 9-3"

$$\theta_r = \text{TAN}^{-1}(H/D)$$

Sun path interaction



$$\theta_r = \text{TAN}^{-1}((H-h)/D)$$

For "shade free from 9 to 3", use Minimum $\theta_r =$
December 21 sun elevation at 9am or 3pm.

Shade measurement strategies

- Take multiple point readings
 - Spacing between readings
- Look for worst case
 - Array corners
 - Points closest to obstructions
- Average solar access readings
- Obstruction elevation angles



Note: Be sure you meet the requirements of your state program and rebate calculators

Using the Solmetric SunEye™

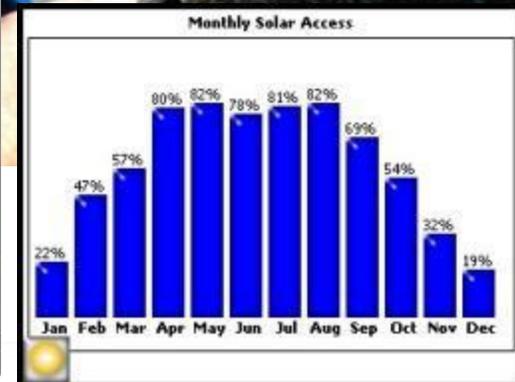
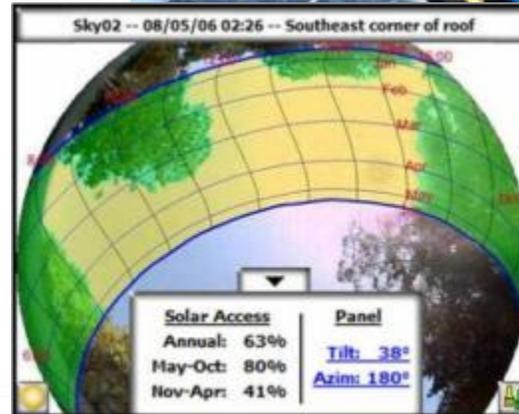
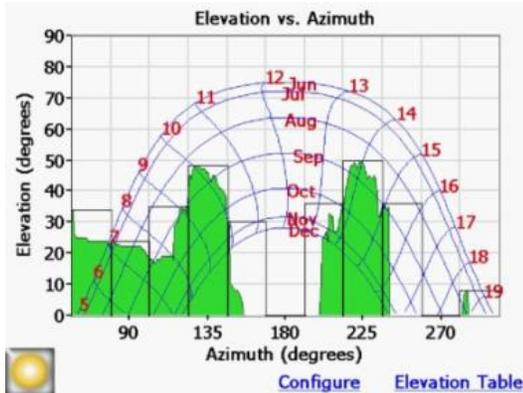


Steps for measuring solar access

Bubble Level

Compass

1. Point south*
2. Hold Level
3. Press the button

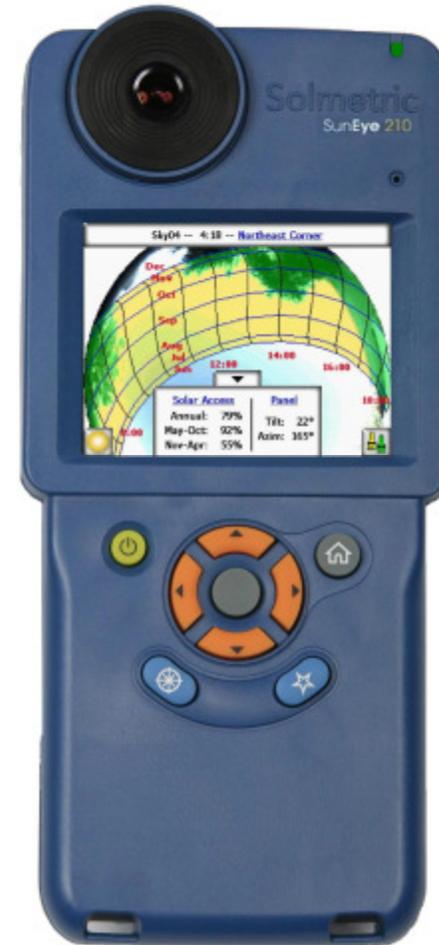


* Point south in the northern hemisphere; point north in the southern hemisphere.

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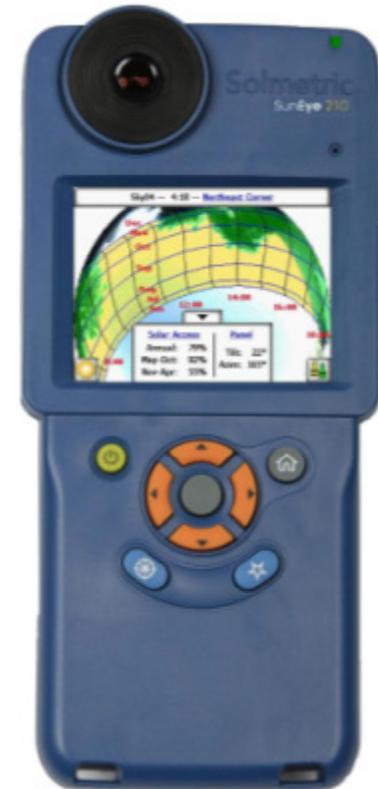
Introducing the Solmetric SunEye™ 210

- What's New?
 - Easy one-handed operation
 - Brighter, higher Res. Display (4x)
 - Electronic compass & inclinometer
 - Dynamic Site-survey mode
 - Large capacity battery
 - Integrated stylus holder
 - Integrated GPS option
 - Impact resistant molded case
 - 2 year warranty



Comparing to the original SunEye

- What's the same?
 - Easy to use and navigate user interface
 - Powerful shade analysis software
 - On-board editing tools for "What-if"
 - Results viewable right on the SunEye
 - Solar Access, Solar Resource
 - Sunpaths, Monthly Solar Access
 - Obstruction Elevation Angles
 - Desktop Companion Software included



(Proven after shipping thousands of Model 110 SunEyes)

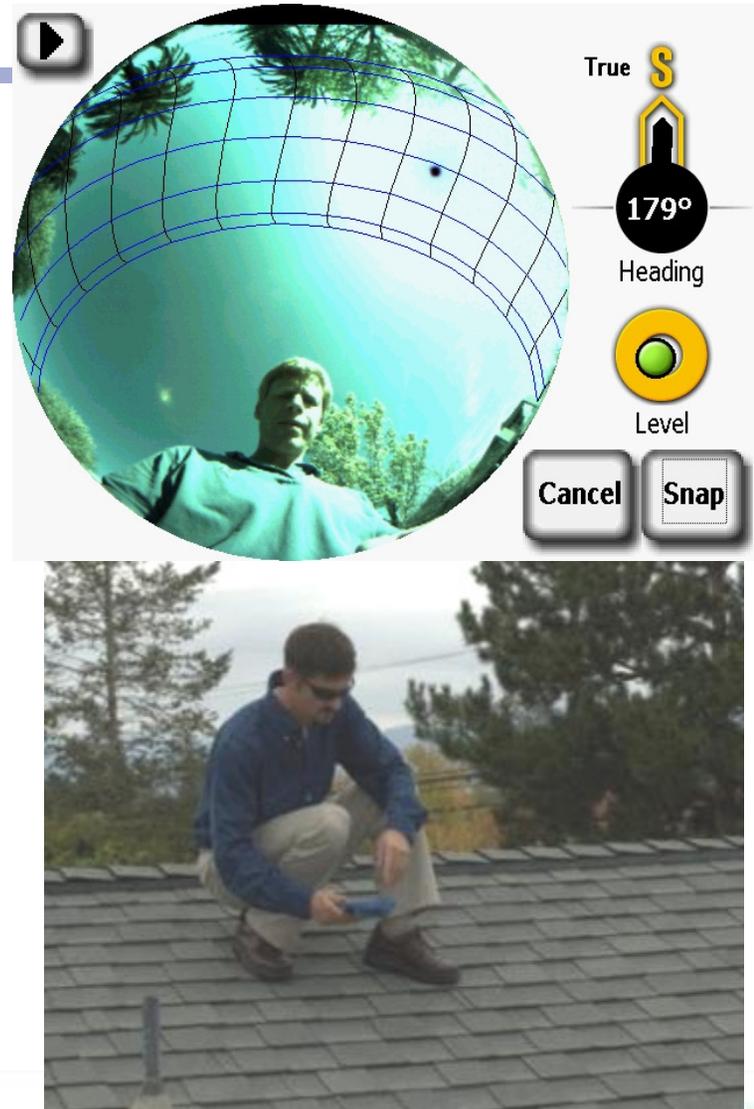
Built-in Inclinometer

- Measure Tilt and Azimuth
 1. Set SunEye on plane of solar array.
 2. Point arrow towards array heading.
 3. Read tilt and azimuth from display.
 4. Enter into panel orientation fields.



Site-Survey Mode

- Find optimum module placement
 1. Find prospective solar site.
 2. Survey potential module locations by:
 1. Pressing Quick-launch survey button.
 2. Scan area while observing obstructions entering the sunpath.

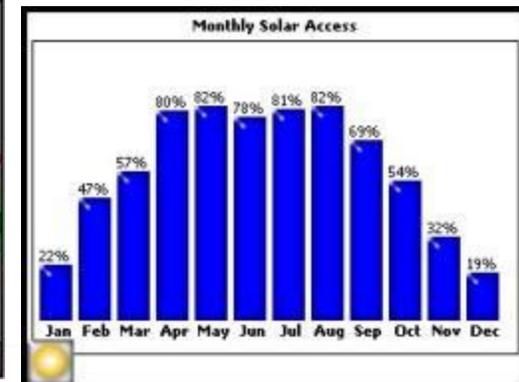
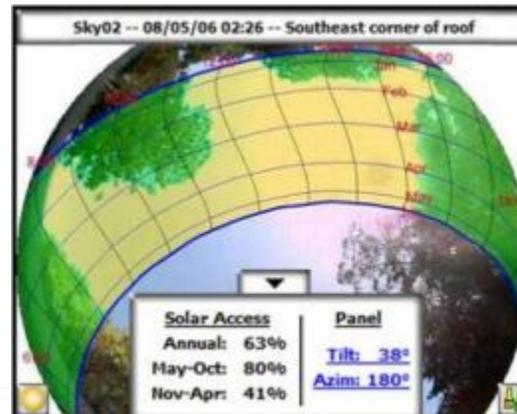


Steps for measuring solar access

Electronic
Bubble Level

Electronic
Compass

1. Point south*
2. Hold Level
3. Press the button



* north in the southern hemisphere

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SunEye's Key Benefits

- Accuracy and repeatability
 - Calibrated fisheye lens
 - Multiple users, different situations, same results
- Speed and convenience
 - Full Sky Preview mode
 - One shot for the entire skyline
 - Point and shoot capability
- Data transfer
 - Solmetric PV Designer
 - Other Programs



Live indoor measurement example (for academic purposes)

- “Sky Simulator” facilitates indoor use (demos and training)
- Small tree toward the east; larger tree toward the west

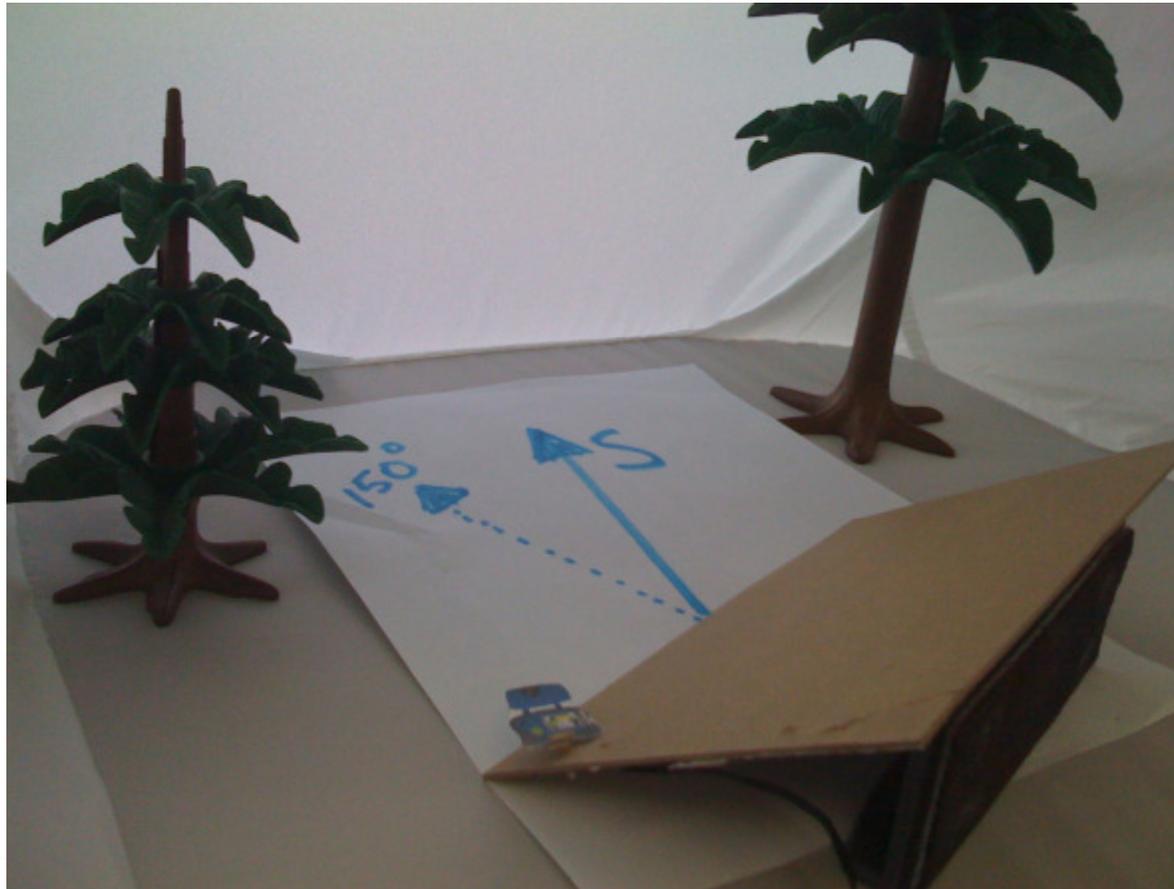


Example azimuth=150°; tilt=20°



SunEye position

Always: Level, toward *magnetic* South



Dealing with Shade



- Optimize Shade-Free production
 - Avoid shade whenever possible
 - Find the best location for the desired season/time-of-day
- Tree removal
 - Reduce shade
 - Minimize debris
- Module Level MPP
 - Incorporate new technologies that mitigate shade impact
 - Micro-inverters
 - Power Optimizers

The SolarMagic™ Power Optimizer



SolarMagic™ Input

- High speed MPPT algorithms maximize panel energy harvest
- Wide-input range accommodates almost all panel types

SolarMagic™ Output

- Automatically scales output current and voltage to optimize power of the *entire string*.
- Wide output range maximizes flexibility

Slide courtesy of:



Predicting energy production

- Solar Calculators:
 - PVWatts by NREL
 - Vendor web sites
 - State rebate calculators
 - CSI Incentive Calculator (EPBB Calculator)
 - NSHP Calculator
 - Commercial software products
 - PV*SOL, PV-Syst, Laplace, Maui
 - On-grid, CPF Tools, Clean Power Estimator
 - Etc.



Solmetric PV Designer

Solmetric SunEye™ - PV Simulation Test

File Session Skyline View Units Tools Help

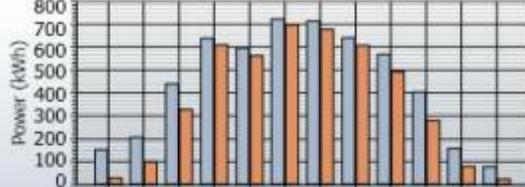


Session
PV Simulation Test

Weather Station
Santa Rosa Select Station...

Minimum / Maximum Temperatures
Min: -2.0 °C Max: 55.0 °C

Results



Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Display Monthly Total AC Power Display Daily Average AC Power

Summary PDF...

Chart	Design	Annual AC Power	Hourly
<input checked="" type="checkbox"/>	Design 1	5,354 kWh (80%)	CSV
<input checked="" type="checkbox"/>	Design 2	4,530 kWh (80%)	CSV

Delta Power: 824 kWh

- Compare Power
- Combine Power

Design Name Design 1

Inverter Change...
SMA Technologie AG - Sunny...

Module Change...
Sunpower Corp. - SPR-300-W...

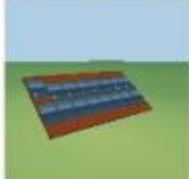
Derating...

Design Name Design 2

Inverter Change...
SMA Technologie AG - Sunny...

New Design...

Site View



Plane Position
Slope: 38.40 ° Azimuth: 180.00 ° Plane Length: 29.25 ft Plane Width: 15.00 ft

Strings:

Number of Modules	National Semiconductor SolarMagic™
1 8	<input checked="" type="checkbox"/>
2 8	<input type="checkbox"/>

Layout View

Modules

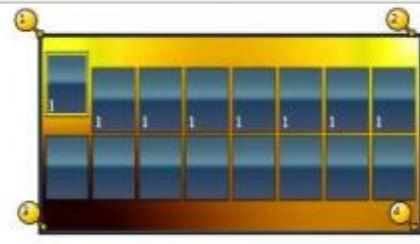
Auto Layout...

Add Module

Delete Selected Items

Shading

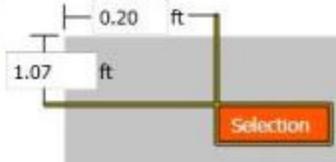
Insolation



Selected: 1 Module

String: 1

Orientation: Portrait Landscape

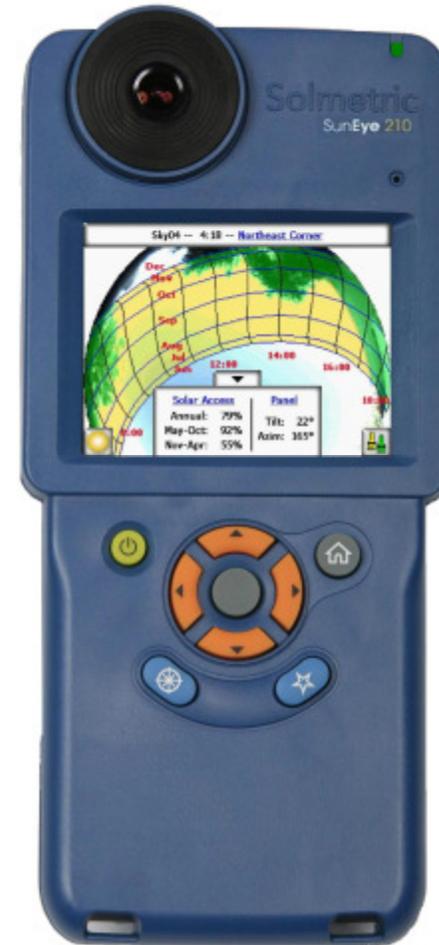




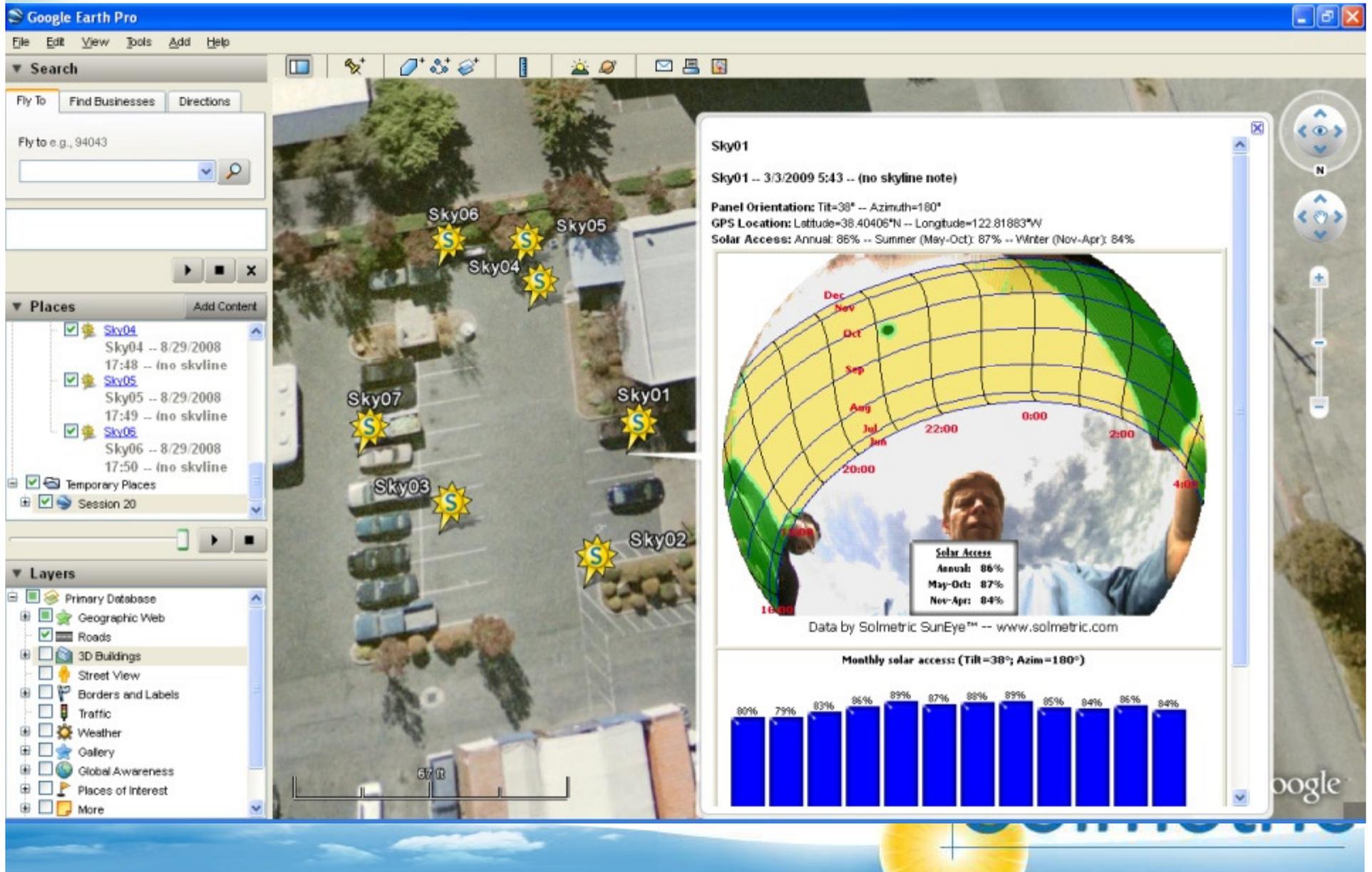
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SunEye GPS Add-On

- GPS option integrated into 210
- Detects latitude/longitude for session location and automatic sunpath generation
- Records location of each skyline data set collected
- Reports include file for Google Earth™

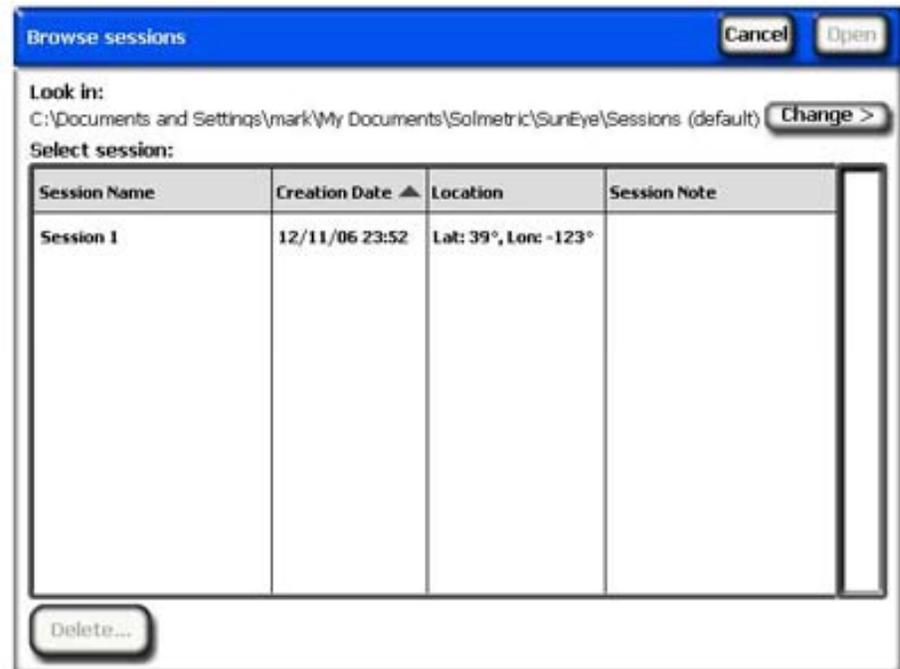


SunEye GPS output to Google Earth™



Data transfer to computer via USB

- SunEye stores more than 100 Skylines in memory
- Transfer data to PC for further analysis
- View and edit data in same way as on hand-held
- Create reports and export files to design tools



Solar Access and Shade Report

- All session data is combined into a single hypertext document
- Converts to MS-Word™
- View, Email, or print

Client Information

Solar Access and Shade Report

11/08/07

For:

John Smith
10 main st
Newark, NJ
123-456-7891

By:

Anderson's Solar Installs
23 Ford st
Newark, NJ 1-800-123-4567

Installer business information/logo



Access raw data files

Additional Files in the ExportedFiles subdirectory:

Daily solar access data in CSV format	Sky01DailySolarAccess.csv
Insolation (quarter-hourly) in CSV format	Sky01Insolation.csv
Shading (quarter-hourly) in CSV format	Sky01Shading.csv
Solar obstruction elevations in CSV format	Sky01ObstructionElevations.csv
Solar obstruction elevations in XML format	Sky01ObstructionElevations.xml
PV*SOL horizon angles file (.hor)	Sky01_PV_SOL.hor
Full resolution fish eye image	Sky01FullFishEye.jpg
Annual access fully annotated sky image	Sky01AnnualAccessFullyAnnotated.jpg

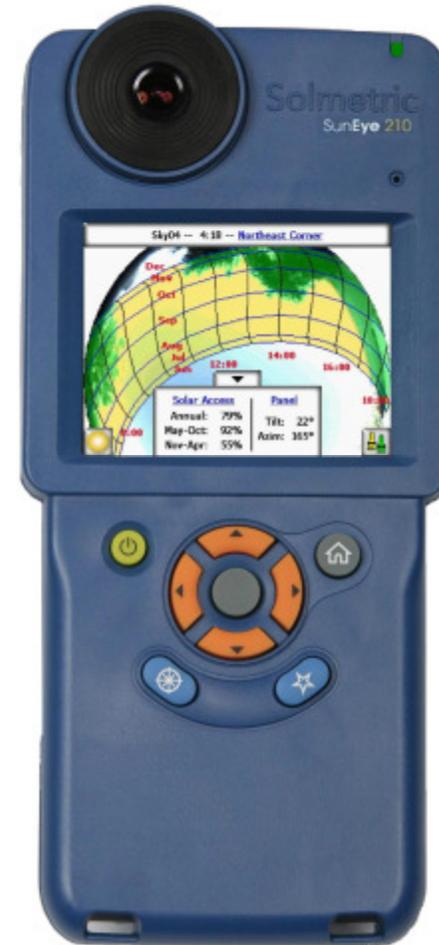
- Import data files into design software
 - Excel spread sheet, OnGrid, PVOptimize, PV*SOL, T*SOL, PVSyst, QuickQuotes, CPF Tools

Day	Month		
	Jan	Feb	Mar
1	54.17	54.99	67.64
2	54.17	54.99	67.64
3	54.17	54.99	67.64
4	54.17	54.99	67.64
5	56.63	54.66	67.77
6	56.63	54.66	67.77
7	56.63	54.66	67.77
8	56.63	54.66	67.77



Updated Software and Accessories

- New software updates available from:
www.solmetric.com
 - Includes handheld and PC updates
 - Set for auto-update

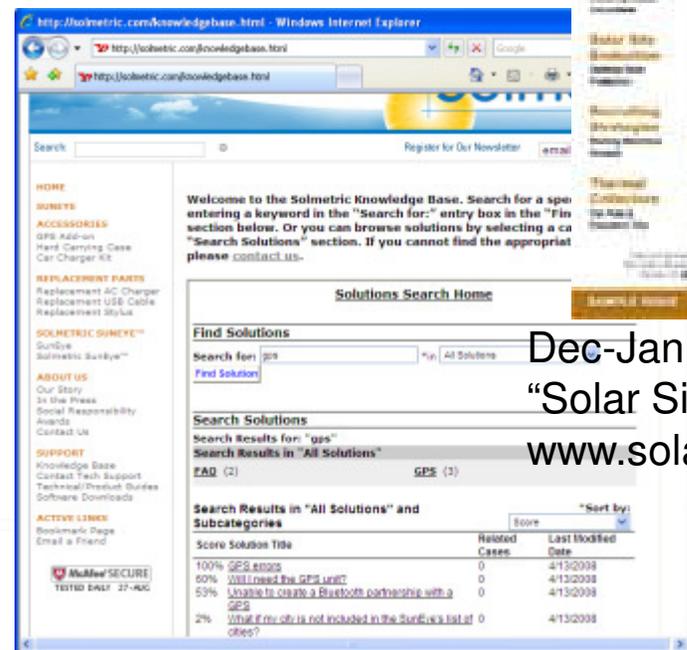


Resources

- User's Guide accessible via desktop software
 - Help>Solmetric SunEye User's Guide...
- Knowledge base at:
 - <http://www.solmetric.com/knowledgebase.html>
- Technical Support
 - 1-877-263-5026, opt 2
 - support@solmetric.com



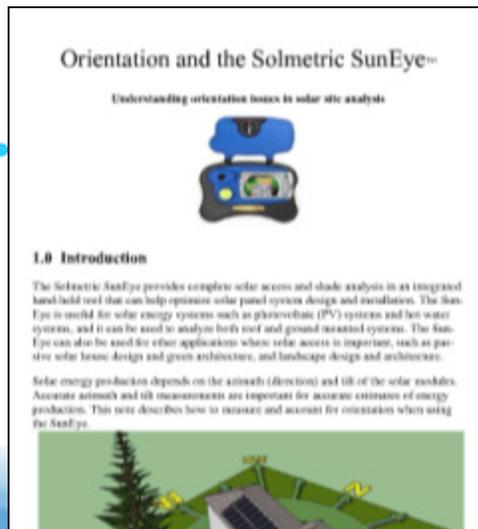
Dec-Jan issue:
"Solar Site Evaluation"
www.solarprofessional.com



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Questions?



Solmetric Corporation

www.solmetric.com

1-877-263-5026

