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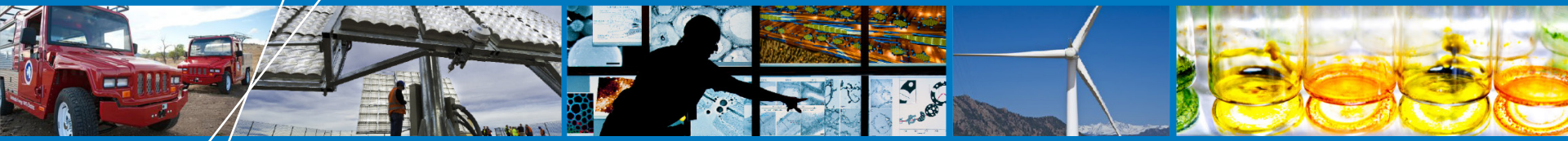
SAM Solar Resource 101



SAM Webinar

Janine Freeman

December 11, 2013
1:00 pm MST

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

SAM Webinar Schedule for 2014

System Advisor Model

Schedule

- **New Features in SAM 2013 and Beyond**
  - October 9, 2013: Paul Gilman
- **SAM PV Model Validation using Measured Performance Data**
  - December 11, 2013: Janine Freeman
- **Solar Resource Data 101**
  - February 12, 2014: Janine Freeman
- **Analysis of Electricity Rate Structures for Residential and Commercial Projects**
  - April 16, 2014: Sean Ong
- **Modeling Parabolic Trough Systems**
  - June 18, 2014: Michael Wagner

Details

- All sessions last one hour and begin at 1 p.m. Mountain Time
- You must register to participate
- Registration is free, but space is limited
- More details and registration information on Learning page of SAM website

https://sam.nrel.gov/content/resources-learning-sam

Webinar Outline

- Basics of the Solar Resource
- Measured and Modeled Resource Data
- Long-Term Historical Data
- Solar Resource Data Types in SAM
- How to Choose a Resource File?

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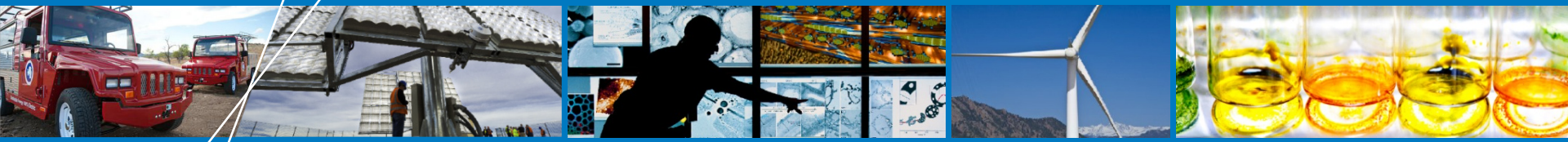


Basics of the Solar Resource

Geometry of Solar Radiation

Zenith & Azimuth Angles

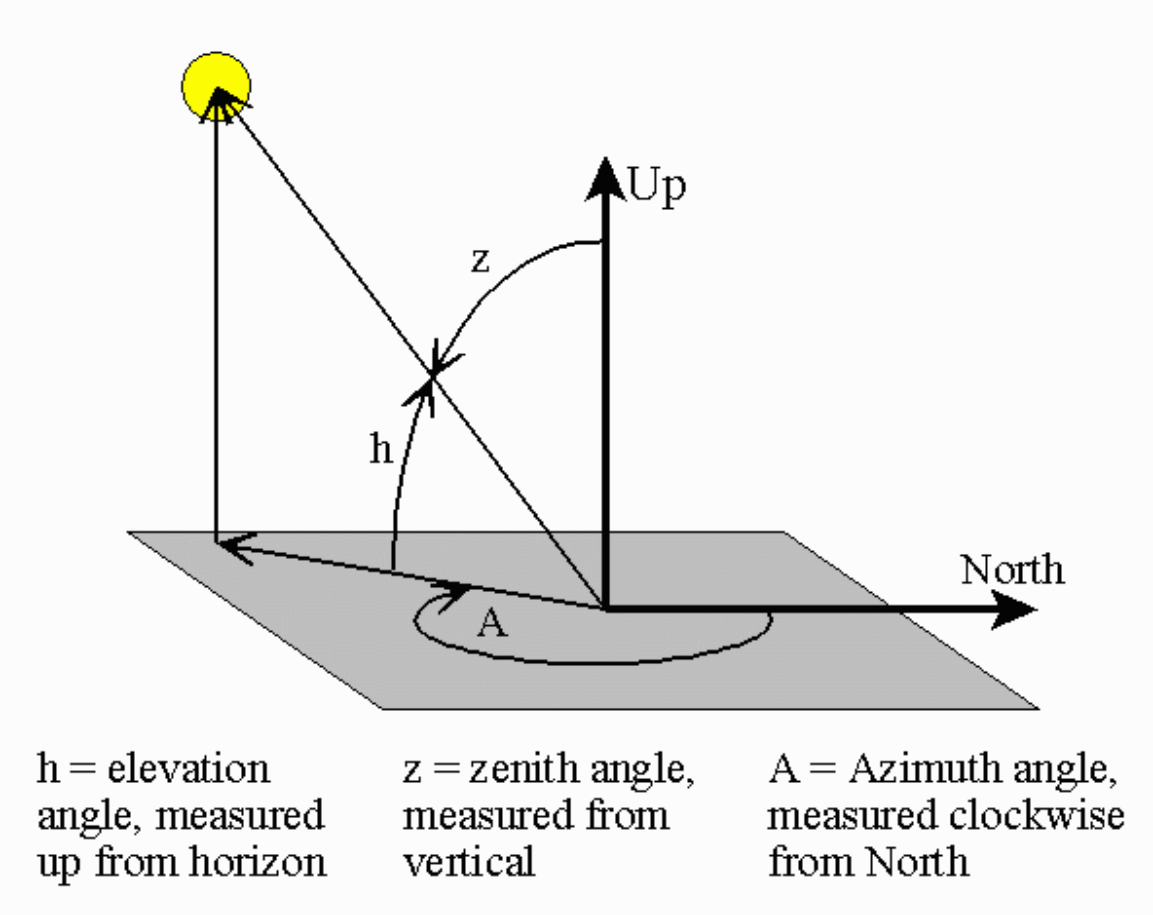


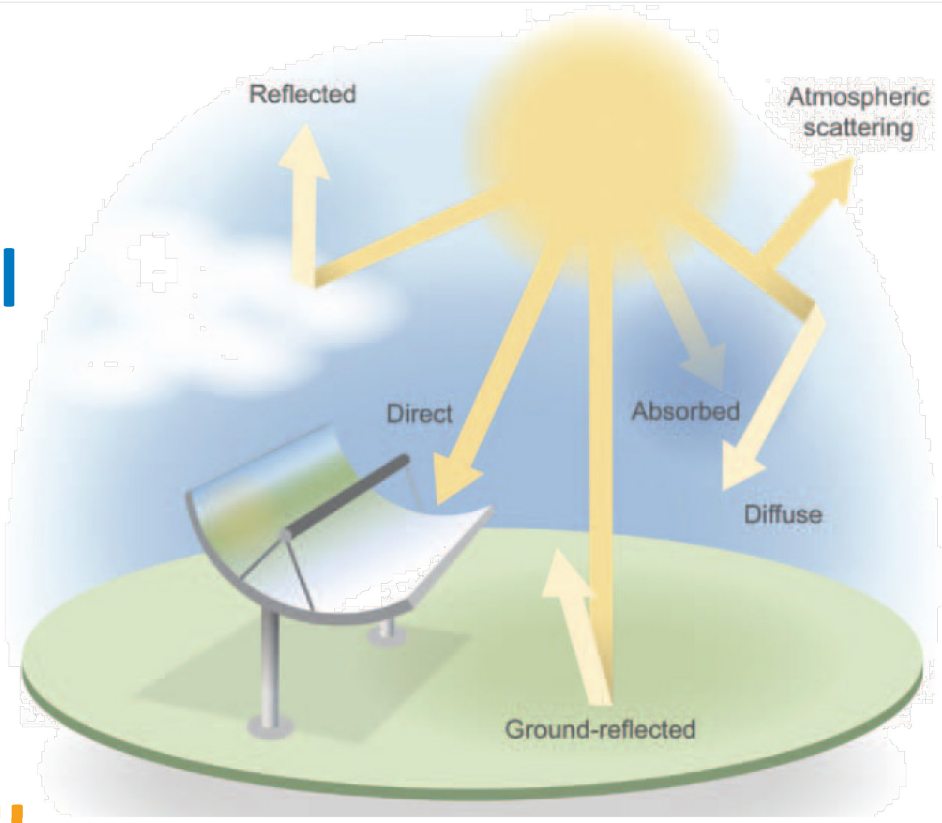
Image from http://capsis.cirad.fr/capsis/help_en/samsaralight

What Is Irradiance?

- Irradiance- the power incident on a surface (Units: W/m^2)
- Extraterrestrial irradiance ~1366 W/m^2
- Irradiance seen at earth's surface affected by atmosphere, cloud cover, particulates, etc.

Irradiance Components

- DNI: Direct Normal Irradiance (also: Beam or Direct)
- DHI: Diffuse Horizontal Irradiance (Diffuse)
- GHI: Global Horizontal Irradiance (Global or Total)
- GHI = DNI*Cos(Z) + DHI



l Hicks, NREL

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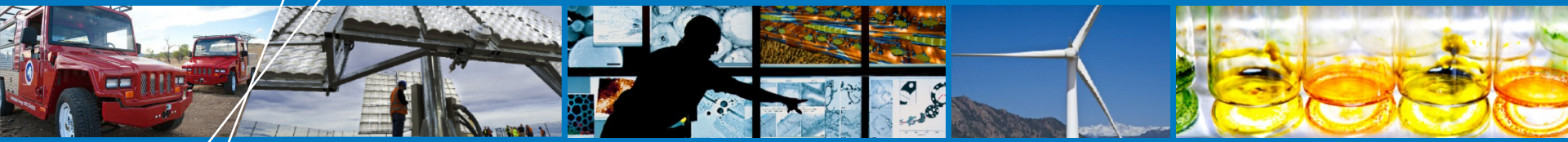


Measured and Modeled Resource Data

Measured vs. Modeled

Measured Data

Advantages

- Site-specific
- Lower uncertainty*
- High temporal resolution

Disadvantages

- Usually not long-term
- Not widely available
- Instruments require maintenance

Modeled Data

Advantages

- Long-term datasets
- Available for most locations
- Satellite instrument calibrated daily

Disadvantages

- Low spatial resolution
- Higher uncertainty*

The most accurate data is a combination of the advantages of each type of data

*If the measurement instruments are properly calibrated and maintained

How To Measure Irradiance?

System Advisor Model

Pyranometer

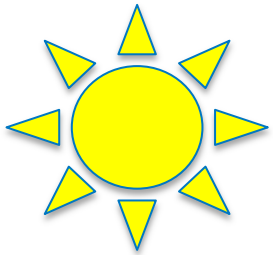
- Measures GHI
- Can measure DHI if shaded
- Typical uncertainty ±3-5% (thermopile pyranometer)

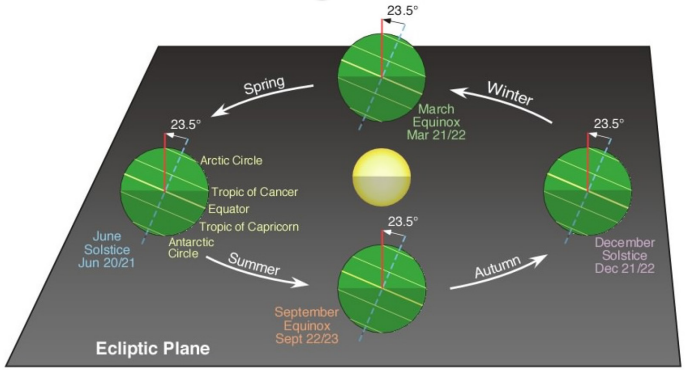
Pyrheliometer

- Measures DNI
- Must be mounted on a tracker
- Typical uncertainty ±2%

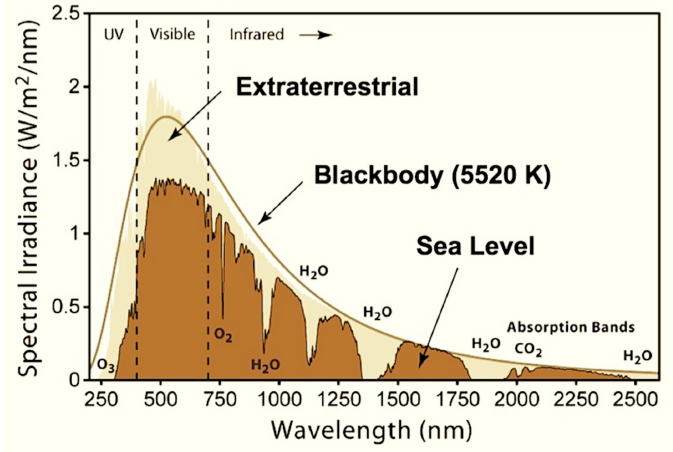
Modeling Solar Radiation

Step 1. Top of Atmosphere



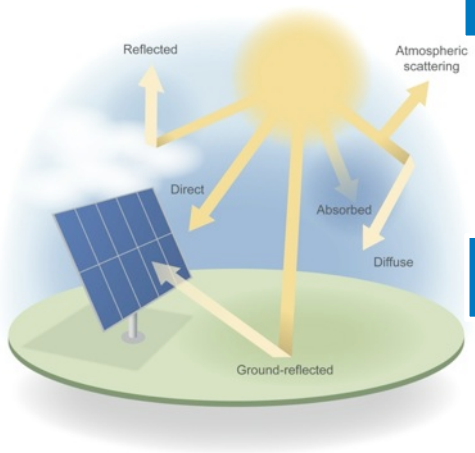


Total Solar Irradiance (TSI): 1366 ± 7 W/m2



Sun-earth distance: ~3% less TSI in summer

Step 2. Through a Clear-Sky Atmosphere



Absorbing & Scattering:

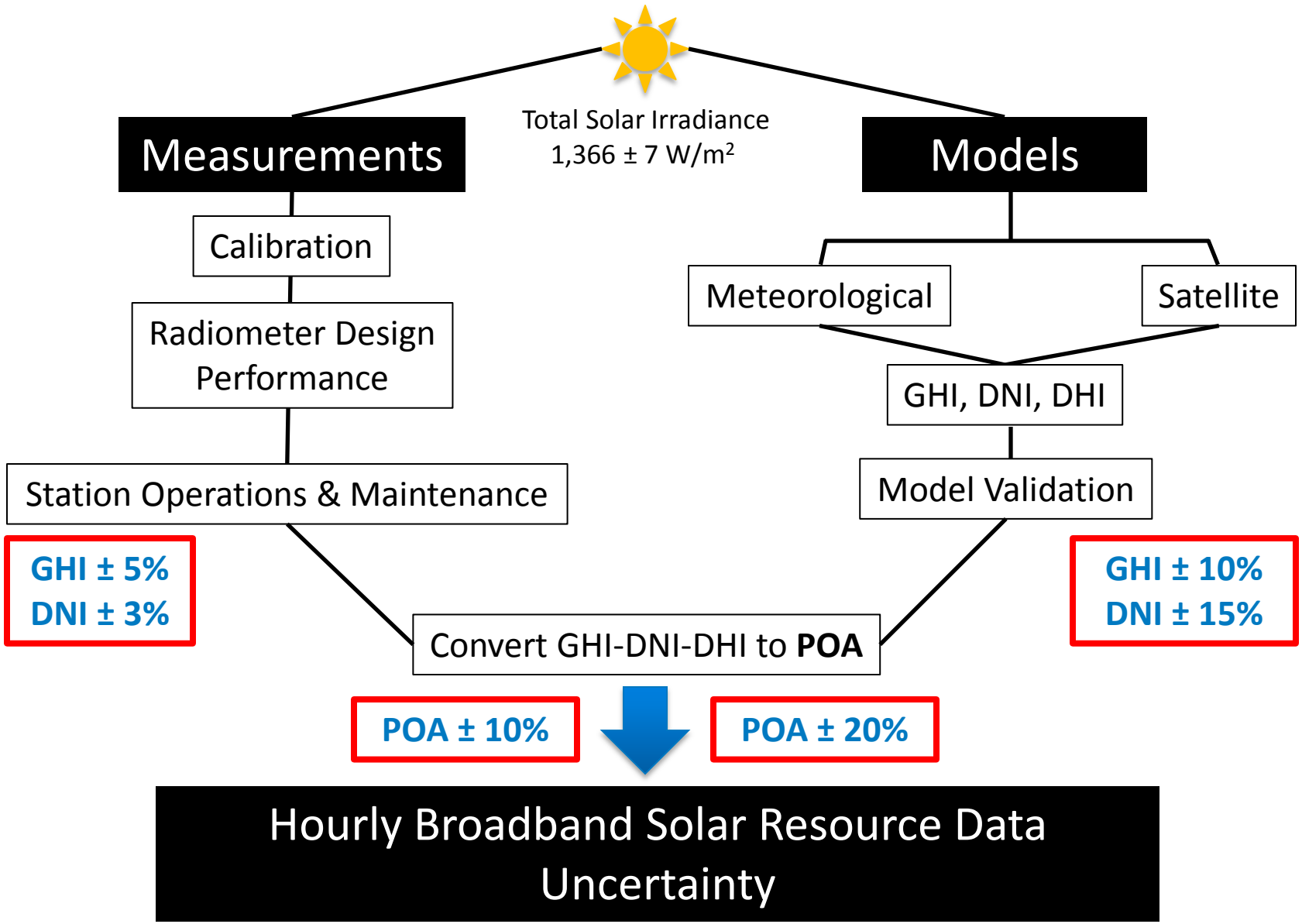
Gases, water vapor, **aerosols**

Step 3. Effects of Clouds

- Empirical Relationships – Cloud Index
- Physical Properties – Radiative Transfer

Modeled vs. Measured Resource Data Uncertainty

System Advisor Model



Choosing Irradiance Components

System Advisor Model

My project

Select Technology and Market... | Flat Plate PV, Commercial

Location and Resource
Location: PHOENIX SKY HARBOR INTL AP, AZ
Lat: 33.5 Long: -112.0 Elev: 337.0 m

Module
SunPower SPR-210-BLK-U
Output: 215.3 Wdc

Inverter
SMA America: ST36 (240) 240V
Capacity: 36000 Wac

Array
Power: 199.752 kWdc
Area: 1154.4 m2

PV Subarrays
Number of subarrays: 1

Performance Adjustment
Percent of annual output: 100 %
Year-to-year decline: 0.5 % per year

PV System Costs
Total: $ 515,401.32
Per Capacity: $ 2.58 per Wdc

Financing
Analysis: 25 years
Debt Fraction: 100.0% percent

Incentives
Fed. ITC
No cash incentives

Depreciation
5-yr MACRS (Federal)
5-yr MACRS (State)

Utility Rate
Net Metering? Yes

Electric Load
Annual Energy: 7.6463e+006 kWh
Annual Peak: 1687.62 kW

Exchange Variables
(For Excel Exchange and custom TRNSYS only.)

Layout

Specify System Size

(●) Specify desired array size ( ) Specify modules and inverters

Desired array size	200 kWdc	Modules per string	21
DC to AC ratio	1.1	Strings in parallel	95
		Number of inverters	50

Sizing messages (see Help for details):

Actual DC to AC Ratio is 0.92. Check for more sizing messages after running simulations.

Actual Layout

Modules			Inverters		
Nameplate capacity	199.752	kWdc	Total capacity	216	kWac
Number of modules	928		Total capacity	224.723	kWdc
Modules per string	8		Number of inverters	6	
Strings in parallel	116		Maximum DC voltage	600	Vdc
Total module area	1154.43	m2	Minimum MPPT voltage	250	Vdc
String Voc	381.6	V	Maximum MPPT voltage	480	Vdc
String Vmp	328	V			

Nameplate capacity and string Vmp are at module reference conditions. String Voc is at 1000 W/m2 incident irradiance and 25 °C cell temperature.

Interconnection Derates (AC)

AC wiring losses	0.99	(0..1)
Step-up transformer losses	1	(0..1)
Total interconnection derate	0.99	(0..1)

Ground Reflectance

[ ] Use albedo in weather file if it is specified

Monthly ground reflectance (albedo) | Edit values...

Land Area

Packing factor	2.5	
Total land area	0.71315	acres

Tilted Surface Radiation Model (Advanced)

( ) Isotropic
( ) HDKR
(●) Perez

Radiation Components
(●) Beam and diffuse
( ) Total and beam

Self Shading Calculator for Fixed Tilt Arrays

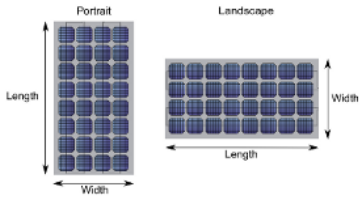
[ ] Enable Self-Shading Calculator

Module

Orientation	Landscape	
Length	1.848	m
Width	0.673	m
Number of Cells along Length	12	
Number of Cells along Width	6	
Number of Bypass Diodes	3	

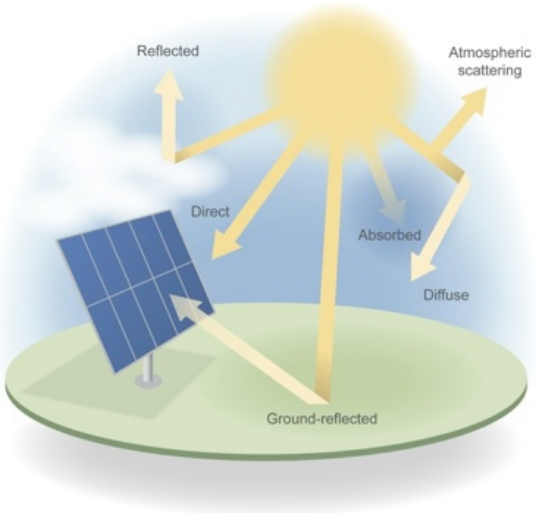
Characteristics from Module Page

Area 1.244 m2 Number of cells 72



Plane of Array Irradiance

- **Depends on:**
  - Sun position
  - Array orientation and tracking or fixed
  - Ground surface reflectivity (albedo)



- **Can be measured with a pyranometer, BUT:**
- **All module models in SAM require this computed separately for direct and diffuse**
- **Isotropic, Perez, or HDKR models**

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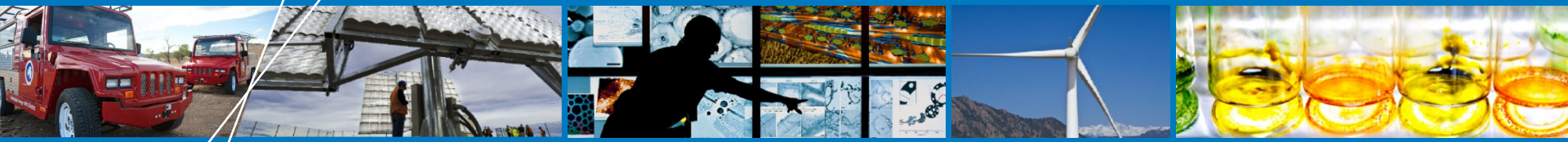


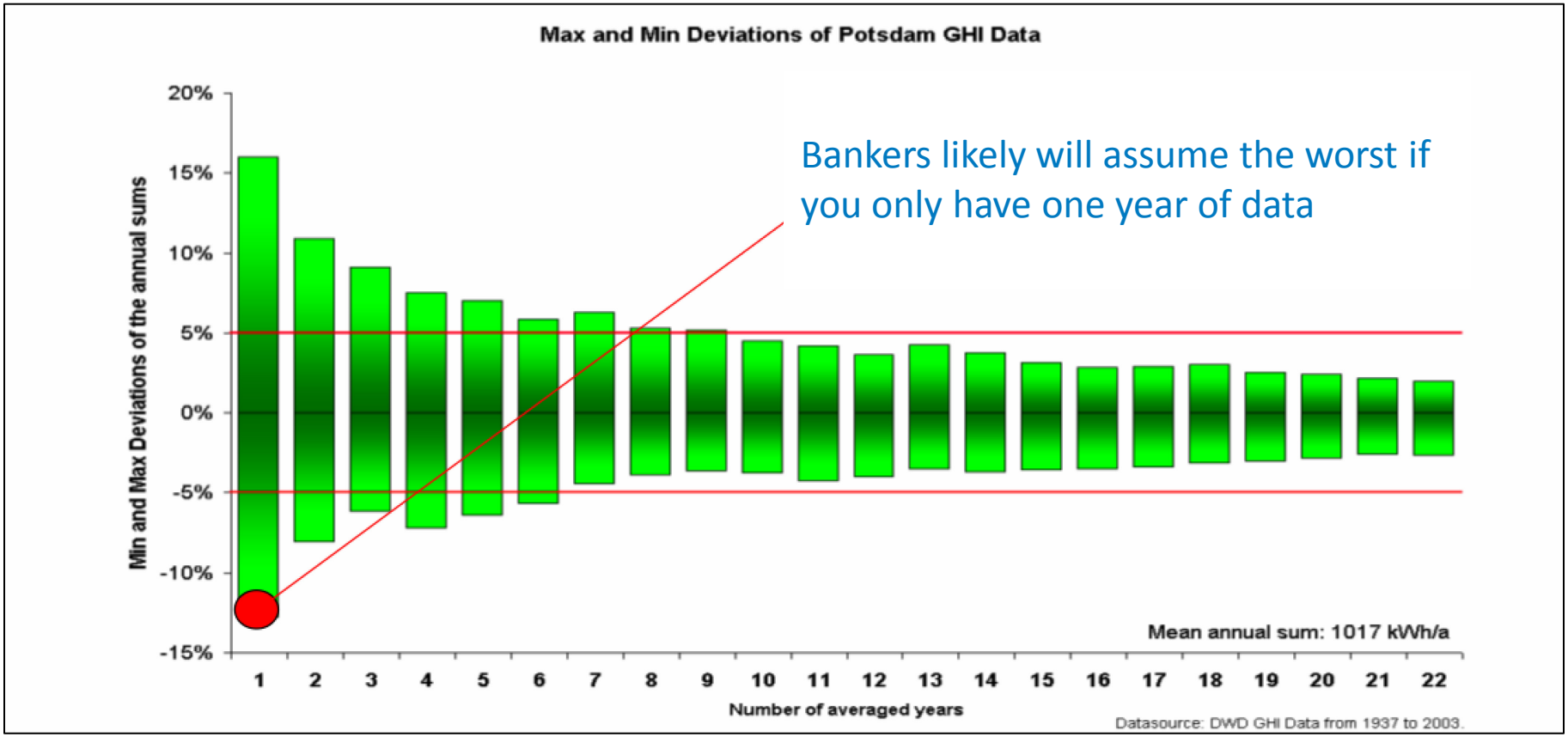
Long-Term Historical Data

Interannual Variability

System Advisor Model

Natural Variations in the Weather:

How much data do I need[1]?



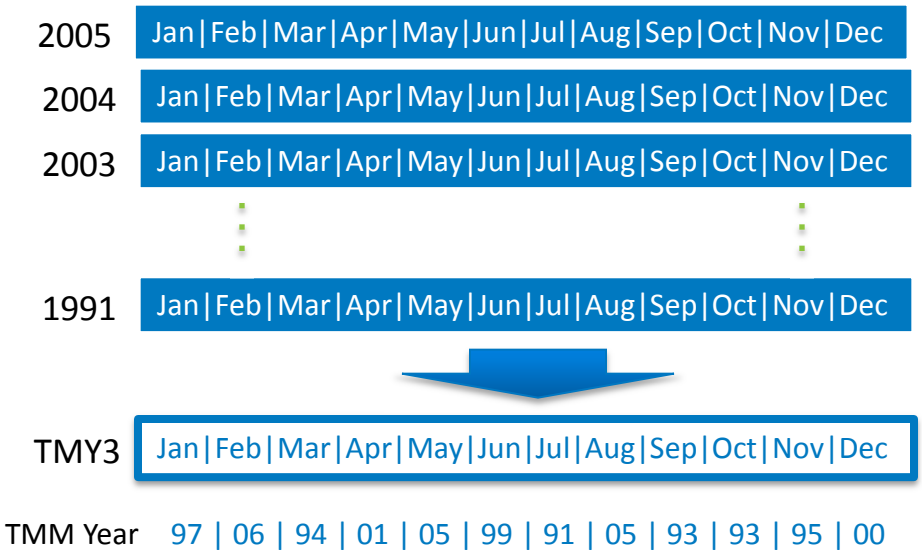
[1]Robert Pitz Paal, DLR: 7-10 years for ±5% GHI for a system in Potsdam, Germany

Leveraging Historical Data

1. Statistically average the available historical data
2. Run a simulation for each year of historical data and look at the distribution

Typical Meteorological Year (TMY)

System Advisor Model



- **TMY-** weighting criteria below
- **TGY-** typical months selected ONLY on global
- **TDY-** typical months selected ONLY on direct/beam irradiance

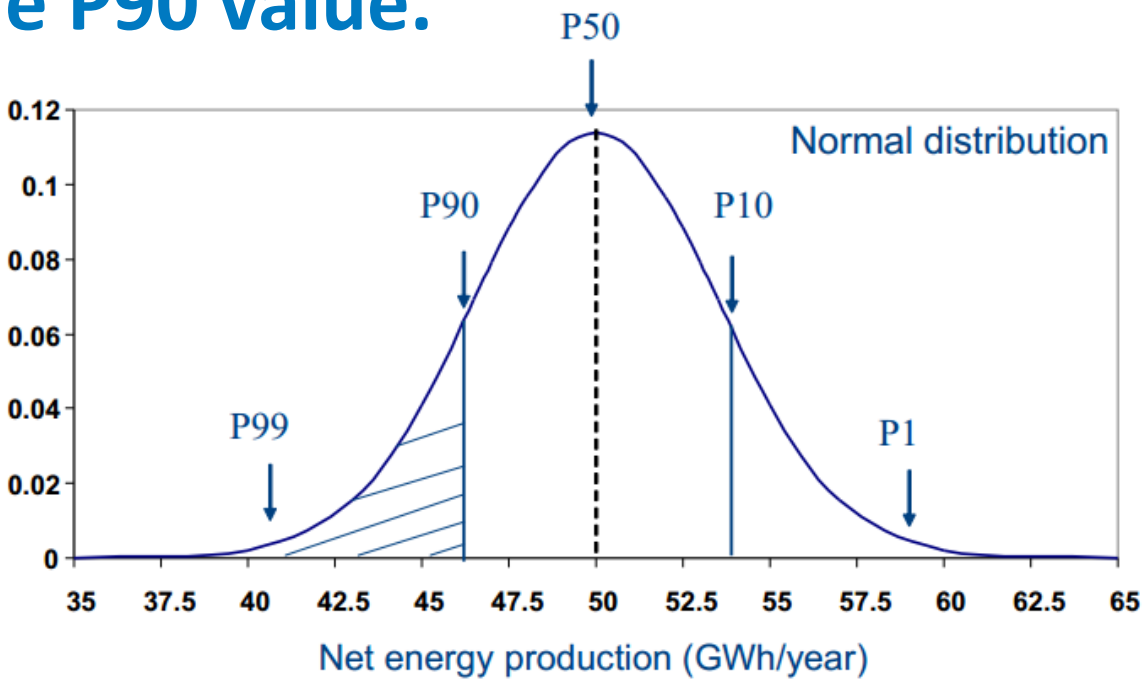
Hourly values for a full year created from a data bank which is significantly longer than a year. "Typical" months, which are representative of the average weather in that month (excluding major events, such as natural disasters and uncharacteristically unusually behavior, e.g. abnormally high winds), are selected and then aggregated according to weighted criteria ---------->

Index	NSRDB TMY
Max Dry Bulb Temp	1/20
Min Dry Bulb Temp	1/20
Mean Dry Bulb Temp	2/20
Max Dew Point Temp	1/20
Min Dew Point Temp	1/20
Mean Dew Point Temp	2/20
Max Wind Velocity	1/20
Mean Wind Velocity	1/20
Global Radiation	5/20
Direct Radiation	5/20

*Hall, et al. (1978) Generation of Typical Meteorological Years for 26 SOLMET Stations, SAND78-1601

P50/P90 Analysis

- **P50 value – 50% chance a result will be greater than the P50 value, 50% chance a result will be less than P50 value.**
- **P90 value – 90% chance a result will be greater than the P90 value.**

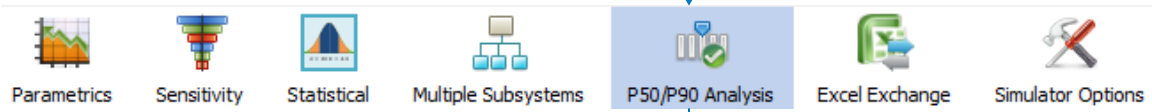


P50/P90 Analysis in SAM

System Advisor Model

1

2



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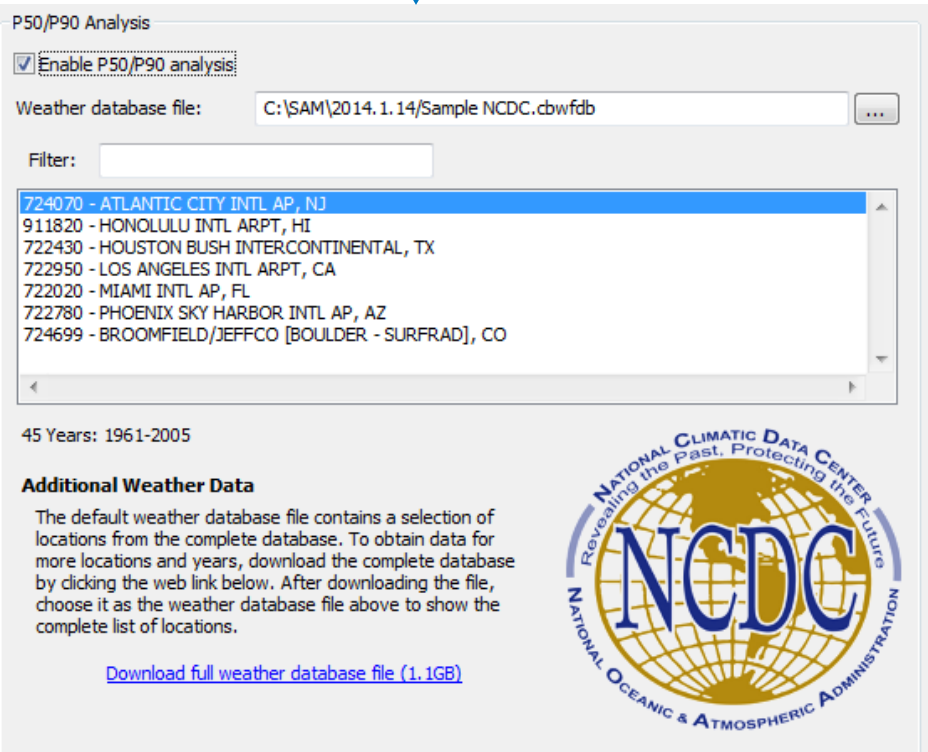

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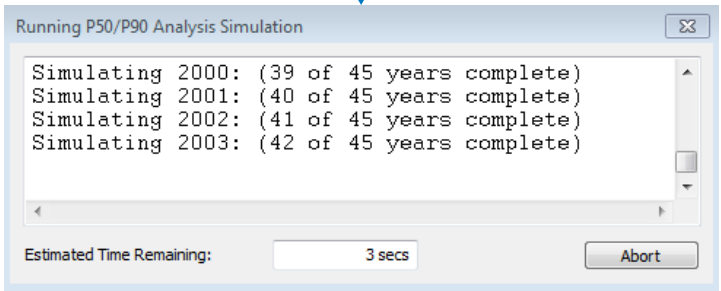

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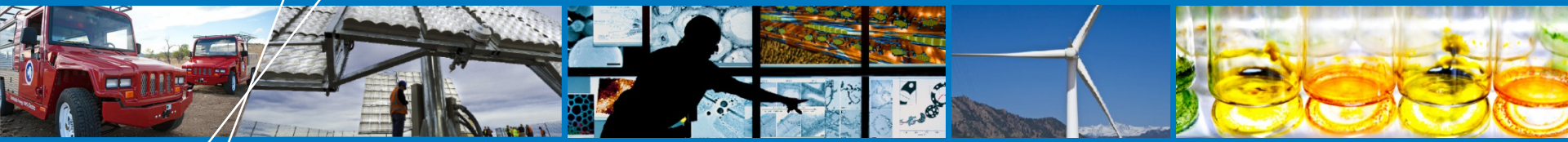
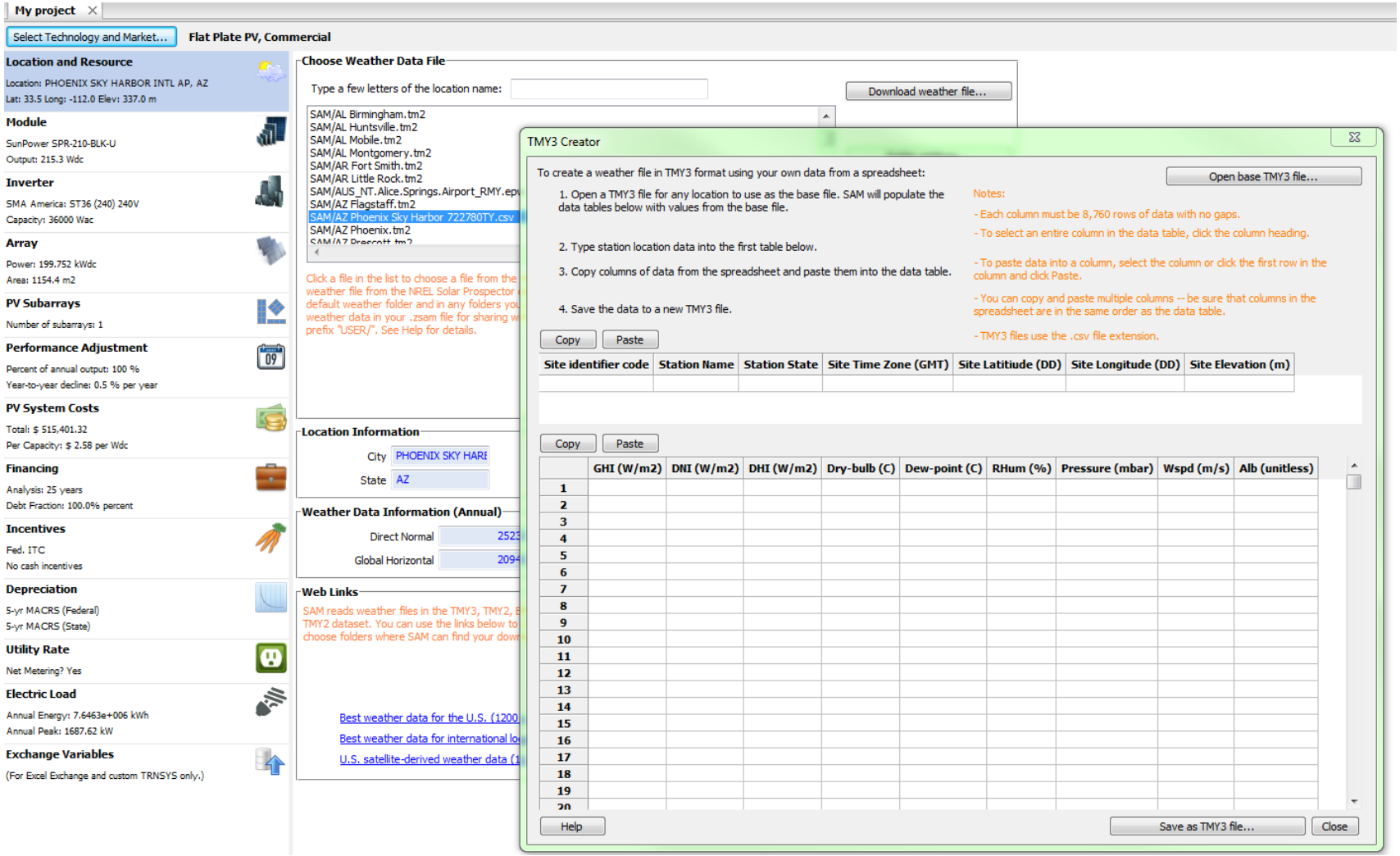


Solar Resource Data in SAM

Use Your Own Data: “Create a TMY3”

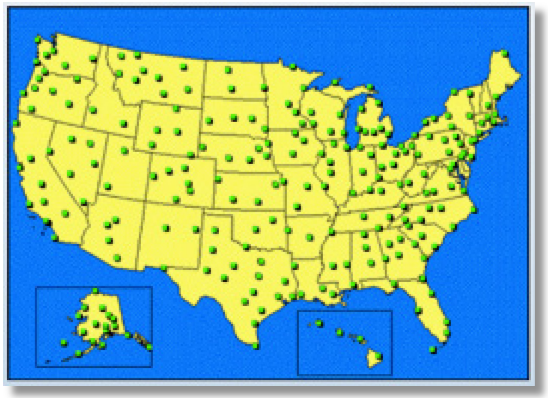
System Advisor Model



TMY2 and TMY3

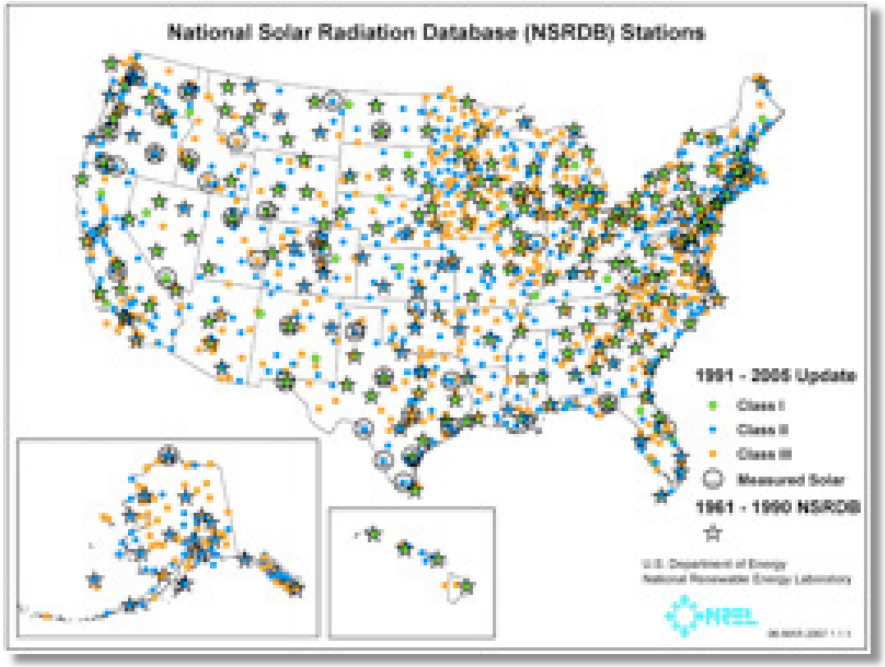
TMY2

- 239 Measured and ***Modeled*** Locations
- 1961-1990



TMY3

- 1,020 Measured and ***Modeled*** Locations
- 1991-2005



TMY Variability

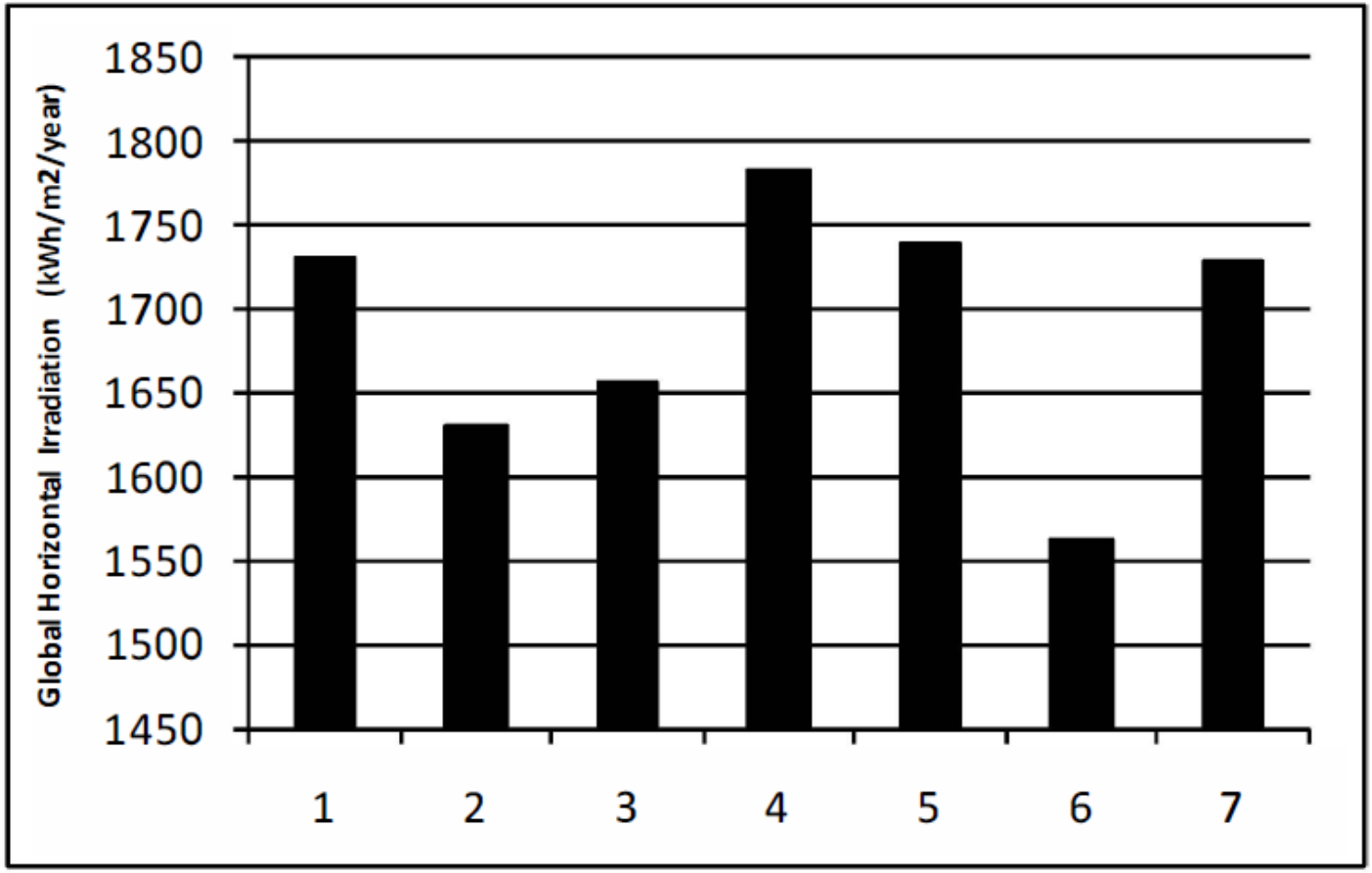
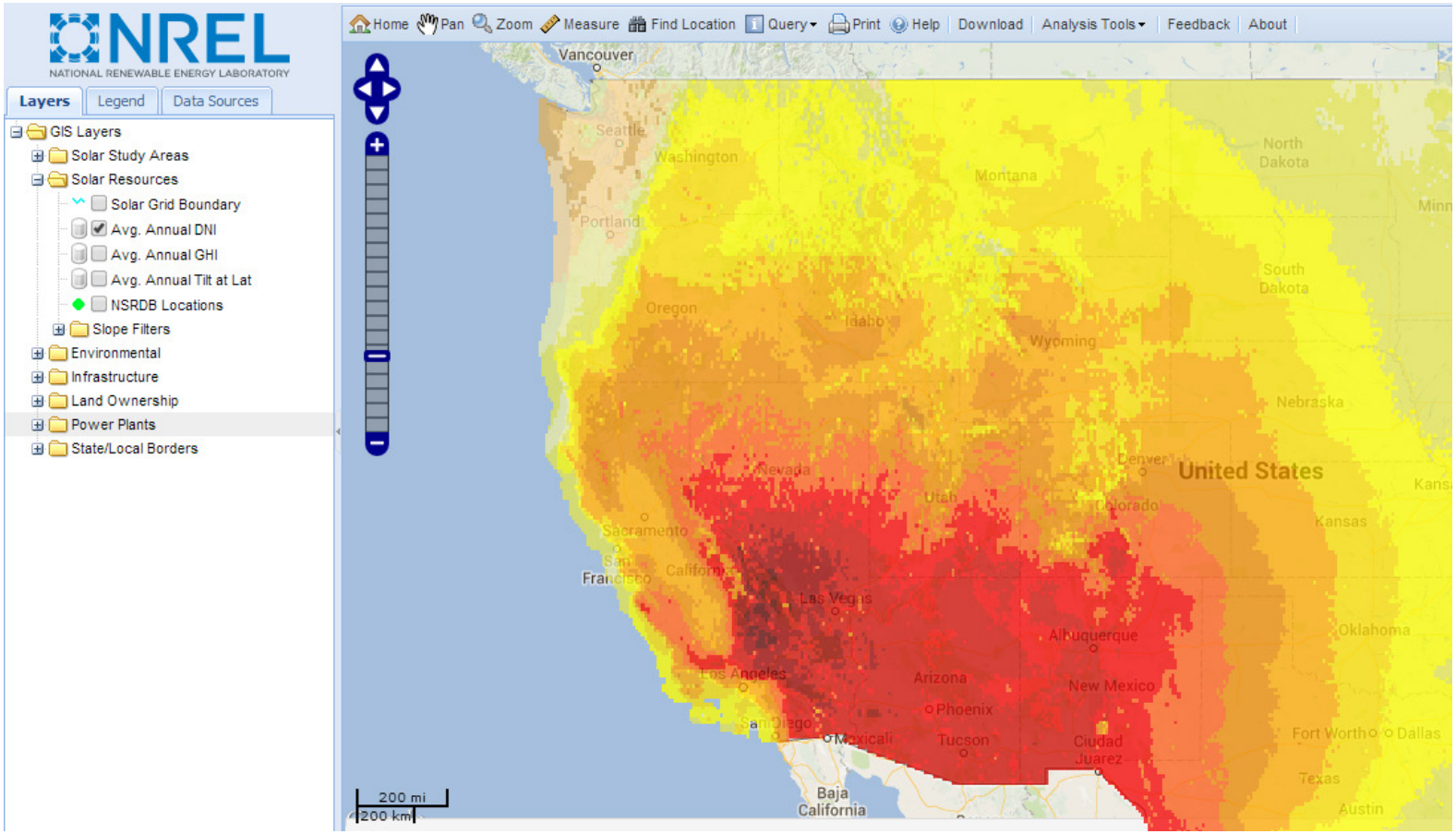


Fig. 1: Annual GHI of Seven NSRDB TMY3 Data Sets Near Dallas, TX.

Image from "Solar Input Data for Photovoltaic Performance Modeling", Schnitzer et al, 2011

Solar Prospector Satellite Data



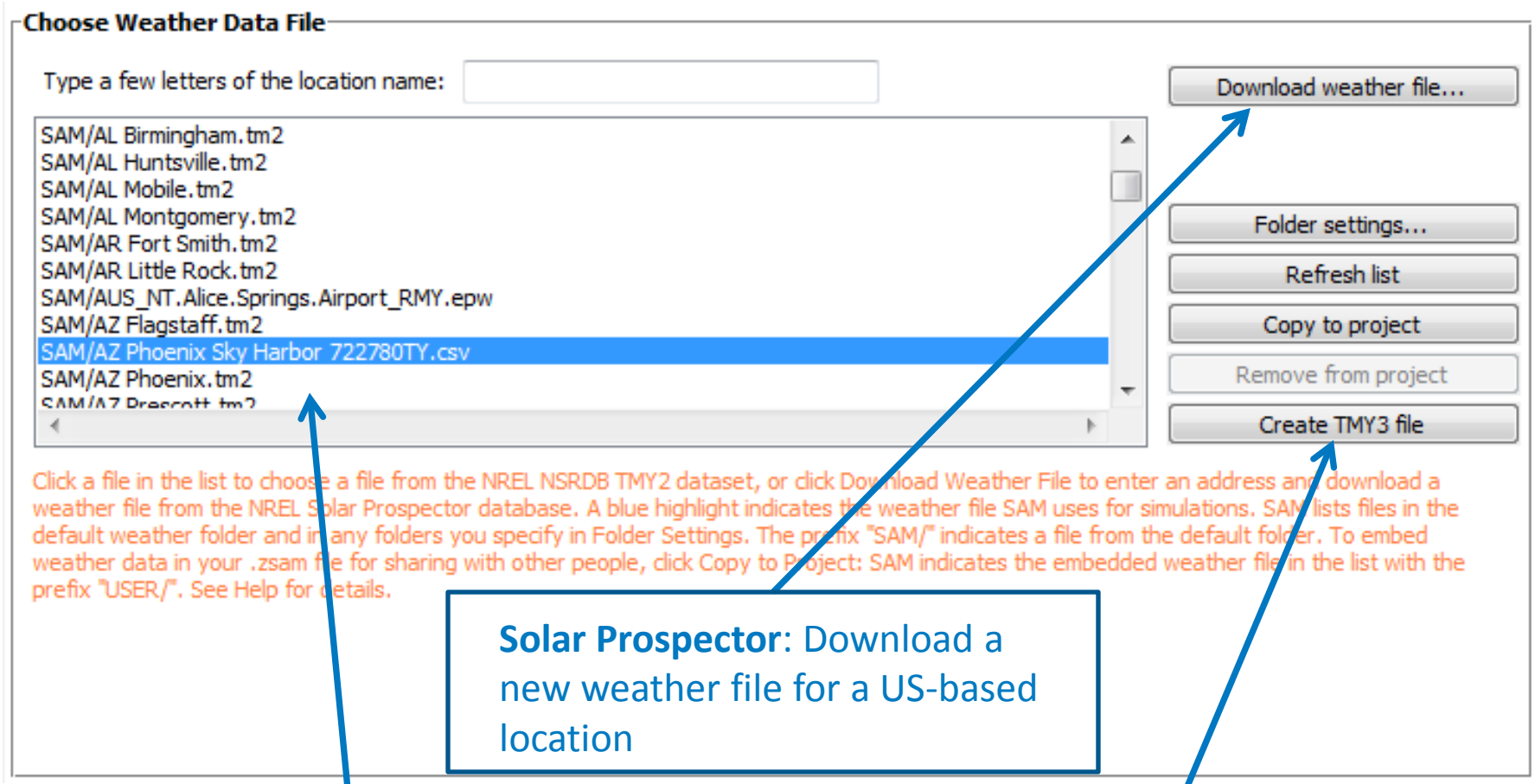
Download a specific year (1998-2009), or TMY, TDY, or TGY made from that 12 year dataset, NOT the same dataset as a TMY2/TMY3!

EPW

- Often best resource data available if location is outside the US and you do not have a weather file.
- Originally collected by EnergyPlus from a variety of international weather sources, a building energy systems modeling tool created by the DOE, and put in a consisten format.

Selecting Resource Data in SAM

System Advisor Model



Solar Prospector: Download a new weather file for a US-based location

TMY2: Select one of the weather files included with SAM

Create TMY3 file from other data (use your own data)

Selecting Resource Data in SAM

System Advisor Model

1

Web Links

SAM reads weather files in the TMY3, TMY2, EPW, and SMW file formats. The default weather folder contains copies of the complete NREL NSRDB TMY2 dataset. You can use the links below to visit websites with other weather files. If you download files from the web, click Folder Settings to choose folders where SAM can find your downloaded weather files. See Help for details.

Best weather data for the U.S. (1200+ locations in TMY3 format)

Best weather data for international locations (in EPW format)

U.S. satellite-derived weather data (10 km grid cells in TMY2 format)

TMY3: Download from NSRDB

EPW

2

View Weather Data

Select a region below to view weather data.

- Africa (WMO Region 1)
- Asia (WMO Region 2)
- South America (WMO Region 3)
- North and Central America (WMO Region 4)
- Southwest Pacific (WMO Region 5)
- Europe (WMO Region 6)

View and download EnergyPlus weather data directly

3

ASHRAE_Copyright_and_IWEC_Lic...	Text Document	2 KB	No
FIN_Tampere.029440_IWEC.ddy	Location and Design Day ...	2 KB	No
FIN_Tampere.029440_IWEC.epw	EPW File	221 KB	No
FIN_Tampere.029440_IWEC.stat	STAT File	10 KB	No

4

Weather Data Settings

Weather File Folders

C:\Users\jwhitmor\SAM Downloaded Weather Files

Add | Remove

Folder for Downloaded Weather Files

C:\Users\jwhitmor/SAM Weather Files ...

OK | Cancel | Help

5

Choose Weather Data File

Type a few letters of the location name:

Download weather file...

SAM/WY Casper.tm2
SAM/WY Cheyenne.tm2
SAM/WY Lander.tm2
SAM/WY Rock Springs.tm2
SAM/WY Sheridan.tm2
C:\Users\jwhitmor\SAM Downloaded Weather Files/DEU_Berlin.103840_IWEC.epw
C:\Users\jwhitmor\SAM Downloaded Weather Files/FIN_Helsinki.029740_IWEC.epw
C:\Users\jwhitmor\SAM Downloaded Weather Files/Golden CO_tmy.tm2
C:\Users\jwhitmor\SAM Downloaded Weather Files/SAM Golden TMY3.csv
C:\Users\jwhitmor\SAM Downloaded Weather Files/SRRL2_Jun10-May11.csv

Folder settings... | Refresh list | Copy to project | Remove from project | Create TMY3 file

Click a file in the list to choose a file from the NREL NSRDB TMY2 dataset, or click Download Weather File to enter an address and download a weather file from the NREL Solar Prospector database. A blue highlight indicates the weather file SAM uses for simulations. SAM lists files in the default weather folder and in any folders you specify in Folder Settings. The prefix "SAM/" indicates a file from the default folder. To embed weather data in your .zsam file for sharing with other people, click Copy to Project: SAM indicates the embedded weather file in the list with the prefix "USER/". See Help for details.

Other International Resource Data

- **India: 7 years of data for 9 locations**
  - 2002-2008
  - Formatted like a TMY3
- **Australia: AUSTELA Solar Data Files**
  - Developed for the Australian Solar Thermal Energy Association
  - Formatted as an EPW file

SEE SAM HELP FOR MORE INFORMATION

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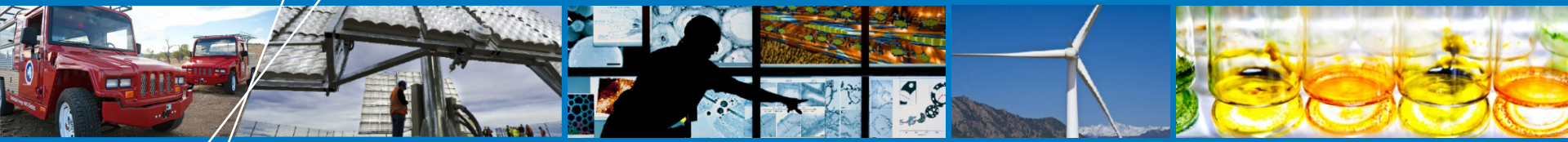


How to Choose a Resource File

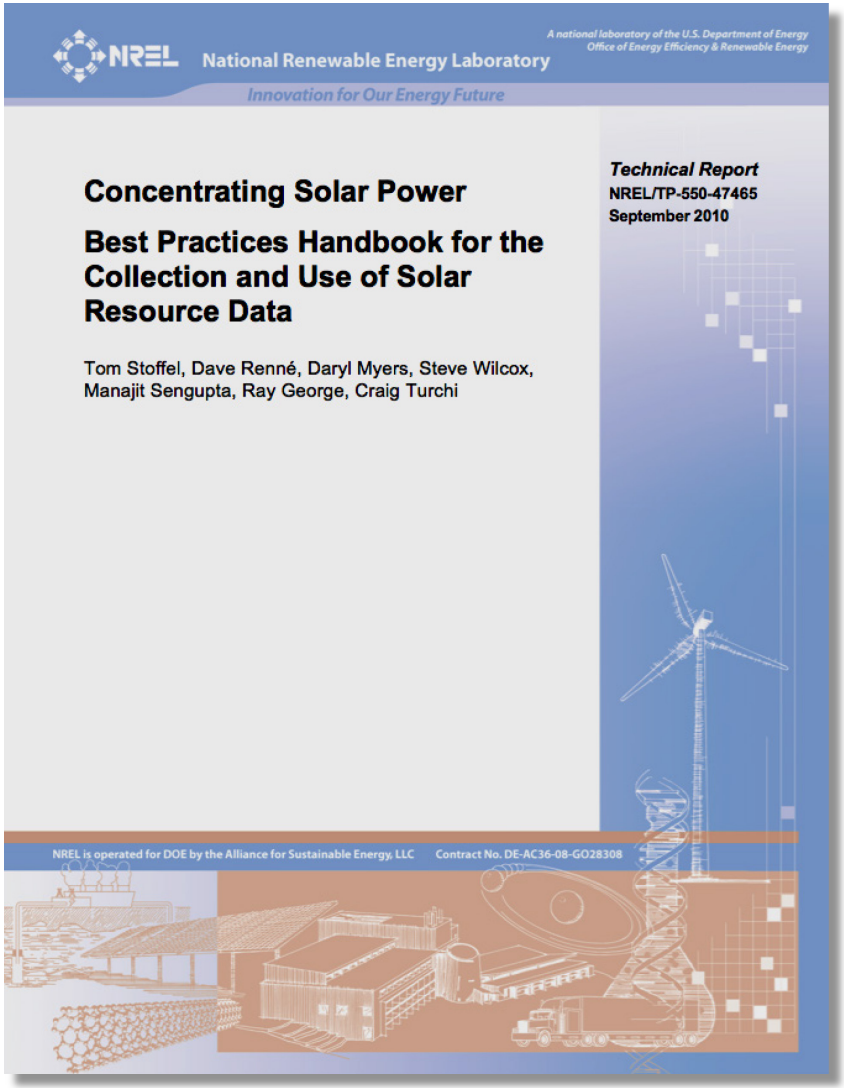
How To Choose a Resource File?

- **Energy Prediction/Feasibility Study: Run as many files as you have!**
  - Closest 2-3 TMY3s
  - Closest 2-3 TMY2s
  - Parametric on multiple years of historical weather data from the Solar Prospector
  - Solar Prospector TMY, TDY, or TGY
  - Measured data for your project
  - Any nearby measured data you can find
- **Design Comparisons: Pick one and be consistent**
- **Historical Comparisons (System Verifications): Use the appropriate year of historical data**

Further Reading

SAM Website →
Resources →
Performance Models →
Weather Data

- CSP Best Practices Handbook →
- TMY2/TMY3 Users Manuals
- EPW Documentation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A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Innovation for Our Energy Future

Technical Report
NREL/TP-550-47465
September 2010

Concentrating Solar Power

Best Practices Handbook for the Collection and Use of Solar Resource Data

Tom Stoffel, Dave Renné, Daryl Myers, Steve Wilcox, Manajit Sengupta, Ray George, Craig Turchi

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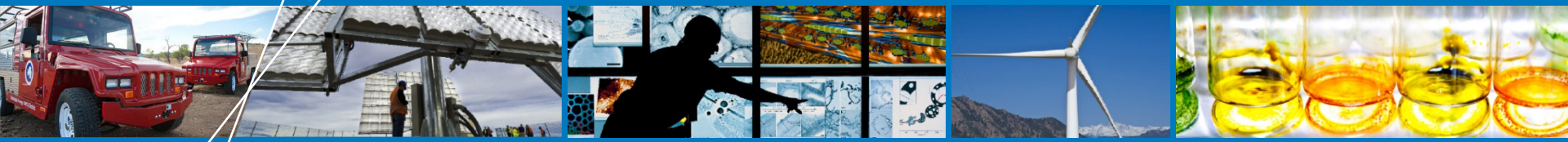

Questions?

Download the full report: