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Sizing Photovoltaic Systems in SAM

SAM Webinar

Janine Freeman

December 18, 2014

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

Webinar Outline

- PV Sizing Demo
- DC to AC System Sizing
- Sizing Distributed Systems for an Electric Load
- Limitations of SAM for System Sizing
- Q & A

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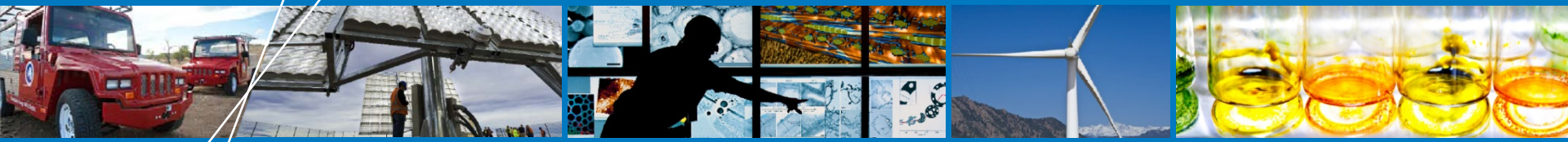


PV Sizing Demo

Defining System Size

$$Nameplate\ capacity\ in\ SAM = DC\ capacity\ of\ PV\ modules\ (kW)$$

$$DC - AC\ Ratio = \frac{DC\ capacity\ of\ PV\ modules\ (kW)}{AC\ capacity\ of\ inverters\ (kW)}$$

DC-AC Ratio Limitations

System Advisor Model

EXAMPLE

PV Panel: 215 kW DC

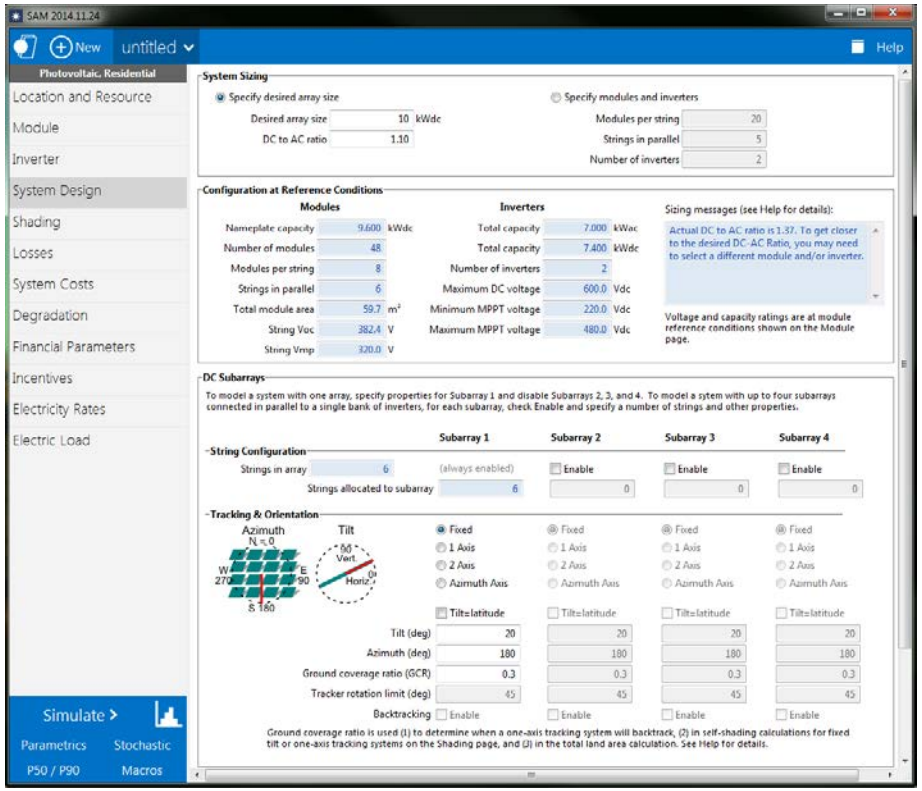
Inverter: 36 kW AC

Desired system size: 100 kW DC
Desired DC-AC ratio: 1

Number of modules:	58	Number of modules:	58
Number of inverters:	3	Number of inverters:	2
Actual DC-AC ratio:	0.92	Actual DC-AC ratio:	1.39

Images from http://www.lowcarboneconomy.com/profile/sec_industrial_battery_co_ltd/_products_and_services/sec-s_series_photovoltaic_panels/9213 and http://solarenergy.advanced-energy.com/commercial-solar-inverters/AE-500TX

PV Sizing Demo in SAM



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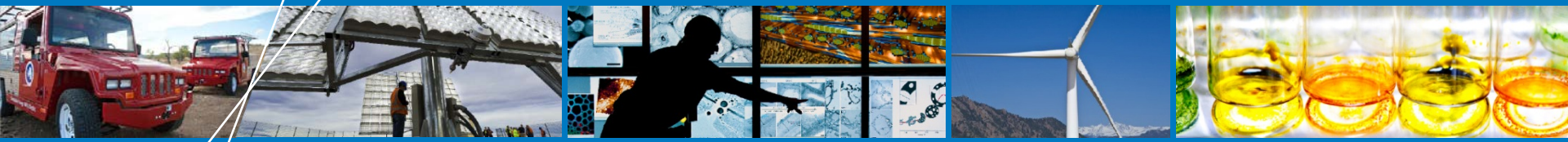


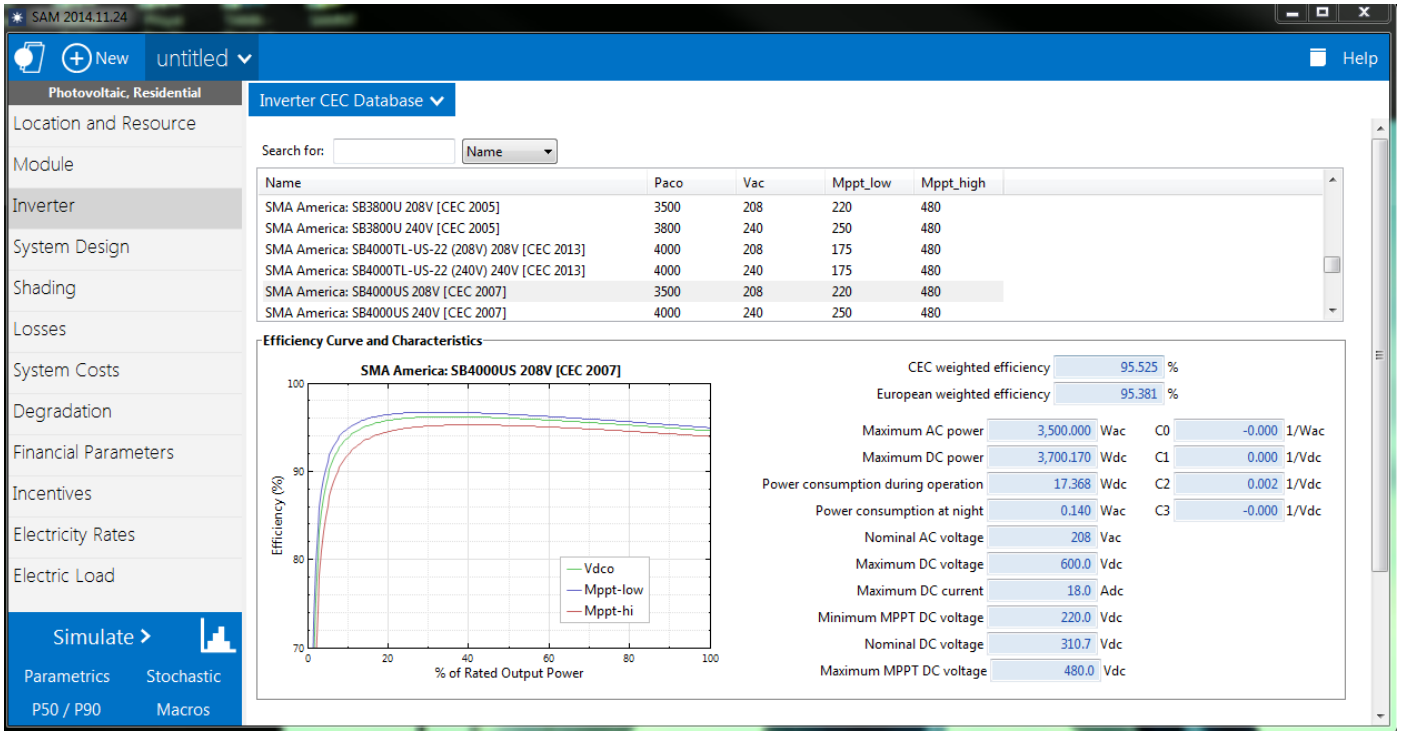
DC to AC System Sizing

Selecting a DC-AC Ratio

System Advisor Model

Ideal DC-AC ratio isn't always 1:

- Price difference in inverter sizes
- Inverter efficiency- inverter's kW-DC rating

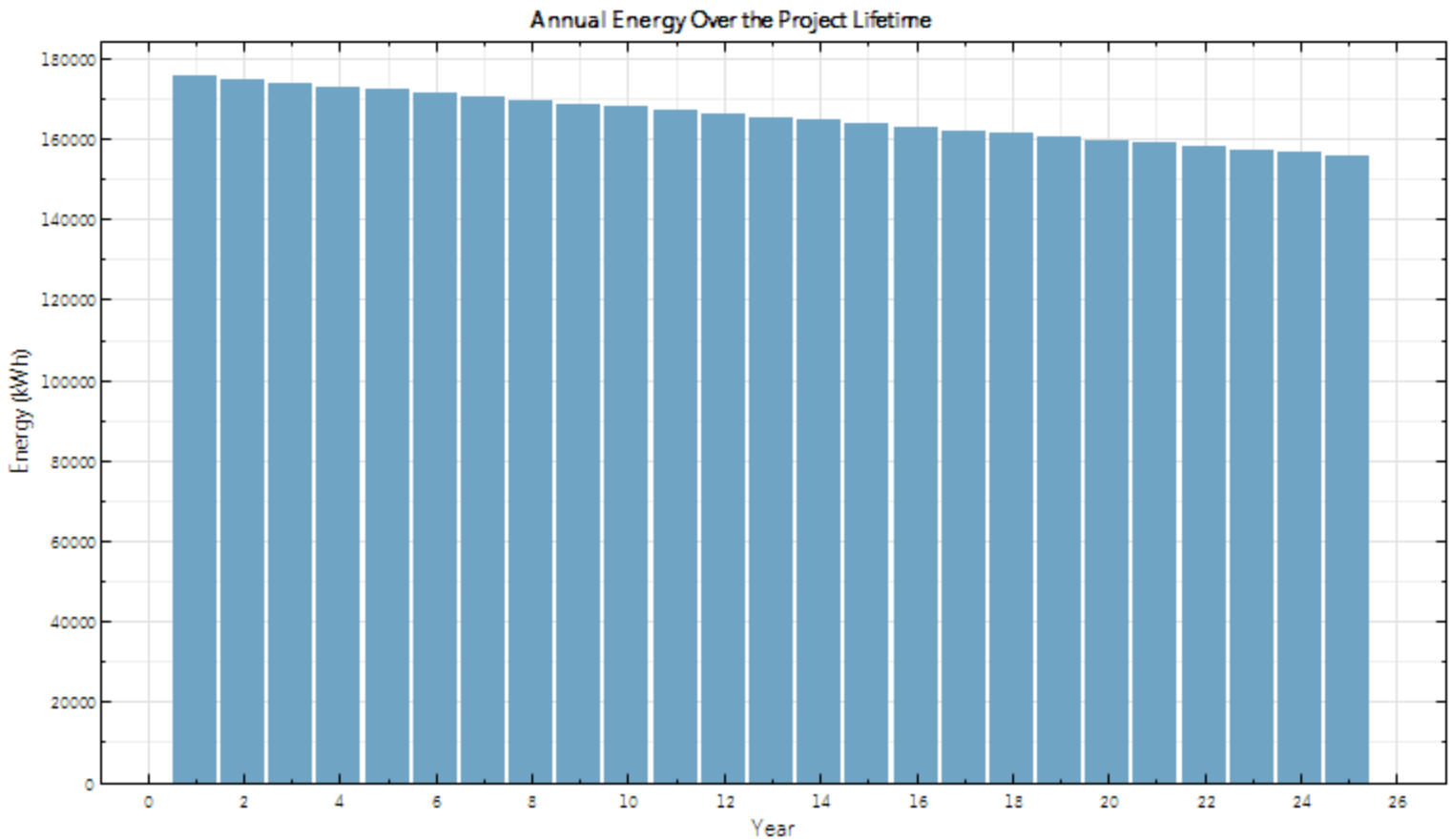


Selecting a DC-AC Ratio

System Advisor Model

Ideal DC-AC ratio isn't always 1:

- Planning for degradation of PV modules

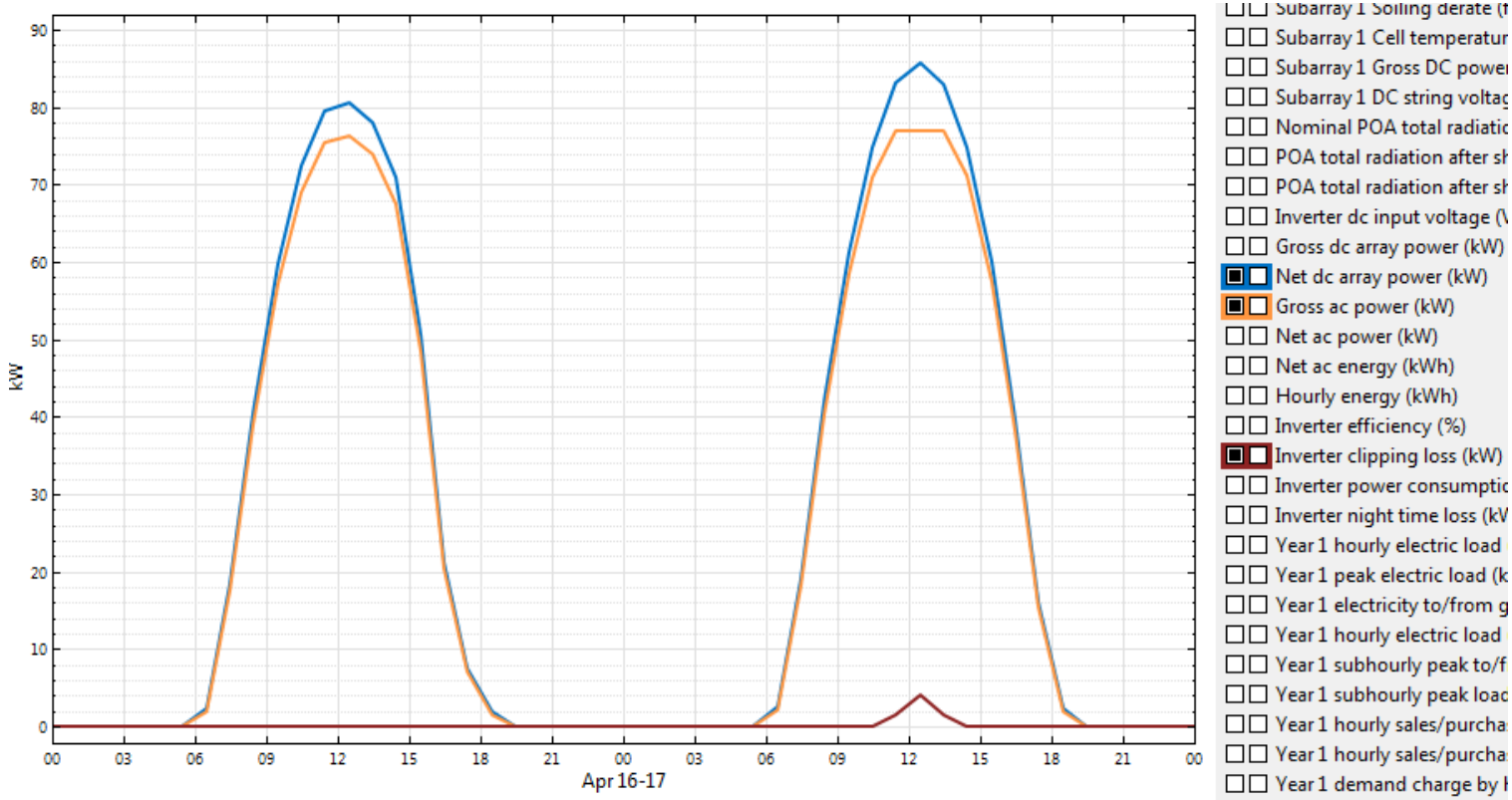


Selecting a DC-AC Ratio

System Advisor Model

Ideal DC-AC ratio isn't always 1:

- Infrequent occurrence of rated module conditions (aka planning for inverter clipping)



Selecting a DC-AC Ratio

Inverter Voltage Specifications

- System performance is reduced if the inverter is not operating within MPPT range
- Inverter could be damaged or warranty could be voided if DC system voltage exceeds maximum inverter rated voltage

SAM's Inverter Sizing Information Macro

System Advisor Model

Inverter Sizing Results

Inverter Sizing Information

DC-AC Ratio

- The nameplate DC-AC ratio is defined as the rated capacity of the modules (W-DC) to the rated capacity of the inverters (W-AC).
- The effective Year 1 DC-AC ratio is computed after light-induced degradation has been applied.
- The effective Year 25 DC-AC ratio is computed after light-induced degradation and annual module degradation have been applied. Assumes no inverter degradation.

Nameplate DC-AC Ratio	4.57143
Effective DC-AC Ratio, Year 1	4.52571
Effective DC-AC Ratio, Year 25	0.3249

First Year Inverter Clipping

There are multiple ways to reduce inverter clipping. You can choose a larger capacity inverter, increase the number of inverters, reduce the number of modules, or reduce the number of modules per string. Some inverter clipping may be financially worthwhile in order to avoid the additional cost of increasing your inverter size, or to produce more power with the same inverter in the rest of the hours of the year.

Number of Hours Clipped	2979
Total kWh (AC) lost	126553
% of DC Power lost	53.0916

Inverter MPPT Performance

System performance is reduced if the inverter is not operating within its MPPT range. Additionally, if the maximum voltage of the inverter is exceeded, this could damage the inverter and/or void the warranty. Exceeding voltage limits may be mitigated by selecting an inverter with different voltage limits, selecting a different size module, or reducing the number of modules per string.

Inverter Specifications	V	Actual System Voltages	Subarray 1	Subarray 2	Subarray 3
MPPT Voltage Minimum	220	Actual Voltage Minimum	355.383	357.609	353.564
MPPT Voltage Maximum	480	Actual Voltage Maximum	502.383	502.827	503.162
Maximum Allowable Voltage	600	Actual Maximum Voltage	502.383	502.827	503.162

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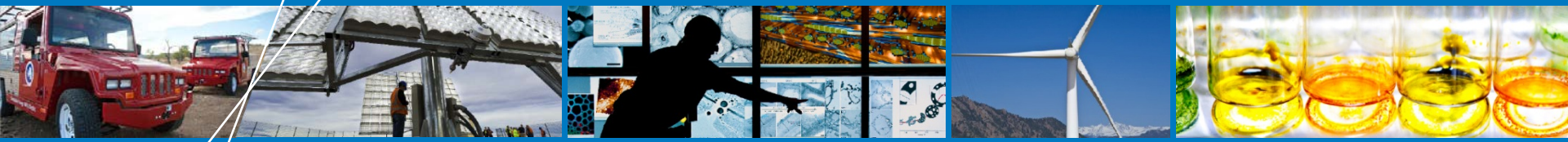
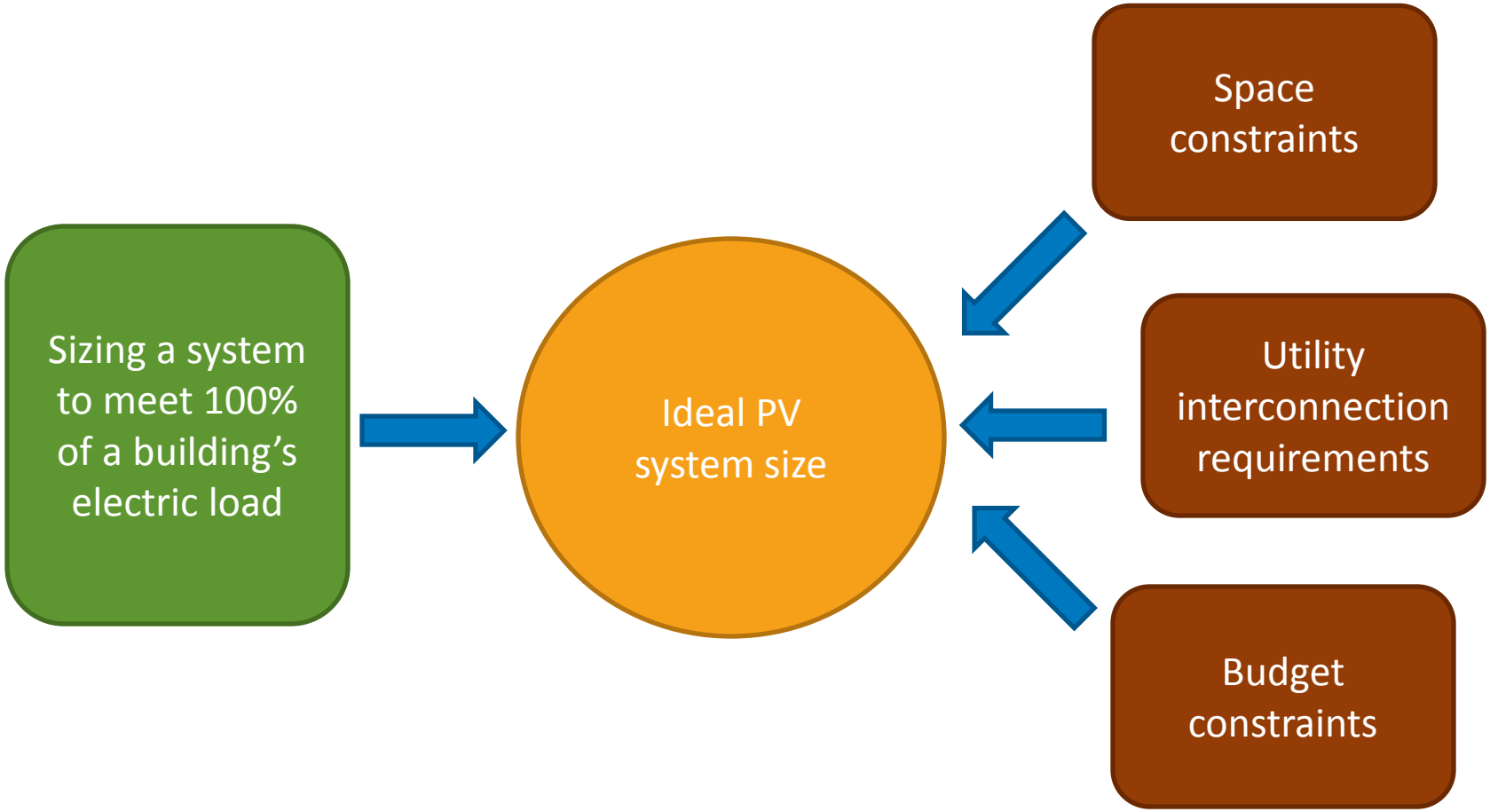


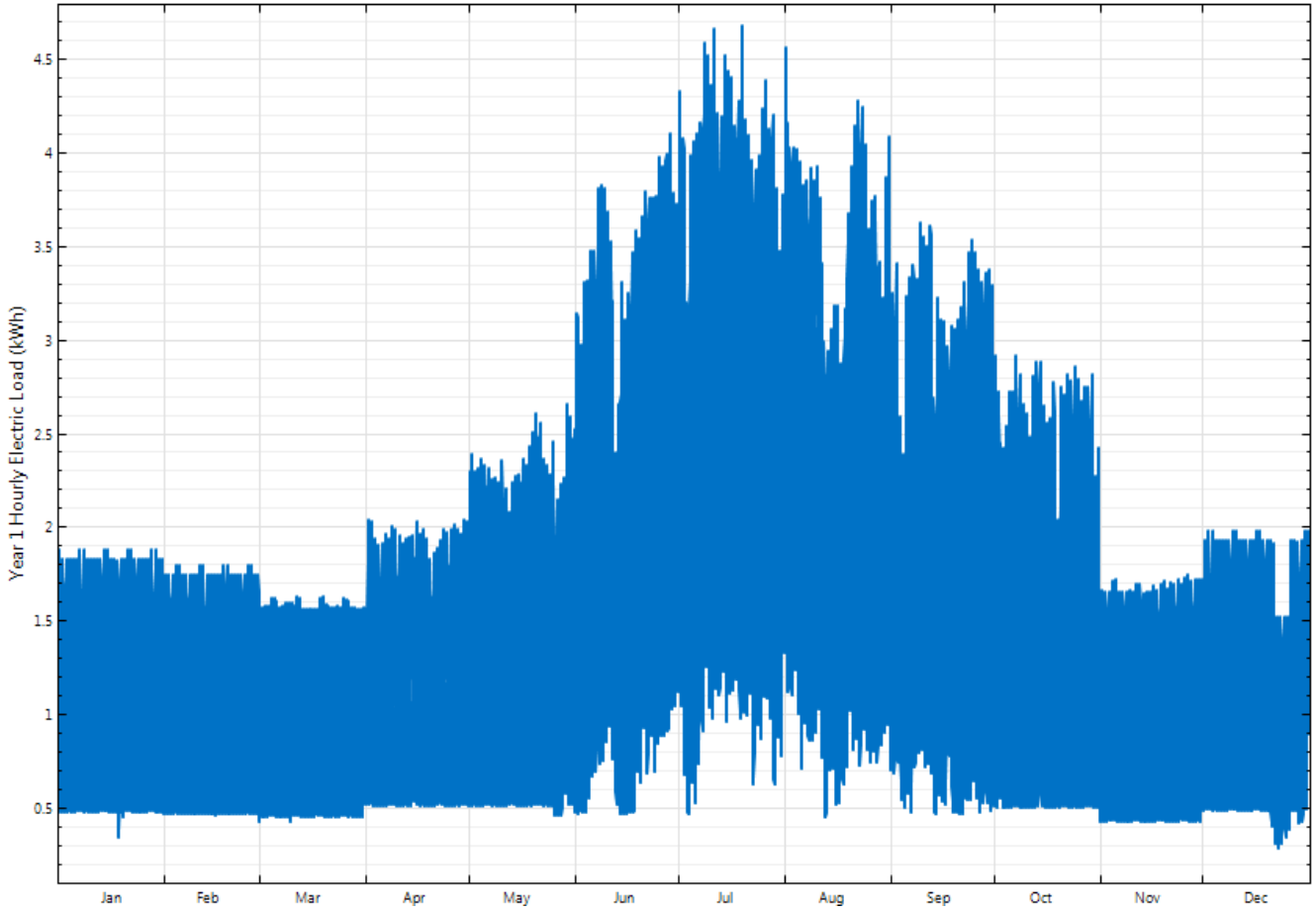
Sizing Distributed Systems for an Electric Load

Distributed PV Sizing Considerations

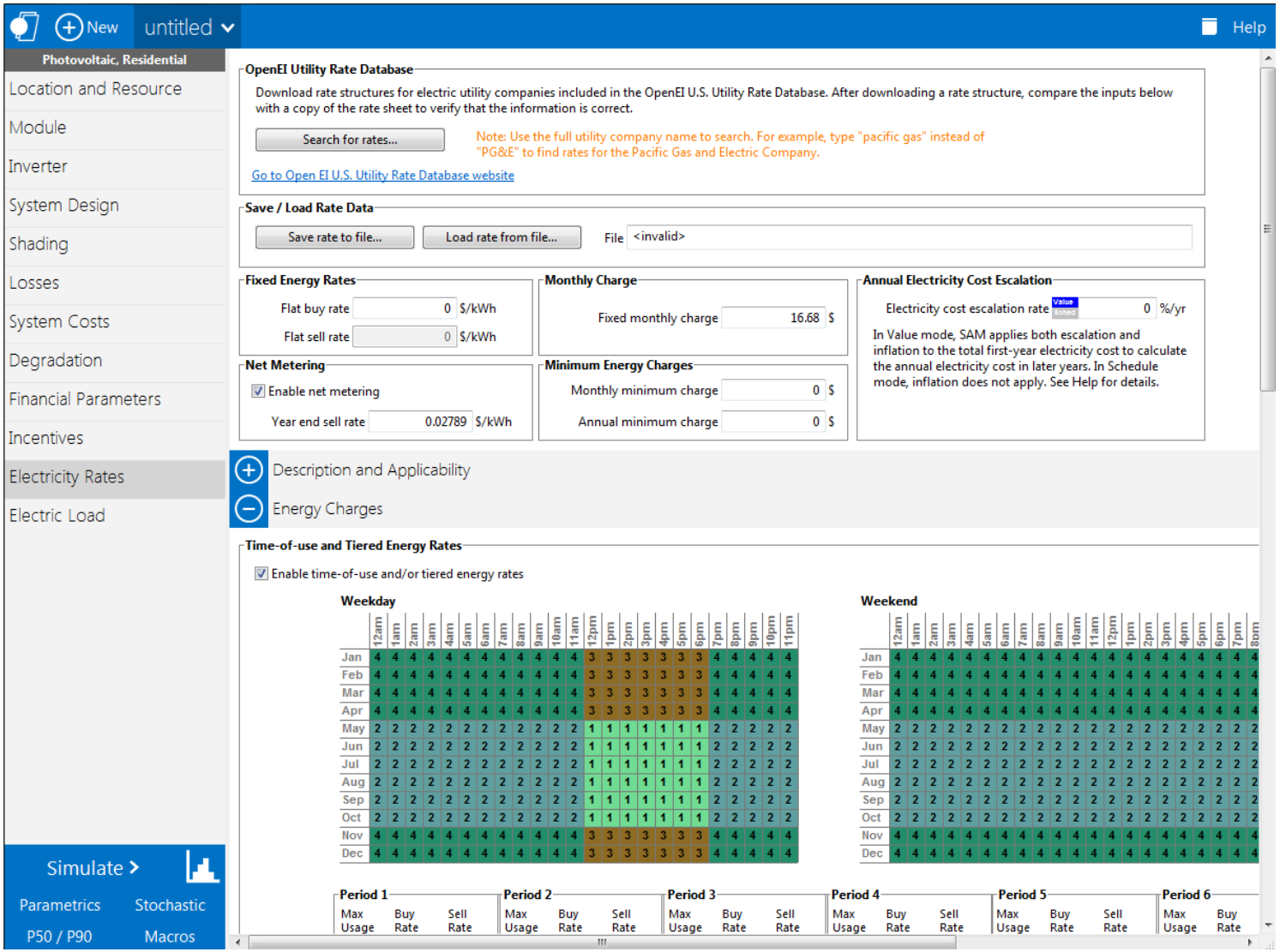
System Advisor Model



Electric Load Input Options Demo



Electricity Rates



Budget Constraints

System Advisor Model

New untitled Help

Photovoltaic, Residential

- Location and Resource
- Module
- Inverter
- System Design
- Shading
- Losses
- System Costs
- Degradation
- Financial Parameters
- Incentives
- Electricity Rates
- Electric Load

Simulate >

Parametrics | Stochastic | P50 / P90 | Macros

Direct Capital Costs

Module	35	units	0.200	kWdc/unit	7.0	kWdc	0.70	$/Wdc	$ 4,900.00
Inverter	2	units	3.500	kWac/unit	7.0	kWac	0.33	$/Wdc	$ 2,310.00

	$		$/Wdc		$/m²		
Balance of system equipment	0.00		0.82		0.00		$ 5,740.00
Installation labor	0.00	+	0.30	+	0.00	=	$ 2,100.00
Installer margin and overhead	0.00		0.95		0.00		$ 6,650.00
						Subtotal	$ 21,700.00

Contingency

Contingency	0	% of subtotal	$ 0.00
		Total direct cost	$ 21,700.00

Indirect Capital Costs

	% of direct cost		$/Wdc		$		
Permitting and environmental studies	0		0.10		0.00		$ 700.00
Engineering	0	+	0.00	+	0.00	=	$ 0.00
Grid interconnection	0		0.00		0.00		$ 0.00

Land Costs

Land area	0.0	acres						
Land purchase	$ 0/acre	+	0	+	0.00	+	0.00	=	$ 0.00
Land preparation	$ 0/acre		0		0.00		0.00		$ 0.00

Sales Tax

Sales tax basis	58	Sales tax rate	5.0	%	$ 629.30
				Total indirect cost	$ 1,329.30

Total Installed Cost

Total installed cost	$ 23,029.30
Total installed cost per capacity	$ 3.29/Wdc

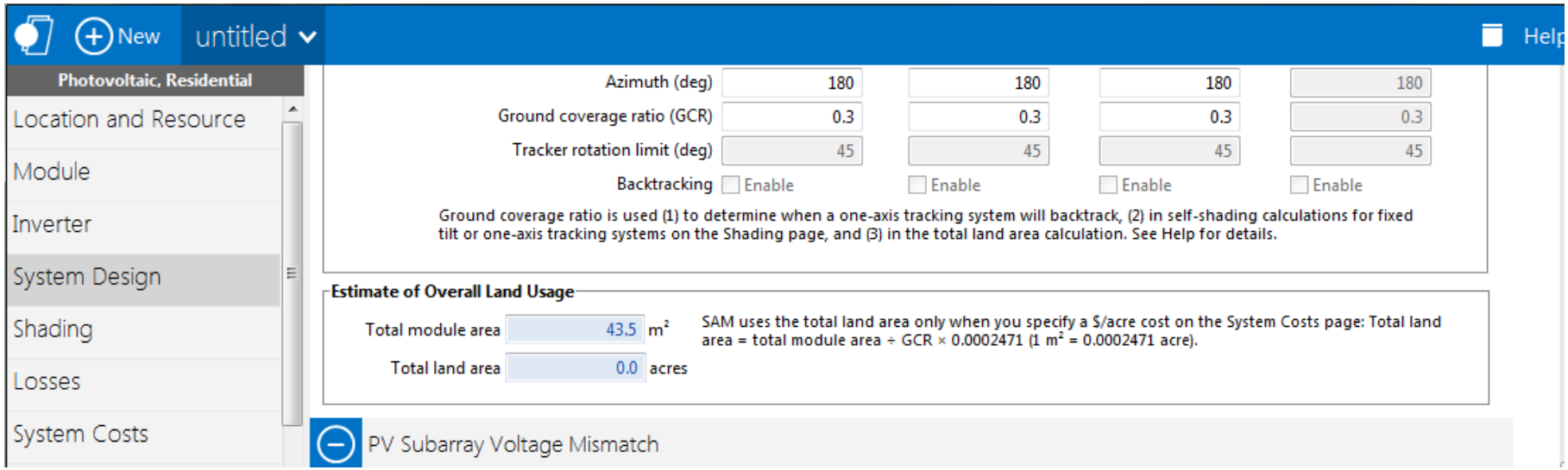
Operation and Maintenance Costs

		First year cost		Escalation rate (above inflation)
Fixed annual cost	Value / Solved	0	$/yr	0 %
Fixed cost by capacity	Value / Solved	20	$/kW-yr	0 %
Variable cost by generation	Value / Solved	0	$/MWh	0 %

In Value mode, SAM applies both inflation and escalation to the first year cost to calculate out-year costs. In Schedule mode, neither inflation nor escalation applies. See Help for details.

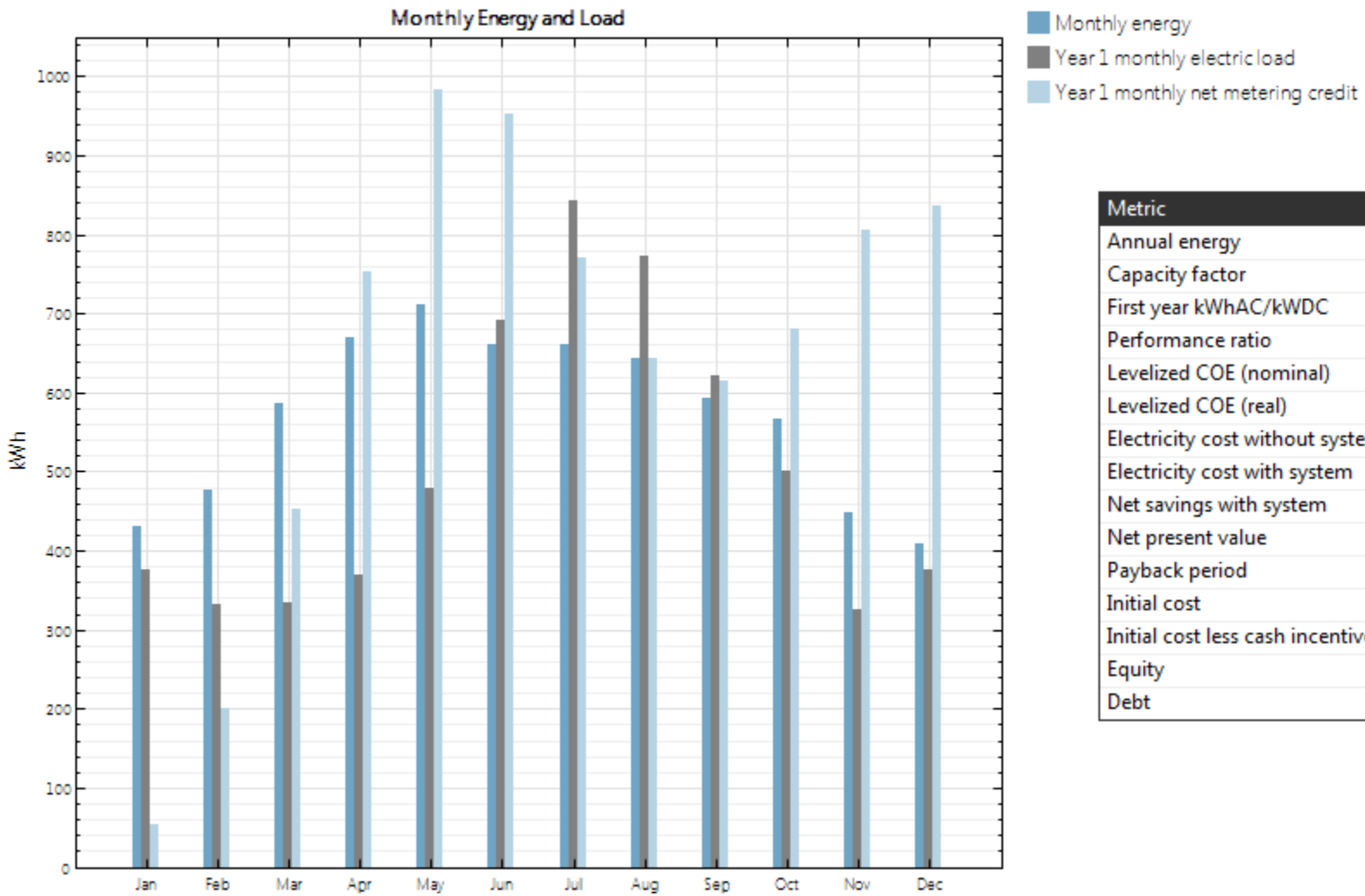
Space Constraints

System Advisor Model



Comparing Results

System Advisor Model

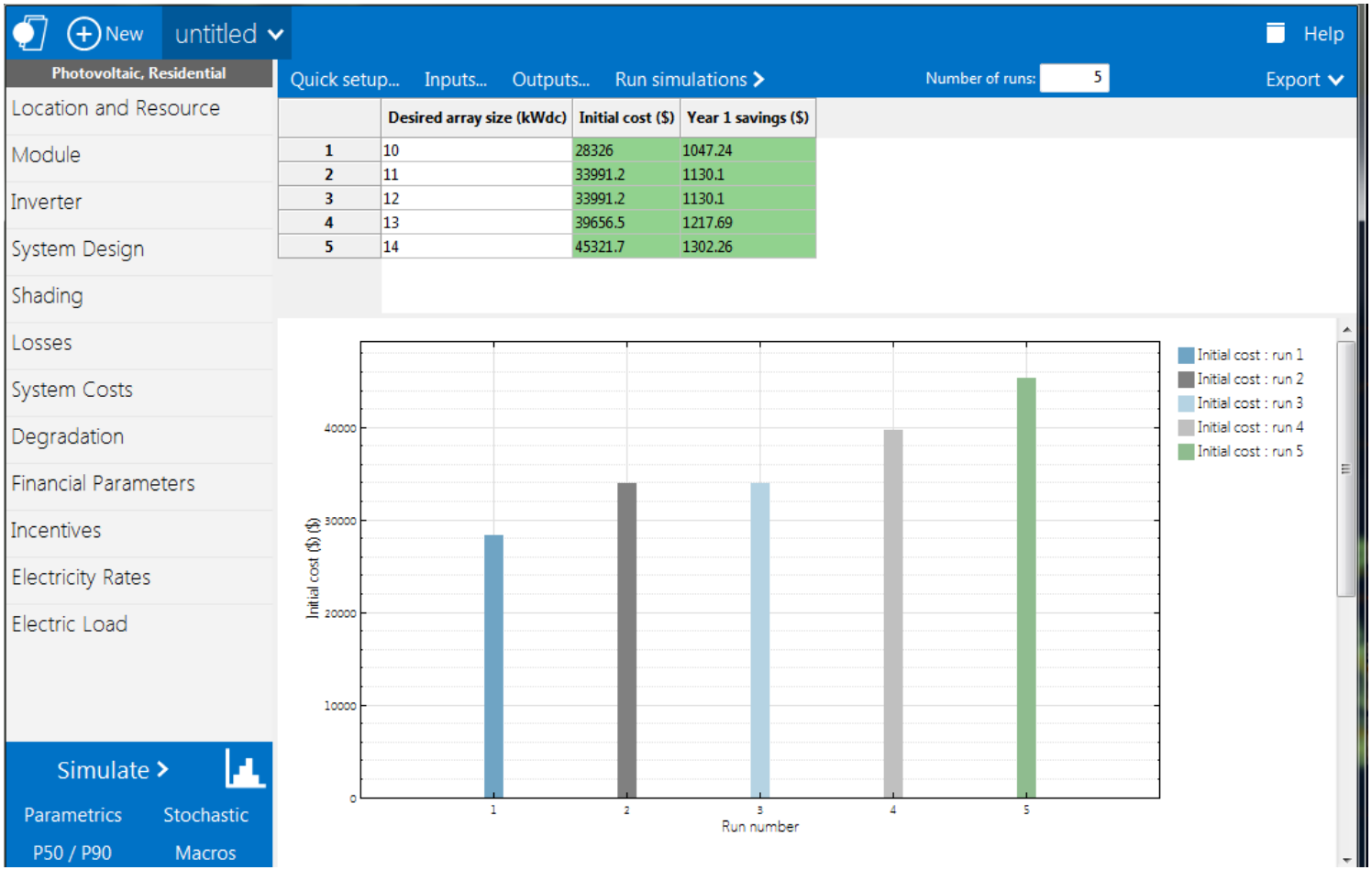


Metric	Value
Annual energy	6,857 kWh
Capacity factor	20.2%
First year kWhAC/kWDC	1,770
Performance ratio	0.79
Levelized COE (nominal)	8.23 ¢/kWh
Levelized COE (real)	6.51 ¢/kWh
Electricity cost without system	$973
Electricity cost with system	$160
Net savings with system	$813
Net present value	$4,783
Payback period	11.1 years
Initial cost	$12,747
Initial cost less cash incentives	$12,747
Equity	$0
Debt	$12,747

Optimizing Your System Size

System Advisor Model

Parametric Analysis



	Desired array size (kWdc)	Initial cost ($)	Year 1 savings ($)
1	10	28326	1047.24
2	11	33991.2	1130.1
3	12	33991.2	1130.1
4	13	39656.5	1217.69
5	14	45321.7	1302.26

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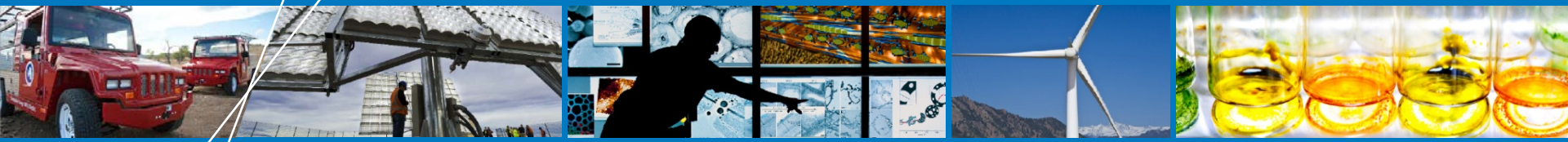

Limitations of SAM for System Sizing

Limitations of SAM for System Sizing

System Advisor Model

- Does not perform a full electrical model
- Does not show frequency effects
- Does not properly model inverter operation if the string voltage is outside of the MPPT range
- Assumes that the grid can handle any level of power created for distributed system models
- Does not calculate wiring losses (% loss)
- Cannot currently model stand-alone systems (system must be grid-tied)
- Does not model lifetime power production- degradation is applied to the first year production which does not appropriately model clipping in the out-years

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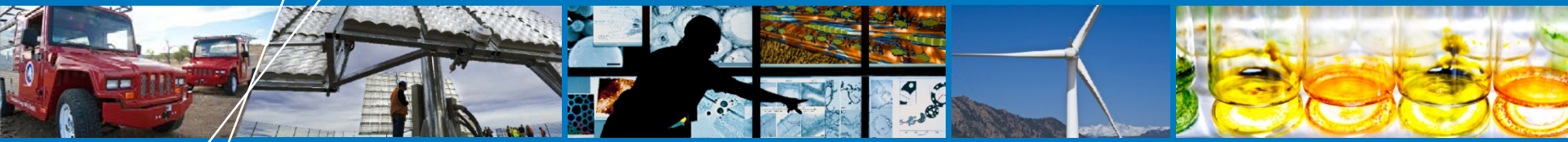

Thank you! Questions?