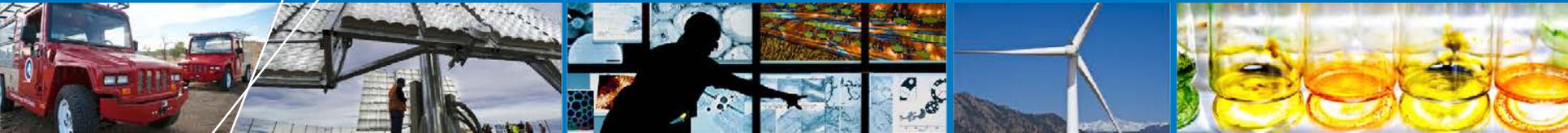


# Modeling Residential and Commercial Photovoltaic Systems in SAM 2013.1.15



**SAM Webinar**

**Paul Gilman**

**July 10, 2013**



- **The System Advisor Model (SAM) is a free computer model that calculates a renewable energy system's hourly energy output over a single year, and calculates the cost of energy for a renewable energy project over many years of operation.**



- **<https://sam.nrel.gov>**
  - Developed by NREL with funding from DOE
  - Free
  - Windows and OS X
  - One new version per year
- **Support**
  - Help system
  - Documents on website
  - <https://sam.nrel.gov/forums/support-forum>

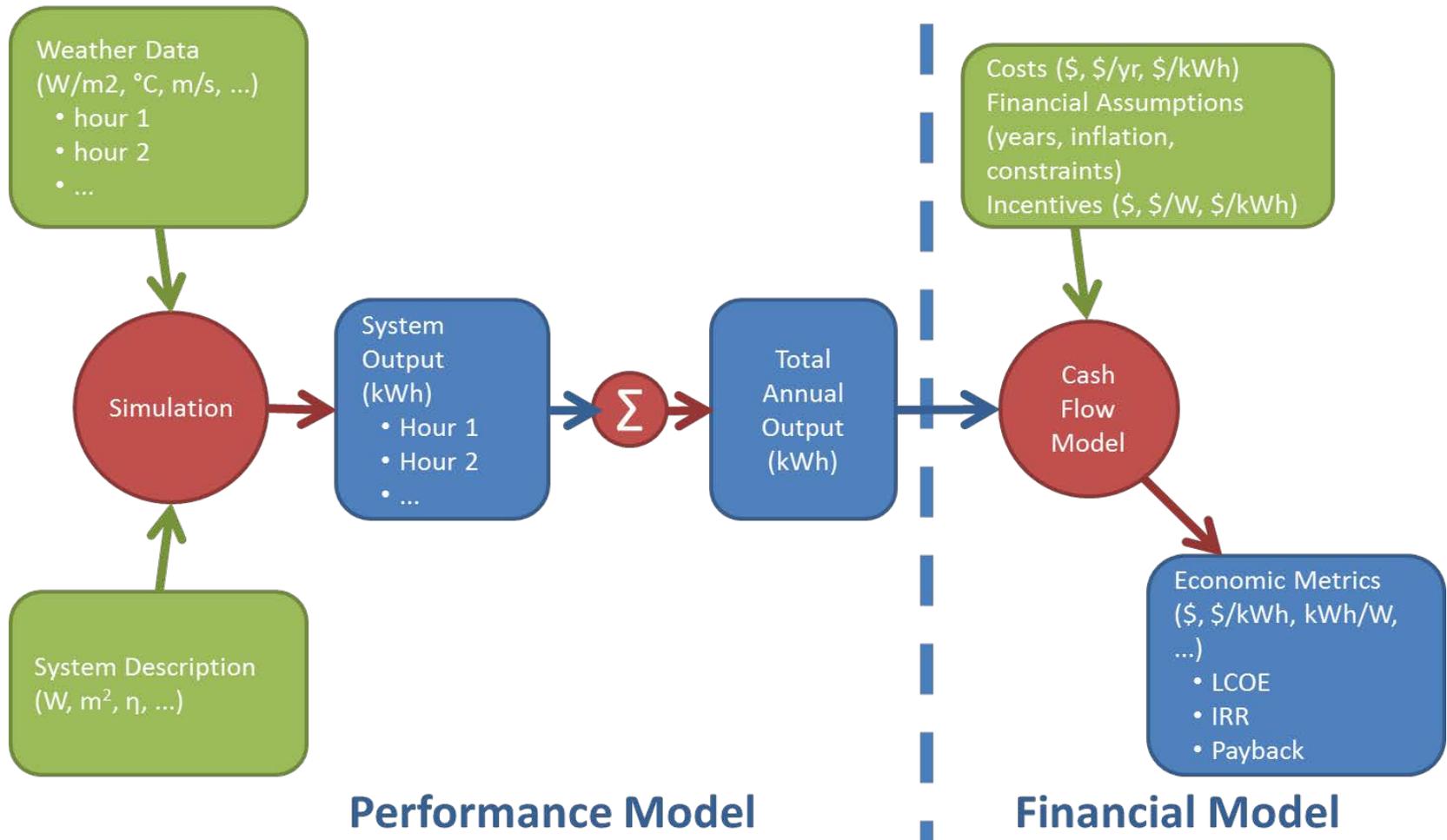


- **Feasibility studies**
  - Project developers, Federal Energy Management Program
- **Use as benchmark for other models**
  - System integrators and utilities
- **Research projects**
  - Universities and engineering firms
- **Plant acceptance testing for parabolic trough systems**
- **Evaluate technology research opportunities and grant proposals**
  - Department of Energy

**35,000+ Downloads**

Manufacturers  
Engineering Firms  
Utilities  
Consultants  
Developers  
Venture Capitalists  
Policy Analysts

# SAM combines performance and financial models





- Photovoltaics
- Concentrating Solar Power
  - Parabolic Troughs
  - Power Towers
  - Dish-Stirling
  - Linear Fresnel
- Solar Water Heating
- Wind turbines and farms
- Geothermal power plants
- Biomass power

## Performance model key outputs

- Hourly energy production (kWh)
- Capacity factor

- Residential, commercial, and utility-scale projects
- Installation and operating costs
- Tax credit and payment incentives
- Complex electricity rates

## Financial model key outputs

- Levelized Cost of Electricity (LCOE)
- PPA Price and IRR
- Payback
- Net present value
- Multi-year cash flow



- **No storage**
- **No size limit**
- **Model options**
- **Simpler PVWatts model represents entire system using a single derate factor**
- **More detailed Flat Plate PV model represents system using separate module and inverter model with derate factors**
- **Electric load for residential and commercial systems with TOU and tiered rates**
- **Array shading and self shading**

# Residential and commercial financing option is for projects that buy and sell electricity at retail rates



SAM 2013.1.15



A new PV array system is installed on a home of a city employee who participated in the group buy pilot in 2010. (NREL PIX 19492)

- **Meets a building load and sells excess electricity to the grid**
  - Grid meets load when PV output cannot meet load
- **Is project economically feasible given costs and energy production?**

# PPA models are for power generation projects that sell electricity at a negotiated price



SAM 2013.1.15



Aerial view of the 2 MW PV system at U.S. Army Fort Carson financed through a Power Purchase Agreement (PPA). (NREL PIX 17394)

**Can the project meet target internal rate of return (IRR) requirements given cost, production, and PPA price?**



- **SAM is a feasibility screening tool**
- **It does not replace “bank quality” analysis required for actual financing**
- **It is limited to annual cash flows**
- **Designed to model a wide range of projects, so uses simplified assumptions**
- **An actual project requires tax and financial counsel that SAM does not replace**
- **The actual structure of a project is more about risk allocation and investor comfort than returns**

# Garbage in, garbage out!



SAM 2013.1.15



© Rex Features





- **6 kW array**
- **Two financial options**
  - TOU rate with no state incentives
  - State incentives with no TOU rate
- **Does it make economic sense to install the system?**



- **Set up comparison with PVWatts**
  - Simple performance model inputs
  - Focus on financial parameters
- **Repeat with Flat Plate PV model**
  - Refine system design to include specific modules and inverters

# Choose a weather file



SAM 2013.1.15

**1. Click Location and Resource to show the Location and Resource page**

**2. Type a few letters of the location name.**

**3. Click the file name.**

If your location is in the United States but not in the list, you can use Location Lookup to find a file for your location.

**Choose Weather Data File**

Filter locations by name: portl

- SAM/ME Portland.tm2
- SAM/OP Portland.tm2

SAM's solar models read weather files in TMY2, TMY3, EPW, and SMW format. The default weather file library includes a complete set of TMY2 files for U.S. locations. SAM looks for weather files in the specified folders. To change the search folders, click "Add/Remove". The prefix "SAM/" indicates a location from the standard SAM library, and those preceded by "USER/" are stored in your project file to facilitate sharing with other people.

Folder Settings...  
Refresh list  
Copy to project  
Remove from project  
Create TMY3 file  
Location Lookup...

Latitude: 45.6 deg  
Longitude: -122.6 deg

**Weather Data Information (Annual)**

Direct Normal	1154.7 kWh/m2	Dry-bulb Temp	11.7 °C
Global Horizontal	1297.9 kWh/m2	Wind Speed	3.6 m/s

View hourly data...

**Web Links**

Solar Advisor reads weather files in TMY2, TMY3, and EPW format. The default weather file library includes a complete set of TMY2 files for U.S. locations. You can use the web links below to find weather data for other locations. After you have downloaded the desired weather files, click Add/Remove above to help SAM locate the downloaded weather files on your computer.

# Specify system parameters on the PVWatts Solar Array page



SAM 2013.1.15

The screenshot shows the SAM 2013.1.15 software interface. The main window title is "SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam". The menu bar includes "File", "Case", "Analysis", "Tools", "Script", and "Help". The "TOU" tab is active, and the "Incentives" sub-tab is selected. The "Select Technology and Market..." dropdown is set to "[ PVWatts, Residential ]".

The interface is divided into several sections:

- Location and Resource:** Location: PORTLAND, OR; Lat: 45.6 Long: -122.6 Elev: 12.0 m.
- PVWatts Solar Array:** DC Rating: 6 kW; AC-DC Derate: 0.86.
- Performance Adjustment:** Percent of annual output: 100 %; Year-to-year decline: 0.5 % per year.
- PV System Costs:** Total: \$ 27,000.00; Per Capacity: \$ 4.50 per Wdc.
- Financing:** Analysis: 30 years; Debt Fraction: 80.0% percent.
- Incentives:** Fed. ITC; No cash incentives.
- Utility Rate:** Net Metering? No.
- Electric Load:** Annual Energy: 6054.07 kWh; Annual Peak: 2.46804 kW.
- Exchange Variables:** (For Excel Exchange and custom TRNSYS only.)

The "PVWatts System Inputs" section is the primary focus, with three blue callout boxes providing instructions:

- 1. Type the system's DC capacity in kilowatts.** This points to the "Nameplate Capacity" input field, which is set to "6 kWdc".
- 2. Use a DC to AC derate factor of 0.86 for current system designs.** This points to the "DC to AC Derate Factor" input field, which is set to "0.86 (0, 1)".
- 3. Type 40 for the tilt angle.** This points to the "Tilt" input field, which is set to "40 deg".

Other parameters in the "PVWatts System Inputs" section include:

- Array Tracking Mode: Fixed (dropdown menu)
- Force Tilt = Latitude:
- Azimuth: 180 deg
- Define shading scene: Edit shading... (button)

Below the "PVWatts System Inputs" section, there is a note: "Tilt: horizontal=0, vertical=90".

The "Advanced: POA Irradiance Input" section includes:

- Use measured plane-of-array irradiance as model input
- Enter hourly POA irradiance data: Edit data... (button) Wh/m2
- POA values assume the measurement is taken at the midpoint of the hour. Meteorological data is taken from the weather file. See Help for details.

# Review the performance adjustment factors



SAM 2013.1.15

SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam

File Case Analysis Tools Script Help

TOU X Incentives

Select Technology and Market... [ PVWatts, Residential ]

**Location and Resource**  
 Location: PORTLAND, OR  
 Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
 DC Rating: 6 kW  
 AC-DC Derate: 0.86

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

**PV System Costs**  
 Total: \$ 27,000.00  
 Per Capacity: \$ 4.50 per Wdc

**Financing**  
 Analysis: 30 years  
 Debt Fraction: 80.0% percent

**Incentives**  
 Fed. ITC  
 No cash incentives

**Utility Rate**  
 Net Metering? No

**Electric Load**  
 Annual Energy: 6054.07 kWh  
 Annual Peak: 2.46804 kW

**Exchange Variables**  
 (For Excel Exchange and custom

**System Output Adjustments**

Percent of annual output

Year-to-year decline in output  (compounded annually)

Use the system output adjustments to model system availability, annual degrad that cause the system's output (delivered energy) to be less than the value calc (net energy). Use annual schedules to specify different percentages for differe

If you use combinations of adjustments, SAM multiplies the resulting percentage examples.

Hourly Factors (24-hour profile for each month) 0=No Output, 1=Full Output

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10p
Jan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Feb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mar	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Apr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jul	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oct	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The default **Year-to-year decline in output** value of 0.5% results in an annual reduction in the system's electrical output from year to year. This might represent the degradation of PV module performance over time.

# Specify the installation cost



To specify the total installed cost as a \$/Wdc value, use the **Module** cost category to represent the system cost, and set all other values to zero.

SAM's financial model uses the total installed cost.

You can start your analysis with a single \$/Wdc cost, and then refine the costs using the category detail as you get more information.

Category	Units	Value	Unit	Cost	Unit	Total
Module	1	6.0	kWdc/unit	6	kWdc	\$ 4.5 \$/Wdc \$ 27,000.00
Inverter	1	6.0	kWac/unit	6	kWac	\$ 0 \$/Wac \$ 0.00
Balance of system, equipment		0	\$	0	\$/Wdc	0 \$/m2 \$ 0.00
Installation labor		0	\$	0	\$/Wdc	0 \$/m2 \$ 0.00
Installer margin and overhead		0	\$	0	\$/Wdc	0 \$/m2 \$ 0.00
Contingency				0	%	\$ 0.00
<b>Total Direct Cost</b>						<b>\$ 27,000.00</b>

Category	% of Direct Cost	Cost \$/Wdc	Fixed Cost	Total
Permitting, Environmental Studies	0 %	0.00	\$ 0.00	\$ 0.00
Engineering	0 %	0.00	\$ 0.00	\$ 0.00
Grid interconnection	0 %	0.00	\$ 0.00	\$ 0.00
<b>Total Indirect Cost</b>				<b>\$ 0.00</b>

Category	Cost \$/acre	% of Direct Cost	Cost \$/Wdc	Fixed Cost	Total
Land	0.00	0 %	0.00	\$ 0.00	\$ 0.00
<b>Total Land Cost</b>					<b>\$ 0.00</b>

<b>Total Installed Cost</b>	<b>\$ 27,000.00</b>
<b>Total Installed Cost per Capacity (\$/Wdc)</b>	<b>\$ 4.50</b>

# Specify operation and maintenance costs



SAM 2013.1.15

**Location and Resource**  
Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**  
Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC  
No cash incentives

**Utility Rate**  
Net Metering? No

**Electric Load**  
Annual Energy: 6054.07 kWh  
Annual Peak: 2.46804 kW

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

**Indirect Capital Costs**

	% of Direct Cost	Cost \$/Wdc	Fixed Cost	Total
Permitting, Environmental Studies	0 %	0.00	\$ 0.00	\$ 0.00
Engineering	0 %	0.00	\$ 0.00	\$ 0.00
Grid interconnection	0 %	0.00	\$ 0.00	\$ 0.00

**Land Costs**

Total Land Area: 0 acres

	Total
Land	\$ 0.00
Land preparation	\$ 0.00
	\$ 0.00
	\$ 0.00

**Total Installed Costs**

Total Installed Cost: \$ 27,000.00  
Total Installed Cost per Capacity (\$/Wdc): \$ 4.50

**Operation and Maintenance Costs**

	First Year Cost	Escalation Rate (above inflation)
Fixed Annual Cost	Value: 0.00 \$/yr	0 %
Fixed Cost by Capacity	Value: 20.00 \$/kW-yr	0 %
Variable Cost by Generation	Value: 0.00 \$/MWh	0 %

Escalation rates apply only to single values, not to values in annual schedules.

# Financial parameters



SAM 2013.1.15

- 20% down payment for a 15-year, 4.5% interest rate loan with tax-deductible interest payments
- 30 year project life
- 1.5% inflation rate,
- 4% real discount rate represents value of alternative investment
- No sales tax in Oregon

The screenshot displays the SAM 2013.1.15 software interface for a residential photovoltaic example. The interface is organized into several sections:

- Location and Resource:** Location: PORTLAND, OR; Lat: 45.6 Long: -122.6 Elev: 12.0 m.
- PVWatts Solar Array:** DC Rating: 6 kW; AC-DC Derate: 0.86.
- Performance Adjustment:** Percent of annual output: 100 %; Year-to-year decline: 0.5 % per year.
- PV System Costs:** Total: \$ 27,000.00; Per Capacity: \$ 4.50 per Wdc.
- Financing:** Analysis: 30 years; Debt Fraction: 80.0% percent.
- Incentives:** Fed. ITC; No cash incentives.
- Utility Rate:** Net Metering? No.
- Electric Load:** Annual Energy: 6054.07 kWh; Annual Peak: 2.46804 kW.
- Exchange Variables:** (For Excel Exchange and custom TRNSYS only.)
- Loan Type:**  Standard Loan;  Mortgage.
- Residential Loan Parameters:** Debt Fraction: 80.00 %; Loan Term: 15 years; Loan Rate: 4.50 %/year; WACC: 3.24 %.
- Analysis Parameters:** Analysis Period: 30 years; Inflation Rate: 1.50 %/year; Real Discount Rate: 4.00 %/year; Nominal Discount Rate: 5.56 %/year.
- Tax and Insurance Rates:** Federal Income Tax Rate: 35.00 %/year; State Income Tax Rate: 9.00 %/year; Sales Tax: 0.00 % of installed cost; Insurance Rate (Annual): 0.00 % of installed cost.
- Property Tax:** Assessed Percent: 100.00 % of installed cost; Assessed Value: \$ 27,000.00; Annual Decline: 0.00 %/year; Property Tax: 0.00 %/year.
- Salvage Value:** End of Analysis Period Value: \$ 0.00; Net Salvage Value: 0.00 % of installed cost.

The weighted average cost of capital (WACC) is the after-tax return the project must earn to cover financing (debt) costs. SAM shows the value for reference, but does not use it in calculations.

# Scenario 1: No state incentives available with the TOU rate structure



**Location and Resource**  
Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**  
Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC  
No cash incentives

**Utility Rate**  
Net Metering? No

**Electric Load**  
Annual Energy: 6054.07 kWh  
Annual Peak: 2.46804 kW

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

**Investment Tax Credit (ITC)**

	Amount	
Federal	\$ 0	
State	\$ 0	

**Production Tax Credit (PTC)**

	Amount	Term	Escalation
Federal	0.51111	10 years	2.5 %
State			2.5 %

**Investment Based Incentive (IBI)**

	Amount		
Federal	\$ 0		
State	\$ 0		
Utility	\$ 0		
Other	\$ 0		

**Taxable Incentive**

	Federal	State
Federal	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
State	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Utility	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Other	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

**Capacity Based Incentive (CBI)**

	Amount	Maximum		
Federal	0 \$/W	\$ 1e+099		
State	0 \$/W	\$ 1e+099		
Utility	0 \$/W	\$ 1e+099		

**Taxable Incentive**

	Federal	State
Federal	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
State	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Utility	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

# Specify the rate schedule



**1. Click Search for rates to download rate schedules from the NREL OpenEI online database.**

**2. Type a few characters of the utility company's name.**

**3. Click the utility name.**

**3. Click the rate schedule.**

**4. Click Download and apply utility rate.**

Follow the link to see the database entry on the OpenEI website.

Go to rate page on OpenEI.org...

Download and apply utility rate

Close

# Review and revise the rate schedule



SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam

File Case Analysis Tools Script Help

TOU X Incentives

Select Technology and Market... [ PVWatts, Residential ]

In some cases (like this one) the rate schedule in the database is not correct.

**Description**

Name: 7-TOU (Residential Time-Of-Use)

Description: In all territory served by the Company. To Residential Customers.

Schedule: Portland General Electric Co: 7-TOU (Residential Time-Of-Use)

Source: <http://en.openei.org/wiki/Data:18c185d0-ce95-4ad0-b2f8-4c7fb5dd2ct>

rate repository. After downloading a rate structure, compare the inputs below with a copy of the rate sheet to verify that the information is correct.

**Performance Adjustment**

DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**

Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**

Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**

Fed. ITC  
No cash incentives

**Utility Rate**

Net Metering? No

**Net Metering**

Enable net metering (buy=sell)

Net metering applies to Flat Rate and Time of Use Rate.

**Flat Rate**

Flat Buy Rate: 0 \$/kWh

**Fixed Monthly Charges**

Fixed Monthly Charge: 9.85 \$

**Rate Escalation**

Out-years esca  
Applies to all rates. In annual schedule. Use Help for details.

In this case, the monthly charge from the database is correct.

**Time of Use Rate (E**

Enable TOU Rates

	Buy \$/kWh	Sell \$/kWh
Period 1	0.0622	0.0442
Period 2	0.0928	0.075
Period 3	0.1506	0.1327
Period 4	0.0621	0.0422
	0.0562	0.1326
	0.093	0.075
	0	0
	0	0
	0	0
	0	0

	Weekday											Weekend												
	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Jan	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2	1	1
Feb	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2	1	1
Mar	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2	1	1
Apr	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2	1	1
May	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4
Jun	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4
Jul	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4
Aug	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4
Sep	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4
Oct	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4
Nov	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2	1	1
Dec	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2	1	1

**Peak Demand Charges**

Enable Demand Charges

Monthly fixed demand charge (\$/kW,peak)

Make sure the **Enable** check boxes are correct.

Copy the rate schedule from the OpenEI website

# Specify the electric load



SAM 2013.1.15

1. Click User entered hourly data.

2. Click Edit data.

3. Click Import.

3. Navigate to the sample load data folder.

3. Choose a file. In this case, I assume that the Seattle residential load profile is similar to Portland.

You can also import your own load data if you have hourly data over a single year.

The screenshot shows the SAM 2013.1.15 software interface. The 'Electric Load Data' section is active, with 'User entered hourly data' selected. The 'Edit Data' dialog box is open, showing the 'Import' button. A file selection window is also open, displaying a list of sample load data files in the 'C:\SAM\2013.1.15\samples\Simulated Electric Load Data - Residential' folder. The 'Seattle.txt' file is selected. The 'File name' field in the dialog box contains 'Seattle.txt'. The 'File name' field in the file selection window also contains 'Seattle.txt'. The 'File name' field in the file selection window is highlighted.

Name	Date modified	Type	Size
Ft Worth.txt	10/3/2011 8:25 AM	TXT File	76 KB
Helena.txt	10/3/2011 8:25 AM	TXT File	76 KB
Honolulu.txt	10/3/2011 8:25 AM	TXT File	76 KB
Houston.txt	10/3/2011 8:25 AM	TXT File	76 KB
Lexington.txt	10/3/2011 8:25 AM	TXT File	76 KB
Los Angeles.txt	10/3/2011 8:25 AM	TXT File	76 KB
Medford.txt	10/3/2011 8:25 AM	TXT File	76 KB
New York City.txt	10/3/2011 8:25 AM	TXT File	76 KB
Phoenix.txt	10/3/2011 8:25 AM	TXT File	76 KB
Sacramento.txt	10/3/2011 8:25 AM	TXT File	76 KB
Seattle.txt	10/3/2011 8:25 AM	TXT File	76 KB

# How to use monthly demand data (not used for this example)



If you have monthly demand values (kWh) from a utility bill, you can scale the hourly data to match the monthly values.

1. Click Normalize supplied load profile to monthly utility bill data.

2. Click Edit values.

3. Type monthly demand values in the table.

4. Click OK.

Performance Adjustment

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

Normalize supplied load profile to monthly utility bill data

Monthly energy usage (kWh) Edit values...

PV System Costs

Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

Financing

Analysis: 30 years  
Debt Fraction: 80.0% percent

Incentives

Fed. ITC  
No cash incentives

Utility Rate

Net Metering? No

Electric Load

Annual Energy: 4200 kWh  
Annual Peak: 2.46804 kW

Exchange Variables

(For Excel Exchange and custom TRNSYS only.)

Month	Energy (kWh)	Peak (kW)
Jan	543.024	1.28905
Feb	479.159	1.28905
Mar	525.027	1.28305
Apr	484.954	1.21405
May	456.781	1.10505
Jun	511.349	2.45804
Jul	592.666	2.46804
Aug	498.973	2.11262
Sep	427.619	1.10505
Oct	489.608	1.21405
Nov	493.106	1.24905
Dec	551.803	1.28905

Annual Total 4200 kWh  
Annual Peak 2.46804 kW

Visualize load data...

These are normalized values.

These values reflect the original hourly data, not the normalized values.

# Run a simulation and review cash flow



SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam

File Case Analysis Tools Script Help

TOU X Incentives

Select Technology and Market... [ PVWatts, Residential ]

**Location and Resource**  
 Location: PORTLAND, OR  
 Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
 DC Rating: 6 kW  
 AC-DC Derate: 0.86

**Performance Adjustment**  
 Percent of annual...  
 Year-to-year de...

**PV System Costs**  
 Total: \$ 27,000.00  
 Per Capacity: \$ 4.50 per Wdc

**Financing**  
 Analysis: 30 years  
 Debt Fraction: 80.0% percent

**Incentives**  
 Fed. ITC  
 No cash in...

**Utility Rate**  
 Net Metering? No

**View and export data:** Graphs Tables Cash Flows Time Series Loss Diagram

Add a new graph... Edit... Remove Remove All Copy Graph Data Show Graph Data

**After Tax Cashflow (Base Case)**

**Federal ITC**

**Down payment**

**Debt payments**

**Positive cash flow after debt is paid off**

Metric	Base
Annual Energy	6,947 kWh
LCOE Nominal	18.17 ¢/kWh
LCOE Real	15.24 ¢/kWh
Total revenue without system (\$)	\$ -616.02
Total revenue with system (\$)	\$ -92.41
First Year Net Revenue	\$ 523.61
Net present value (\$)	\$ -8,813.87
Payback (years)	1. #INF
Capacity Factor	13.2 %
First year kWhac/kWdc	1,158

**Monthly Output (Base Case)** **After Tax Cashflow (Base Case)** **Annual Output (Base Case)** **Cost per Watt (Base Case)** **Stacked Real LCOE (Base Case)** **Stacked Nominal LCOE (Base Case)**

# Review metrics table



SAM 2013.1.15

Metric	Base
Annual Energy	6,947 kWh
LCOE Nominal	18.17 ¢/kWh
LCOE Real	15.24 ¢/kWh
Total revenue without system (\$)	\$ -616.02
Total revenue with system (\$)	\$ -92.41
First Year Net Revenue	\$ 523.61
Net present value (\$)	\$ -8,813.87
Payback (years)	1. #INF
Capacity Factor	13.2 %
First year kWhac/kWdc	1,158

- You can compare the real LCOE to the retail electricity price.
- The positive first year net revenue value represents net savings.
- The negative net present value shows that the project is worth less over its life than an investment with a 4% return.
- The “1.#INF” payback period indicates a payback period greater than the 30-year project life.

The 4% real discount rate and 25 year analysis period are inputs on the Financing page.

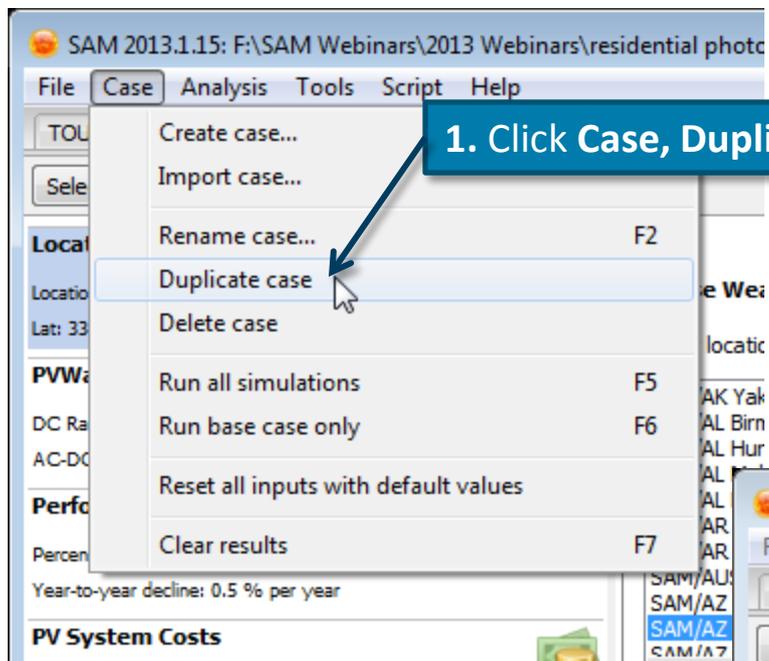


- **If the project uses TOU rates, it saves the owner money by lowering the annual electric bill, but it has a negative NPV, and too long of a payback period**
- **Now, let's see if we can do better with the state incentives option instead of the TOU rate option**

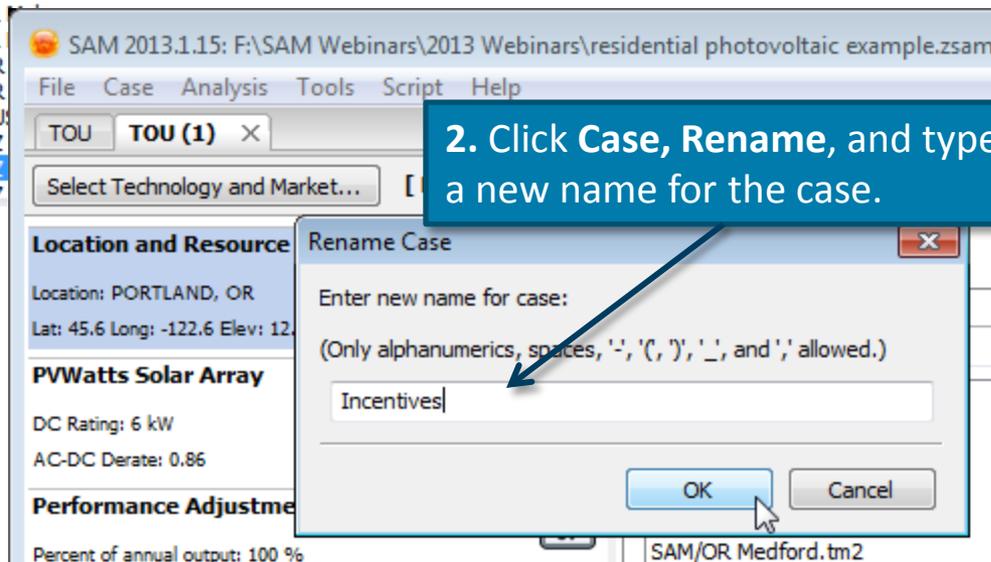
# Create a duplicate case



SAM 2013.1.15



By duplicating the case, you create a copy of the first scenario. We will change only the utility rate and incentives for the second case, and then compare results for the two cases.



# Replace the TOU rate with a flat 6 cents/kWh rate



SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam

File Case Analysis Tools Script Help

TOU Incentives X

Select Technology and Market... [ PVWatts, Residential ]

**Location and Resource**  
 Location: PORTLAND, OR  
 Lat: 45.6 Long: -122.6 Elev: 12.0 m

**OpenEI Online Utility Rate Database**  
 Search for rates... Go to website...  
 Download rate structures for electric utility companies included in the rate repository. After downloading a rate structure, compare the copy of the rate sheet to verify that the information is correct.

**Net Metering**  
 Enable net metering (buy=sell)  
 Net metering applies to Flat Rate and Time of Use Rate.

**Flat Rate**  
 Flat Buy Rate: 0.06 \$/kWh  
 Flat Sell Rate: 0 \$/kWh

**Fixed Monthly Charges**  
 Fixed Monthly Charge: 9.85 \$

**Rate Escalation**  
 Applies to annual schedule. Help for...

**Time of Use Rate (Energy Charge)**  
 Enable TOU Rates

	Weekday												Weekend																						
	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am	1am	2am	3am	4am	5am	6am	7am	8am		
Jan	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	3	3	3	2	2	1	1	Jan	1	1	1	1	1	1	1	1	1	1	1
Feb	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	3	3	3	2	2	1	1	Feb	1	1	1	1	1	1	1	1	1	1	1
Mar	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	3	3	3	2	2	1	1	Mar	1	1	1	1	1	1	1	1	1	1	1
Apr	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	3	3	3	2	2	1	1	Apr	1	1	1	1	1	1	1	1	1	1	1
May	4	4	4	4	4	4	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4	May	1	1	1	1	1	1	1	1	1	1	1
Jun	4	4	4	4	4	4	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4	Jun	1	1	1	1	1	1	1	1	1	1	1
Jul	4	4	4	4	4	4	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4	Jul	1	1	1	1	1	1	1	1	1	1	1
Aug	4	4	4	4	4	4	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4	Aug	1	1	1	1	1	1	1	1	1	1	1
Sep	4	4	4	4	4	4	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4	Sep	1	1	1	1	1	1	1	1	1	1	1
Oct	4	4	4	4	4	4	6	6	6	6	6	6	6	6	5	5	5	5	5	6	6	4	4	Oct	1	1	1	1	1	1	1	1	1	1	1
Nov	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	3	3	3	2	2	1	1	Nov	1	1	1	1	1	1	1	1	1	1	1
Dec	1	1	1	1	1	1	3	3	3	3	3	2	2	2	2	2	3	3	3	2	2	1	1	Dec	1	1	1	1	1	1	1	1	1	1	1

**Buy \$/kWh**      **Sell \$/kWh**

Period 3      0.1506      0.1327

Period 4      0.0621      0.0422

Period 5      0.0562      0.1326

Period 6      0.093      0.075

Period 7      0      0

Period 8      0      0

Period 9      0      0

**Peak Demand Charges**  
 Enable Demand Charges  
 Monthly fixed demand charge (\$/kW peak)

**1. Clear Enable TOU Rates.**

**2. Check Enable net metering (buy=sell).**

**3. Type the flat rate for Flat Buy Rate.**

SAM 2013.1.15 does net metering accounting on an hour-by-hour basis. The next version will do accounting on a more realistic monthly basis.

# Download incentives from DSIRE



1. Click Download incentives.

DSIRE Online Incentives Database

Download incentives...

[Go to website...](#)

Download incentives from the Database of State Incentives for Renewables and Efficiency (DSIRE) for the location in your weather file (U.S. locations only).

Query

The incentives below are available for your query. Check the incentives that apply to your case.

Query Parameters: Latitude: 45.6, Longitude: -122.6, Technology: PVWatts, Financing: Residential

**Portland, OR, USA**

- CBI (state) - Energy Trust - Solar Electric Buy-Down Program. Rate: \$1.75/W. Maximum amount: \$20000
- CBI (state) - Energy Trust - Solar Electric Buy-Down Program. Rate: \$1.75/W. Maximum amount: \$20000
- ITC (federal) - Residential Renewable Energy Tax Credit. Percent of cost: 30%
- ITC (other) - Residential Energy Tax Credit. Percent of cost: 50%

Click on an incentive for more info...

Clear all incentives before applying

2. Check each incentive that applies.

2. Click OK.

The Query window displays incentives available for the location on the Location and Resource page, and for the financial model (in this case, it is residential).

# Verify that the incentives are correct



**Location and Resource**  
Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**  
Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC, State ITC  
CBI

**Utility Rate**  
Net Metering? Yes

**Electric Load**  
Annual Energy: 6054.07 kWh  
Annual Peak: 2.46804 kW

**Exchange Variables**

**Investment Tax Credit (ITC)**

	Amount		
Federal	<input type="text" value="\$ 0"/>		
State	<input type="text" value="\$ 0"/>		
	Percentage	Maximum	
Federal	<input type="text" value="30 %"/>	<input type="text" value="\$ 1e+099"/>	
State	<input type="text" value="50 %"/>	<input type="text" value="\$ 6000"/>	

**Investment Based Incentive (IBI)**

	Amount		
Federal	<input type="text" value="\$ 0"/>		
State	<input type="text" value="\$ 0"/>		
Utility	<input type="text" value="\$ 0"/>		
Other	<input type="text" value="\$ 0"/>		
	Percentage	Maximum	
Federal	<input type="text" value="0 %"/>	<input type="text" value="\$ 1e+099"/>	<input checked="" type="checkbox"/>
State	<input type="text" value="0 %"/>	<input type="text" value="\$ 1e+099"/>	<input checked="" type="checkbox"/>
Utility	<input type="text" value="0 %"/>	<input type="text" value="\$ 1e+099"/>	<input checked="" type="checkbox"/>
Other	<input type="text" value="0 %"/>	<input type="text" value="\$ 1e+099"/>	<input checked="" type="checkbox"/>

**Incentive (CBI)**

	Amount	Maximum		
Federal	<input type="text" value="0 \$/W"/>	<input type="text" value="\$ 1e+099"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
State	<input type="text" value="1.75 \$/W"/>	<input type="text" value="\$ 20000"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Utility	<input type="text" value="0 \$/W"/>	<input type="text" value="\$ 1e+099"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

**Taxable Incentive**

	Federal	State
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

**Taxable Incentive**

	Federal	State
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

**Callout 1:** Federal and Oregon Energy Trust investment tax credits

**Callout 2:** Oregon buy-down incentive

**Callout 3:** The incentives database may not be current. If your project qualifies for incentives that are not in the database, or the incentives in the database are out of date, you can change the incentives inputs accordingly.

# Run simulation and review results



SAM 2013.1.15

SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam

File Case Analysis Tools Script Help

TOU Incentives X

Select Technology and Market... [ PVWatts, Residential ]

**Location and Resource**  
Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**  
Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC, State ITC  
CBI

**Utility Rate**  
Net Metering? Yes

**View and export data:** Graphs Tables Cash Flows Time Series Loss Diagram

Add a new graph... Edit... Remove Remove All Copy Graph Data Show Graph Data

**After Tax Cashflow (Base Case)**

Right-click graphs and choose an option to export data and graph images or use them in other programs.

- Edit...
- Copy data to clipboard
- Save data to CSV
- To clipboard (as shown)
- To clipboard (400x300)
- To clipboard (800x600)
- Export (as shown)...
- Export (400x300)...
- Export (800x600)...
- Export as PDF document...

Metric	Base
Annual Energy	6,947 kWh
LCOE Nominal	9.19 ¢/kWh
LCOE Real	7.71 ¢/kWh
Total revenue without system (\$)	\$ -481.45
Total revenue with system (\$)	\$ -64.63
First Year Net Revenue	\$ 416.82
Net present value (\$)	\$ -2,041.72
Payback (years)	26.7623
Capacity Factor	13.2 %
First year kWhac/kWdc	1,158

**Monthly Output (Base Case)** **After Tax Cashflow (Base Case)** **Annual Output (Base Case)** **Cost per Watt (Base Case)** **Stacked Real LCOE (Base Case)** **Stacked Nominal LCOE (Base Case)**

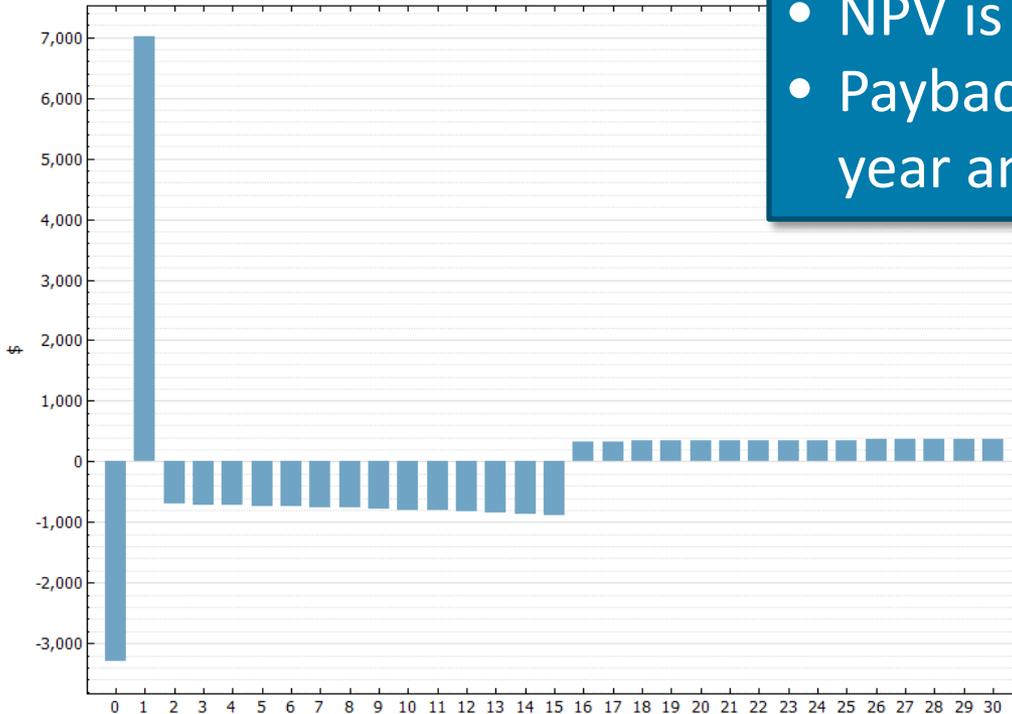
# Results with incentives but no TOU



Metric	Base
Annual Energy	6,947 kWh
LCOE Nominal	9.19 ¢/kWh
LCOE Real	7.71 ¢/kWh
Total revenue without system (\$)	\$ -481.45
Total revenue with system (\$)	\$ -64.63
First Year Net Revenue	\$ 416.82
Net present value (\$)	\$ -2,041.72
Payback (years)	26.7623
Capacity Factor	13.2 %
First year kWhac/kWdc	1,158

- Real LCOE is close to the retail electricity price.
- First year net revenue is higher than for TOU option.
- NPV is still negative.
- Payback period is less than the 30 year analysis period.

After Tax Cashflow (Base Case)



# Use cases for side-by-side comparisons



SAM 2013.1.15

SAM 2013.1.15: F:\SAM Webinars\2013 Webinars\residential photovoltaic example.zsam

File Case Analysis Tools Script Help

TOU X

Select Technology and Market... [ PVWatts, Residential ]

**Location and Resource**  
Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**  
Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC  
No cash incentives

**Utility Rate**  
Net Metering? No

View and export data: Graphs Tables

Add a new graph... Edit... Remove

**After Tax Cashflow (Base Case)**

Metric Base

Annual Energy	6,947 kWh
LCOE Nominal	18.17 ¢/kWh
LCOE Real	15.24 ¢/kWh
Total revenue without system (\$)	\$ -616.02
Total revenue with system (\$)	\$ -92.41
First Year Net Revenue	\$ 523.61
Net present value (\$)	\$ -8,813.87
Payback (years)	1. #INF
Capacity Factor	13.2 %
First year kWhac/kWdc	1,158

Monthly Output (Base Case) After Tax Cashflow (Base Case)

Incentives X

Select Technology and Market... [ PVWatts, Residential ]

**Location and Resource**  
Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**PVWatts Solar Array**  
DC Rating: 6 kW  
AC-DC Derate: 0.86

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

**PV System Costs**  
Total: \$ 27,000.00  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC, State ITC  
CBI

**Utility Rate**  
Net Metering? Yes

View and export data: Graphs Tables

Add a new graph... Edit... Remove

**After Tax Cashflow (Base Case)**

Metric Base

Annual Energy	6,947 kWh
LCOE Nominal	9.19 ¢/kWh
LCOE Real	7.71 ¢/kWh
Total revenue without system (\$)	\$ -481.45
Total revenue with system (\$)	\$ -64.63
First Year Net Revenue	\$ 416.82
Net present value (\$)	\$ -2,041.72
Payback (years)	26.7623
Capacity Factor	13.2 %
First year kWhac/kWdc	1,158

Monthly Output (Base Case) After Tax Cashflow (Base Case)



- **Our initial analysis shows that the incentives option is more economically viable than the TOU option.**
- **This is based on the PVWatts performance model. What if we use the Flat Plate model to model the system's performance in better detail?**

# Duplicate the Incentives case and rename it “Flat Plate PV”



**1. Click Technology and Market .**

**2. Click Flat Plate PV to change the performance model from PVWatts to Flat Plate PV.**

**3. Click Residential – SAM should keep the financial model assumptions from the original case.**

# Choose a module



SAM 2013.1.15

**1. Choose CEC Performance Model with Module Database.**

**2. Type a few characters of the module manufacturer or make.**

**3. Click the module name.**

Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**Module**  
SunPower PL-SUNP-SPR-215  
Output: 214.9 Wdc

**Inverter**  
SMA America: SB5000US 208V  
Capacity: 5000 Wac

**Array**  
Power: 6.01776 kWdc  
Area: 34.8 m<sup>2</sup>

**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: \$ 27,079.92  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC, State ITC  
CBI

**Utility Rate**  
Net Metering? Yes

**Electric Load**  
Annual Energy: 6054.07 kWh  
Annual Peak: 2.46804 kW

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

CEC Performance Model with Module Database

Search for modules by manufacturer or model name: sunpo

- SAM/CEC Modules/Quantum Solar SUNPORT 275P
- SAM/CEC Modules/SunPower PL-PLT-63L-BLK-U
- SAM/CEC Modules/SunPower SPR-76R-BLK-U
- SAM/CEC Modules/SunPower SPR-76RE-BLK-U
- SAM/CEC Modules/SunPower SPR-200-BLK-U
- SAM/CEC Modules/SunPower SPR-200-WHT-U
- SAM/CEC Modules/SunPower SPR-205-BLK-U
- SAM/CEC Modules/SunPower SPR-208-BLK-U
- SAM/CEC Modules/SunPower SPR-210-BLK-U
- SAM/CEC Modules/SunPower SPR-210-WHT-U
- SAM/CEC Modules/SunPower PL-SUNP-SPR-215**
- SAM/CEC Modules/SunPower SPR-215-WHT-U
- SAM/CEC Modules/SunPower SPR-217-WHT-U

**Module Characteristics at Reference Conditions**

Reference conditions: Total Irradiance = 1000 W/m<sup>2</sup>, Cell temp = 25 C

**SAM/CEC Modules/SunPower PL-SUNP-SPR-215**

Parameter	Value	Temperature Coefficients
Efficiency	17.28 %	
Maximum Power (Pmp)	214.92 Wdc	-3.900e-001 %/C -8.382e-001 W/C
Max Power Voltage (Vmp)	39.8 Vdc	
Max Power Current (Imp)	5.4 Adc	
Open Circuit Voltage (Voc)	48.3 Vdc	-2.792e-001 %/C -1.349e-001 V/C
Short Circuit Current (Isc)	5.8 Adc	3.590e-002 %/C 2.082e-003 A/C

**Temperature Correction**

NOCT cell temp model  
 Mounting specific cell temp model

Refer to Help for more information about CEC cell temperature models.

Nominal operating cell temperature (NOCT) parameters

Mounting standoff: Ground or rack mounted  
Array height: One story building height or lower

Mounting configuration heat transfer cell temperature model

Mounting Configuration: Rack  
Heat Transfer Dimensions: Module Dimensions  
Mounting Structure Orientation: Structures do not impede flow underneath module  
Module Width: 1 m

Rows of modules in array: 1  
Columns of modules in array: 10  
Temperature behind the module: 20 C

# Choose an inverter



**1. Choose Sandia Performance Model for Grid Connected Inverters.**

**2. Type a few characters of the inverter manufacturer or make.**

**3. Click the inverter name.**

Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**Module**  
SunPower PL-SUNP-SPR-215  
Output: 214.9 Wdc

**Inverter**  
SMA America: SB5000US 208V  
Capacity: 5000 Wac

**Array**  
Power: 6.01776 kWdc  
Area: 34.8 m<sup>2</sup>

**PV Subarrays**  
Year-to-year decline: 0.5 % per year

**PV System Costs**  
Total: \$ 27,079.92  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC, State ITC  
CBI

**Utility Rate**  
Net Metering? Yes

**Electric Load**  
Annual Energy: 6054.07 kWh  
Annual Peak: 2.46804 kW

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

Sandia Performance Model for Grid Connected PV Inverter

Search for inverters by manufacturer or model name: sma

- SAM/Sandia Inverters/SMA America: SB1100U 240V [CEC 2005]
- SAM/Sandia Inverters/SMA America: SB3000US 208V [CEC 2007]
- SAM/Sandia Inverters/SMA America: SB3000US 240V [CEC 2007]
- SAM/Sandia Inverters/SMA America: SB3300U 240V [CEC 2006]
- SAM/Sandia Inverters/SMA America: SB3800U 208V [CEC 2005]
- SAM/Sandia Inverters/SMA America: SB3800U 240V [CEC 2005]
- SAM/Sandia Inverters/SMA America: SB4000US 208V [CEC 2007]
- SAM/Sandia Inverters/SMA America: SB4000US 240V [CEC 2007]
- SAM/Sandia Inverters/SMA America: SB5000US 208V [CEC 2007]
- SAM/Sandia Inverters/SMA America: SB5000US 240V [CEC 2007]

**Efficiency Curve**  
SAM/Sandia Inverters/SMA America: SB5000US 208V [CEC 2007]

Efficiency vs % of Rated Output Power

- Vdco
- MPPT-low
- MPPT-hi

**Inverter Characteristics**

AC Voltage	208 V	C0	-5.10221e-006 1/W
Power ACo	5000 Wac	C1	6.55495e-005 1/W
Power DCo	5212.84 Wdc	C2	0.00265844 1/W
PowerSo	49.1571 W	C3	0.000854498 1/W
PowerNTare	0.46 W	MPPT_low	250 V
Vdcmx	0 V	Vdco	309.913 V
Idcmx	0 A	MPPT_hi	480 V

SAM can model systems with this inverter. However, because the parameter database for this inverter does not include its rated voltage limits, SAM will not be able to perform the pre-simulation check to verify that the array voltage falls within the inverter's minimum and maximum voltage ratings. If you use this inverter in SAM, please check with the inverter manufacturer specifications to verify that the array open circuit voltage value displayed on the Array page is not above or below the inverter's minimum and maximum voltage ratings. Please see the Inverter page's help topic for details.

# Specify the number of modules and inverters in the array



SAM 2013.1.15

**1. Click Specify numbers of modules and inverters.**

**2. Type values for the number of Modules per string, Strings in parallel, and Number of inverters.**

**3. Check the nominal voltages and message box to verify that the system is viable.**

Array DC capacity is 115% of inverter DC capacity. Check for more sizing messages after running simulations. See help for details.

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

Sizing the array is usually an iterative process – try different sizes of module and inverter, and different string sizes as you find the optimal array layout.

Specify System Size		Actual Layout	
<input type="radio"/> Specify desired array size		<b>Modules</b>	<b>Inverters</b>
<input checked="" type="radio"/> Specify numbers of modules and inverters		Nameplate Capacity: 6.01776 kWdc	Total Capacity: 5 kW
Desired Array Size: 6 kWdc	Modules per String: 7	Number of Modules: 28	Number of Inverters: 1
	Strings in Parallel: 4	Modules per String: 7	Vdcmx (dc-inverter): 0 V
	Number of Inverters: 1	Strings in Parallel: 4	MPPT_low: 250 V
		Total Module Area: 34.832 m2	MPPT_hi: 480 V
		Voc (String): 338.1 V	
		Vmp (String): 278.6 V	

# Specify the array tilt angle



SAM 2013.1.15

SAM 2013.1.15: untitled1

File Case Analysis Tools Script Help

TOU Incentives **Incentives with Flat Plate**

Select Technology and Market... [ Flat Plate PV, Residential ]

Location: PORTLAND, OR  
Lat: 45.6 Long: -122.6 Elev: 12.0 m

**Module**  
SunPower PL-SUNP-SPR-215  
Output: 214.9 Wdc

**Inverter**  
SMA America: SB5000US 208V  
Capacity: 5000 Wac

**Array**  
Power: 6.01776 kWdc  
Area: 34.8 m<sup>2</sup>

**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: \$ 27,079.92  
Per Capacity: \$ 4.50 per Wdc

**Financing**  
Analysis: 30 years  
Debt Fraction: 80.0% percent

**Incentives**  
Fed. ITC, State ITC  
CBI

**Utility Rate**  
Net Metering? Yes

**Electric Load**  
Annual Energy: 6054.07 kWh  
Annual Peak: 2.46804 kW

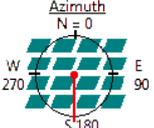
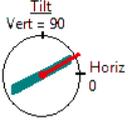
**Exchange Variables**  
(For Excel Exchange and custom TRNSYS only.)

**Defining subarrays**

To model a system with one array, specify properties for Subarray 1 and disable Subarrays 2, 3, and 4.

To model a system with up to four subarrays connected in parallel to a single bank of inverters, for each subarray, check Enable and specify a number of strings and other properties.

Each subarray can have its own set of orientation, tracking, shading, and DC derate properties.

	Subarray 1	Subarray 2	Subarray 3	Subarray 4
<b>-String Configuration</b>				
Strings in array	4	(always enabled)	<input type="checkbox"/> Enable	<input type="checkbox"/> Enable
Strings allocated to subarray	4	0	0	0
<b>-Tracking &amp; Orientation</b>				
	<input checked="" type="radio"/> Fixed			
	<input type="radio"/> 1 Axis			
	<input type="radio"/> 2 Axis			
	<input type="radio"/> Azimuth Axis			
<input type="checkbox"/> Tilt=latitude	<input type="checkbox"/> Tilt=latitude	<input type="checkbox"/> Tilt=latitude	<input type="checkbox"/> Tilt=latitude	<input type="checkbox"/> Tilt=latitude
Tilt (deg)	40	20	20	20
Azimuth (deg)	180	180	180	180
Tracker rotation limit (deg)	45	45	45	45
<input type="checkbox"/> Backtracking	<input type="checkbox"/> Backtracking	<input type="checkbox"/> Backtracking	<input type="checkbox"/> Backtracking	<input type="checkbox"/> Backtracking
Row width (m)	2	2	2	2
Space between edges of adjacent rows (m)	1	1	1	1
<b>-Shading &amp; Soiling</b>				
Configure shading scene	Edit shading...	Edit shading...	Edit shading...	Edit shading...
Monthly soiling factors	Edit soiling...	Edit soiling...	Edit soiling...	Edit soiling...
Annual average soiling (0..1)	0.95	0.95	0.95	0.95
<b>-Pre-inverter Derates</b>				
Mismatch (0..1)	0.98	0.98	0.98	0.98
Diodes and connections (0..1)	0.995	0.995	0.995	0.995
DC wiring loss (0..1)	0.98	0.98	0.98	0.98
Tracking error (0..1)	1	1	1	1
Nameplate (0..1)	1	1	1	1
Estimated DC power derate (0..1)	0.955598	0.955598	0.955598	0.955598

1. Type a value for Tilt.

# Run simulations and review results



SAM 2013.1.15



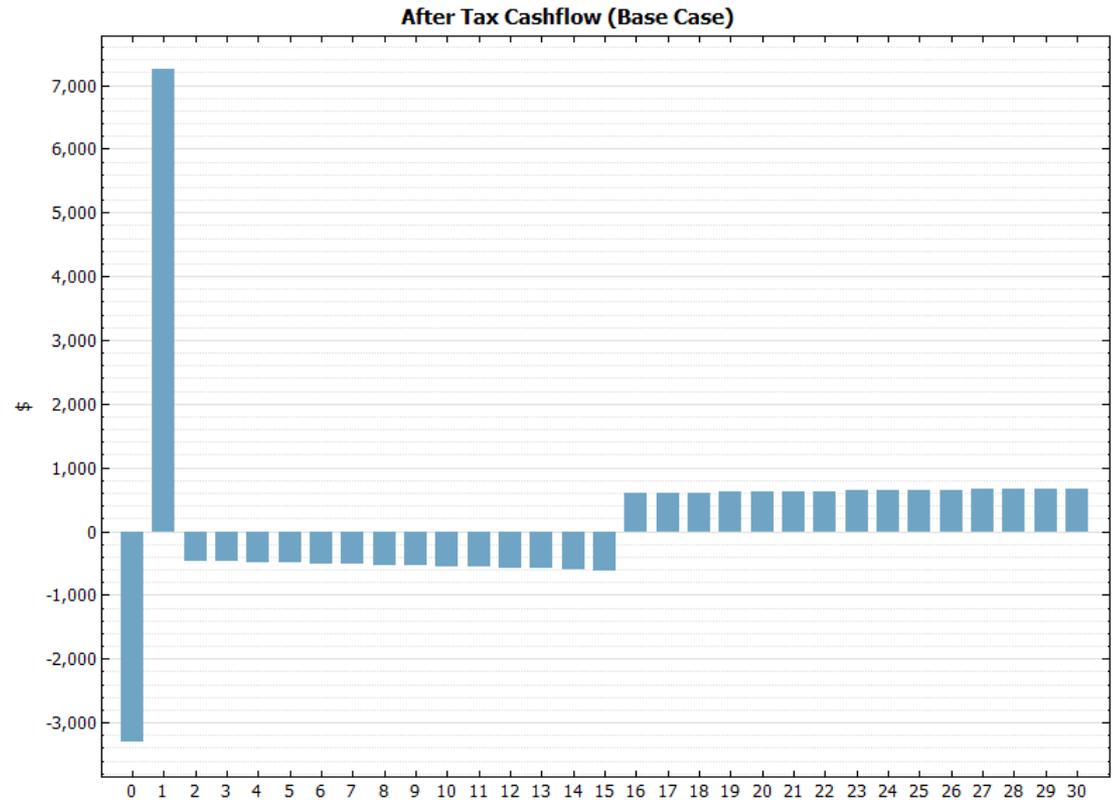
The Warning icon spins when there is a simulation message. These messages provide information about simulation results. In this case, the array's DC output exceeds the inverter's rated input power for 8 of the 8,760 hours of the year. We can ignore this message if we assume the system is designed to handle this situation.

# Run simulations and review results



SAM 2013.1.15

Metric	Base
Annual Energy	7,175 kWh
LCOE Nominal	8.94 ¢/kWh
LCOE Real	7.50 ¢/kWh
Total revenue without system (\$)	\$ -663.07
Total revenue with system (\$)	\$ -17.35
First Year Net Revenue	\$ 645.70
Net present value (\$)	\$ 1,603.20
Payback (years)	15.7462 years
Capacity Factor	13.6 %
First year kWhac/kWdc	1,192
System performance factor (%)	0.86
Total Land Area	0.02 acres





- **Flat Plate PV model confirm PVWatts results: So far, this project appears to be economically feasible with the state incentives option**
- **Next step could be to refine costs. Because the Flat Plate PV model allows you to use different inverter and array capacities, by specifying their costs separately, you can investigate the cost benefit of “oversizing” the array compared to the inverter**
- **Another next step would be to refine the financial and incentives assumptions after doing further research**