NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Modeling Residential and Commercial Photovoltaic Systems in SAM 2013.1.15

SAM Webinar

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July 10, 2013

What is SAM?

- **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.**

System Advisor Model (SAM)

- **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

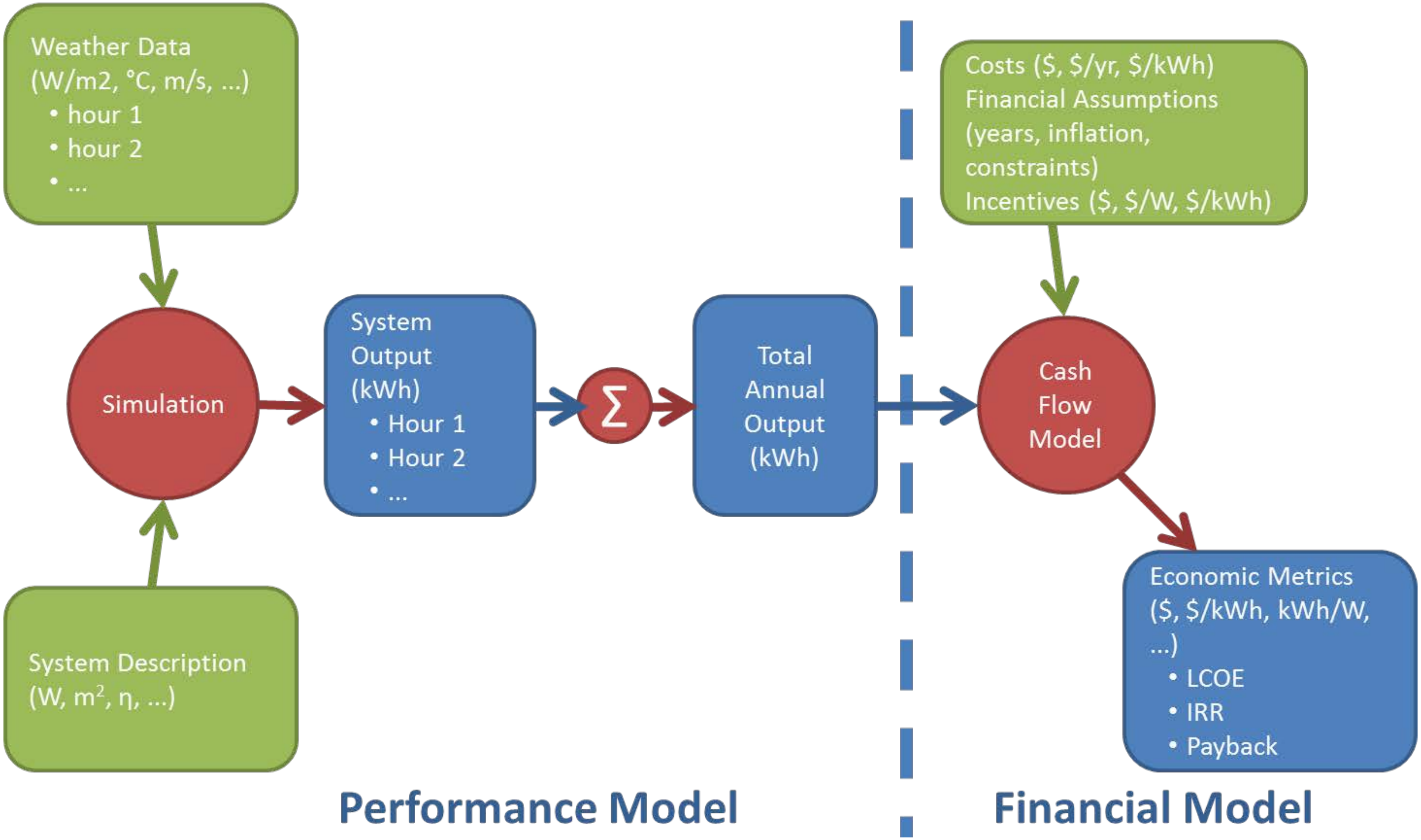
People use SAM for a wide variety of purposes

- **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



SAM models many types of projects

- 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

Photovoltaic performance model is for grid-connected systems

- 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

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

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 has limitations

- 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!

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Residential rooftop system in Portland, OR

- **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?**

Analysis strategy

- **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

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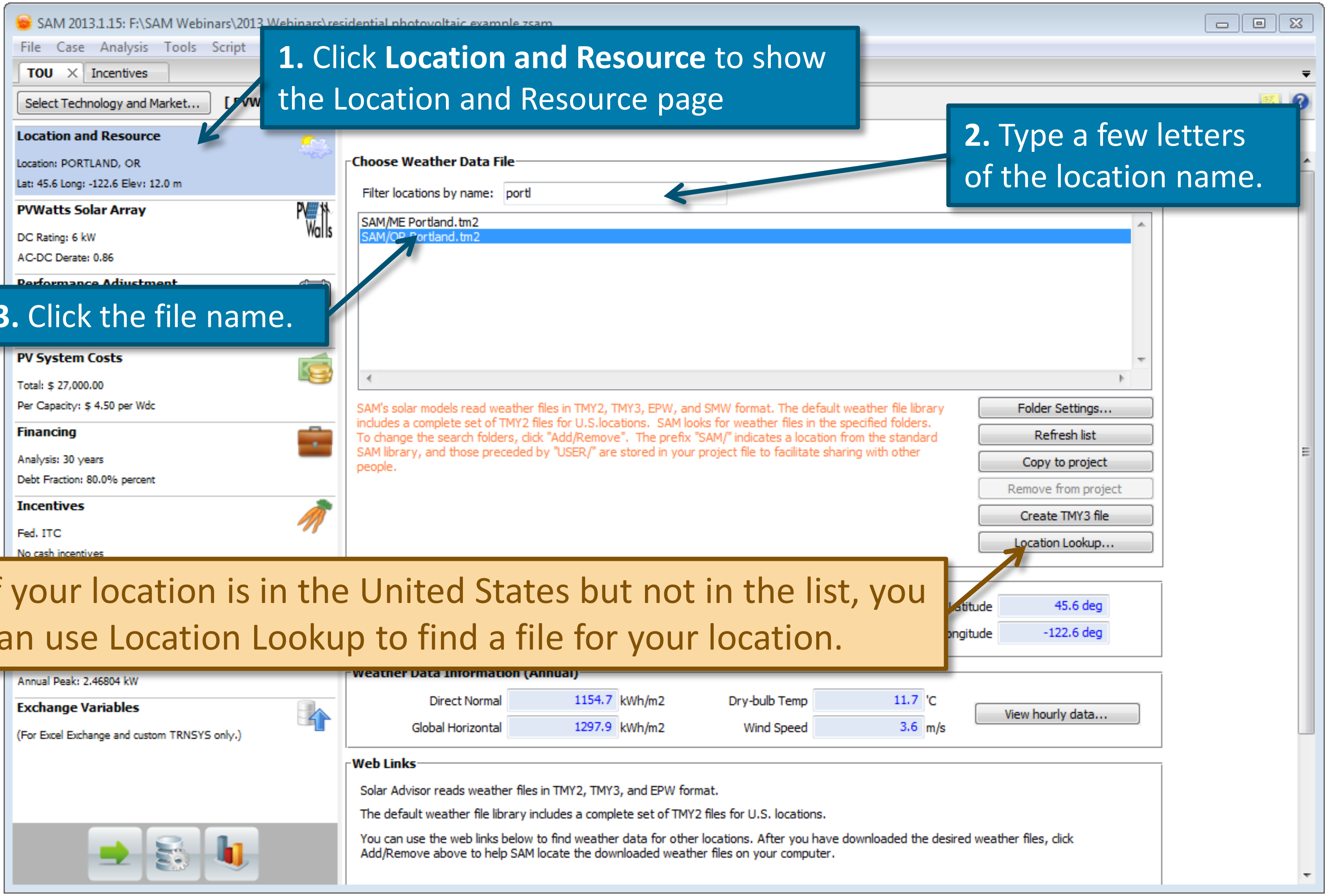


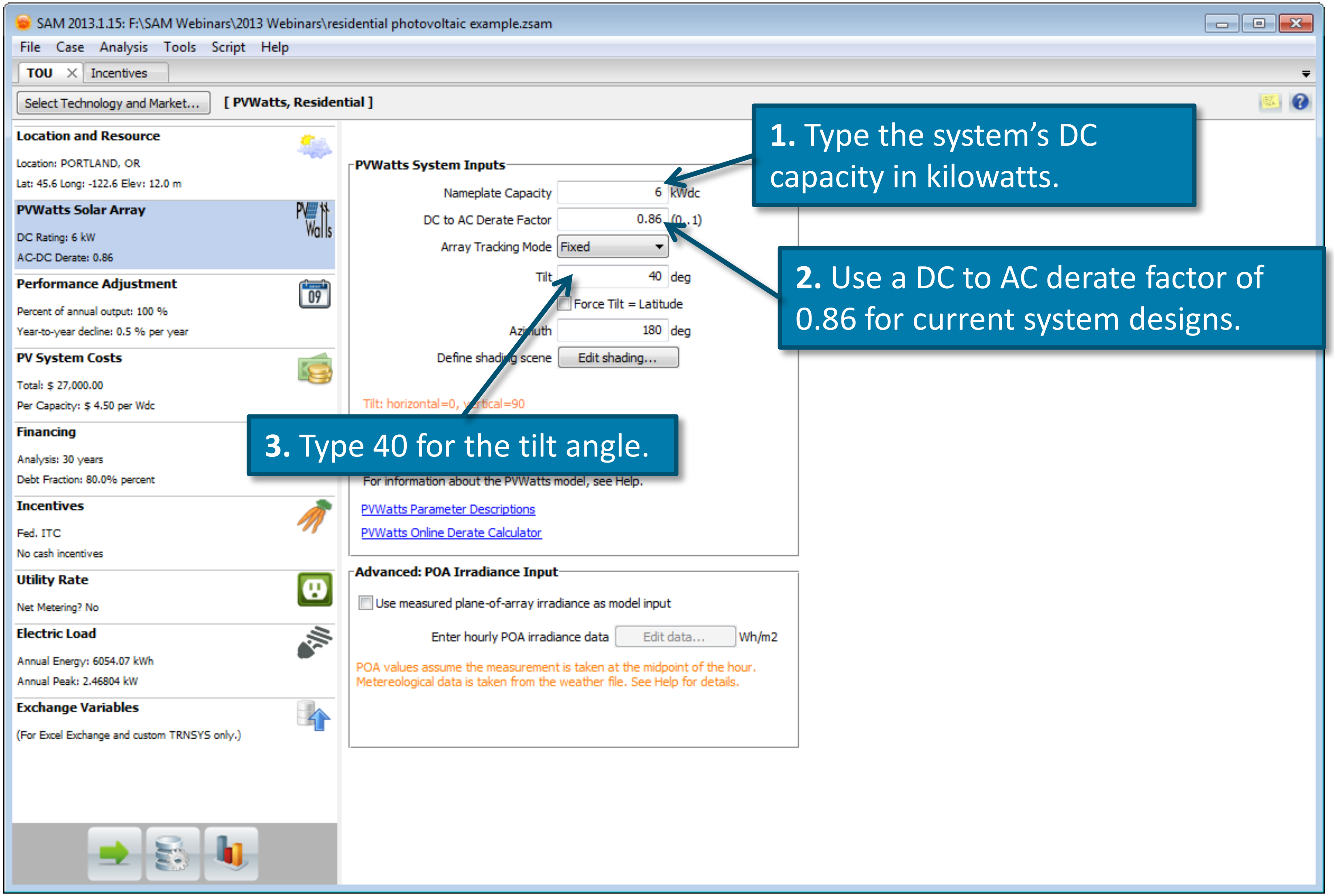
1. Click **Location and Resource** to show the Location and Resource page

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.

Specify system parameters on the PVWatts Solar Array page

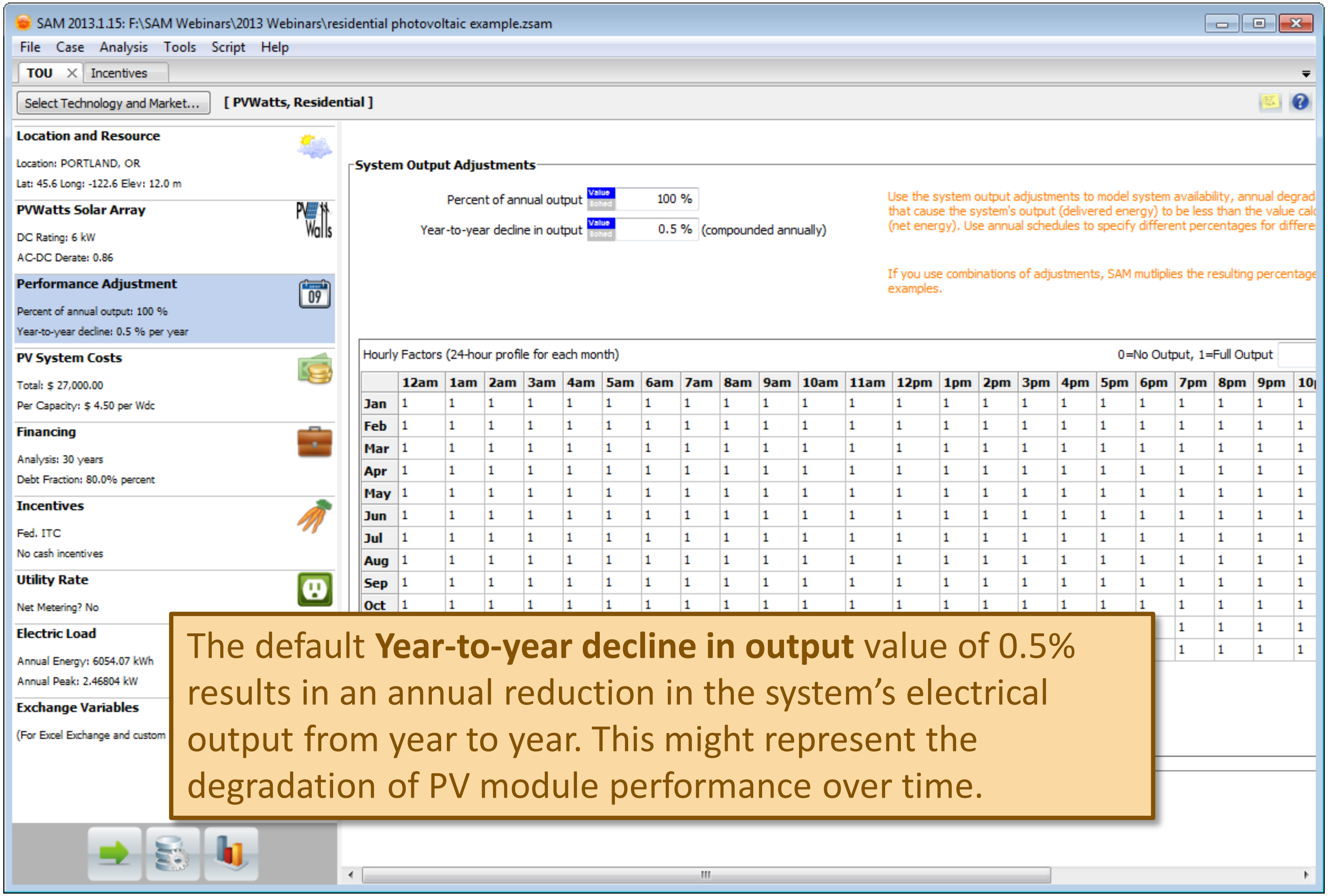


1. Type the system's DC capacity in kilowatts.

2. Use a DC to AC derate factor of 0.86 for current system designs.

3. Type 40 for the tilt angle.

Review the performance adjustment factors



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

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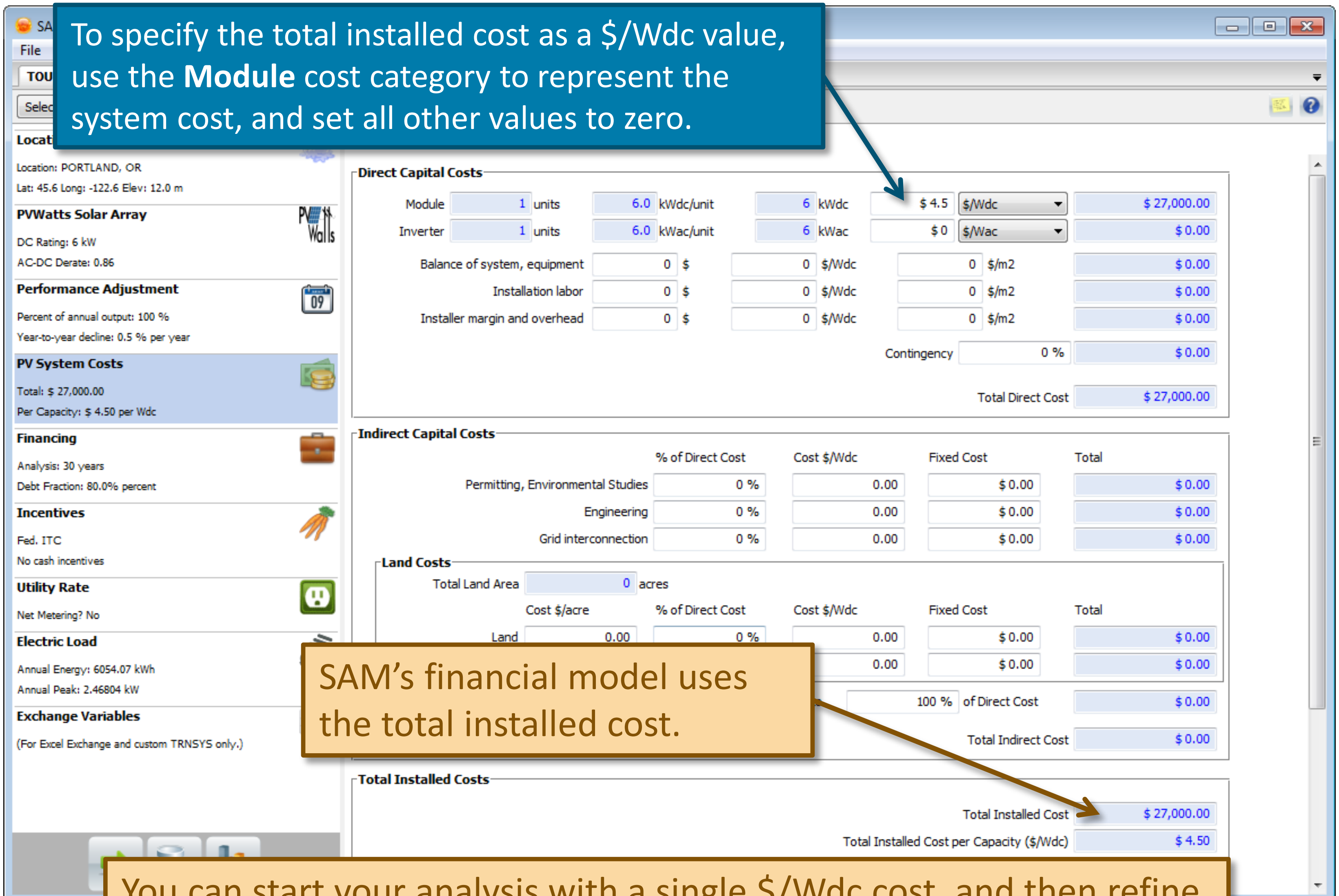

To specify the total installed cost as a $/Wdc value, use the **Module** cost category to represent the system cost, and set all other values to zero.

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.

Specify operation and maintenance costs

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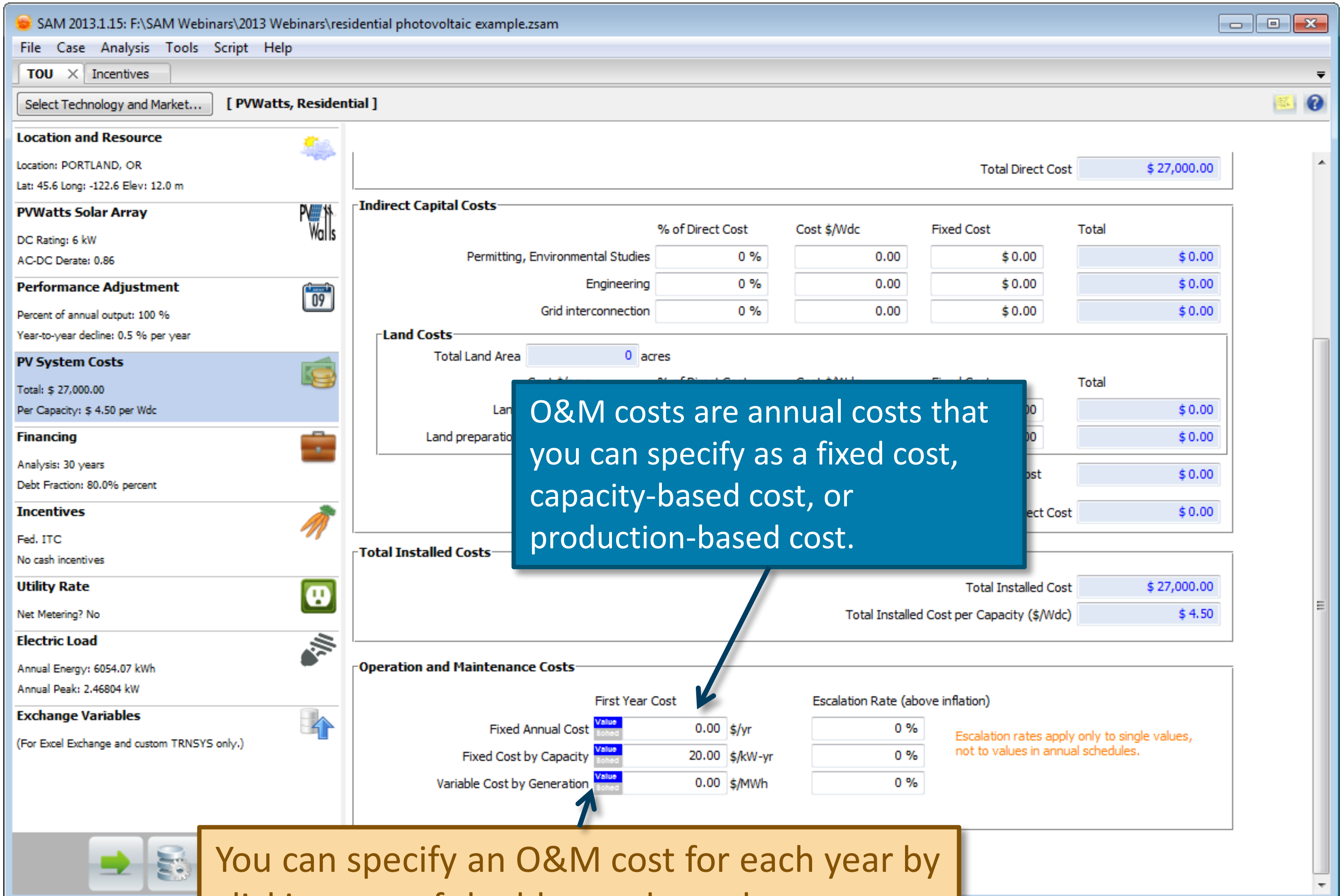

O&M costs are annual costs that you can specify as a fixed cost, capacity-based cost, or production-based cost.

You can specify an O&M cost for each year by clicking one of the blue and grey buttons.

Financial parameters

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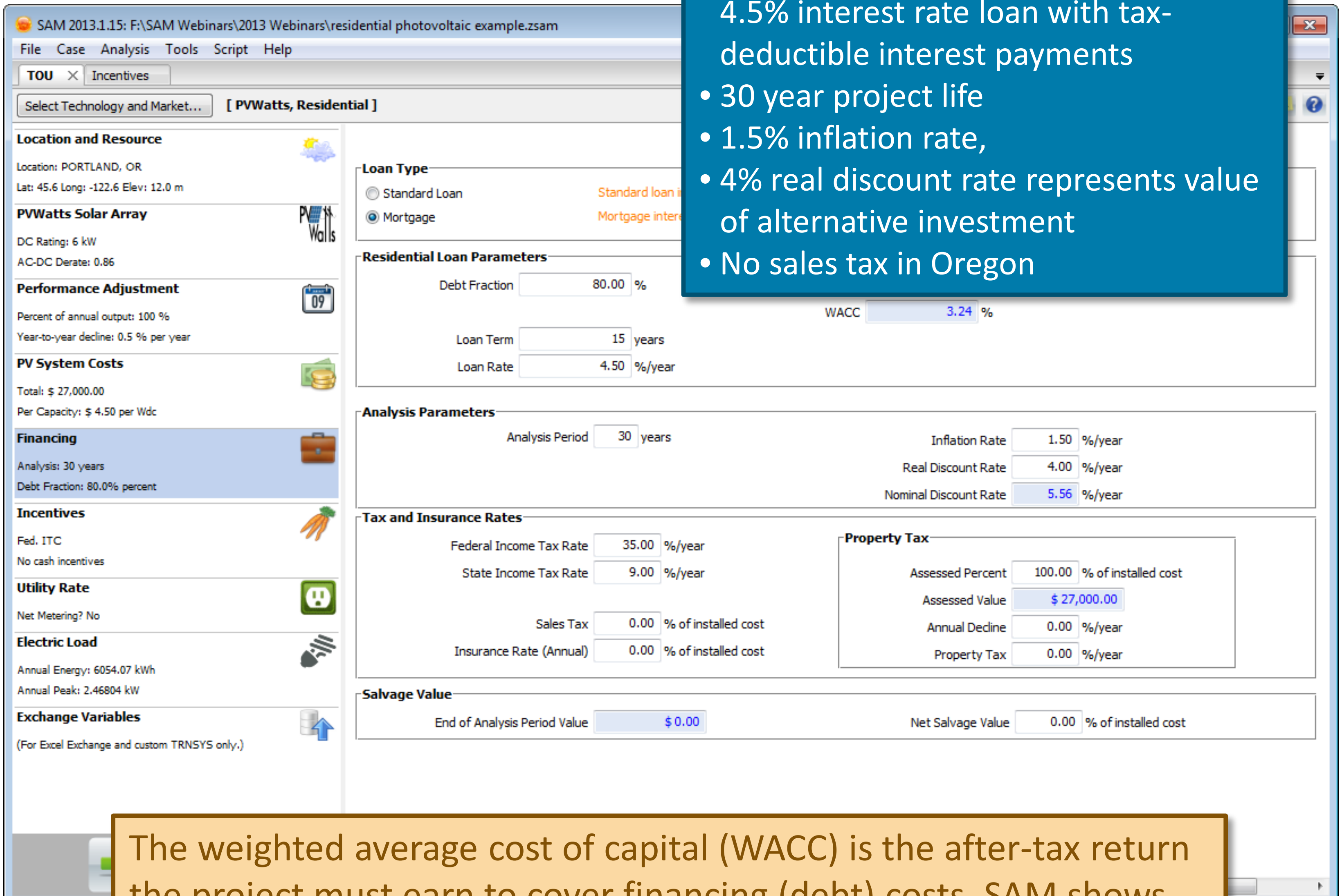
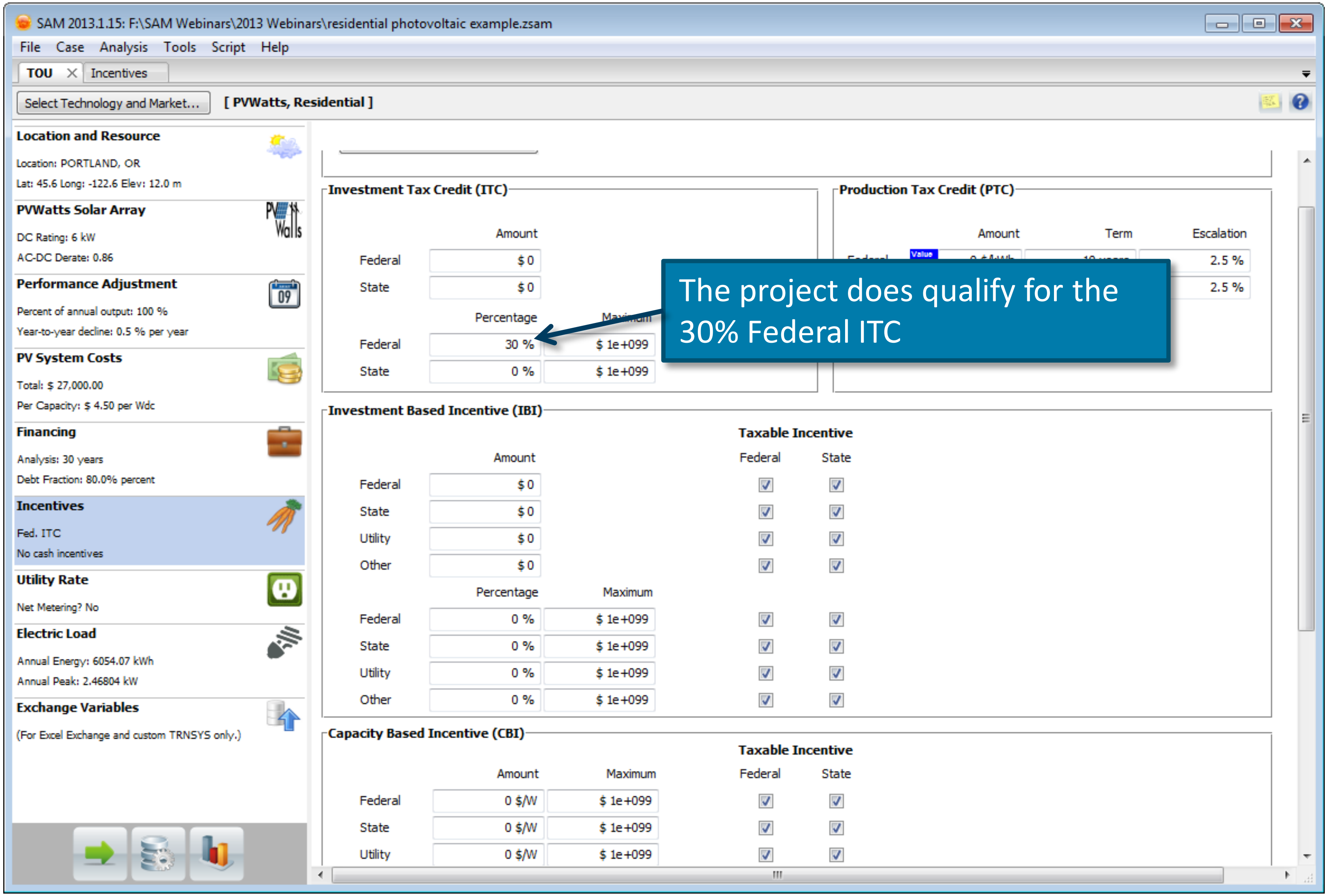
- 20% down payment for a 15-year, 4.5% interest rate loan with tax-deductible interest payments
- 30 year project life
- 1.5% inflation rate,
- 4% real discount rate represents value of alternative investment
- No sales tax in Oregon



The 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



Specify the rate schedule

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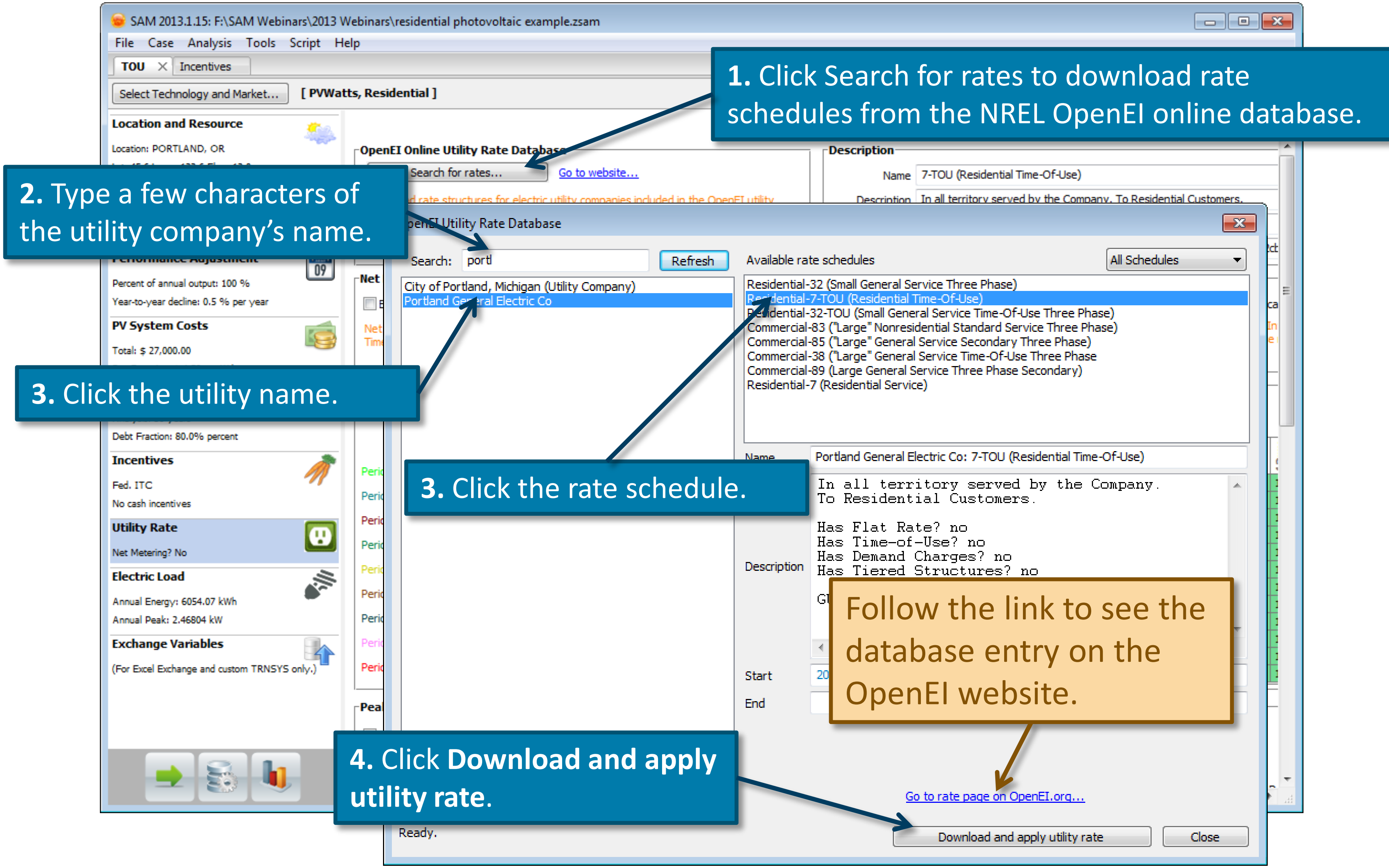

Review and revise the rate schedule

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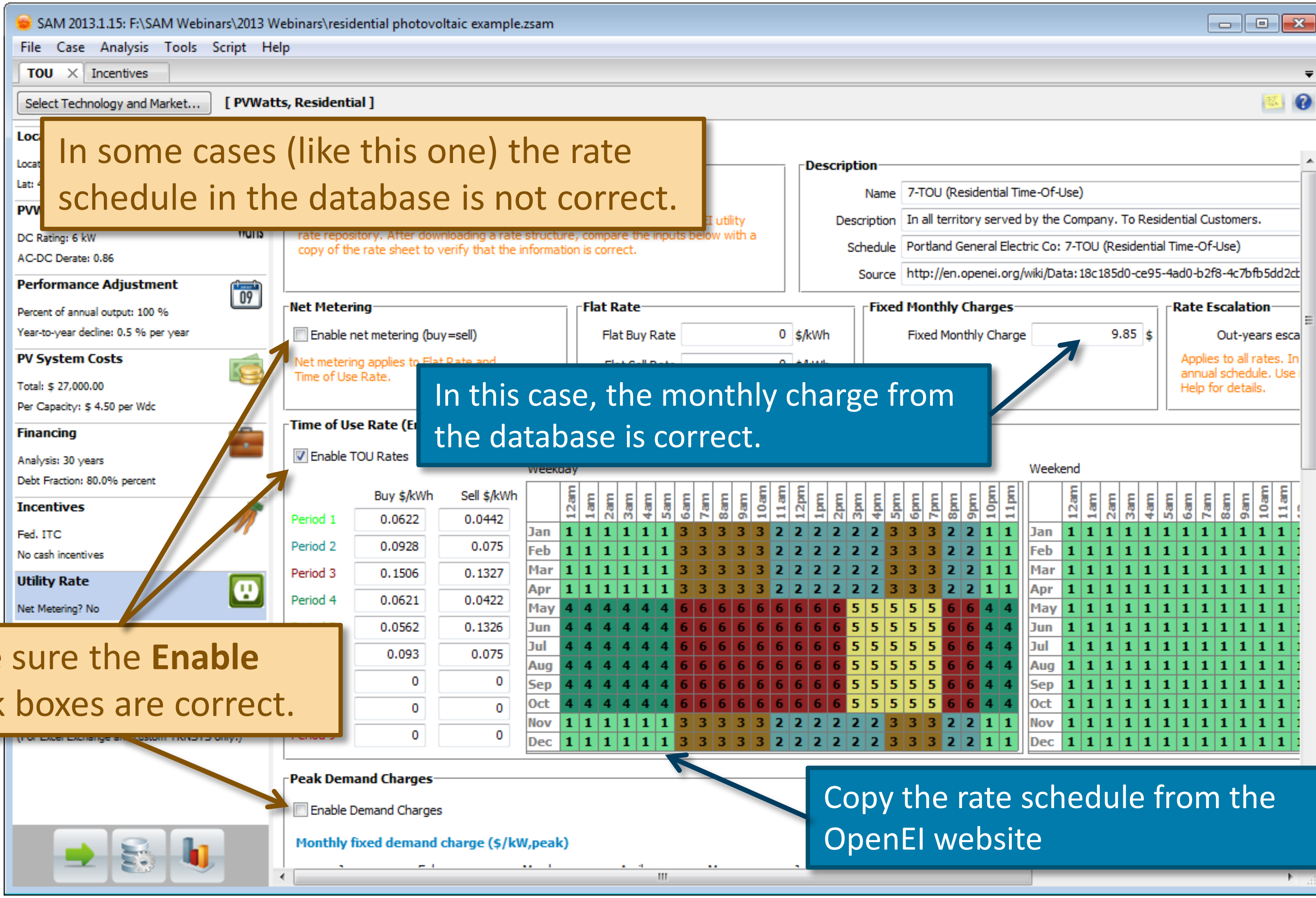


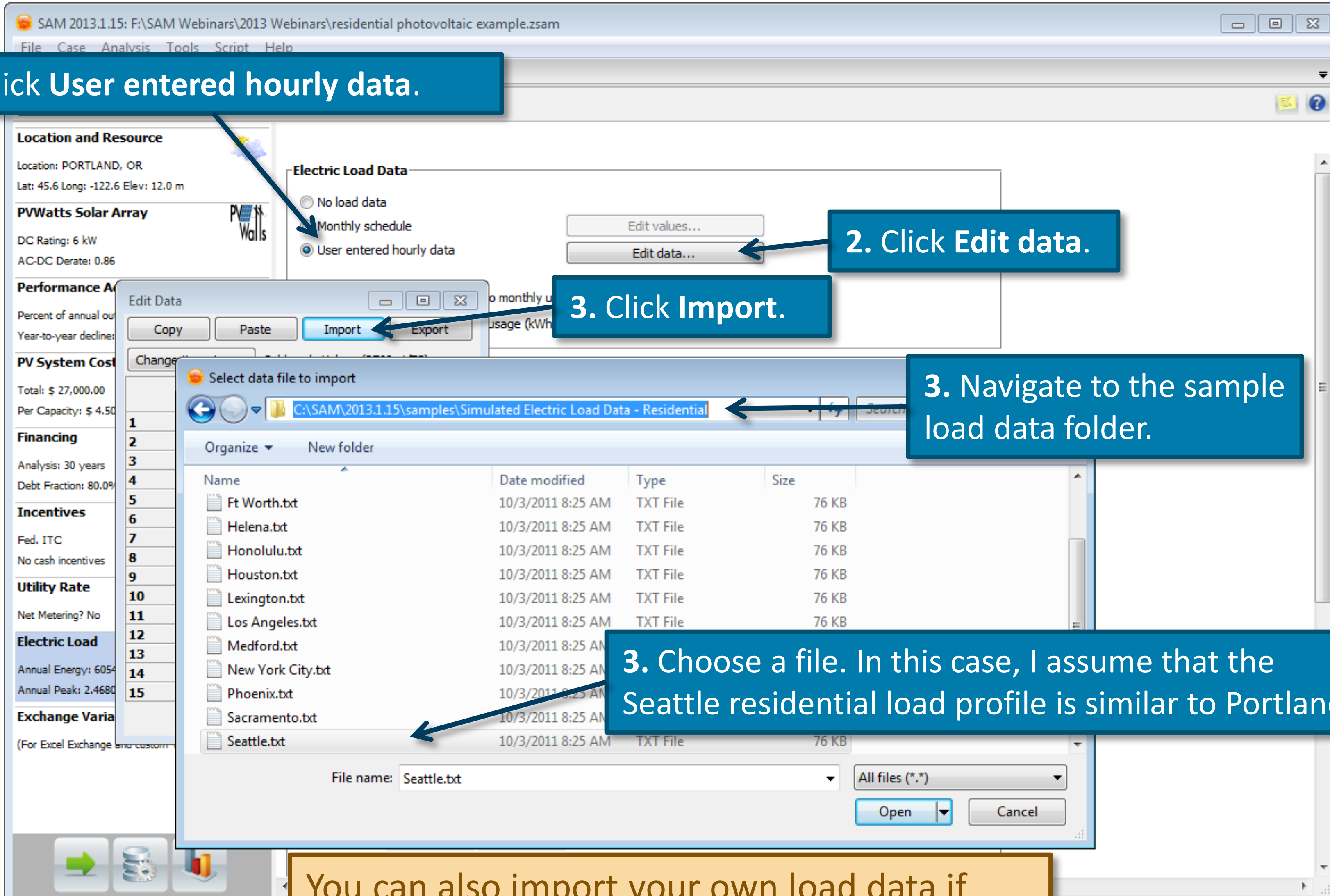
In some cases (like this one) the rate schedule in the database is not correct.

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

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

Copy the rate schedule from the OpenEI website

Specify the electric load



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.

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

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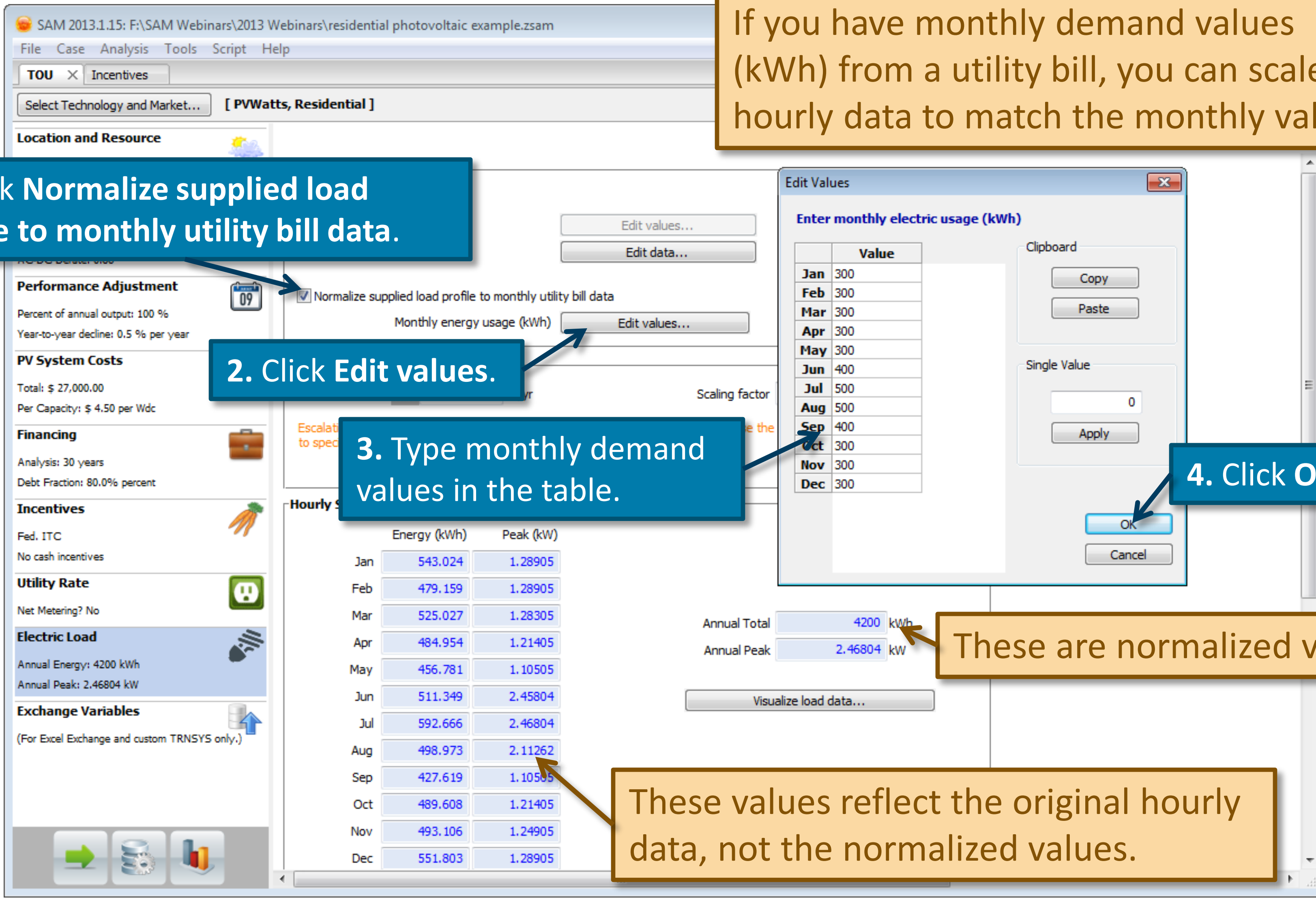

If you have monthly demand values (kWh) from a utility bill, you can scale the hourly data to match the monthly values.

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**.

These are normalized values.

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

Run a simulation and review cash flow

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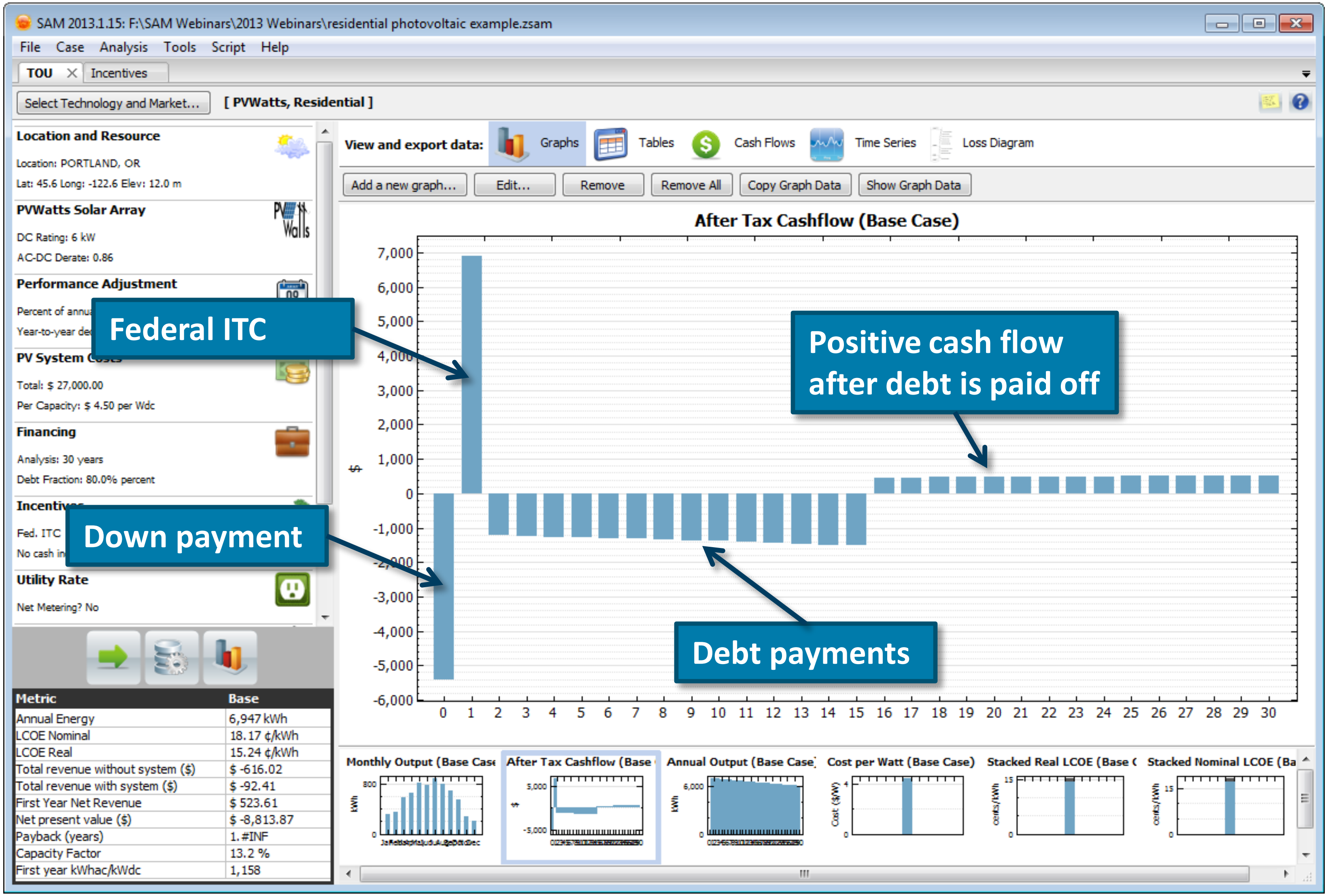


Review metrics table

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

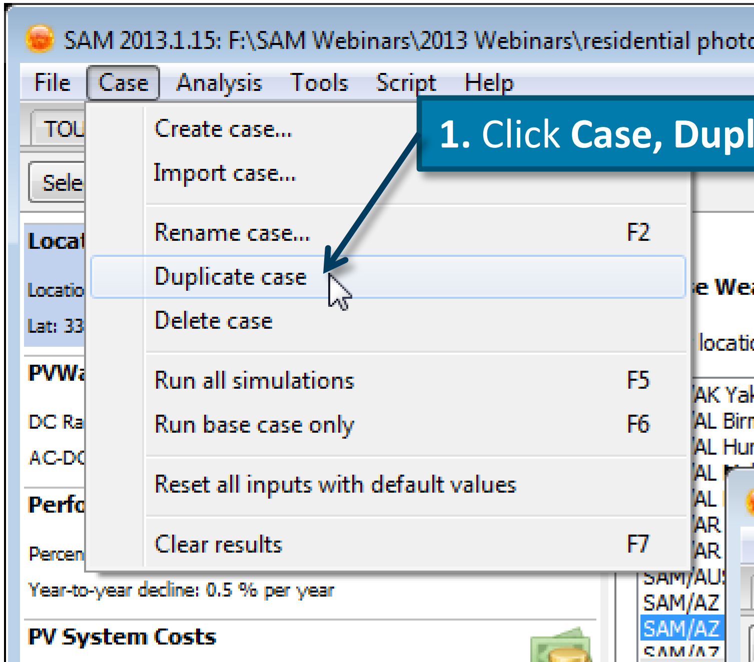
- You can compare the real LCOE to the retail electricity price.
- The positive first year net revenue value represents net savings.
- The negative net present value shows that the project is worth less over its life than an investment with a 4% return.
- The “1.#INF” payback period indicates a payback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

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

Summary of first scenario results

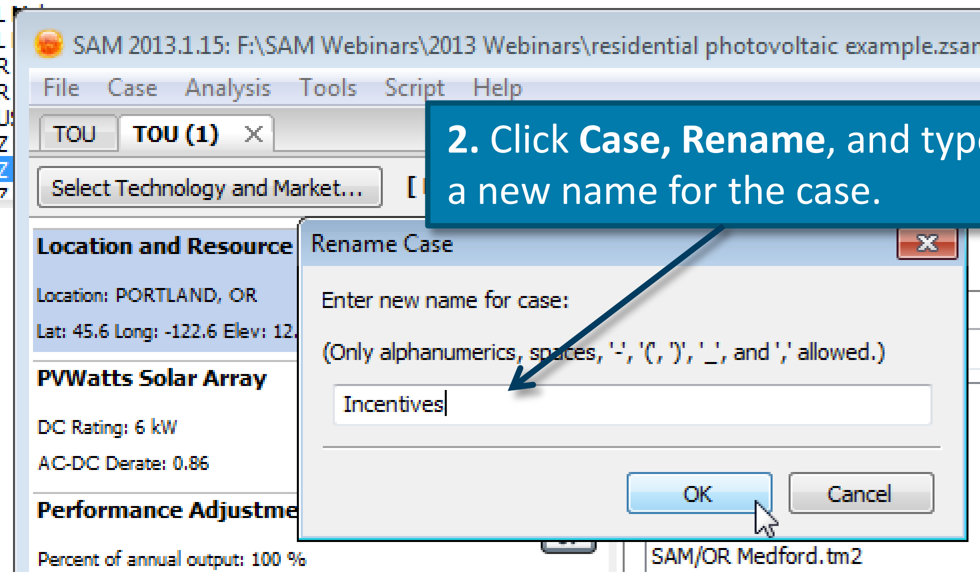
- If the project uses TOU rates, it saves the owner money by lowering the annual electric bill, but it has a negative NPV, and too long of a payback period
- Now, let's see if we can do better with the state incentives option instead of the TOU rate option

Create a duplicate case



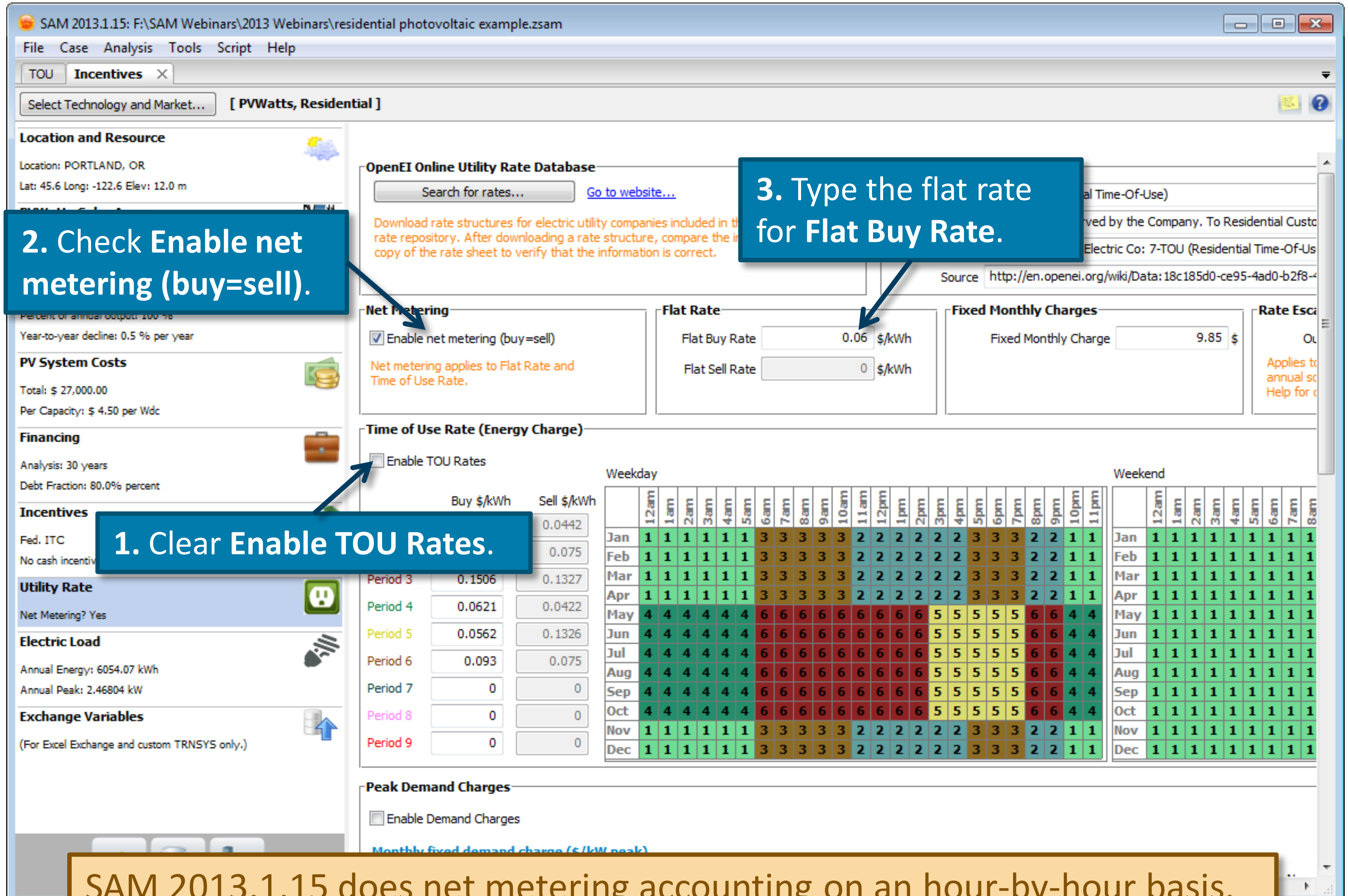
1. Click **Case, Duplicate**.

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.



2. Click **Case, Rename**, and type a new name for the case.

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



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

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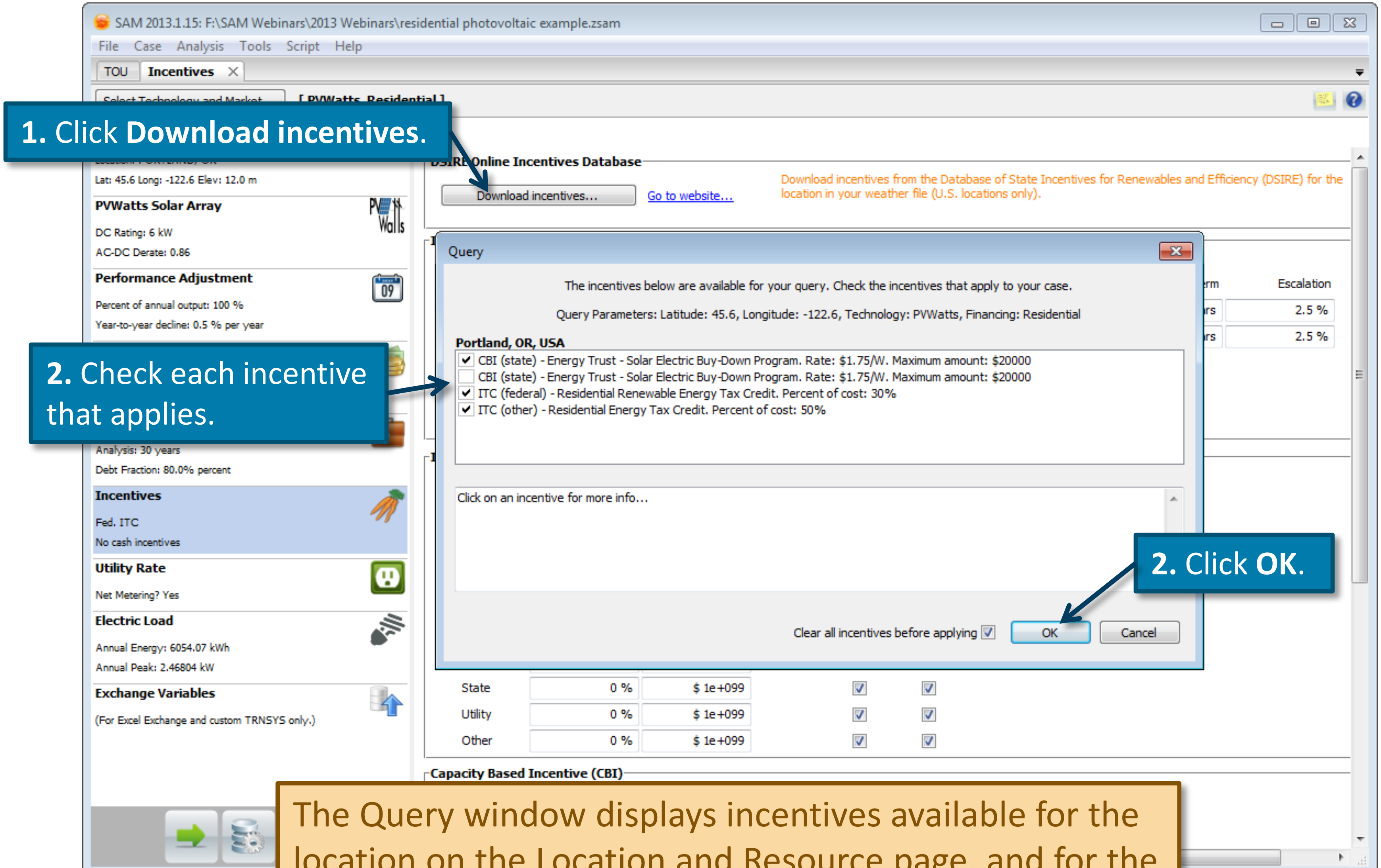

The Query window displays incentives available for the location on the Location and Resource page, and for the financial model (in this case, it is residential).

Verify that the incentives are correct

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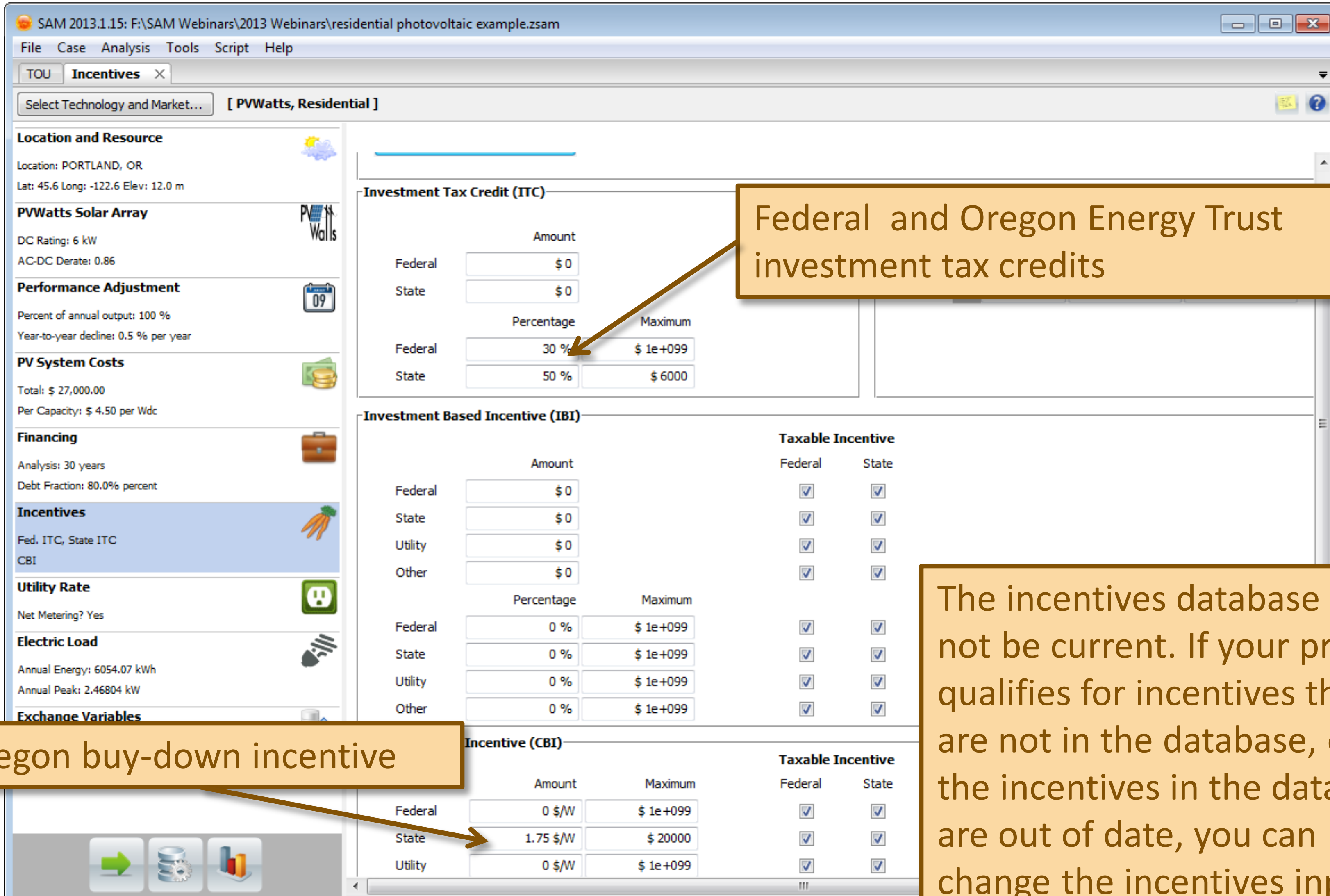

Federal and Oregon Energy Trust investment tax credits

Oregon buy-down incentive

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

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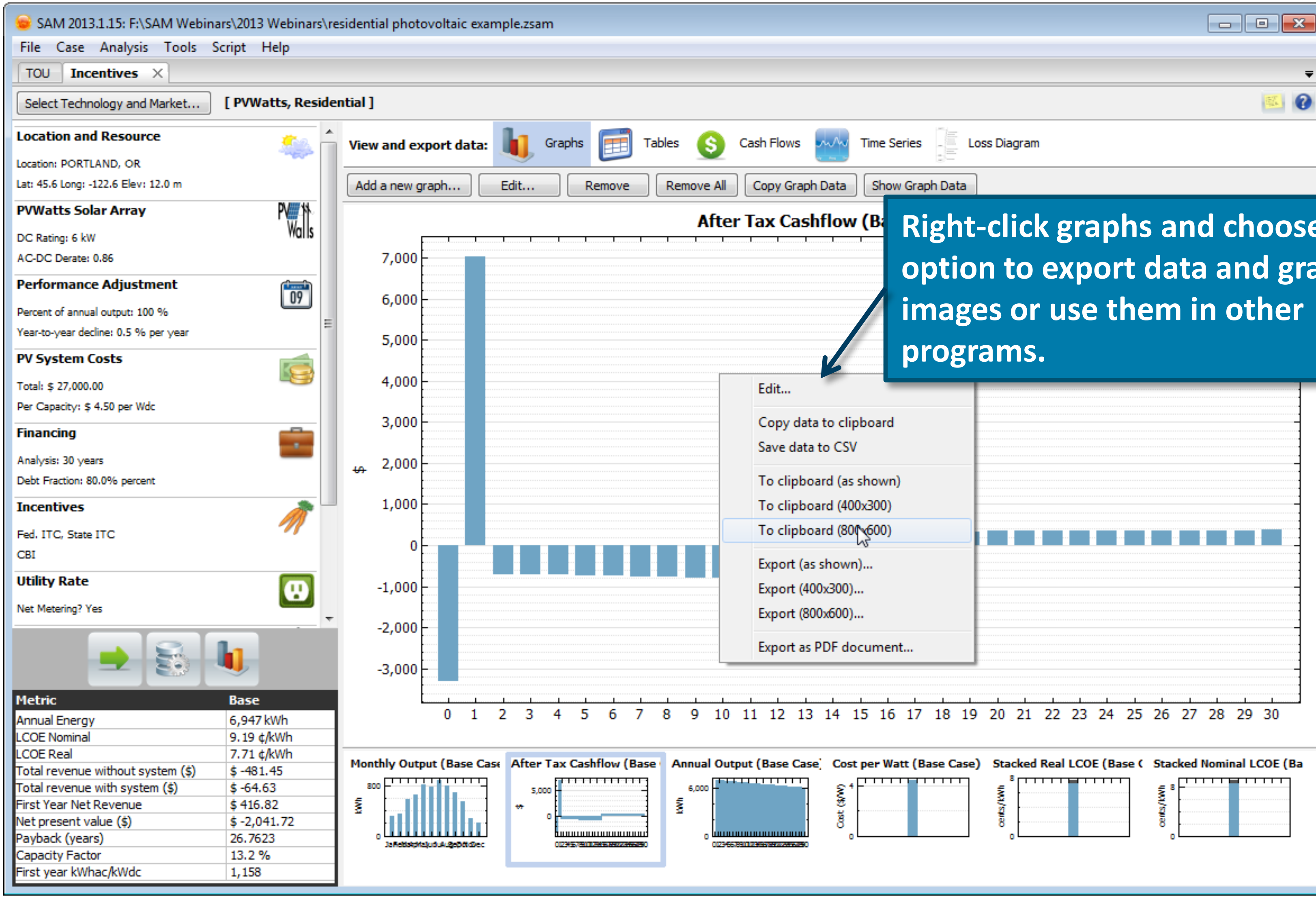
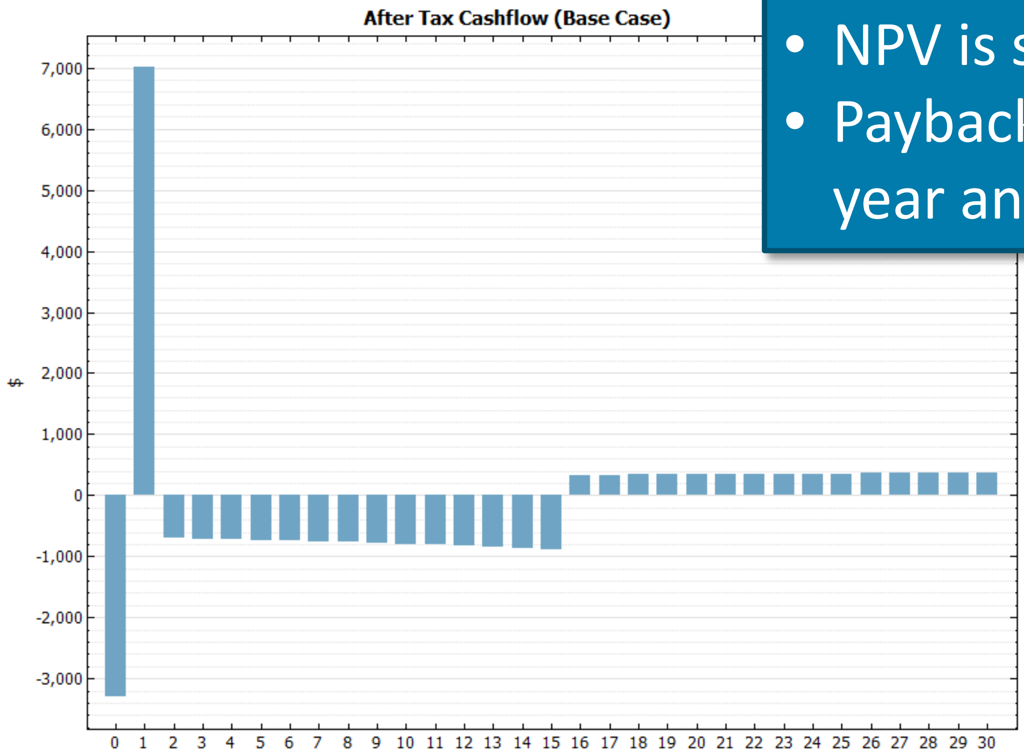


Right-click graphs and choose an option to export data and graph images or use them in other programs.

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.

Use cases for side-by-side comparisons

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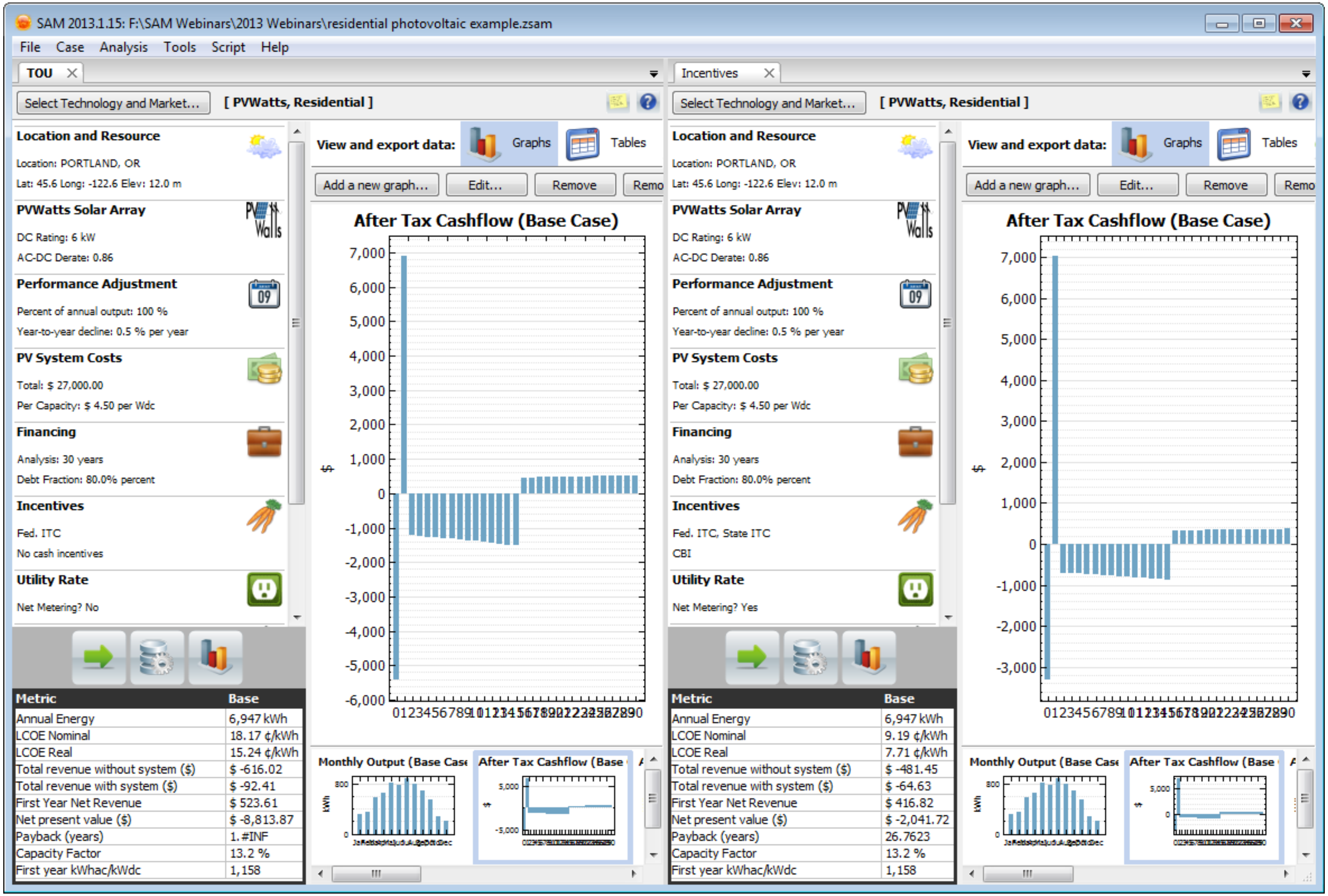

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PVWatts analysis results

- 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"

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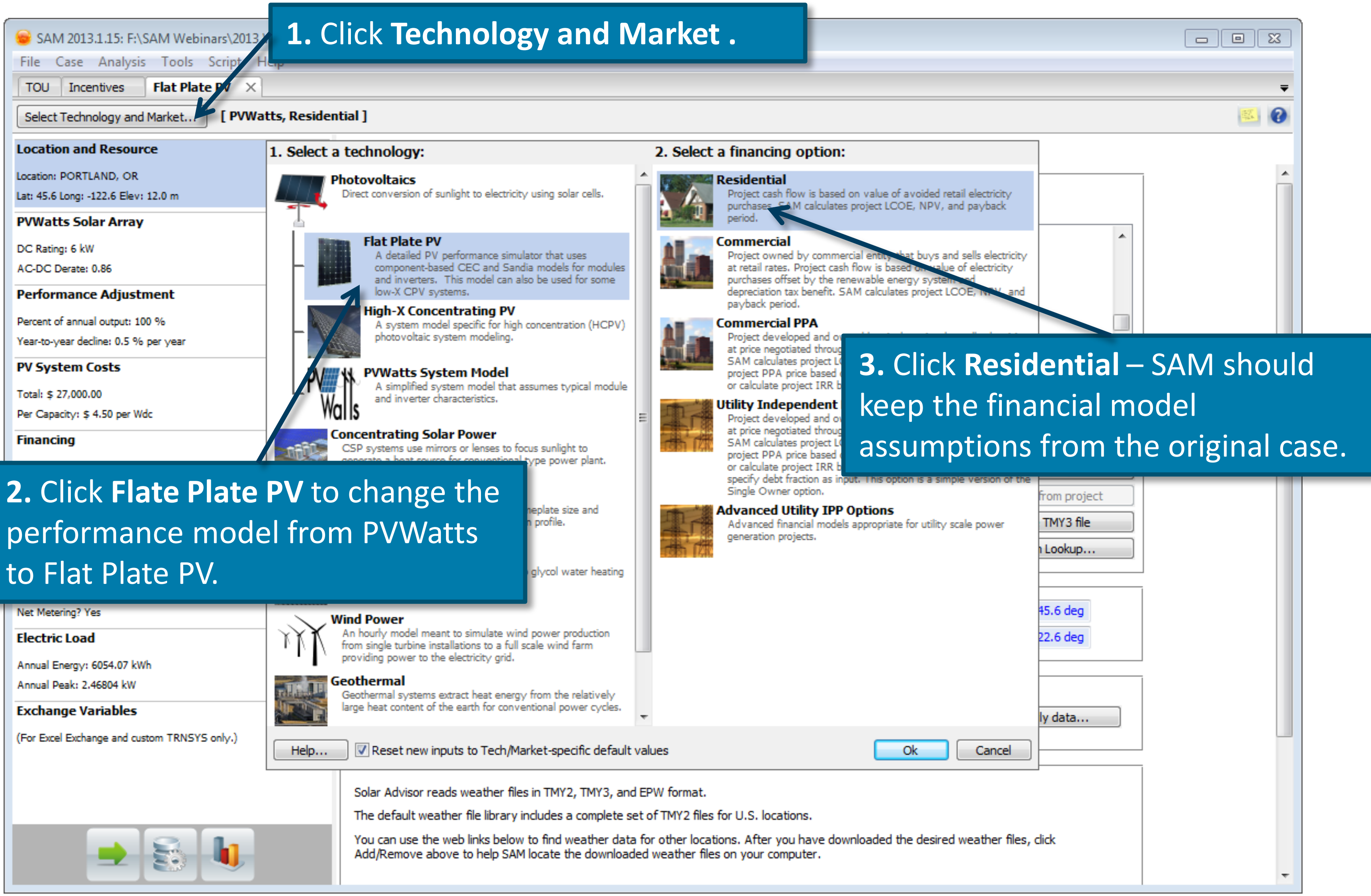

Choose a module

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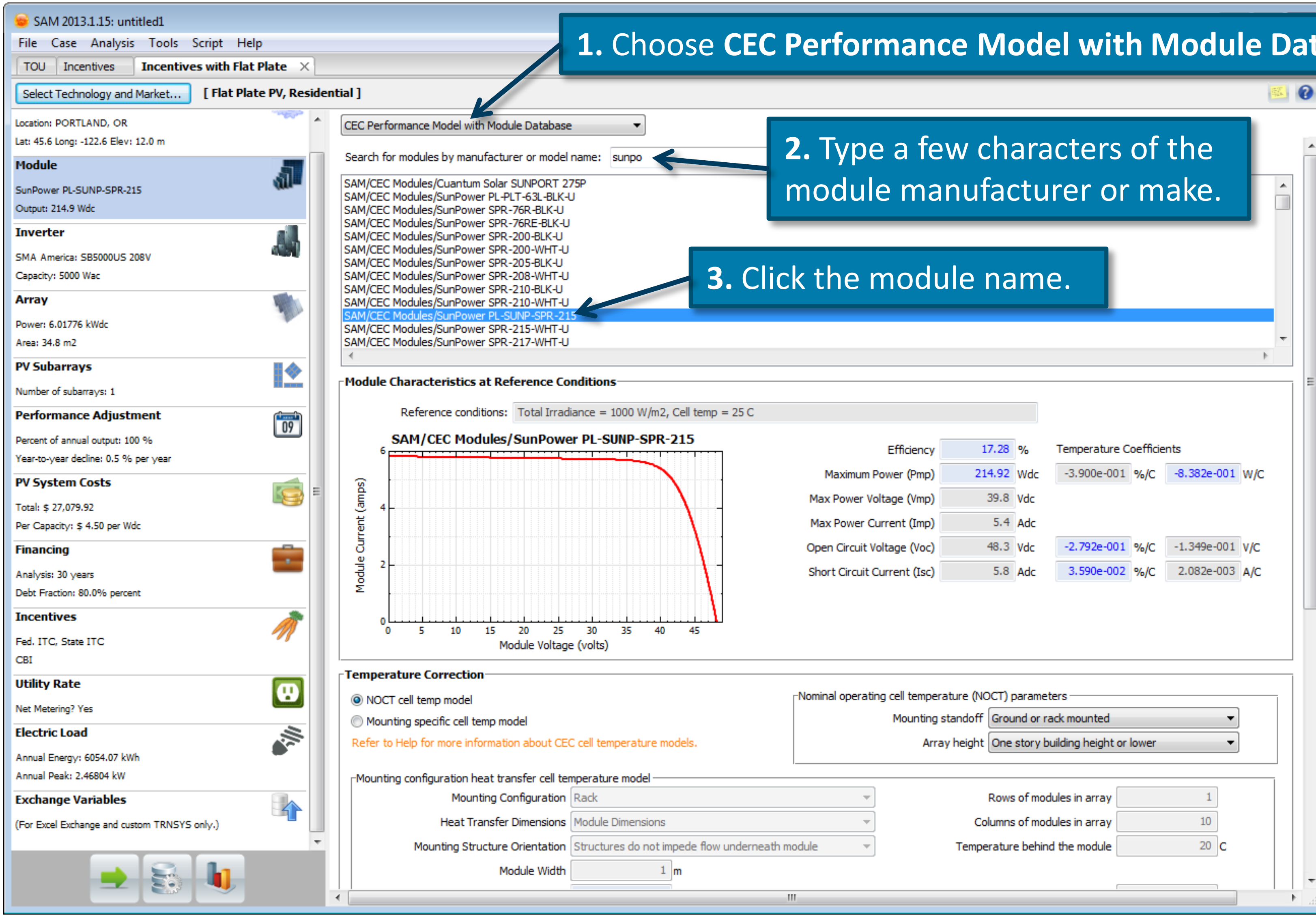

1. Choose **CEC Performance Model with Module Database**.

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

3. Click the module name.

Choose an inverter

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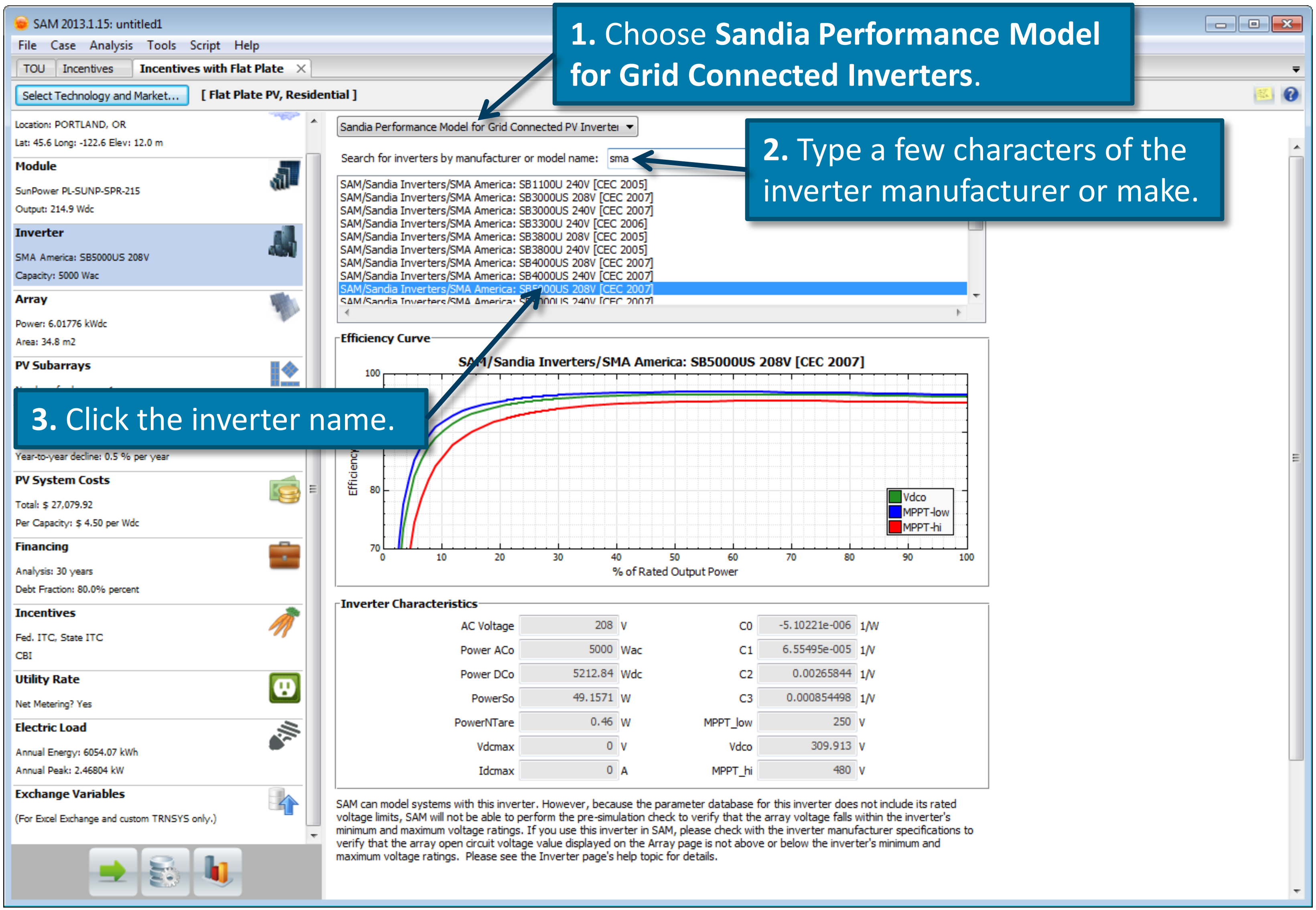

Specify the number of modules and inverters in the array

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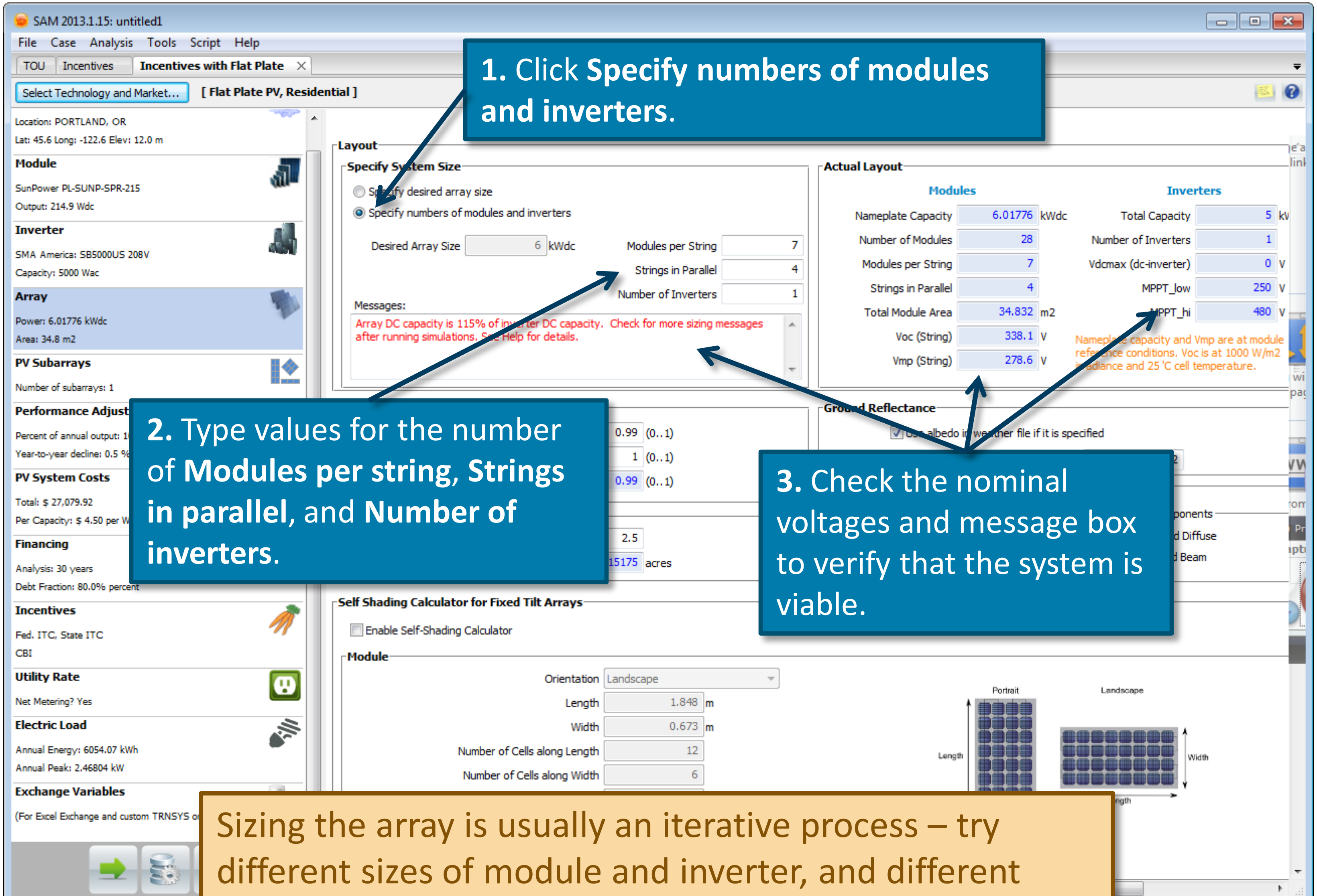

1. Click **Specify numbers of modules and inverters**.

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.

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 the array tilt angle

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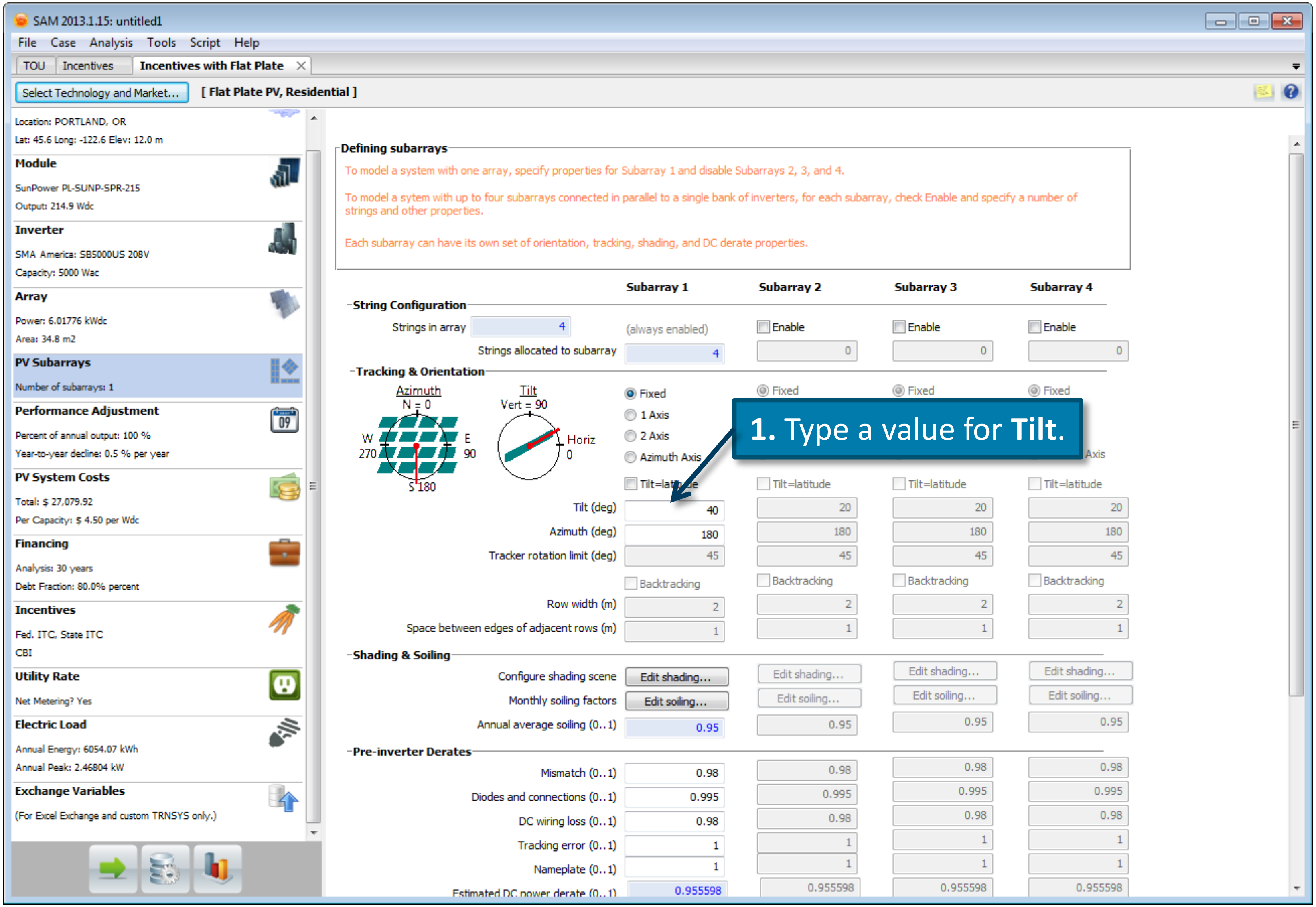

Run simulations and review results

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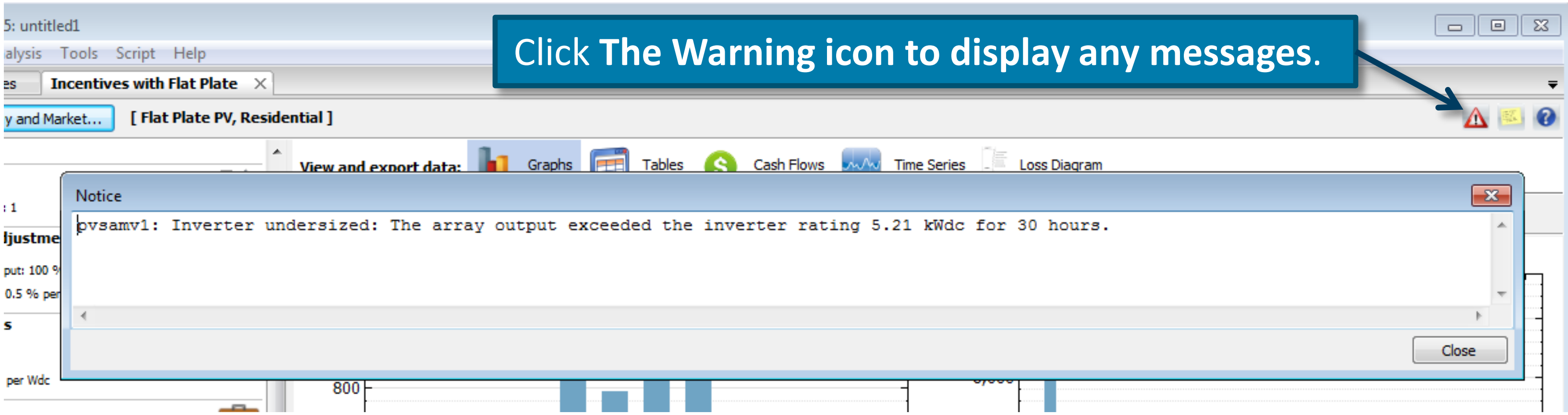
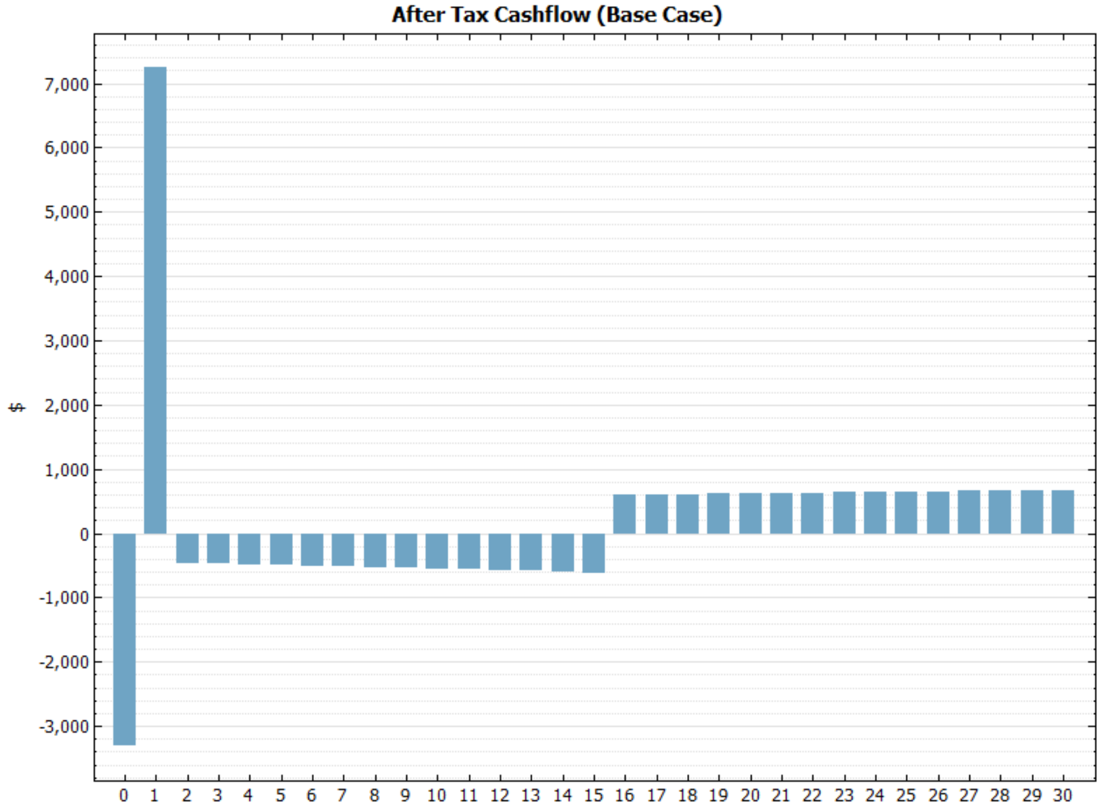


The Warning icon spins when there is a simulation message. These messages provide information about simulation results. In this case, the array's DC output exceeds the inverter's rated input power for 8 of the 8,760 hours of the year. We can ignore this message if we assume the system is designed to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

Run simulations and review results

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 analysis results

- 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