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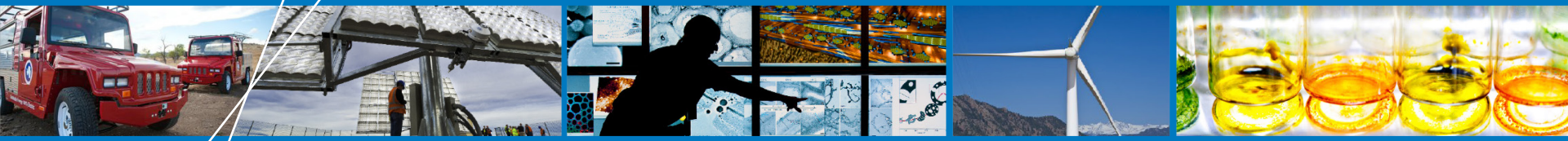
Parametric and Statistical Analysis in SAM



SAM Webinar

Paul Gilman

January 22, 2015

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 2015

System Advisor Model

- **Introduction to New SAM!**
  - Nov 20, 2014: Janine Freeman
- **Sizing Photovoltaic Systems in SAM**
  - Dec 18, 2014: Janine Freeman
- **Parametric and Statistical Analysis in SAM**
  - Jan 22, 2015: Paul Gilman
- **Modeling Power Towers in SAM**
  - Feb 19, 2015: Mike Wagner
- **Scripting in SAM with LK**
  - Mar 19, 2015: Aron Dobos
- **Modeling Wind Systems in SAM**
  - Apr 16, 2015: Janine Freeman
- **SAM's Residential Third Party Financial Model**
  - Aug 20, 2015: Nate Blair
- **Battery Storage for PV Systems in SAM**
  - Sep 17, 2015: Aron Dobos

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

Status of SAM update

- **We're putting finishing touches on an update to SAM:**
  - Improved financial metrics for PPA models
  - Updated CEC PV inverter and module libraries
  - New macros for "combine cases" feature and scaling commercial electric load to monthly bill
  - Fix issues with data viewer and PDF reports
  - Improve listing of output variables
  - Many bug fixes and minor improvements

Webinar Outline

- **Overview**
- **Demonstrations**
  - Using cases for parametric and comparison studies
  - Parametric simulations
  - Stochastic simulations
  - P50/P90 analysis
  - LK script

This webinar describes the techniques for using these features in SAM rather than the theory of their implementation or application.

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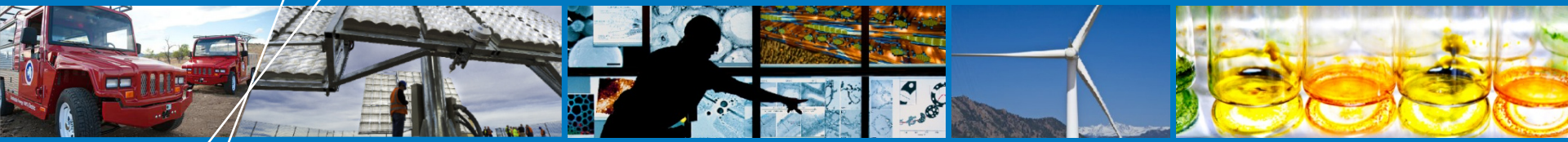


Overview

Baseline or “base case” simulation

System Advisor Model

Run a simulation for a single scenario: One set of inputs and results.

SAM 2015.1.21: F:\SAM Webinars\2015 Webinars\parametric and statistical files\base case.sam

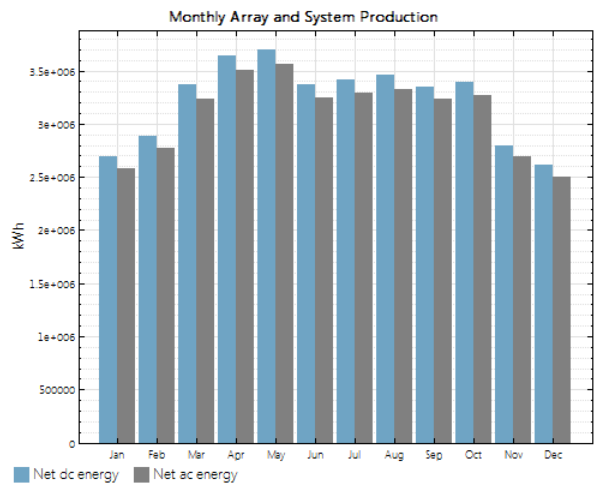
New untitled Help

Photovoltaic, Single owner

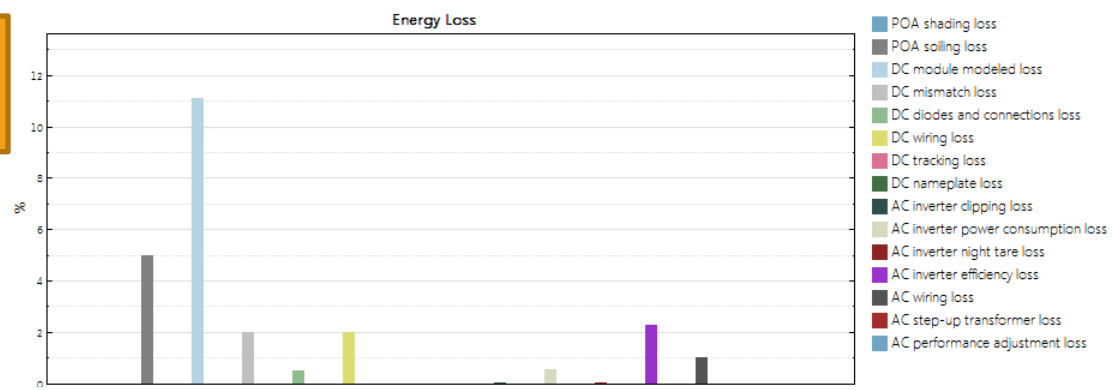
Location and Resource
Module
Inverter
System Design
Shading
Losses
System Costs
Degradation
Financial Parameters
Time of Delivery Factors
Incentives
Depreciation

Summary Losses Graphs Data Cash flow Time series Daily Profiles Statistics Heat map

Metric	Value
Annual energy	37,211,888 kWh
Capacity factor	21.2%
First year kWhAC/kWDC	1,861
Performance ratio	0.82
PPA price (Year 1)	9.64 ¢/kWh
PPA price escalation	1.00 %
Levelized revenue (nominal)	10.38 ¢/kWh
Levelized cost (nominal)	9.97 ¢/kWh
Net present value	$1,422,602
Internal rate of return (IRR)	11.00 %
Year IRR is achieved	20 year
IRR at end of analysis period	11.00 %
Initial cost	$41,060,172
Initial cost less cash incentives	$41,060,172
Equity	$20,088,788
Debt	$20,971,386
Debt fraction	51.07 %



Results for a 20 MW PV system with no shading

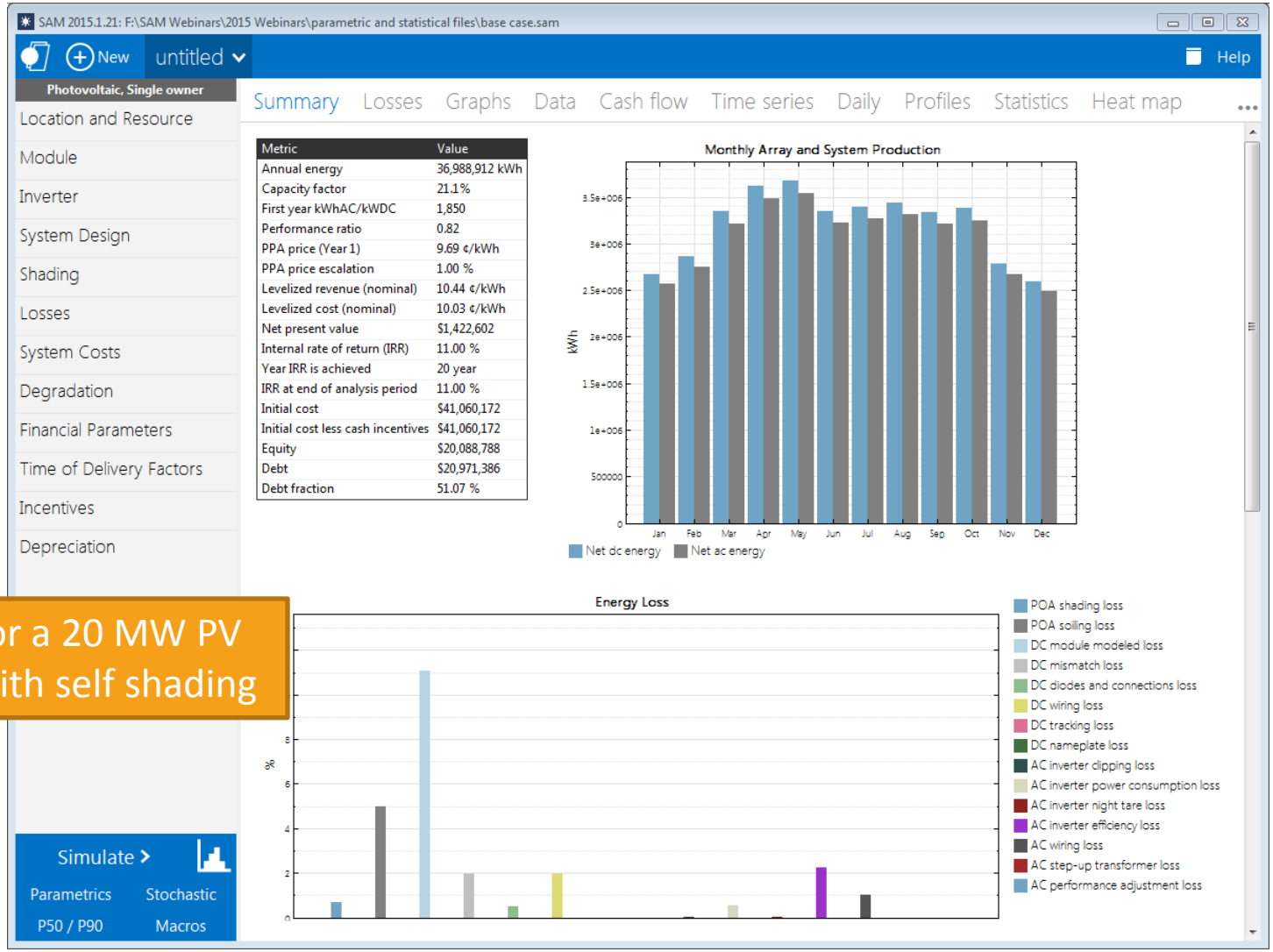


Simulate ›
Parametrics Stochastic
P50 / P90 Macros

Baseline or “base case” simulation

System Advisor Model

You can change values of inputs by hand, run a single simulation, and compare results.



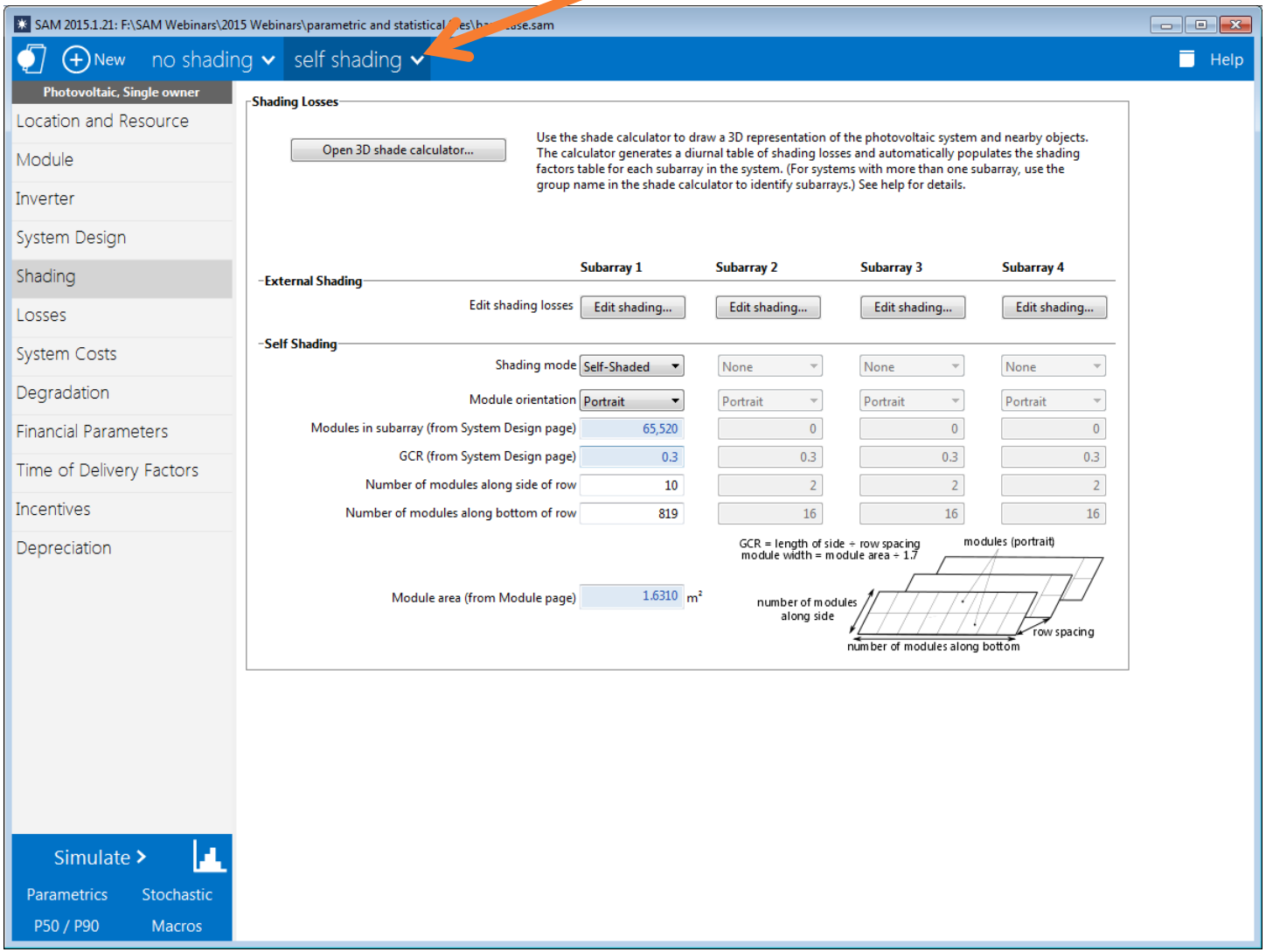
Metric	Value
Annual energy	36,988,912 kWh
Capacity factor	21.1%
First year kWhAC/kWDC	1,850
Performance ratio	0.82
PPA price (Year 1)	9.69 ¢/kWh
PPA price escalation	1.00 %
Levelized revenue (nominal)	10.44 ¢/kWh
Levelized cost (nominal)	10.03 ¢/kWh
Net present value	$1,422,602
Internal rate of return (IRR)	11.00 %
Year IRR is achieved	20 year
IRR at end of analysis period	11.00 %
Initial cost	$41,060,172
Initial cost less cash incentives	$41,060,172
Equity	$20,088,788
Debt	$20,971,386
Debt fraction	51.07 %

Results for a 20 MW PV system with self shading

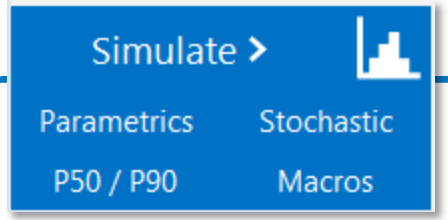
Baseline or “base case” simulation

System Advisor Model

Or, you can create multiple cases to compare different scenarios in a single project file.



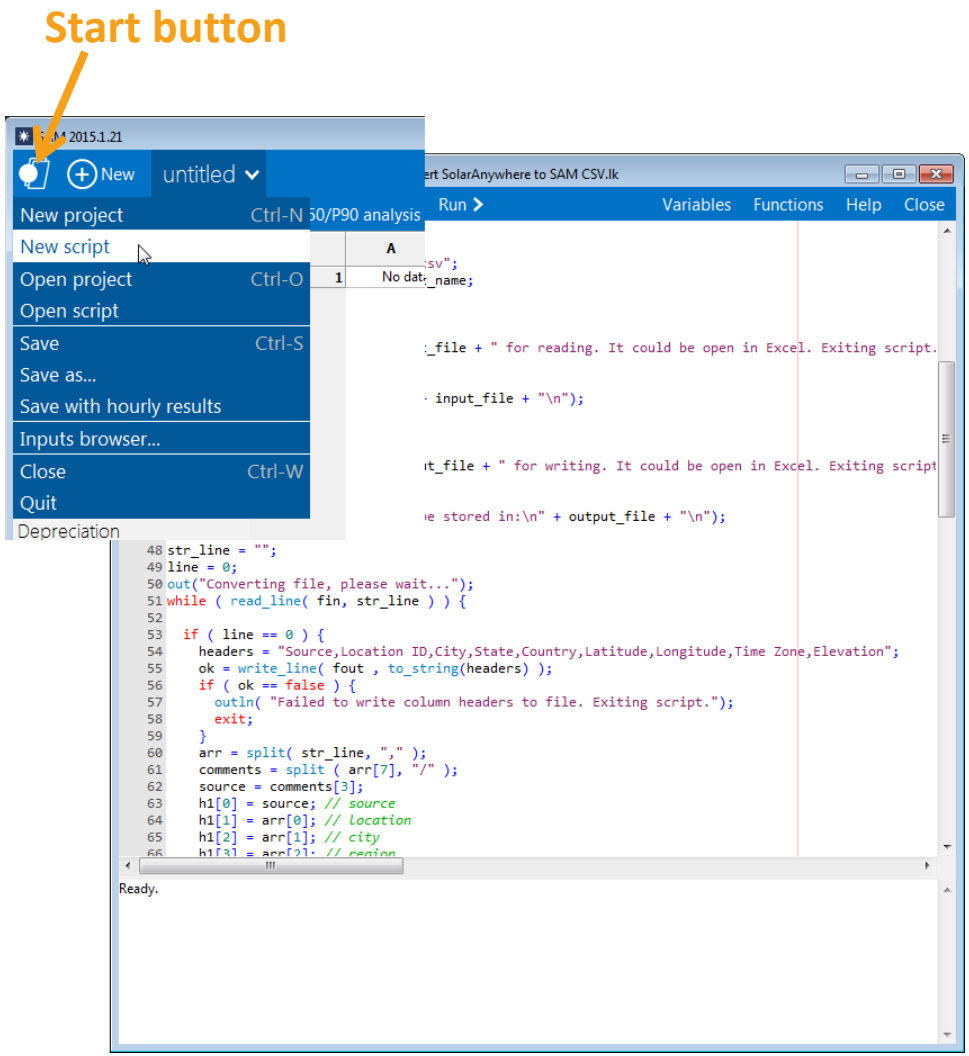
Simulation Options



- **Parametrics:** Use a table to assign multiple values to input variables
- **Stochastic:** Assign a statistical distribution to input variables – SAM calculates a range of input values with results and generates a table of statistical measures
- **P50/P90:** Run simulations with a set of single-year weather files to calculate probability of exceeding different metrics

LK Script

- SAM's built-in scripting language (analogous to Visual Basic in Microsoft applications)
- Most flexible way to control and run simulations, but requires basic knowledge of computer programming
- Includes LHS functions for stochastic analysis
- Different from Software Development Kit, which allows you to control SAM from applications you write in C or other languages



For more on LK, sign up for the webinar on scripting in SAM with LK (March 19, 2015)

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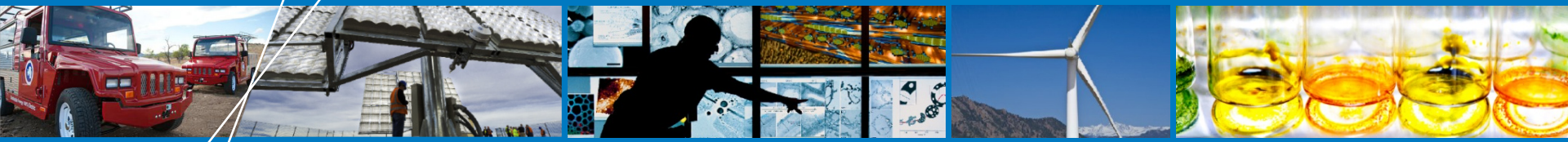
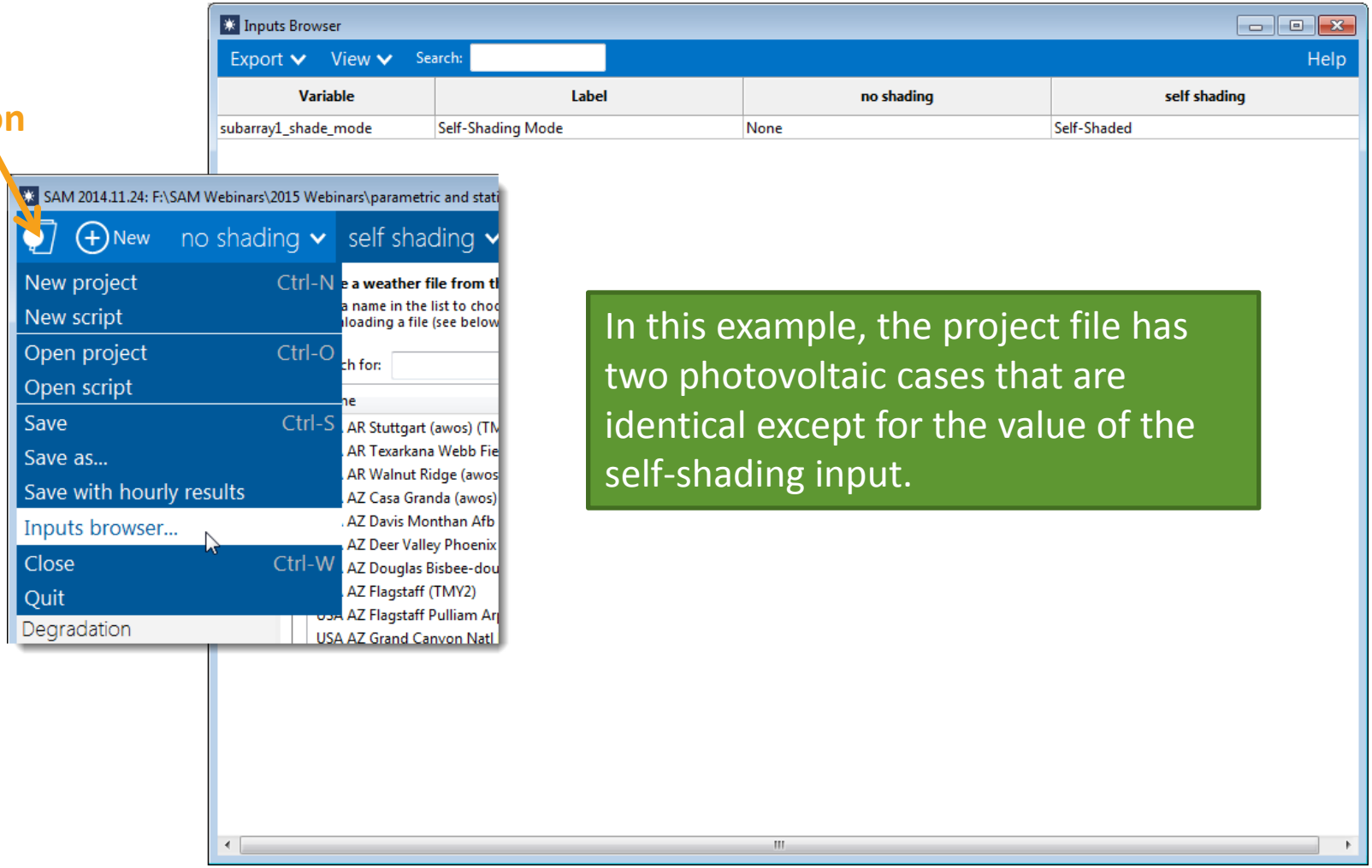


Demonstrations

Compare cases

Use the inputs browser to see a list of all input variables in a case, or, for projects with more than one case, to quickly find variables with different values.

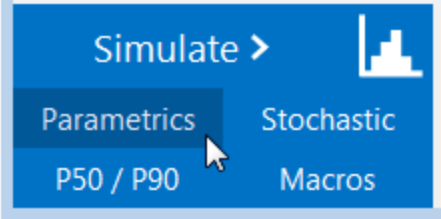
Start button

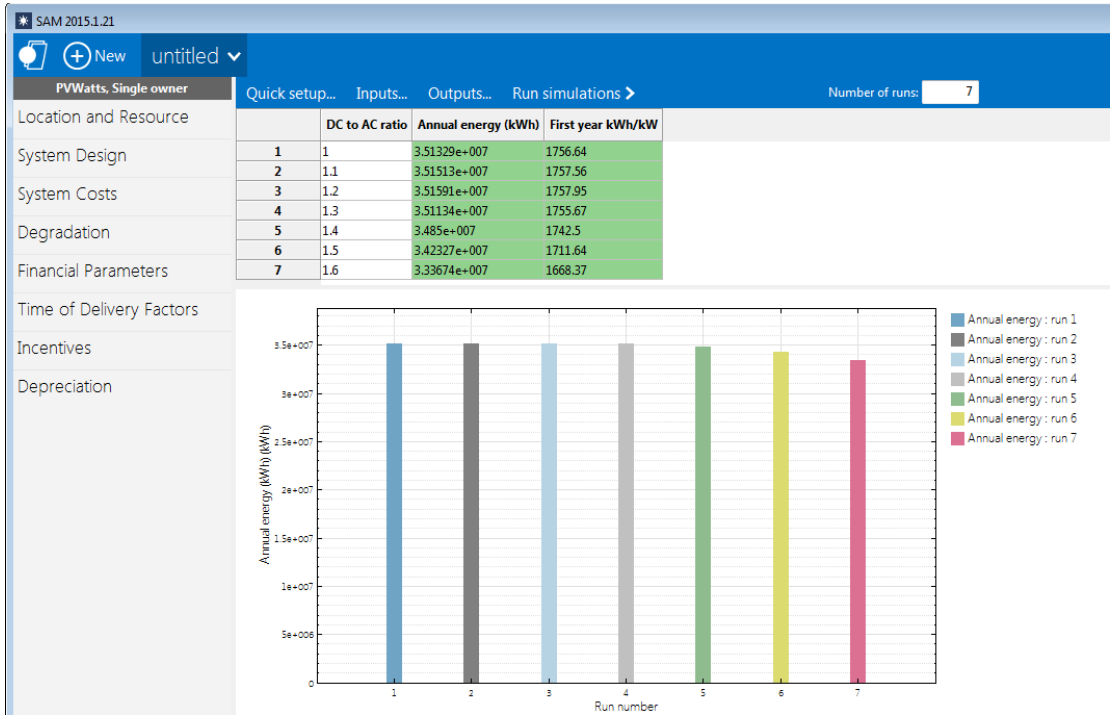


In this example, the project file has two photovoltaic cases that are identical except for the value of the self-shading input.

Parametrics

1. Create a table of input variables with more than one value
2. Choose outputs
3. Run parametric simulations
4. SAM populates table and graphs with results

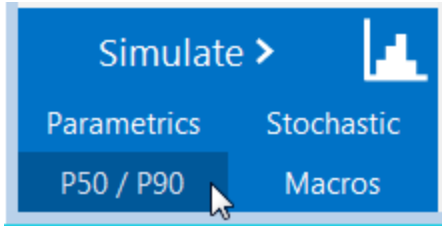




	DC to AC ratio	Annual energy (kWh)	First year kWh/kW
1	1	3.51329e+007	1756.64
2	1.1	3.51513e+007	1757.56
3	1.2	3.51591e+007	1757.95
4	1.3	3.51134e+007	1755.67
5	1.4	3.485e+007	1742.5
6	1.5	3.42327e+007	1711.64
7	1.6	3.33674e+007	1668.37

P50/P90

1. Put a set of single year weather files for the location in a folder on your computer
2. Select the folder
3. Run P50/P90 analysis
4. SAM populates table with results



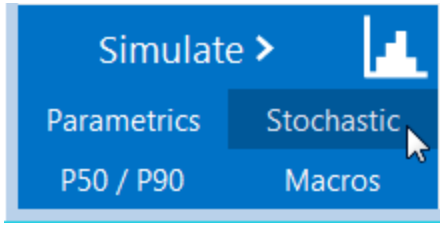
Run P50/P90 analysis > Select weather file folder: F:\SAM P50 P90 ...

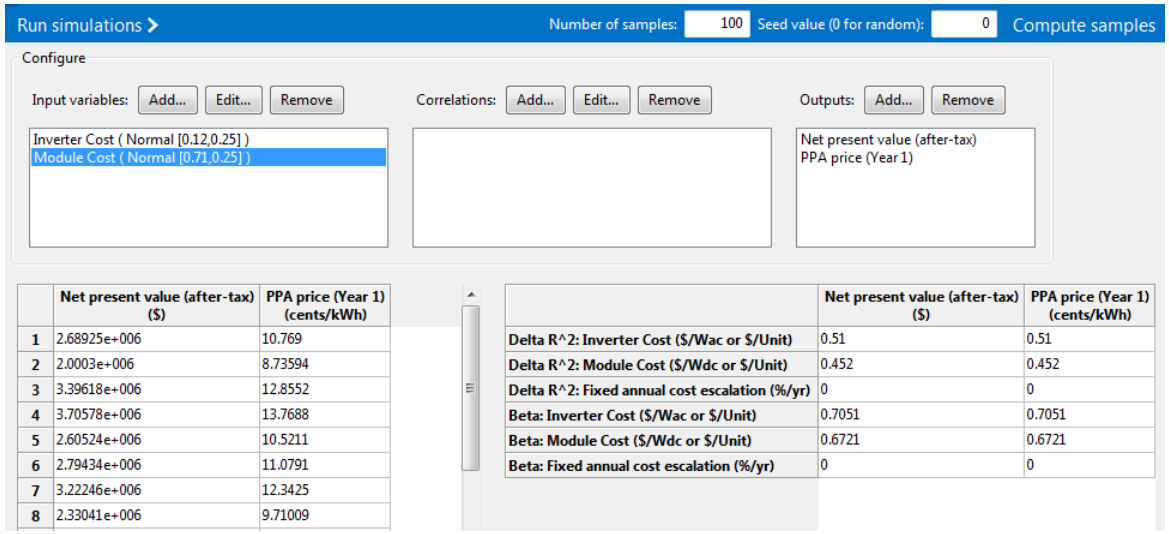
	P50	P90	Min	Max	StdDev	P50-norm	P90-norm
Daily average solar irradiance (kWh/m2/day)	6.53636	6.19959	5.87185	6.73396	0.1967	6.50206	6.24989
Annual AC system output (kWh)	3.49899e+007	3.32423e+007	3.17921e+007	3.63578e+007	1.03829e+006	3.48735e+007	3.35424e+007
Annual energy (kWh)	3.49899e+007	3.32423e+007	3.17921e+007	3.63578e+007	1.03829e+006	3.48735e+007	3.35424e+007
Capacity factor (%)	19.9714	18.9739	18.1462	20.7522	0.592631	19.905	19.1452
First year kWh/kW	1749.5	1662.11	1589.6	1817.89	51.9144	1743.67	1677.12
First year energy from the system in TOD period 1	3.49899e+007	3.32423e+007	3.17921e+007	3.63578e+007	1.03829e+006	3.48735e+007	3.35424e+007
First year energy price for TOD period 1	0.00109325	0.00105925	0.0010523	0.00120342	3.39575e-005	0.00109806	0.00105453
PPA price in first year (cents/kWh)	10.9325	10.5925	10.523	12.0342	0.339575	10.9806	10.5453
Levelized cost (real) (cents/kWh)	8.81392	8.53981	8.48373	9.70209	0.273769	8.85269	8.50172
Levelized cost (nominal) (cents/kWh)	11.1435	10.7969	10.726	12.2664	0.346128	11.1925	10.7488
Levelized revenue (real) (cents/kWh)	9.42246	9.12943	9.06948	10.372	0.292671	9.46391	9.08871
Levelized revenue (nominal) (cents/kWh)	11.9129	11.5424	11.4666	13.1133	0.370026	11.9653	11.4909
PPA price (Year 1) (cents/kWh)	10.9325	10.5925	10.523	12.0342	0.339575	10.9806	10.5453
Present value annual energy (nominal) (kWh)	3.54543e+008	3.36835e+008	3.2214e+008	3.68403e+008	1.05207e+007	3.53363e+008	3.39875e+008
Present value of annual energy (real) (kWh)	4.48251e+008	4.25863e+008	4.07284e+008	4.65775e+008	1.33014e+007	4.4676e+008	4.29707e+008

Tip: Single year historical data from the National Solar Radiation Database for U.S. locations is avialable on the SAM Website: https://sam.nrel.gov/NSRDB

Stochastic

1. Add input variables and define statistical distribution
2. Add any correlated variables
3. Compute samples
4. Run stochastic simulations
5. SAM populates table with results and statistical metrics



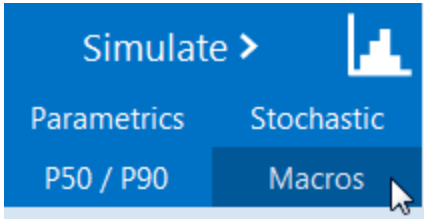


	Net present value (after-tax) ($)	PPA price (Year 1) (cents/kWh)
1	2.68925e+006	10.769
2	2.0003e+006	8.73594
3	3.39618e+006	12.8552
4	3.70578e+006	13.7688
5	2.60524e+006	10.5211
6	2.79434e+006	11.0791
7	3.22246e+006	12.3425
8	2.33041e+006	9.71009

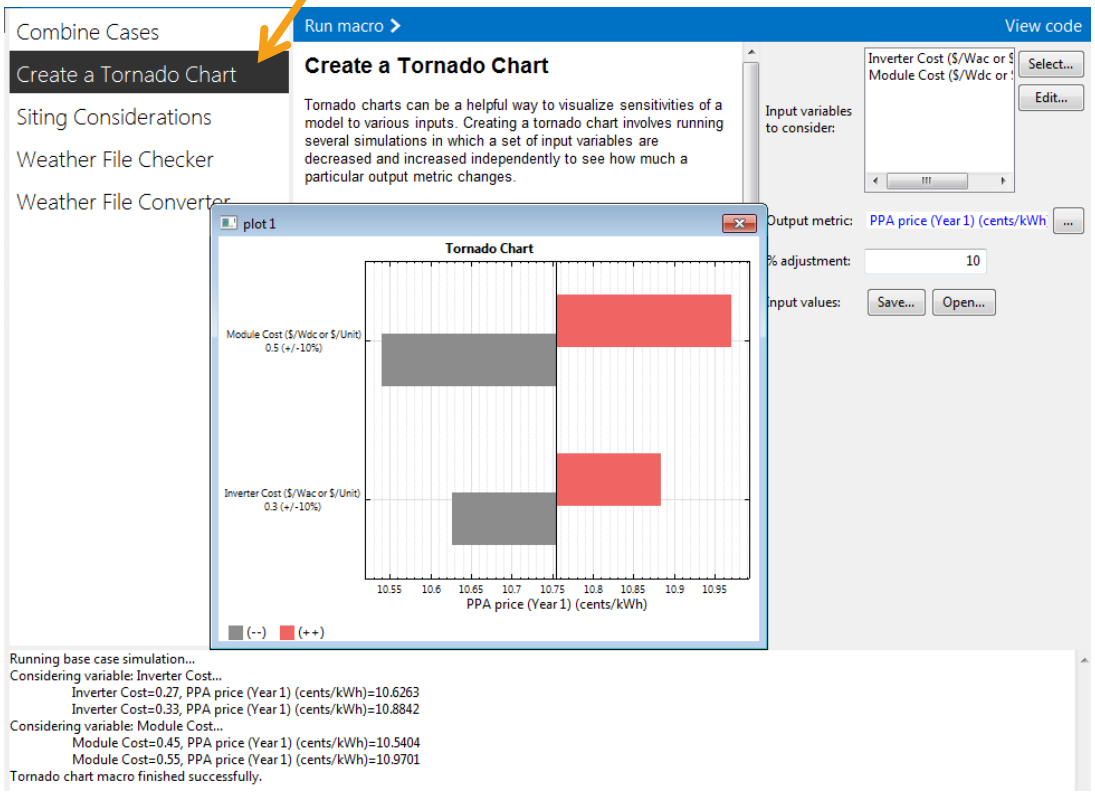
	Net present value (after-tax) ($)	PPA price (Year 1) (cents/kWh)
Delta R^2: Inverter Cost ($/Wac or $/Unit)	0.51	0.51
Delta R^2: Module Cost ($/Wdc or $/Unit)	0.452	0.452
Delta R^2: Fixed annual cost escalation (%/yr)	0	0
Beta: Inverter Cost ($/Wac or $/Unit)	0.7051	0.7051
Beta: Module Cost ($/Wdc or $/Unit)	0.6721	0.6721
Beta: Fixed annual cost escalation (%/yr)	0	0

LK: Tornado Chart Macro

1. Choose input variables
2. Choose an output metric
3. Change the % adjustment (if desired)
4. Click Run Macro



Choose the macro name



You can write your own scripts – click View Code to see how this one was written, or to modify it.