National Renewable Energy Laboratory
Innovation for Our Energy Future

Modeling Wind Systems in SAM

SAM Webinar

Tom Ferguson
Paul Gilman

June 5, 2013
1 p.m. Mountain Time

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

Outline

- Introduction to SAM
- Example 1: Modeling a small wind project
- Example 2: Modeling a wind farm
- Additional topics
- Questions

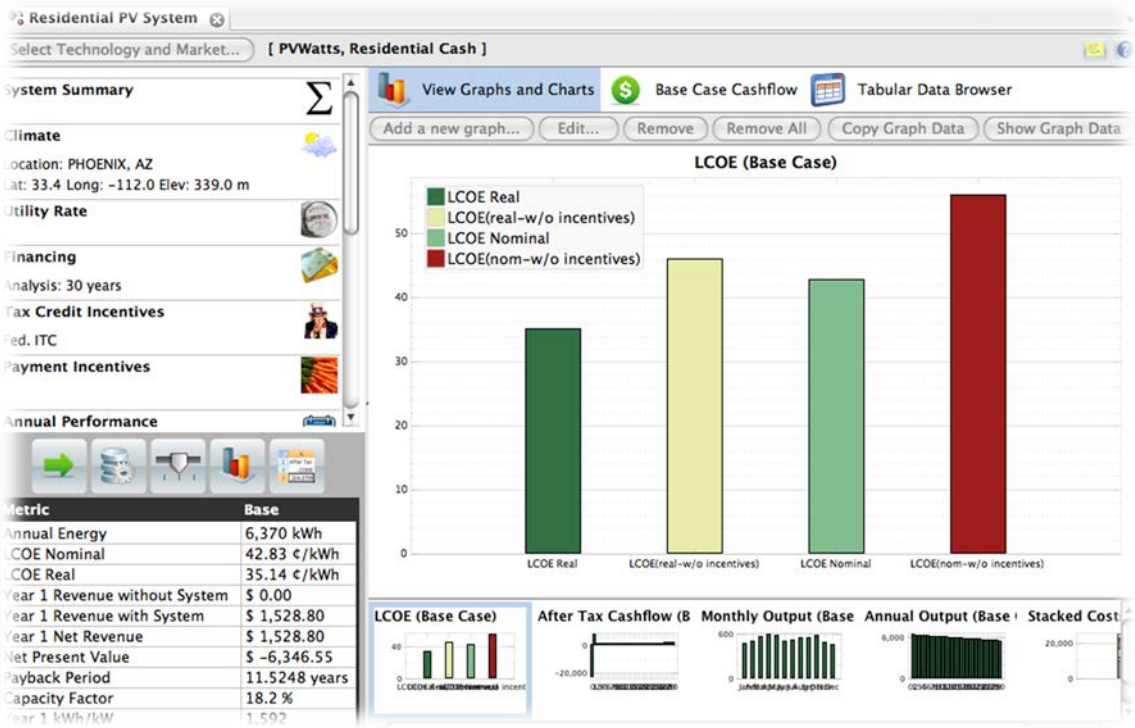
Modeling Wind Systems in SAM

INTRODUCTION TO SAM

What is SAM?

The System Advisor Model (SAM) is a free computer program 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 the life of the project.

These calculations are done using detailed performance models, a detailed cash flow finance model, and a library of reasonable default values for each technology and target market.



What can you do with SAM?

- Model solar, wind, and geothermal power systems in a single application
- Access high-quality performance and economic models developed by NREL, Sandia, and other partners
- Evaluate and compare options using consistent models across technologies
- Calculate economic metrics such as LCOE, NPV, payback for projects in different markets
- Perform parametric and uncertainty analyses
- Present modeling results in graphs and tables

SAM combines performance and financial models

- Photovoltaic systems
- Concentrating Solar Power
  - Parabolic Troughs
  - Power Towers
  - Dish-Stirling
- Solar Water Heating
- Wind turbines and farms
- Geothermal power plants

Key outputs

- Hourly energy production (kWh)
- Capacity factor

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

Key outputs

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

Background

SAM has been a collaborative effort by the Department of Energy, National Renewable Energy Laboratory, and Sandia National Laboratories

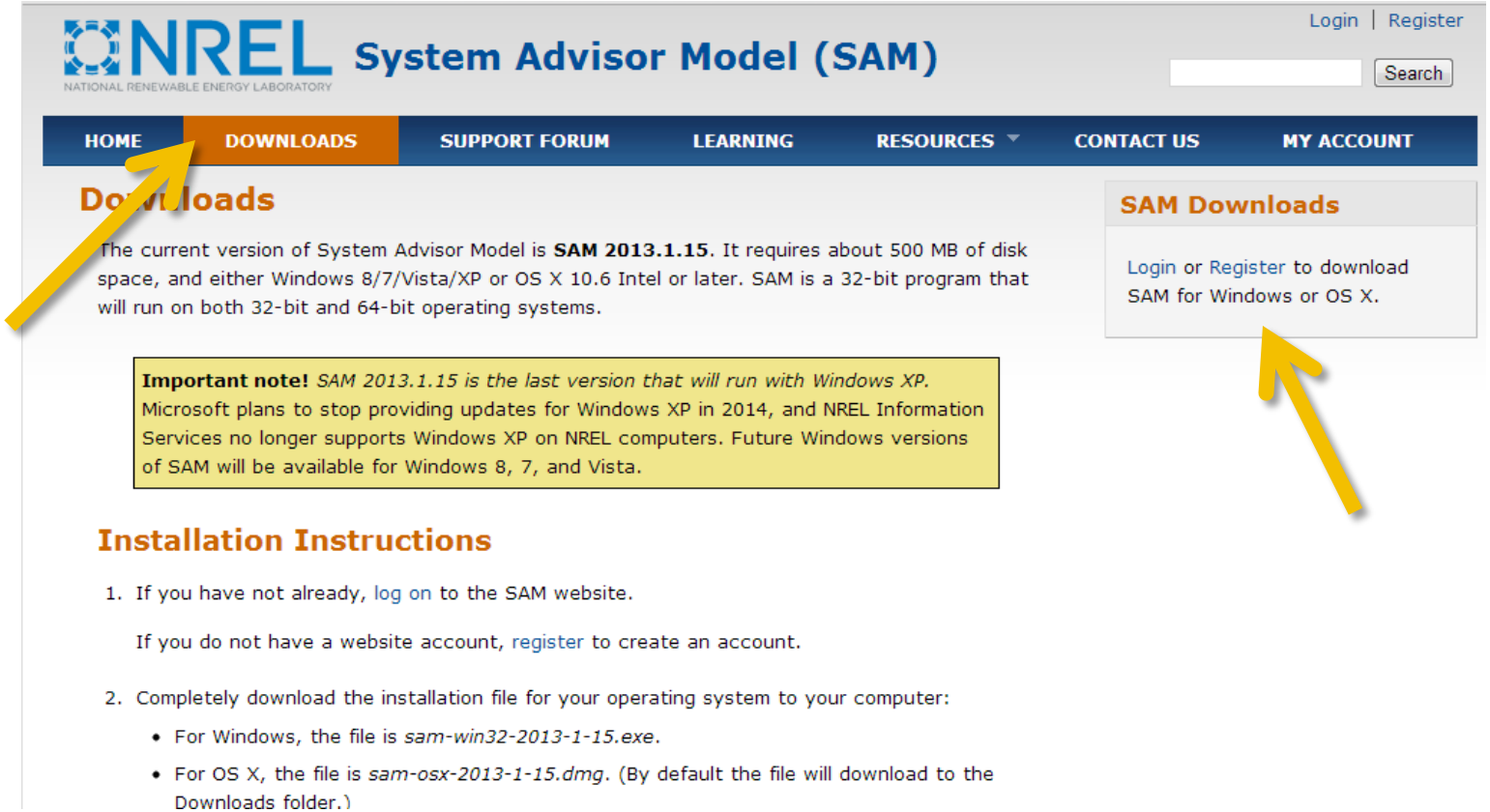
SAM has been downloaded more than 35,000 times by:

- Manufacturers
- Engineering Firms
- Consultants
- Developers
- Venture Capitalists
- Policy Analysts

Downloading SAM

https://sam.nrel.gov/

1) Click Register 2) Complete form 3) Download



Getting Help

Online Help and User Guide

- Help menu and buttons

SAM Website

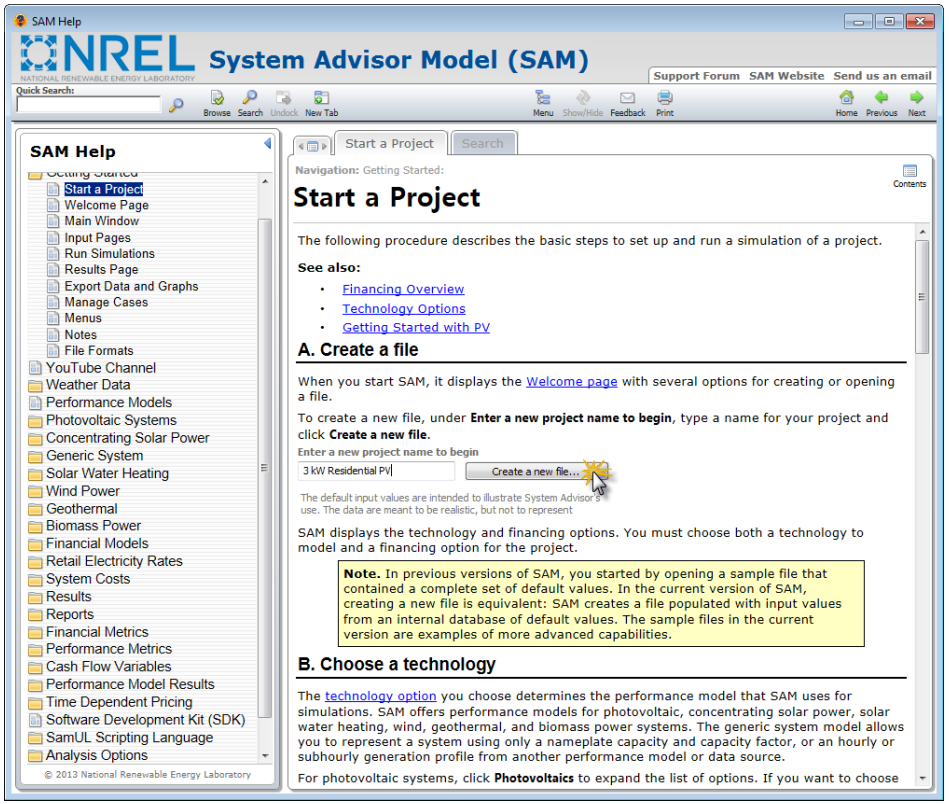
- https://sam.nrel.gov

Support Forum

- https://sam.nrel.gov/forums/support-forum

Email User Support

- sam.support@nrel.gov



Modeling Wind Systems in SAM

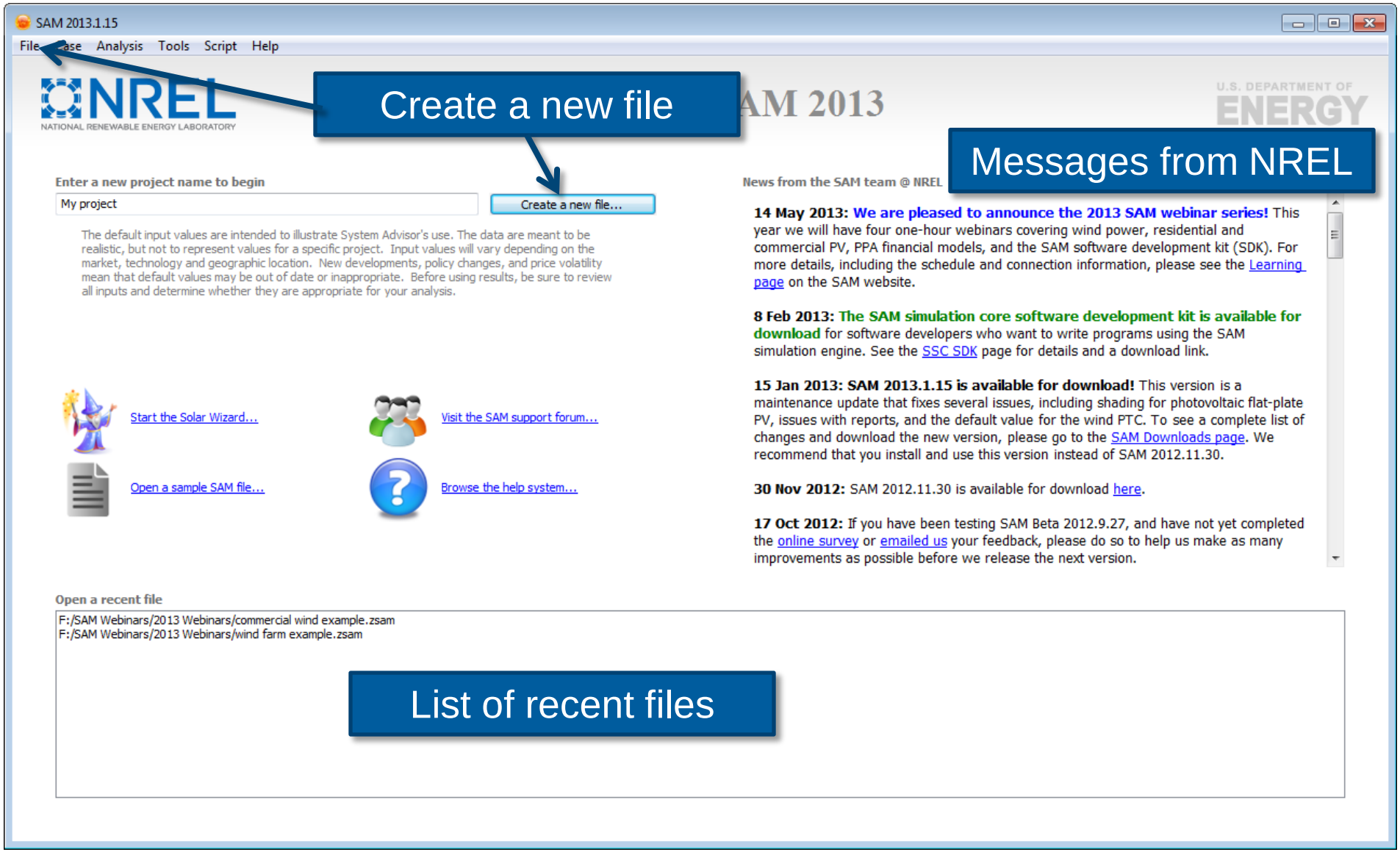
Example 1: One turbine helps meet a farm's electric load

Basic Assumptions

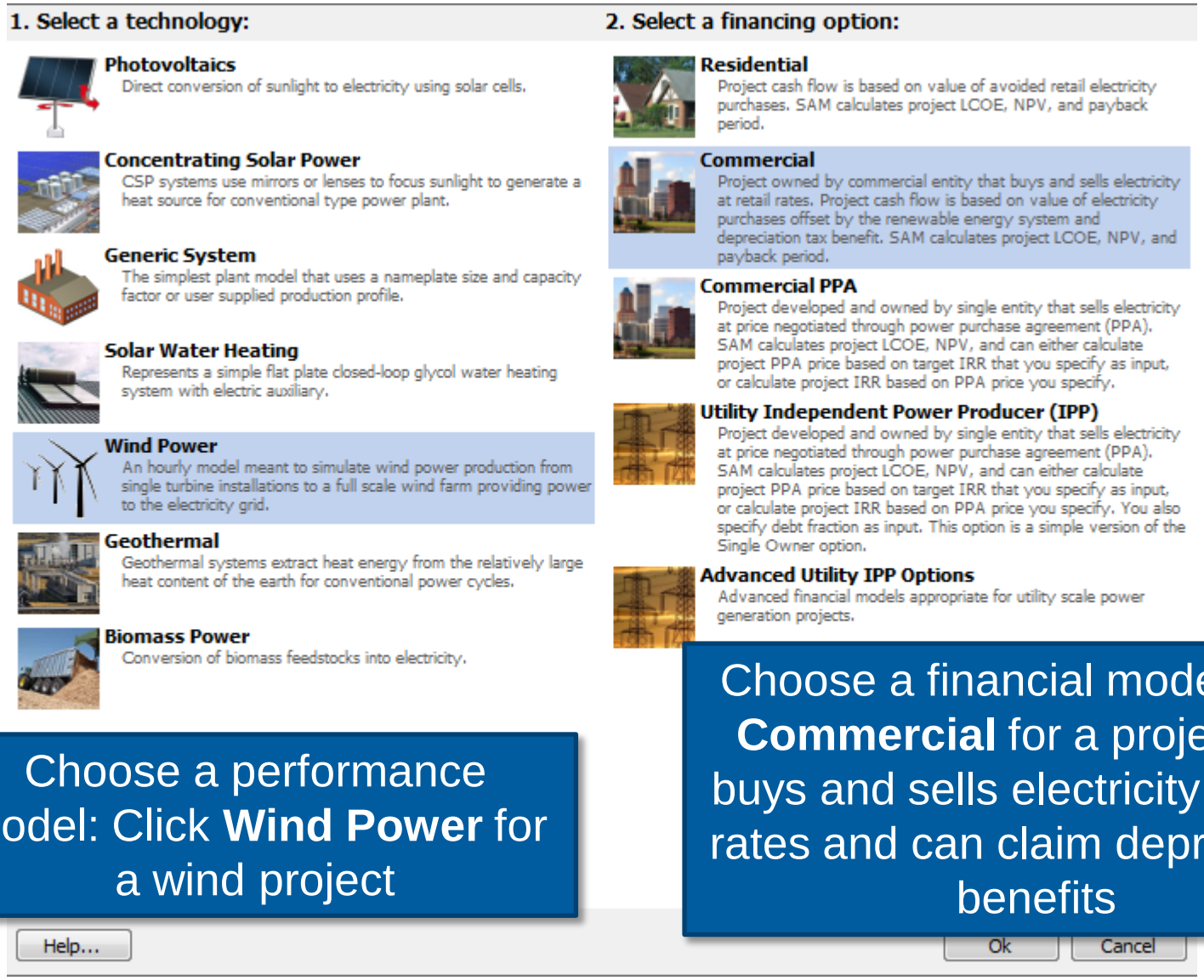
- Project site in North Central Oregon
- One Vestas V-47 wind turbine
- Turbine to help meet load of a small farm
- Retail electricity rate is 8 cents/kWh
- Utility will purchase electricity at 5 cents/kWh
- Total installation cost is $5,000/kW
- Annual operating cost is $10/kW
- Project financed with 60% loan
- Project benefits from 2.2 cent/kWh Federal production tax credit

These assumptions are not for a real project!
We made up the costs and electricity prices and other assumptions for demonstration purposes.

1. Start SAM


SAM 2013.1.15
File Case Analysis Tools Script Help
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Create a new file
AM 2013
U.S. DEPARTMENT OF ENERGY
Messages from NREL
Enter a new project name to begin
My project
Create a new file...
The default input values are intended to illustrate System Advisor's use. The data are meant to be realistic, but not to represent values for a specific project. Input values will vary depending on the market, technology and geographic location. New developments, policy changes, and price volatility mean that default values may be out of date or inappropriate. Before using results, be sure to review all inputs and determine whether they are appropriate for your analysis.
News from the SAM team @ NREL
14 May 2013: We are pleased to announce the 2013 SAM webinar series! This year we will have four one-hour webinars covering wind power, residential and commercial PV, PPA financial models, and the SAM software development kit (SDK). For more details, including the schedule and connection information, please see the Learning page on the SAM website.
8 Feb 2013: The SAM simulation core software development kit is available for download for software developers who want to write programs using the SAM simulation engine. See the SSC SDK page for details and a download link.
15 Jan 2013: SAM 2013.1.15 is available for download! This version is a maintenance update that fixes several issues, including shading for photovoltaic flat-plate PV, issues with reports, and the default value for the wind PTC. To see a complete list of changes and download the new version, please go to the SAM Downloads page. We recommend that you install and use this version instead of SAM 2012.11.30.
30 Nov 2012: SAM 2012.11.30 is available for download here.
17 Oct 2012: If you have been testing SAM Beta 2012.9.27, and have not yet completed the online survey or emailed us your feedback, please do so to help us make as many improvements as possible before we release the next version.
Start the Solar Wizard...
Visit the SAM support forum...
Open a sample SAM file...
Browse the help system...
Open a recent file
F:/SAM Webinars/2013 Webinars/commercial wind example.zsam
F:/SAM Webinars/2013 Webinars/wind farm example.zsam
List of recent files

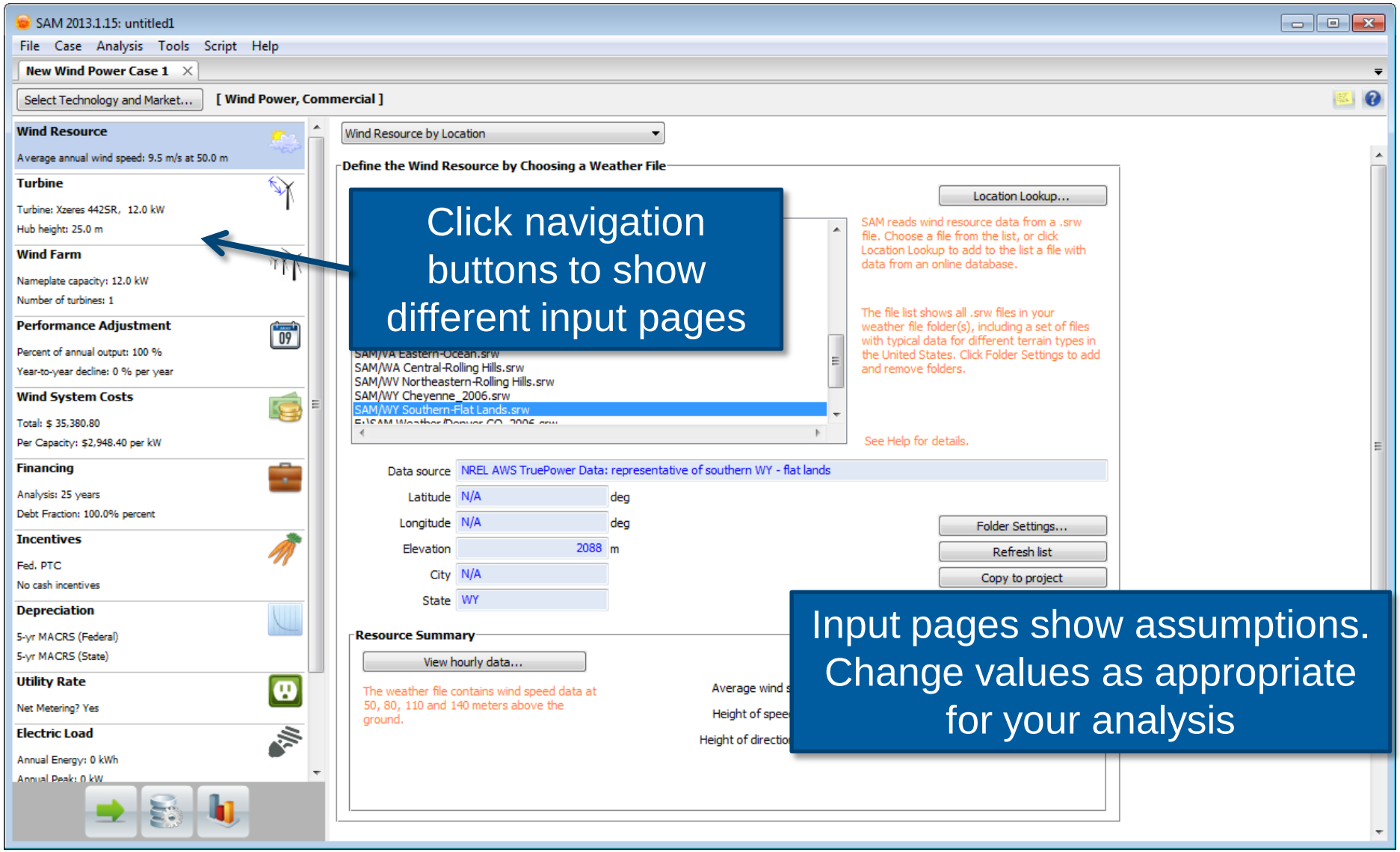
2. Choose a performance and financial model



Choose a performance model: Click **Wind Power** for a wind project

Choose a financial model: Click **Commercial** for a project that buys and sells electricity at retail rates and can claim depreciation benefits

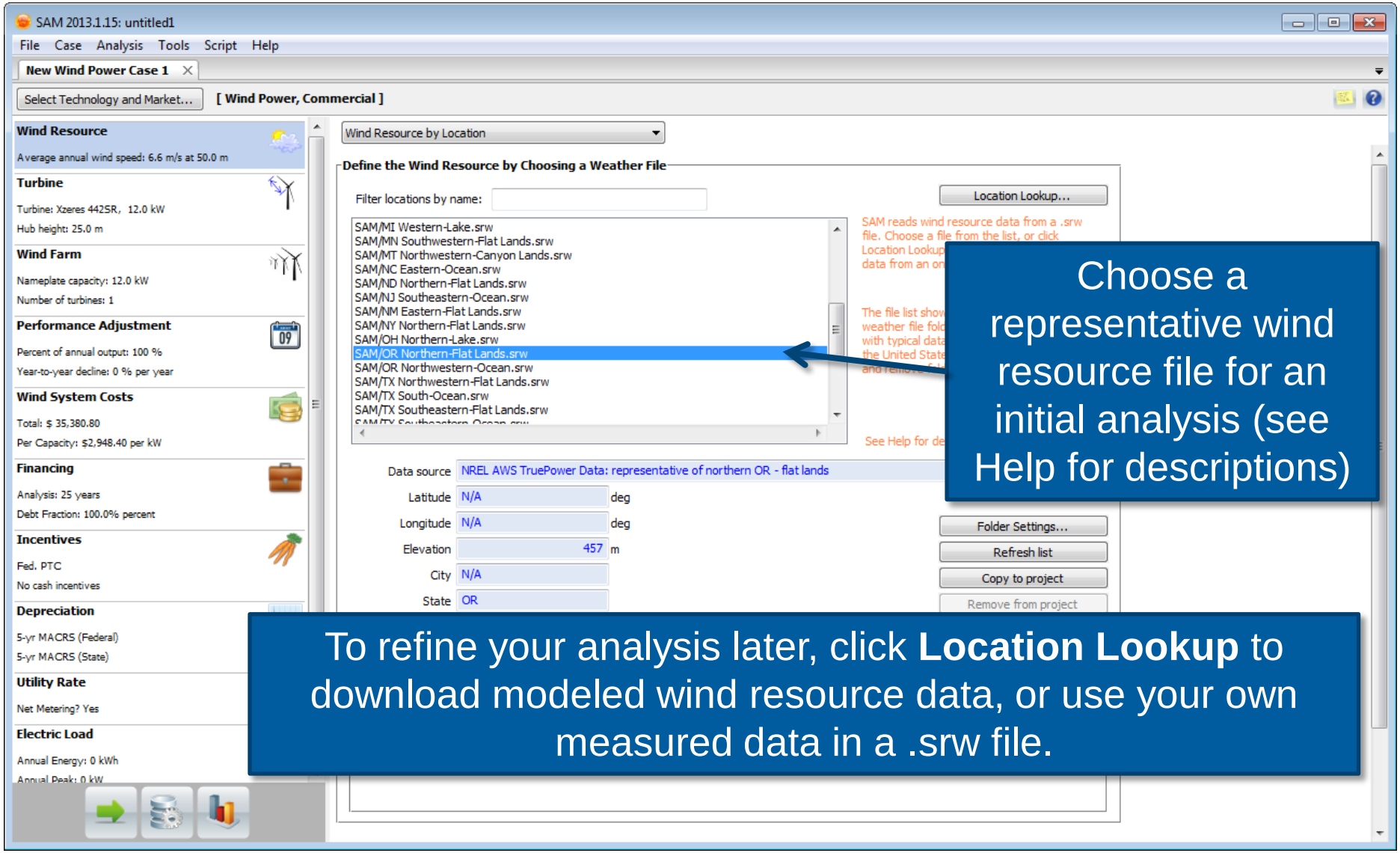
3. Review the default input assumptions



Wind Power – Commercial Model Inputs

Wind Resource	Hourly wind resource data for one year
Turbine:	Choose a turbine, or for advanced studies, specify turbine characteristics
Wind Farm	Turbine layout
Performance Adjustments	Curtailment and availability factors (optional)
Wind System Costs	Installation and operating costs
Financing	Project debt, tax rates, and other financial parameters
Incentives	Federal, state, local and other incentives
Depreciation	Federal and state accelerated depreciation (Commercial Only)
Utility Rate	Retail electricity prices and time-of-use structure, tiered rates, etc.
Electric Load	Building or facility electric demand

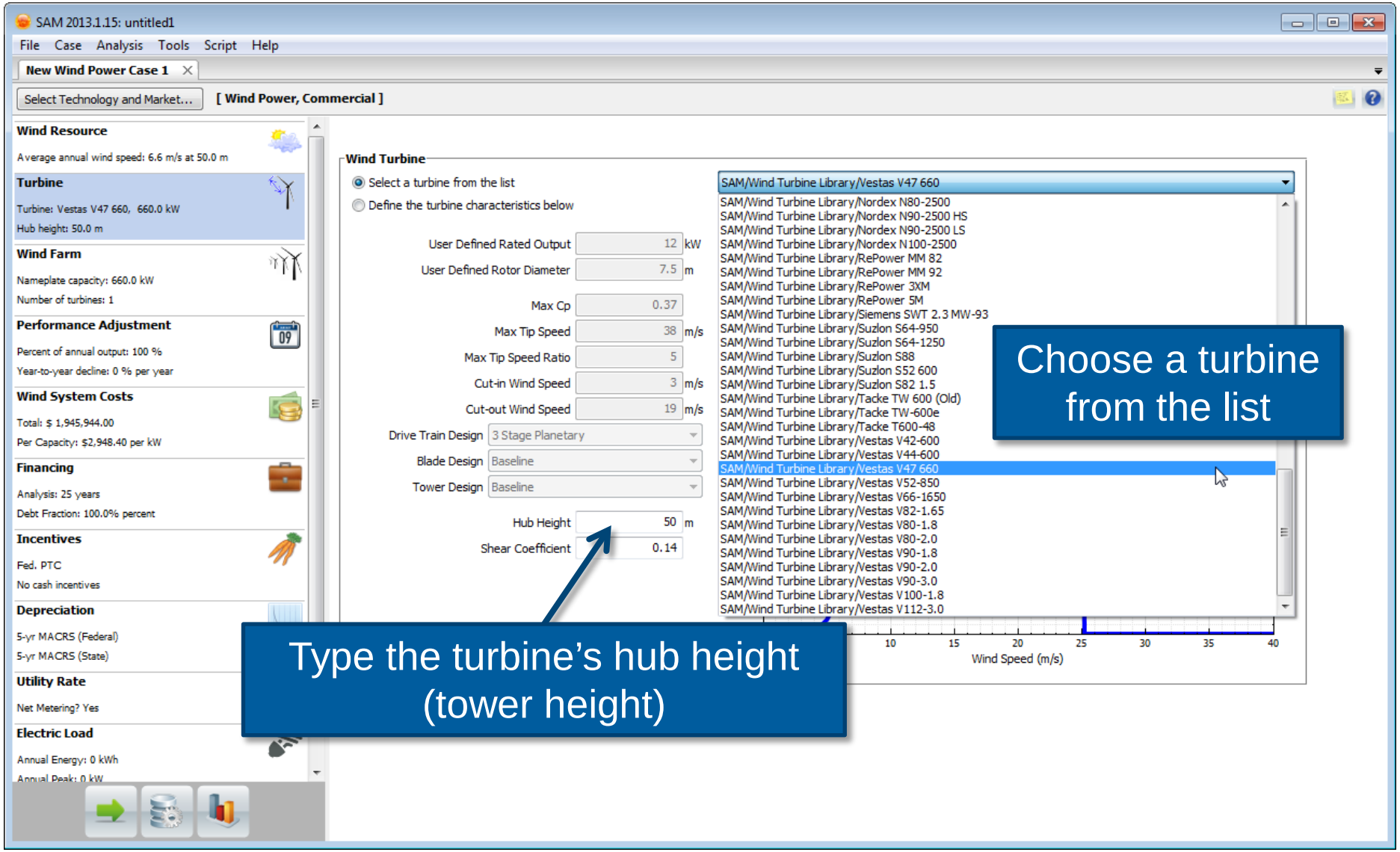
4. Choose wind resource data



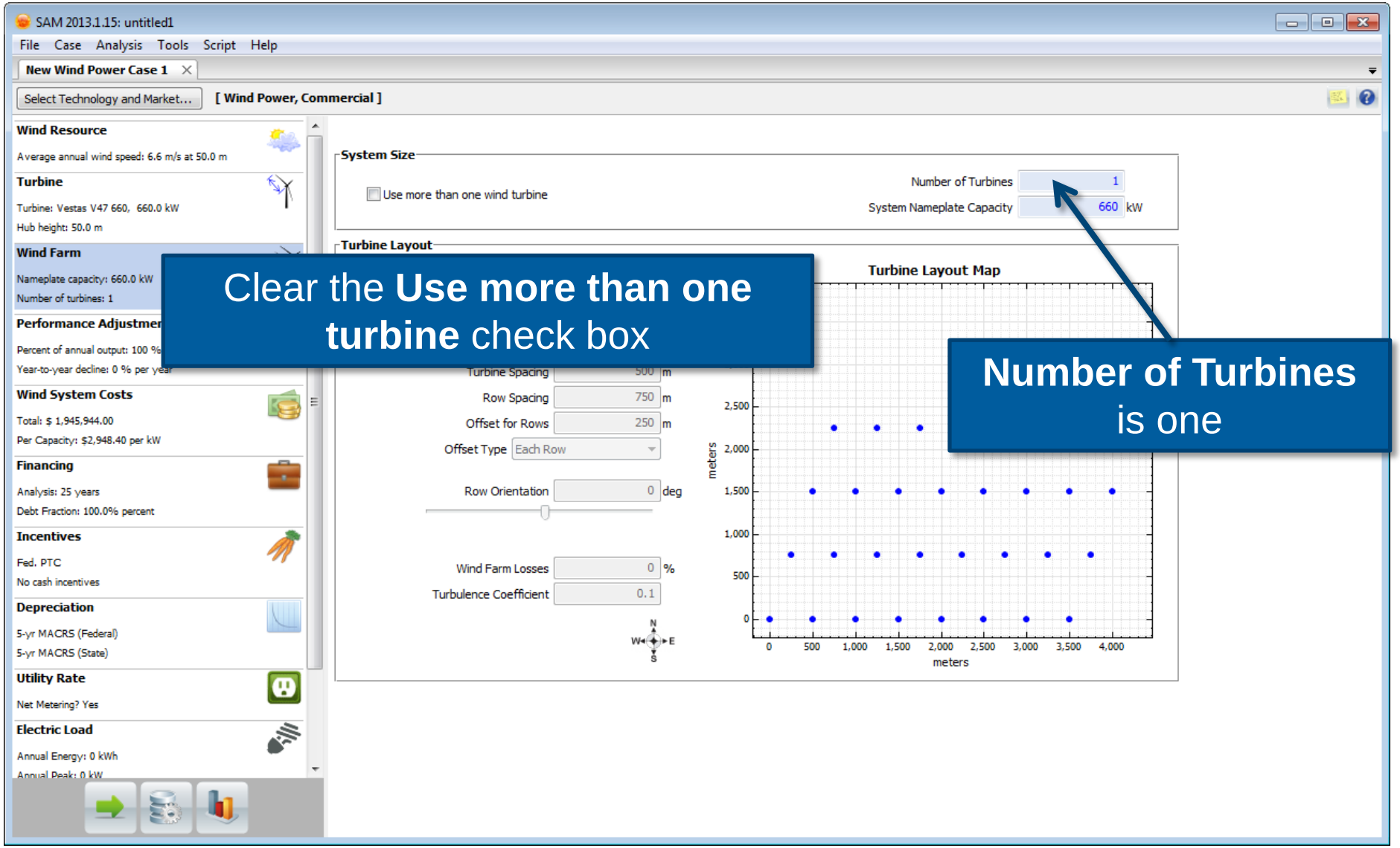
Choose a representative wind resource file for an initial analysis (see Help for descriptions)

To refine your analysis later, click **Location Lookup** to download modeled wind resource data, or use your own measured data in a .srw file.

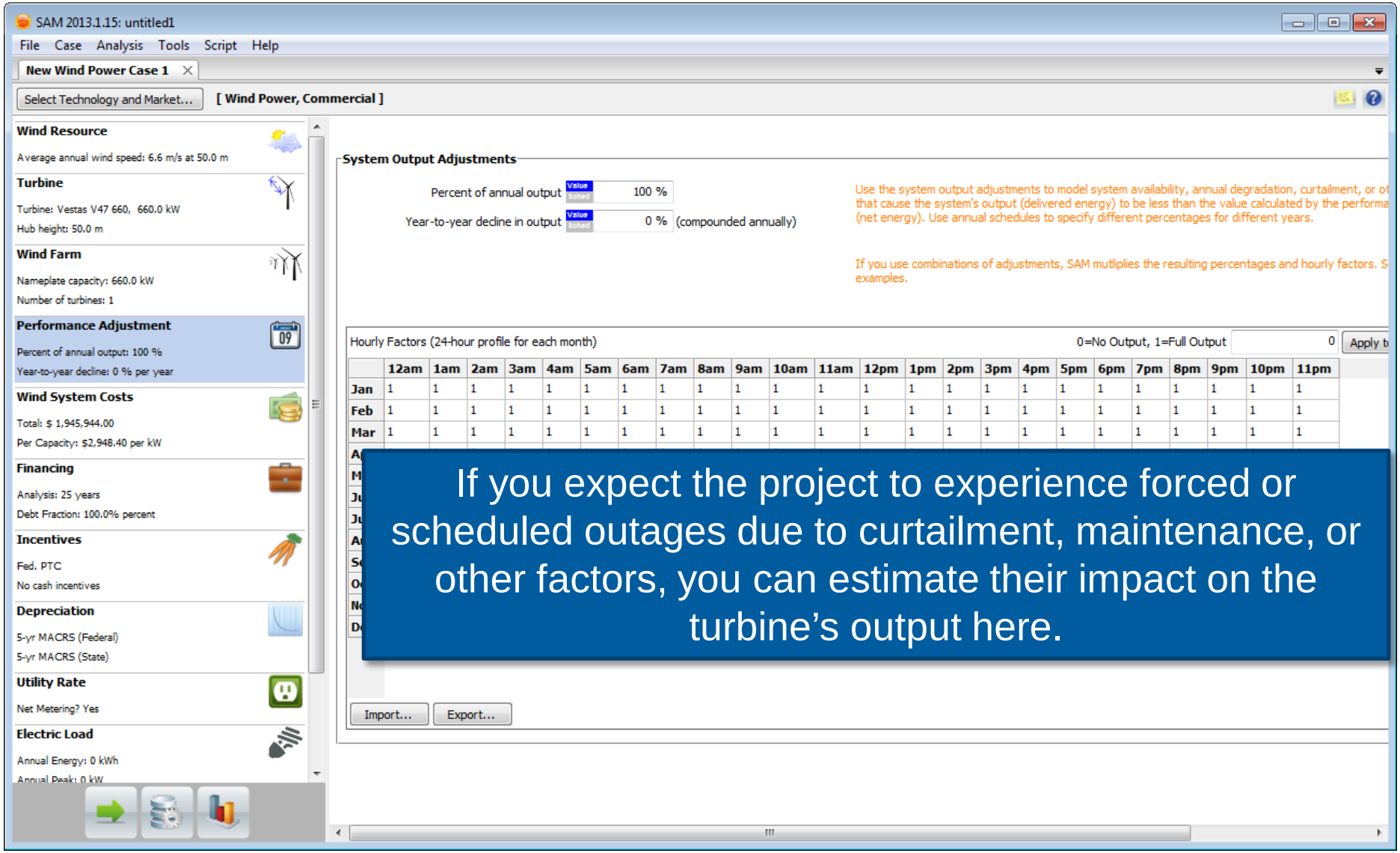
4. Choose a wind turbine



4. Ignore turbine layout for project with one turbine

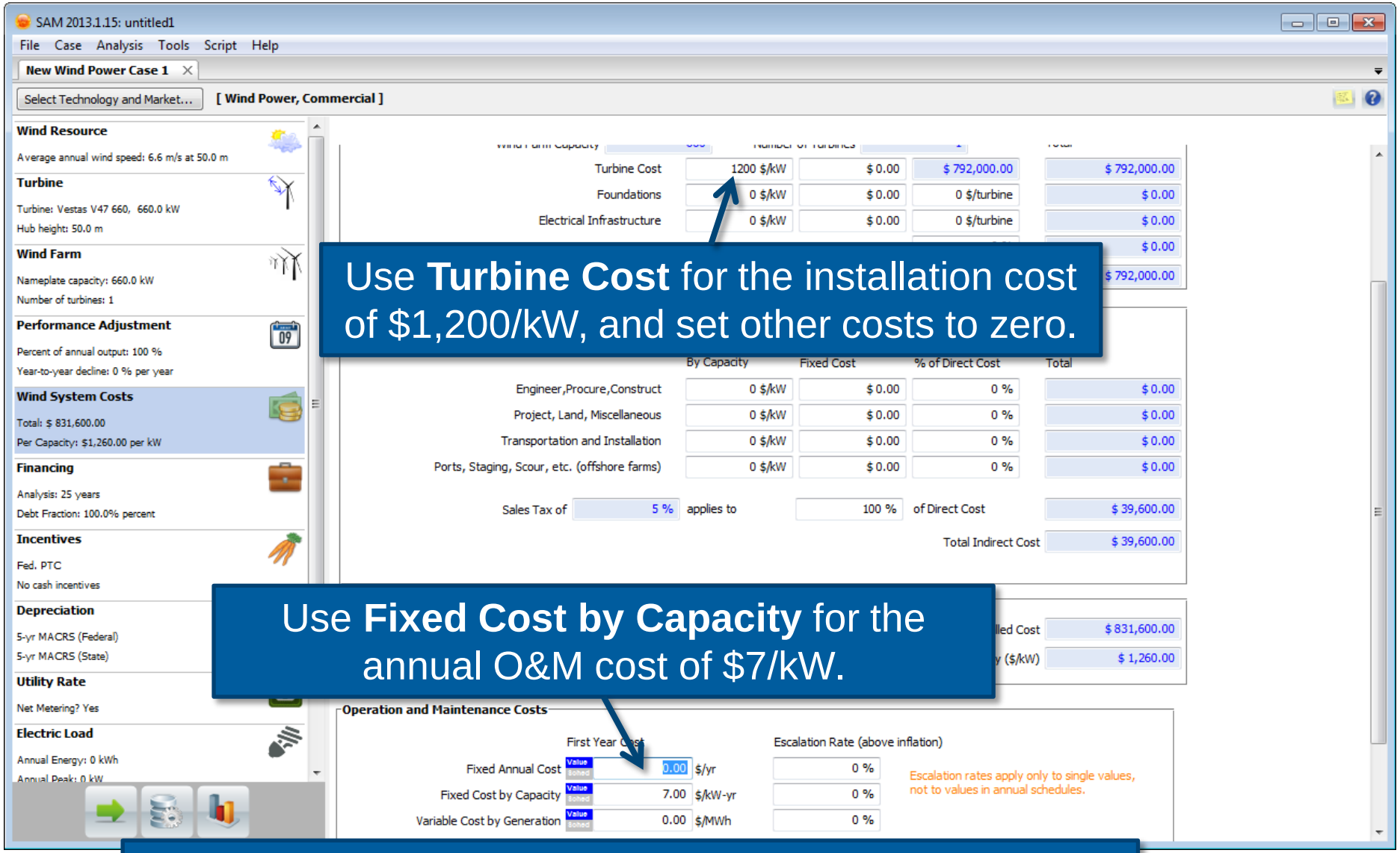


5. Use performance adjustments for outages



If you expect the project to experience forced or scheduled outages due to curtailment, maintenance, or other factors, you can estimate their impact on the turbine's output here.

6. Project installation and operating costs

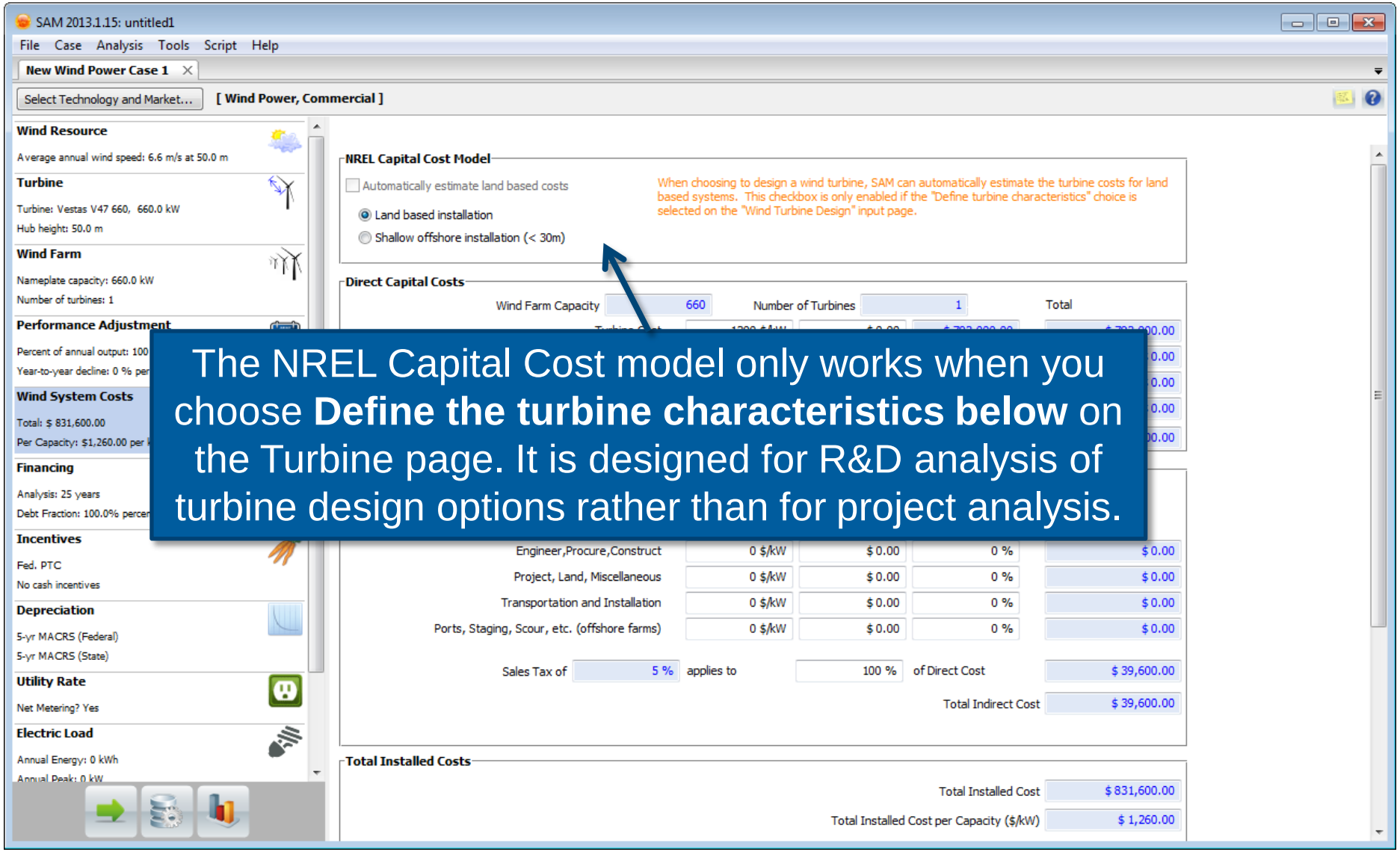


Use **Turbine Cost** for the installation cost of $1,200/kW, and set other costs to zero.

Use **Fixed Cost by Capacity** for the annual O&M cost of $7/kW.

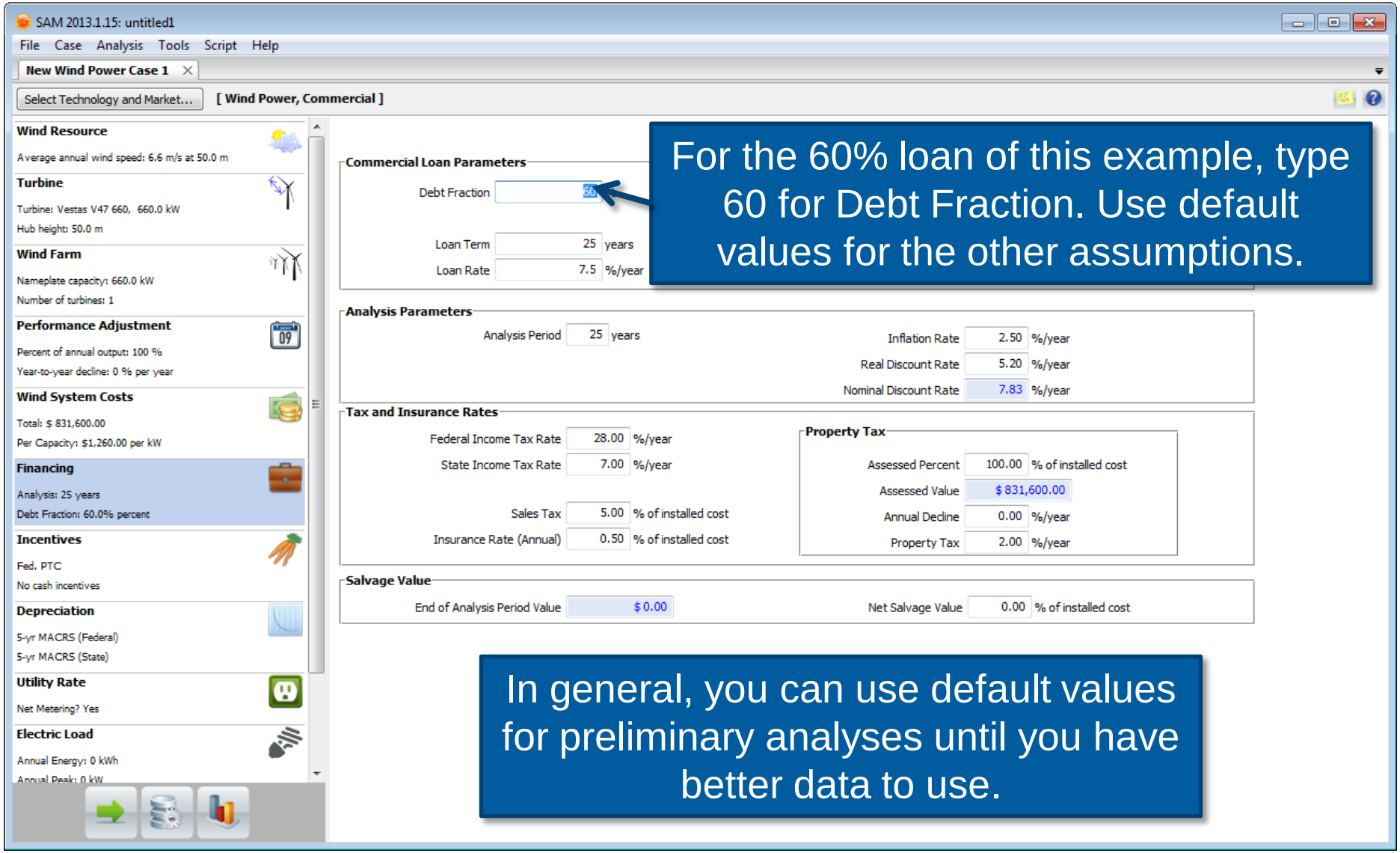
You can refine costs later as you get more data.

6. Project installation and operating costs



The NREL Capital Cost model only works when you choose **Define the turbine characteristics below** on the Turbine page. It is designed for R&D analysis of turbine design options rather than for project analysis.

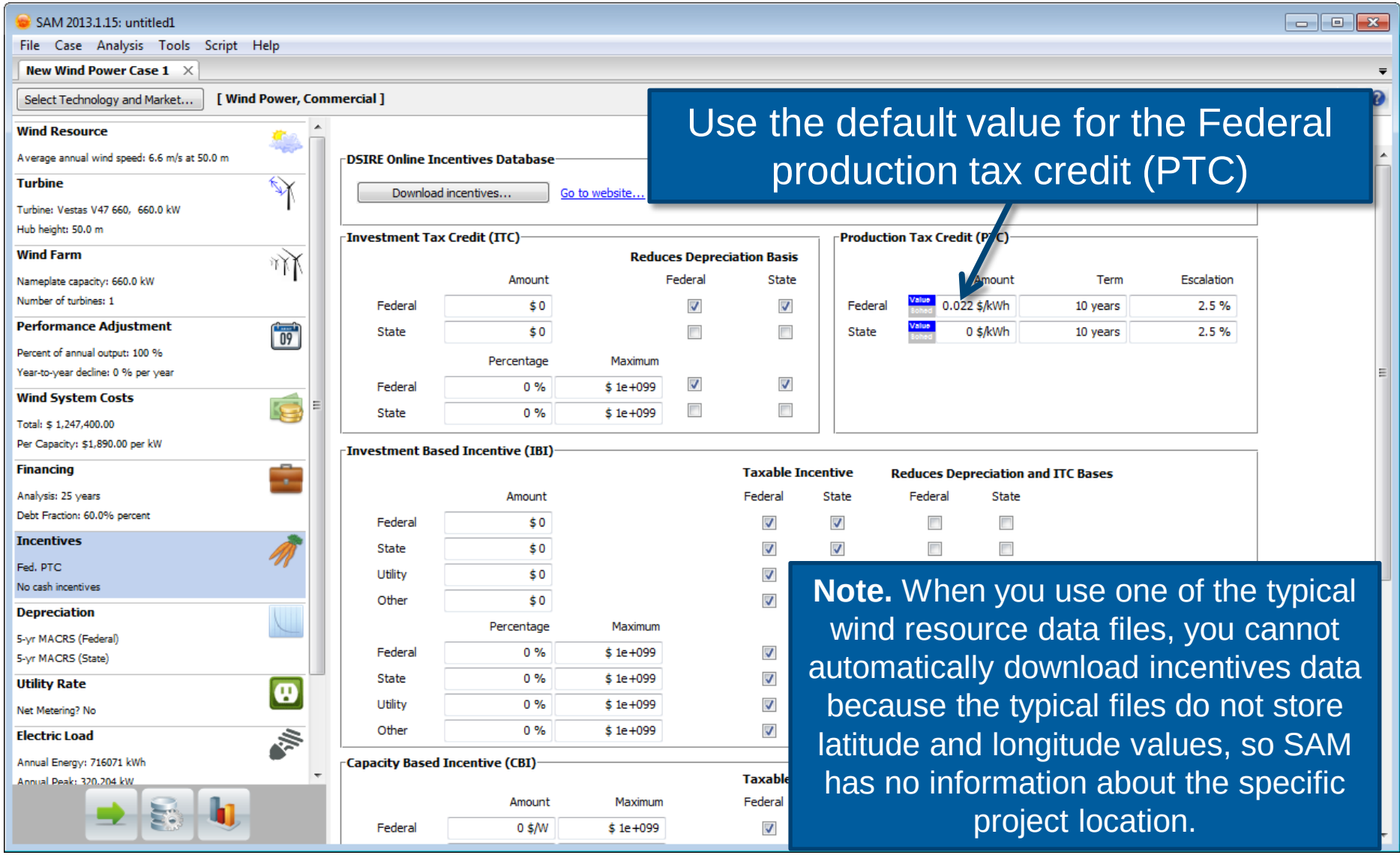
7. Project debt and financial parameters



For the 60% loan of this example, type 60 for Debt Fraction. Use default values for the other assumptions.

In general, you can use default values for preliminary analyses until you have better data to use.

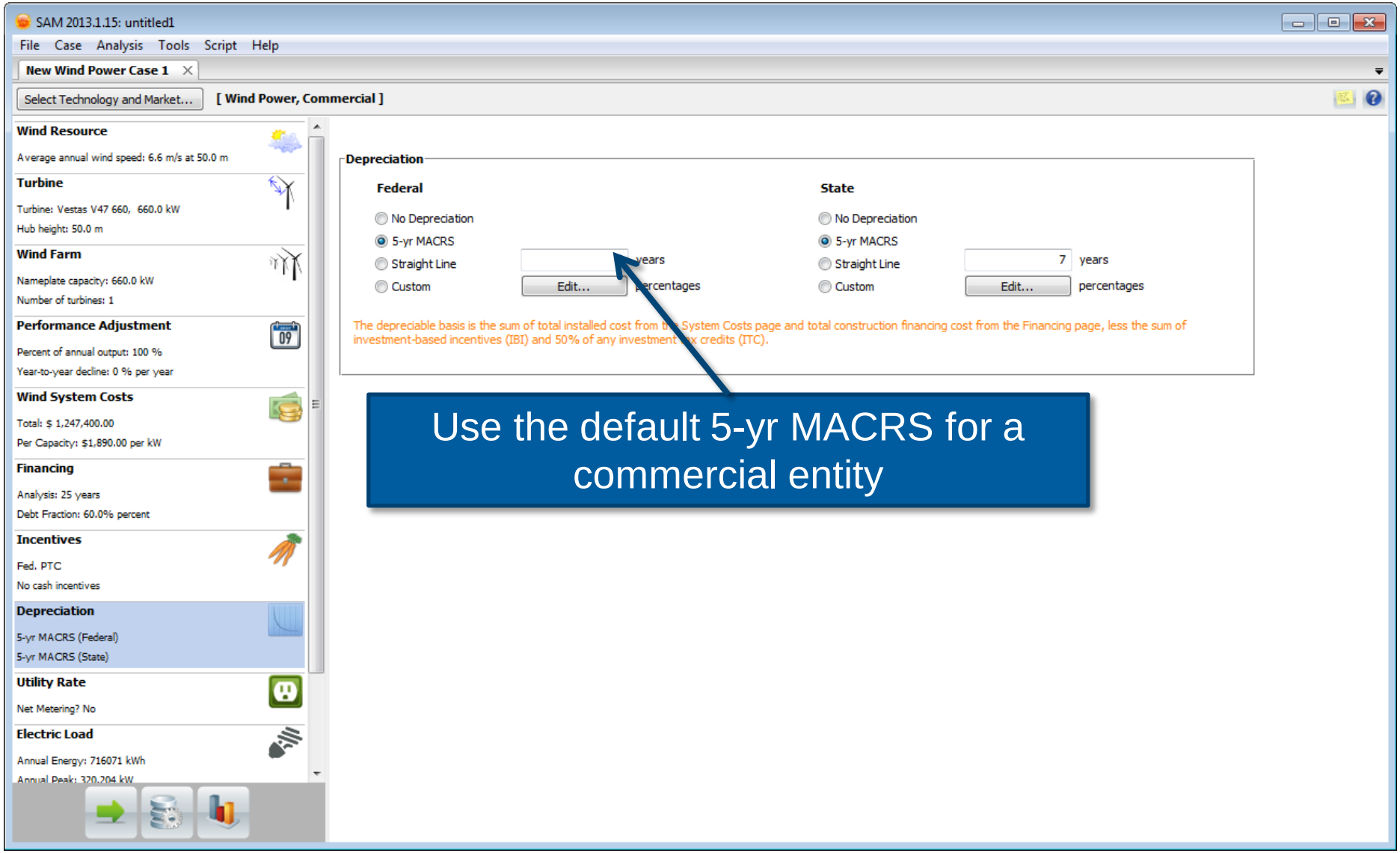
7. Incentives



Use the default value for the Federal production tax credit (PTC)

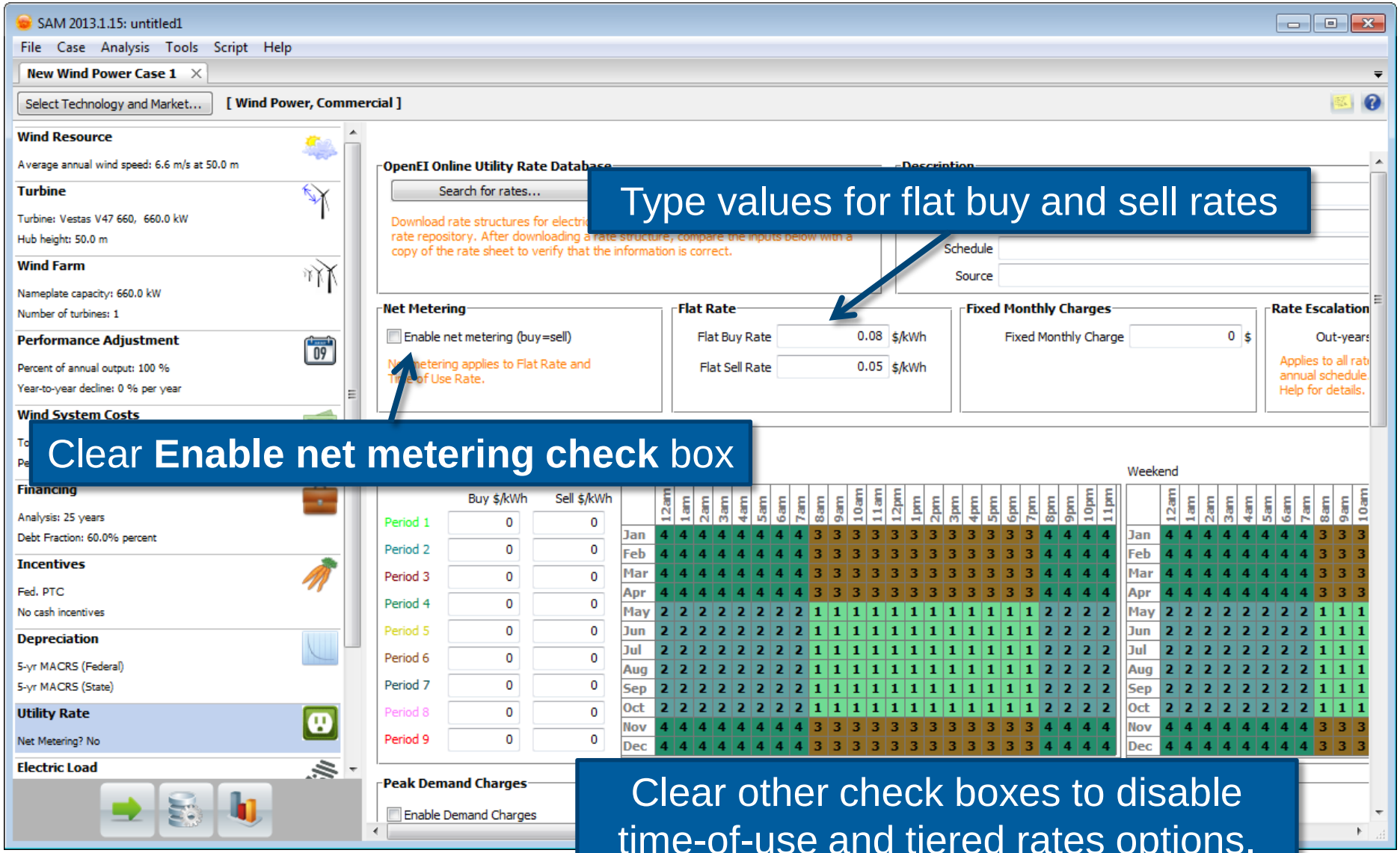
Note. When you use one of the typical wind resource data files, you cannot automatically download incentives data because the typical files do not store latitude and longitude values, so SAM has no information about the specific project location.

8. Depreciation



Use the default 5-yr MACRS for a commercial entity

9. Retail electricity rates

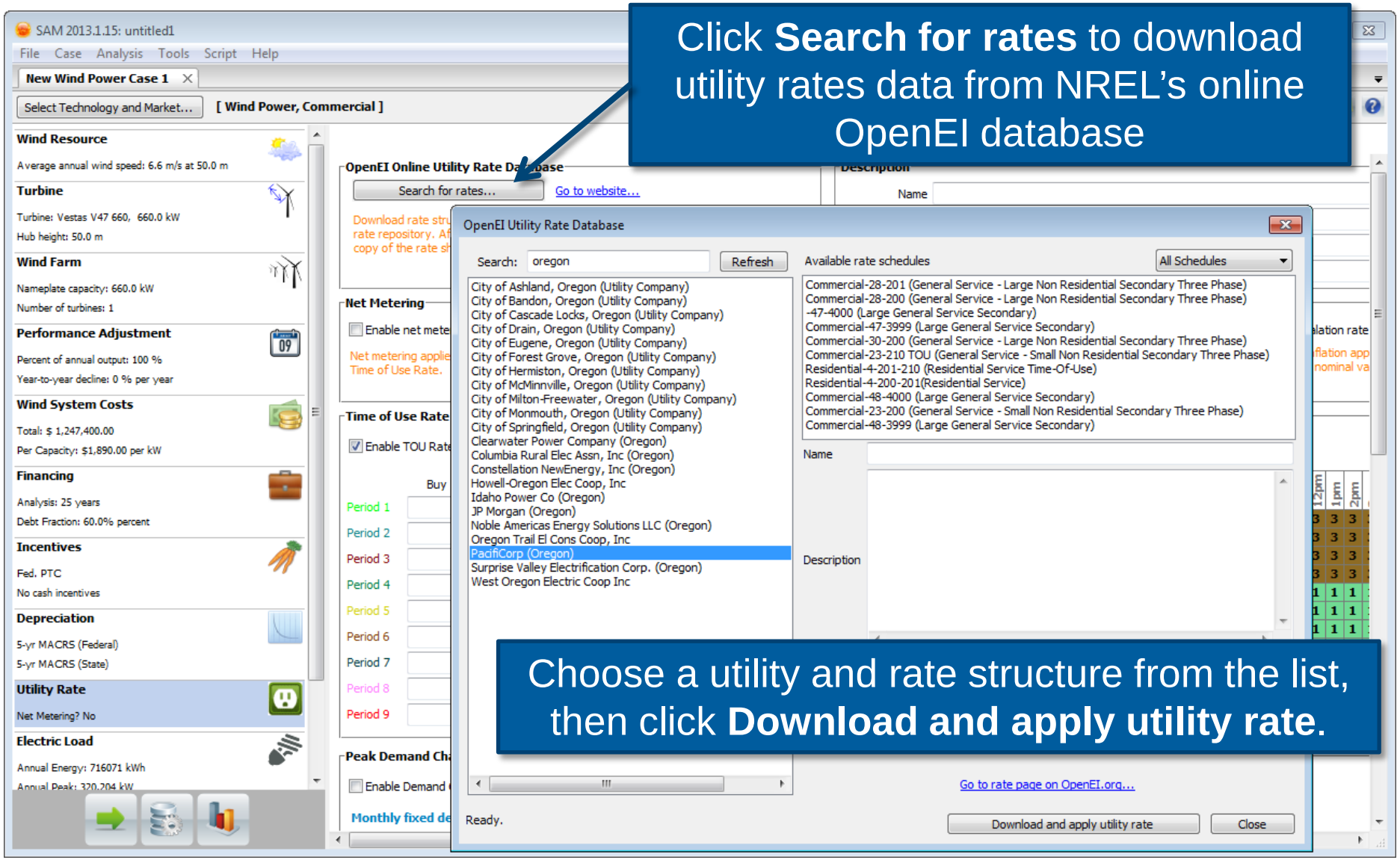


Type values for flat buy and sell rates

Clear **Enable net metering check** box

Clear other check boxes to disable time-of-use and tiered rates options.

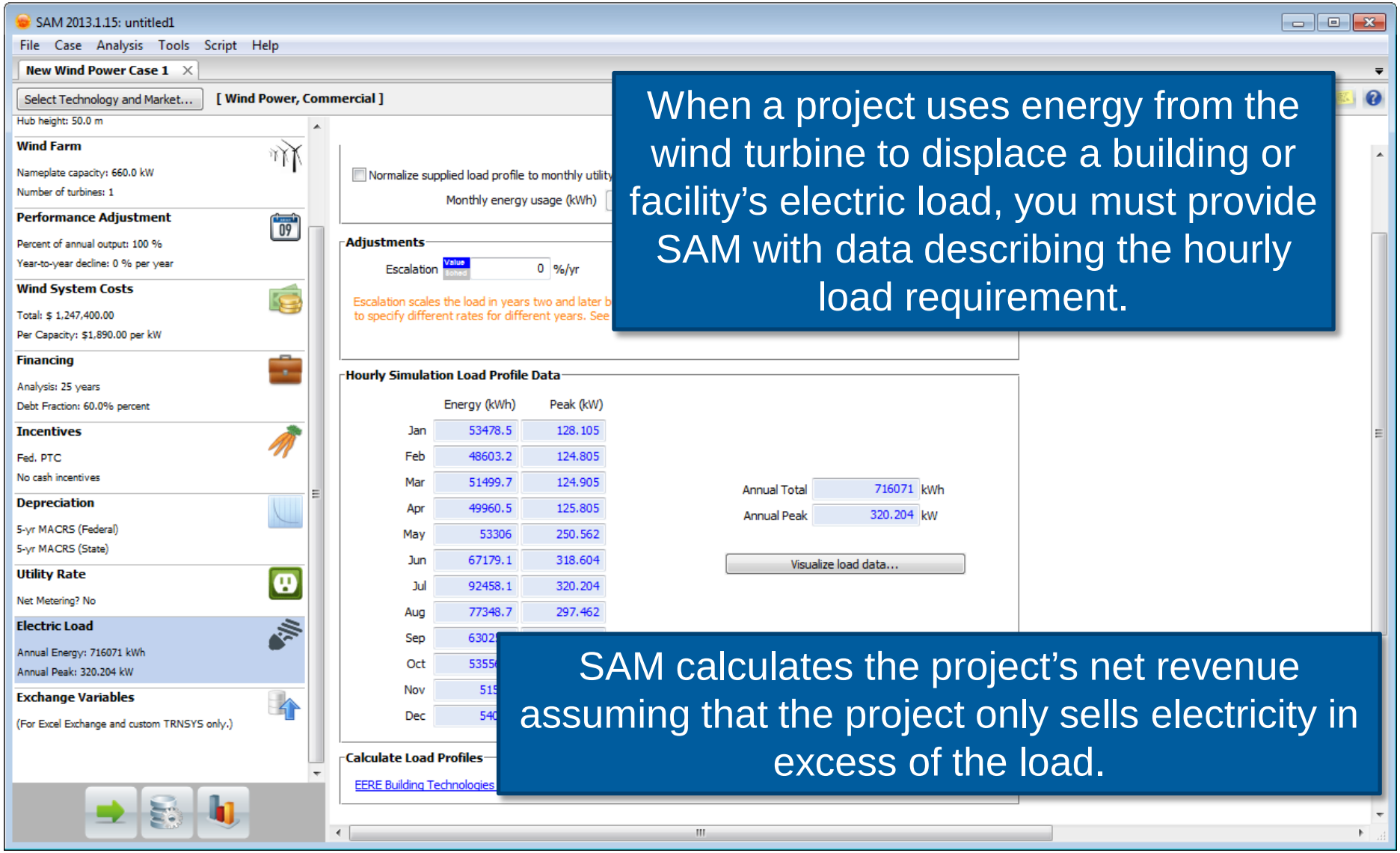
9. Retail electricity rates



Click **Search for rates** to download utility rates data from NREL's online OpenEI database

Choose a utility and rate structure from the list, then click **Download and apply utility rate**.

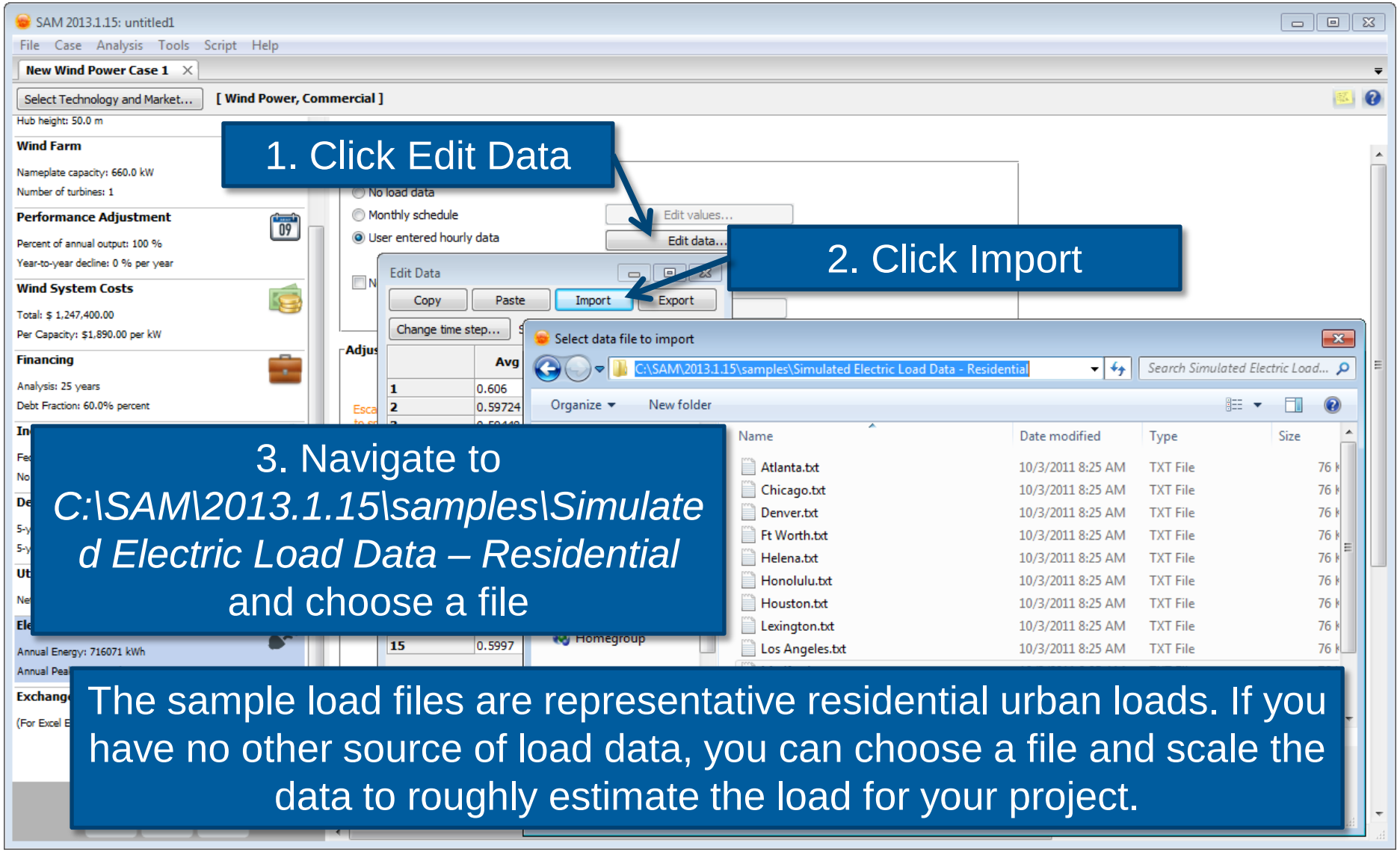
10. Electric load data



When a project uses energy from the wind turbine to displace a building or facility's electric load, you must provide SAM with data describing the hourly load requirement.

SAM calculates the project's net revenue assuming that the project only sells electricity in excess of the load.

10. Electric load data: Open sample load data file



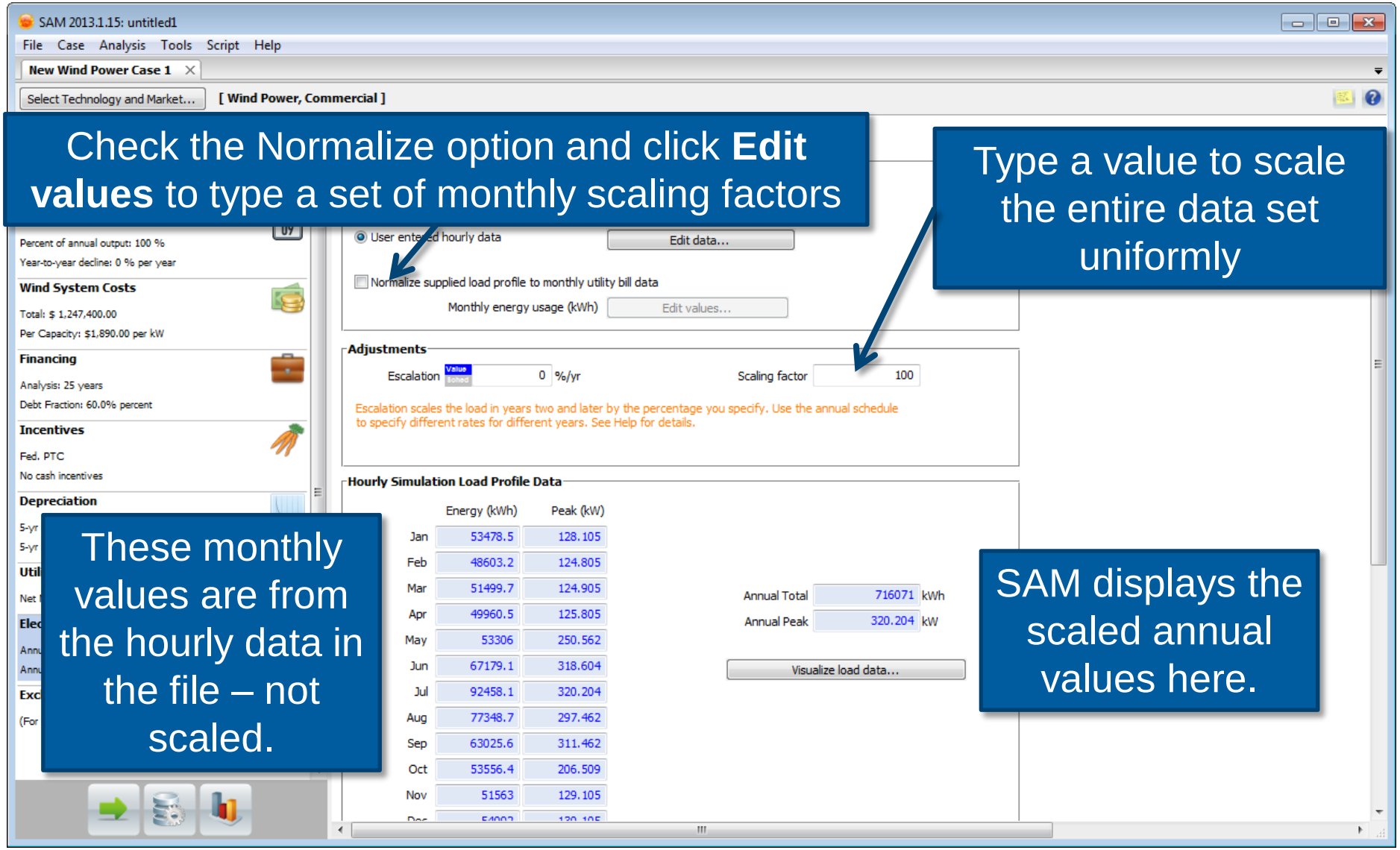
1. Click Edit Data

2. Click Import

3. Navigate to *C:\SAM\2013.1.15\samples\Simulated Electric Load Data – Residential* and choose a file

The sample load files are representative residential urban loads. If you have no other source of load data, you can choose a file and scale the data to roughly estimate the load for your project.

10. Electric load data: Scale sample load data



Check the Normalize option and click **Edit values** to type a set of monthly scaling factors

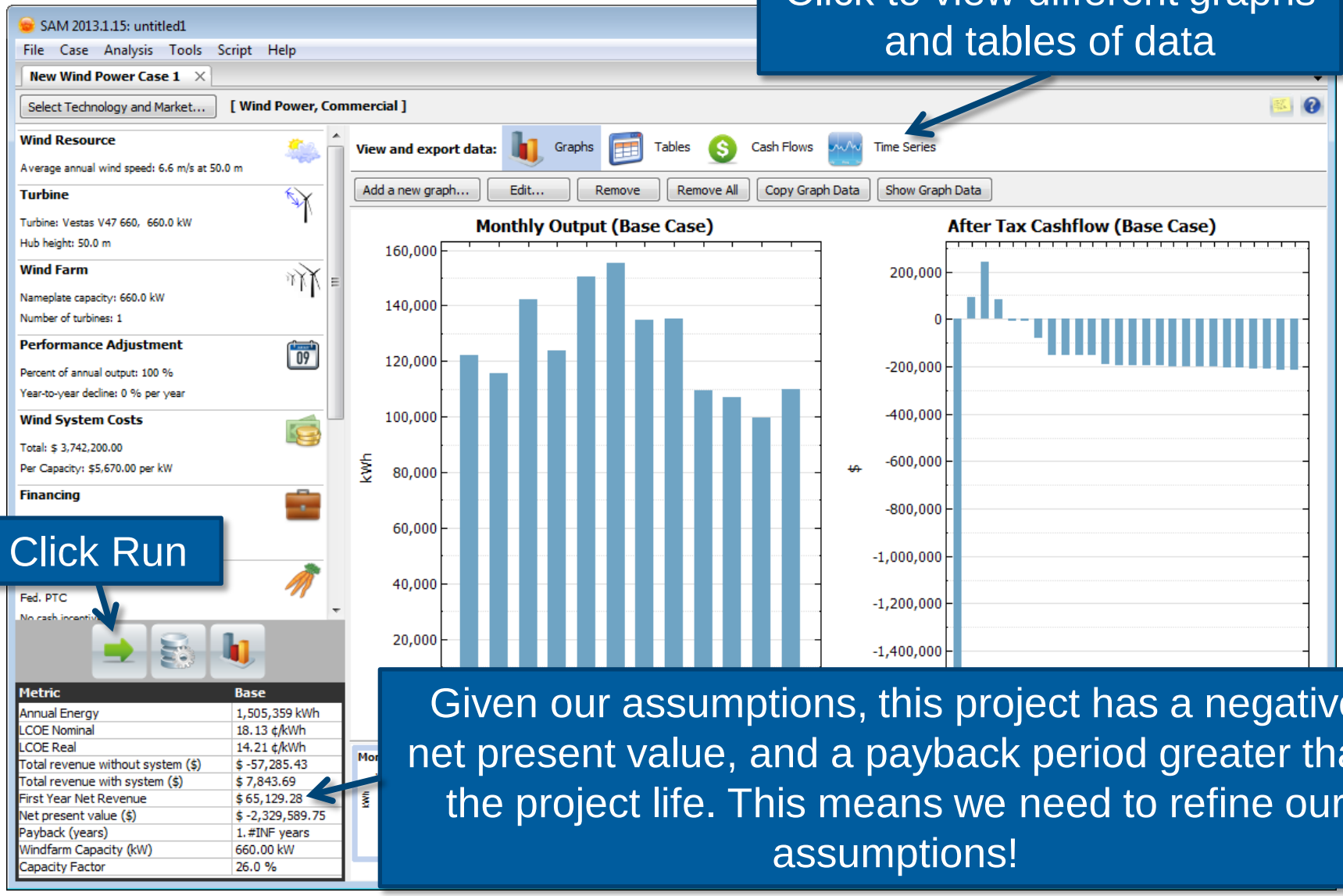
Type a value to scale the entire data set uniformly

These monthly values are from the hourly data in the file – not scaled.

SAM displays the scaled annual values here.

11. Run the model and review results

Click to view different graphs and tables of data

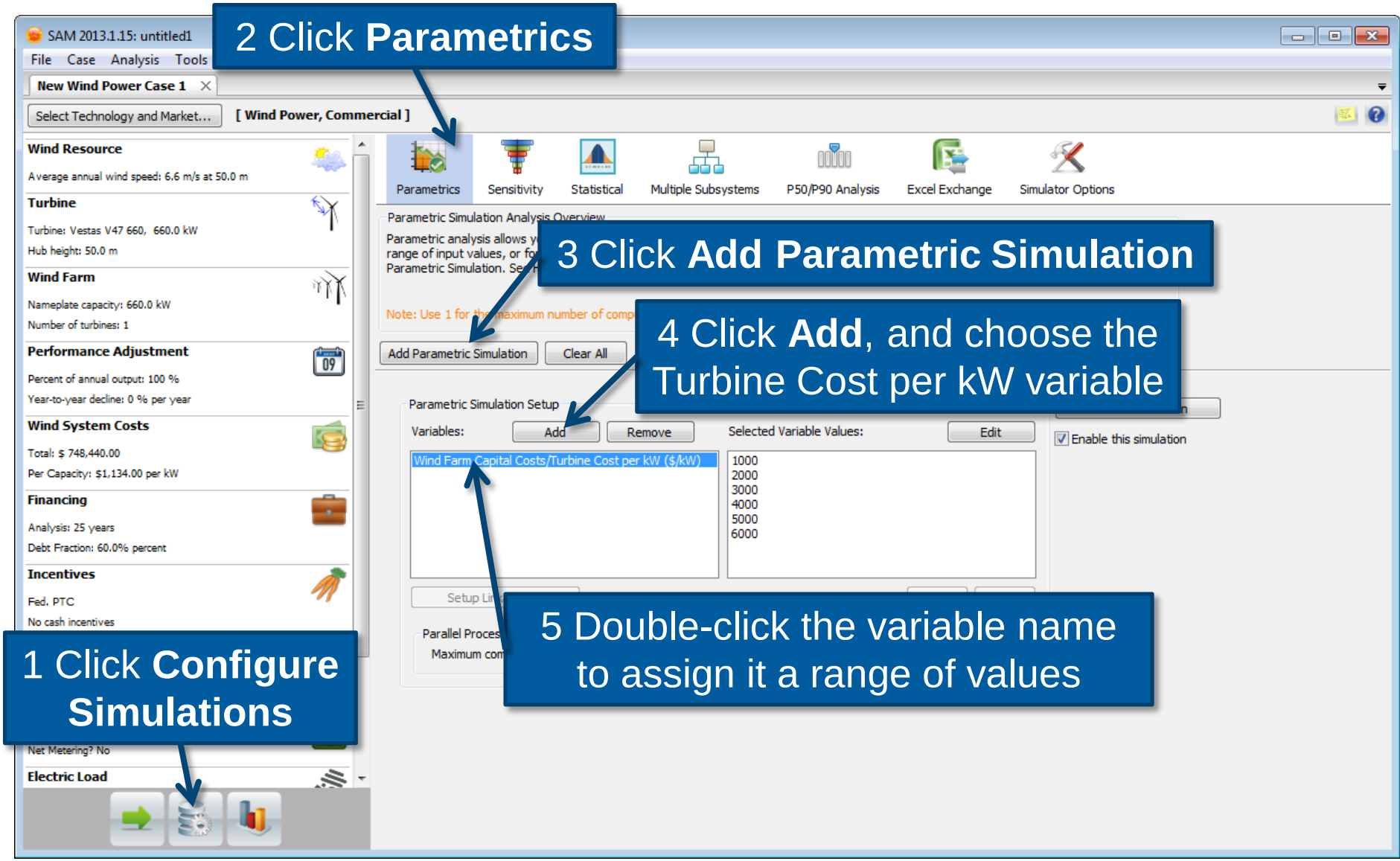


Metric	Base
Annual Energy	1,505,359 kWh
LCOE Nominal	18.13 ¢/kWh
LCOE Real	14.21 ¢/kWh
Total revenue without system ($)	$ -57,285.43
Total revenue with system ($)	$ 7,843.69
First Year Net Revenue	$ 65,129.28
Net present value ($)	$ -2,329,589.75
Payback (years)	1.#INF years
Windfarm Capacity (kW)	660.00 kW
Capacity Factor	26.0 %

Click Run

Given our assumptions, this project has a negative net present value, and a payback period greater than the project life. This means we need to refine our assumptions!

12. Use parametric analysis to explore assumptions



12. Use parametric analysis to explore assumptions

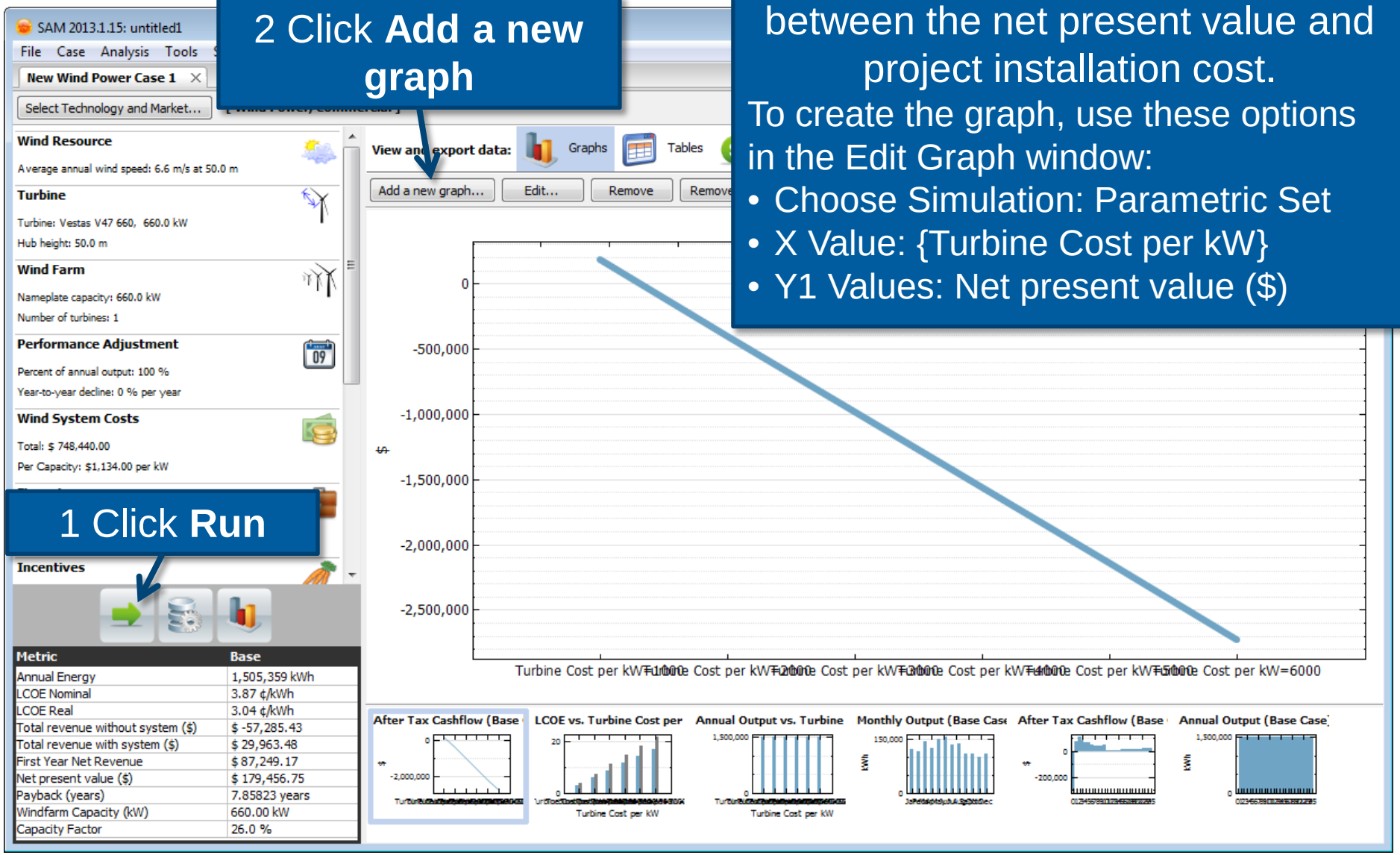
This graph shows the relationship between the net present value and project installation cost.

To create the graph, use these options in the Edit Graph window:

- Choose Simulation: Parametric Set
- X Value: {Turbine Cost per kW}
- Y1 Values: Net present value ($)

2 Click **Add a new graph**

1 Click **Run**



Metric	Base
Annual Energy	1,505,359 kWh
LCOE Nominal	3.87 ¢/kWh
LCOE Real	3.04 ¢/kWh
Total revenue without system ($)	$ -57,285.43
Total revenue with system ($)	$ 29,963.48
First Year Net Revenue	$ 87,249.17
Net present value ($)	$ 179,456.75
Payback (years)	7.85823 years
Windfarm Capacity (kW)	660.00 kW
Capacity Factor	26.0 %

Modeling Wind Systems in SAM

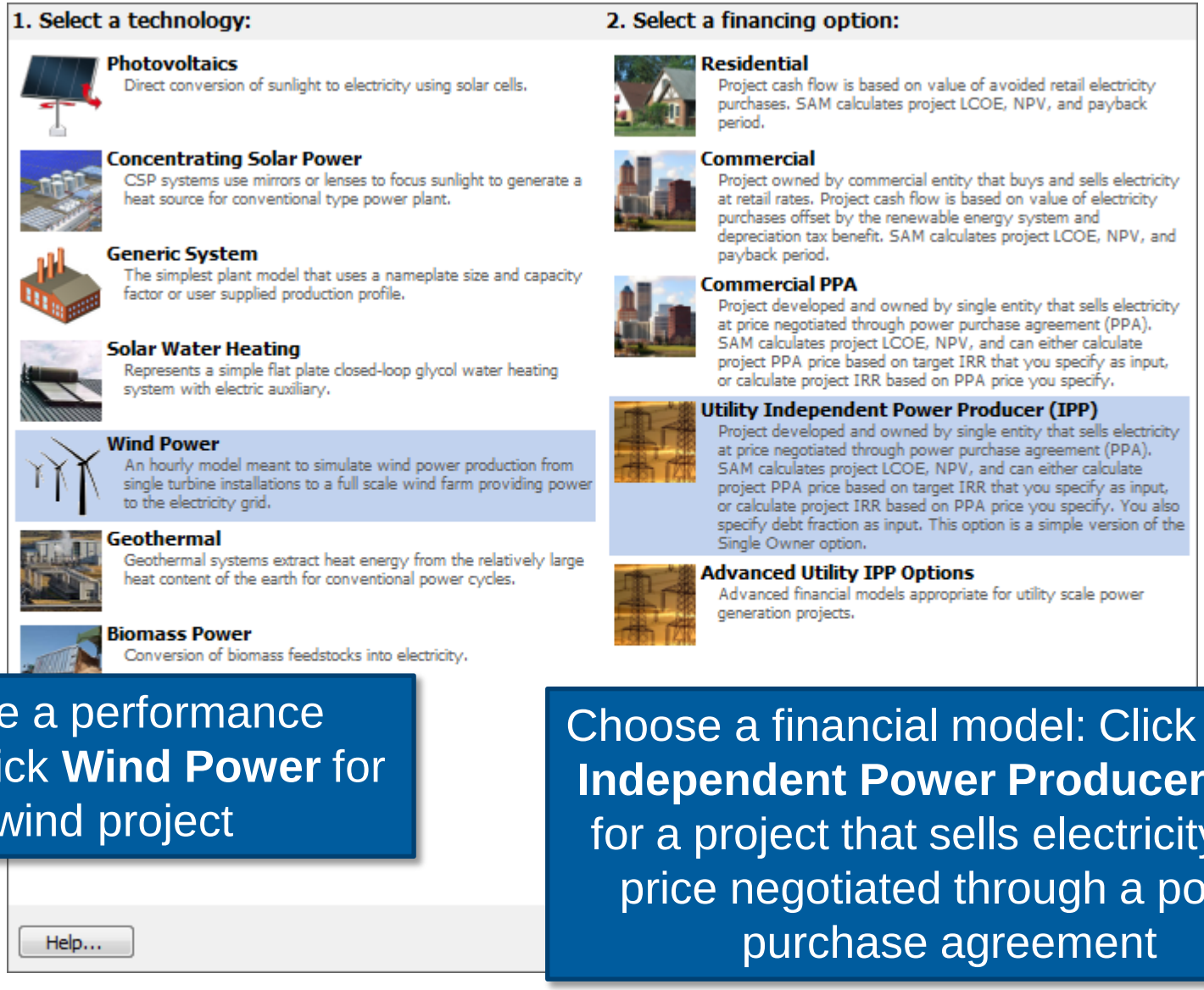
Example 2: Modeling a Wind Farm

Basic Assumptions

- Project site in South Eastern Wyoming
- 30 GE 1.5MW turbines on 80m towers
- Farm to provide power to the grid with a negotiated PPA price of $80/MWh, additional 10% ($88/MWh) during peak periods in the summer
- Total installation cost is $2,093/kW
- Operating and maintenance costs are $50/kW-yr
- Project will be started in time to take advantage of the 2.2 cent/kWh Federal production tax credit
- Will the project meet internal goal of 12% IRR?

These assumptions are not for a real project!
We made up the costs and electricity prices for demonstration purposes.

1. Choose a performance and financial model



Choose a performance model: Click **Wind Power** for a wind project

Choose a financial model: Click **Utility Independent Power Producer (IPP)** for a project that sells electricity at a price negotiated through a power purchase agreement

Wind Power – Utility IPP Model Inputs

Wind Resource: Hourly wind resource data for one year

Turbine: Choose a turbine, or for advanced studies, specify turbine characteristics

Wind Farm: Turbine layout

Performance Adjustments: Curtailment and availability factors (optional)

Wind System Costs: Installation and operating costs

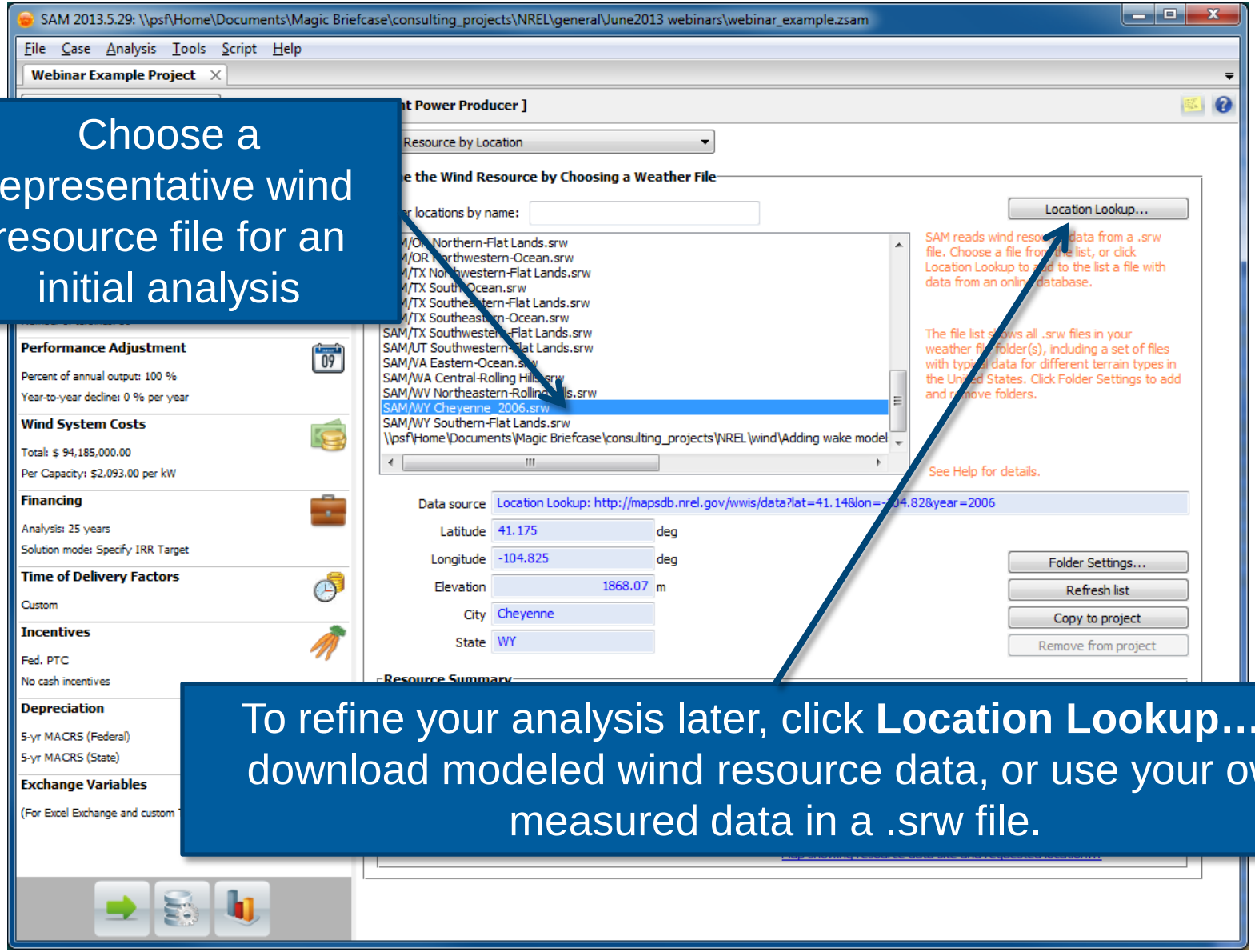
Financing: Project debt, tax rates, and other financial parameters

Time of Delivery Factors: Adjust the PPA price by time of day and month of the year

Incentives: Federal, state, local and other incentives

Depreciation: Federal and state accelerated depreciation (Commercial Only)

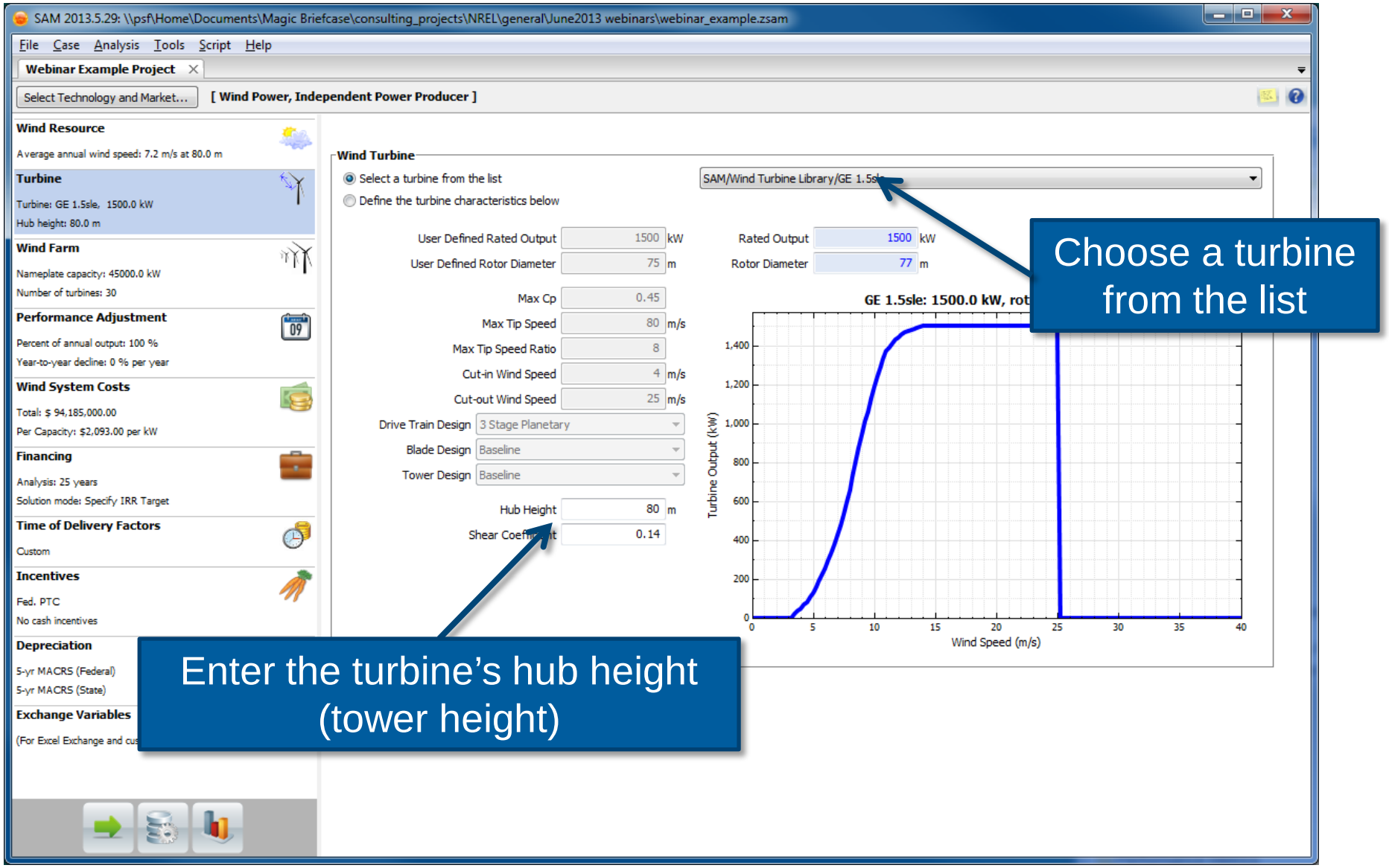
2. Choose wind resource data



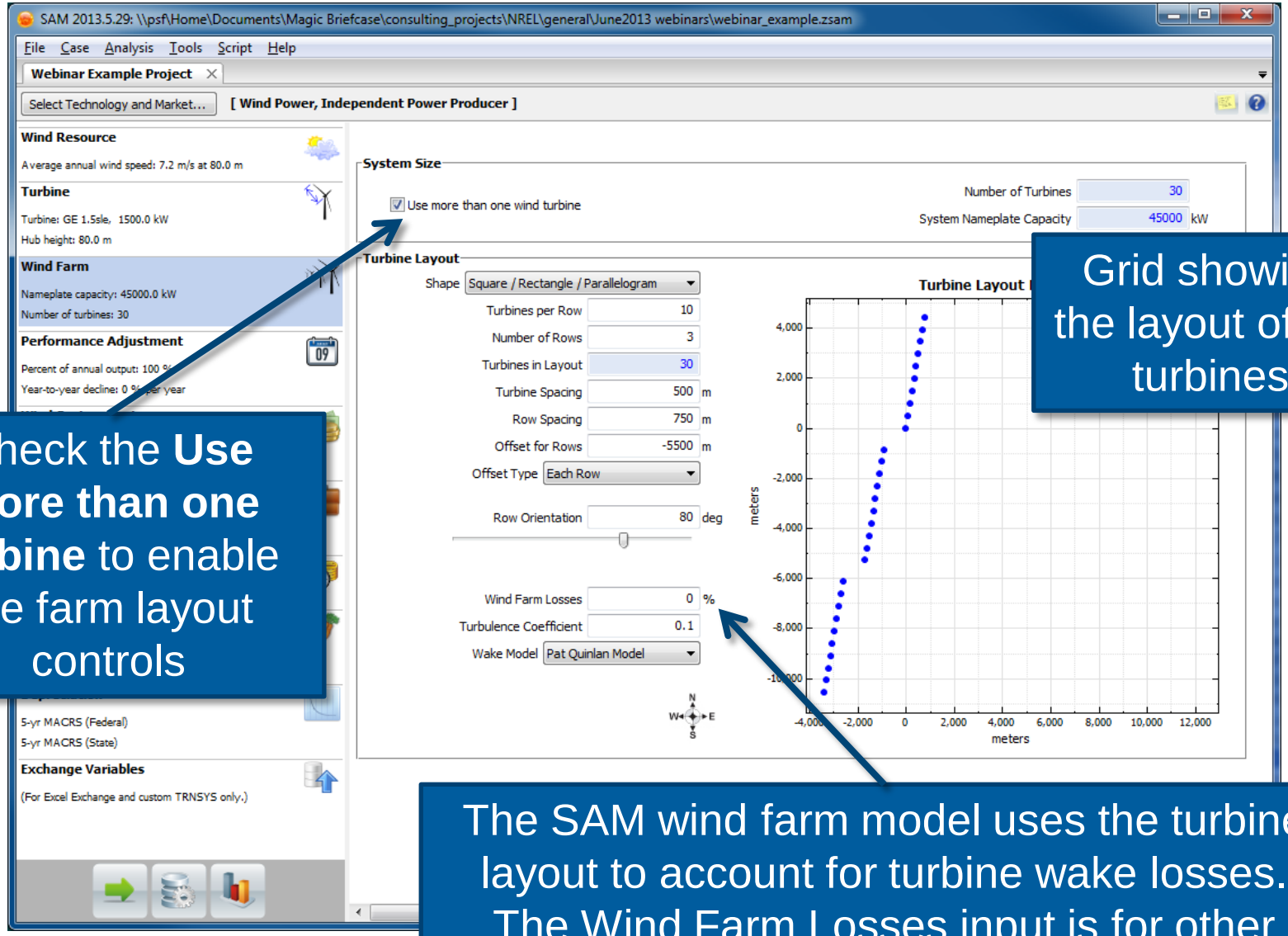
Choose a representative wind resource file for an initial analysis

To refine your analysis later, click **Location Lookup…** to download modeled wind resource data, or use your own measured data in a .srw file.

3. Choose a wind turbine



4. Layout the farm

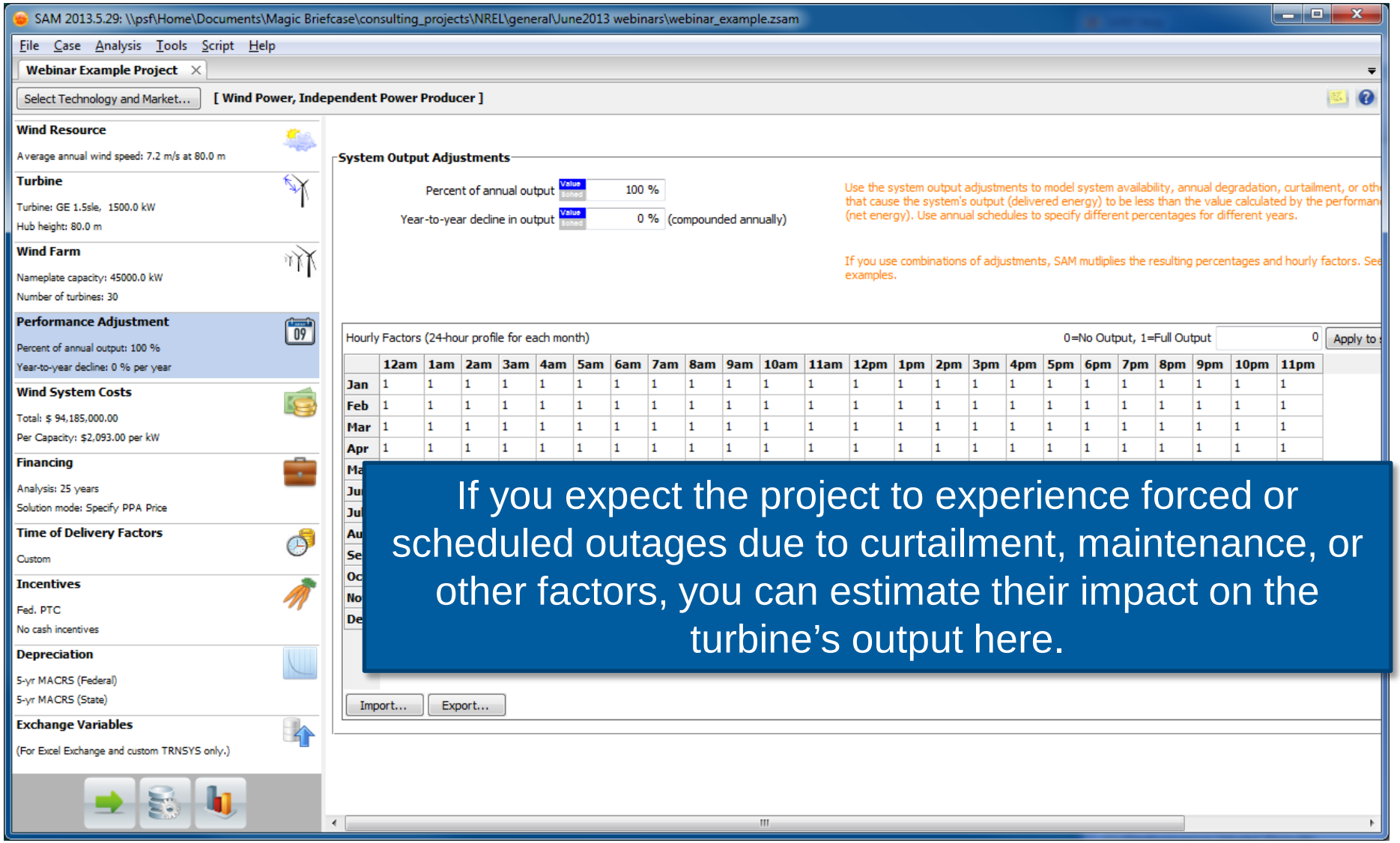


Grid showing the layout of the turbines

Check the **Use more than one turbine** to enable the farm layout controls

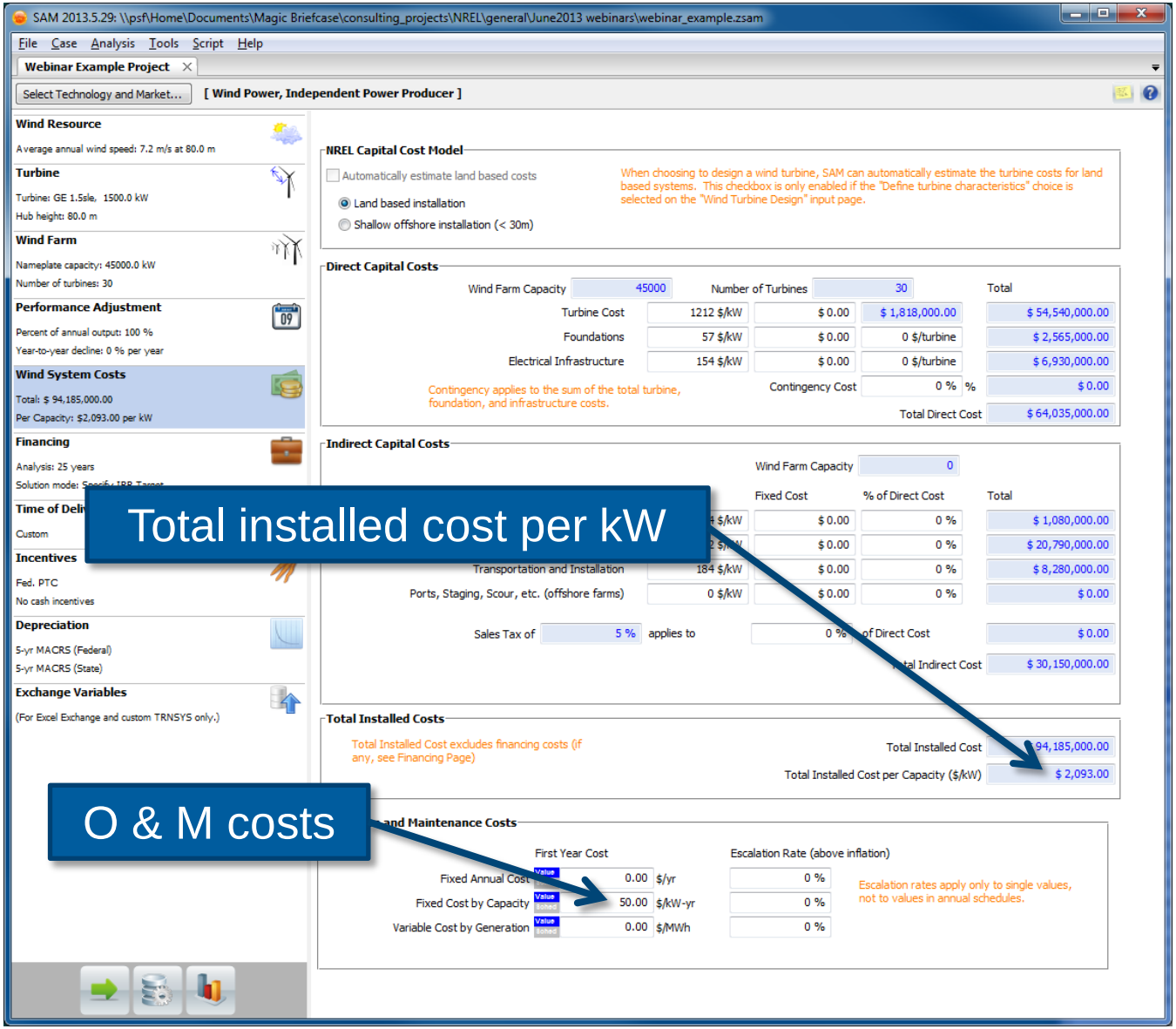
The SAM wind farm model uses the turbine layout to account for turbine wake losses. The Wind Farm Losses input is for other losses (e.g. electrical).

5. Use performance adjustments for outages

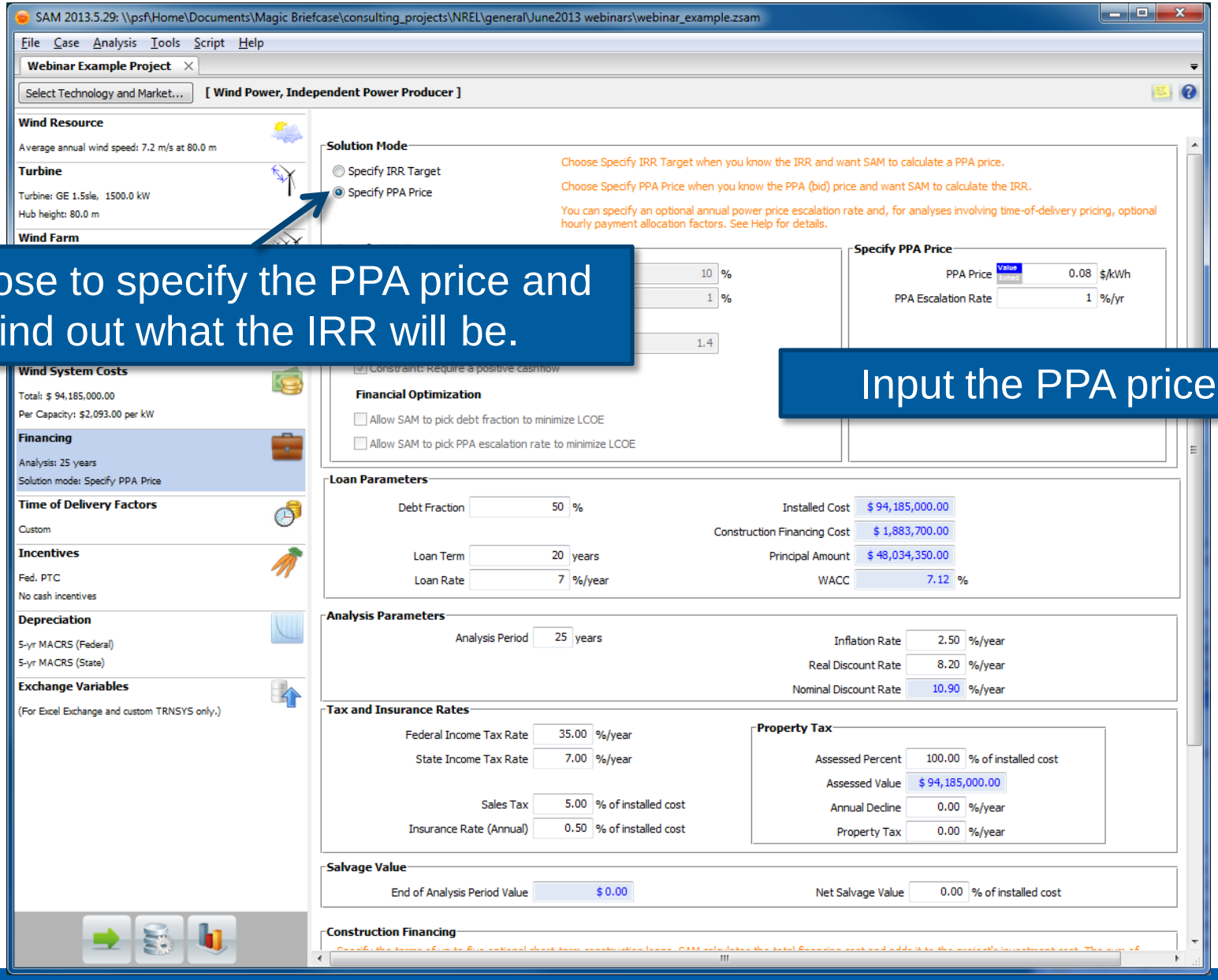


If you expect the project to experience forced or scheduled outages due to curtailment, maintenance, or other factors, you can estimate their impact on the turbine's output here.

6. Project installation and operating costs



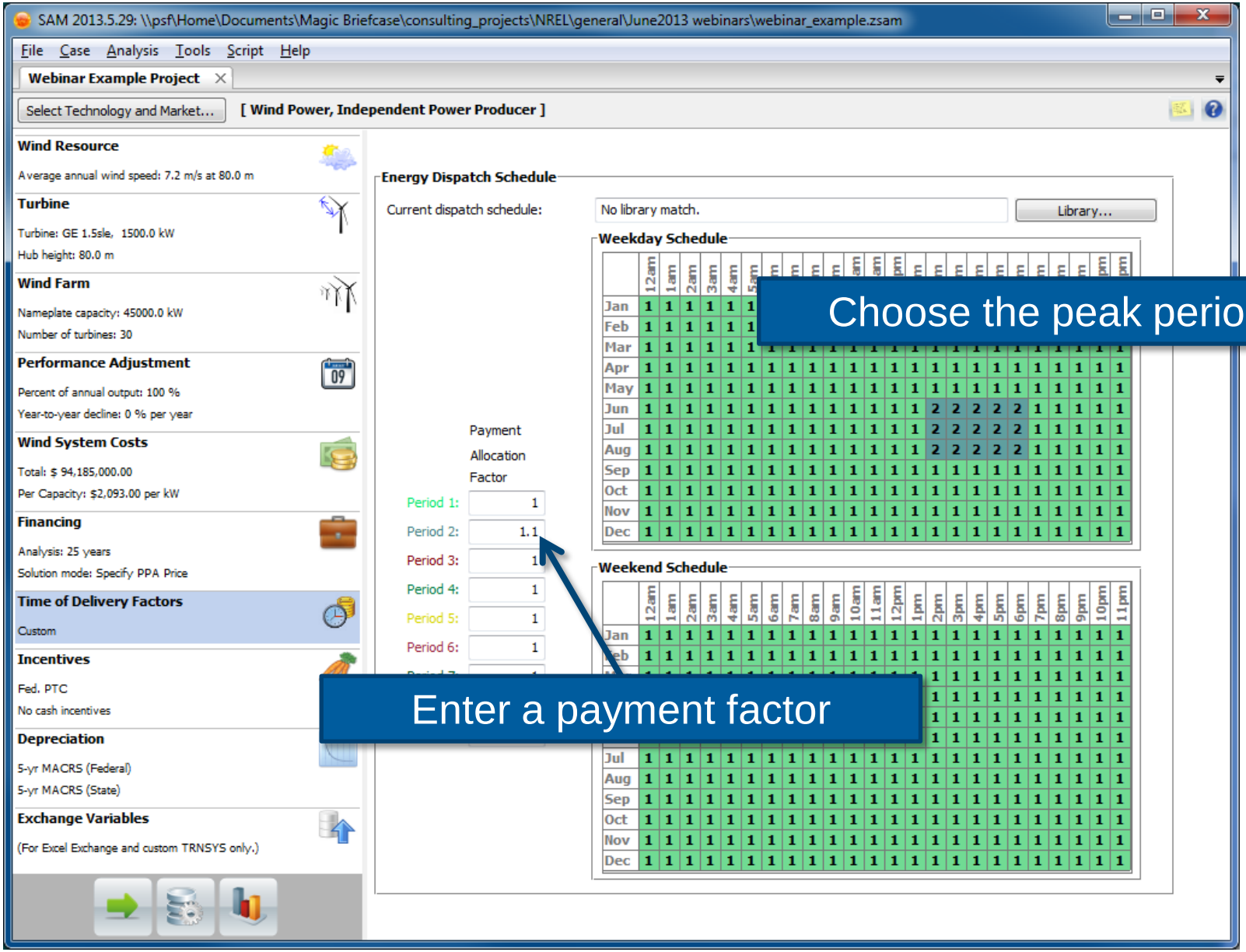
7. Project debt and financial parameters



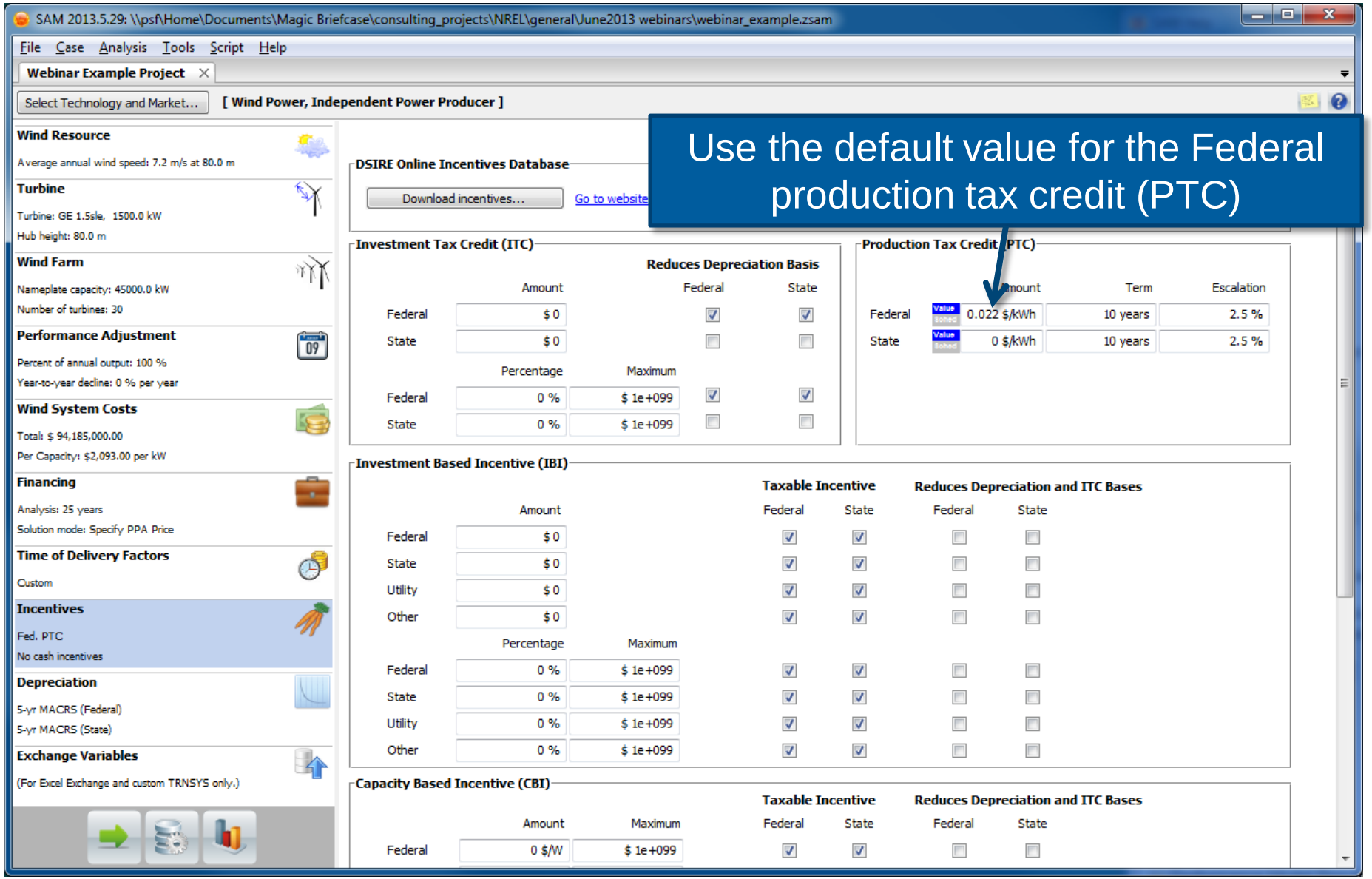
Choose to specify the PPA price and find out what the IRR will be.

Input the PPA price

8. Time of Delivery Factors

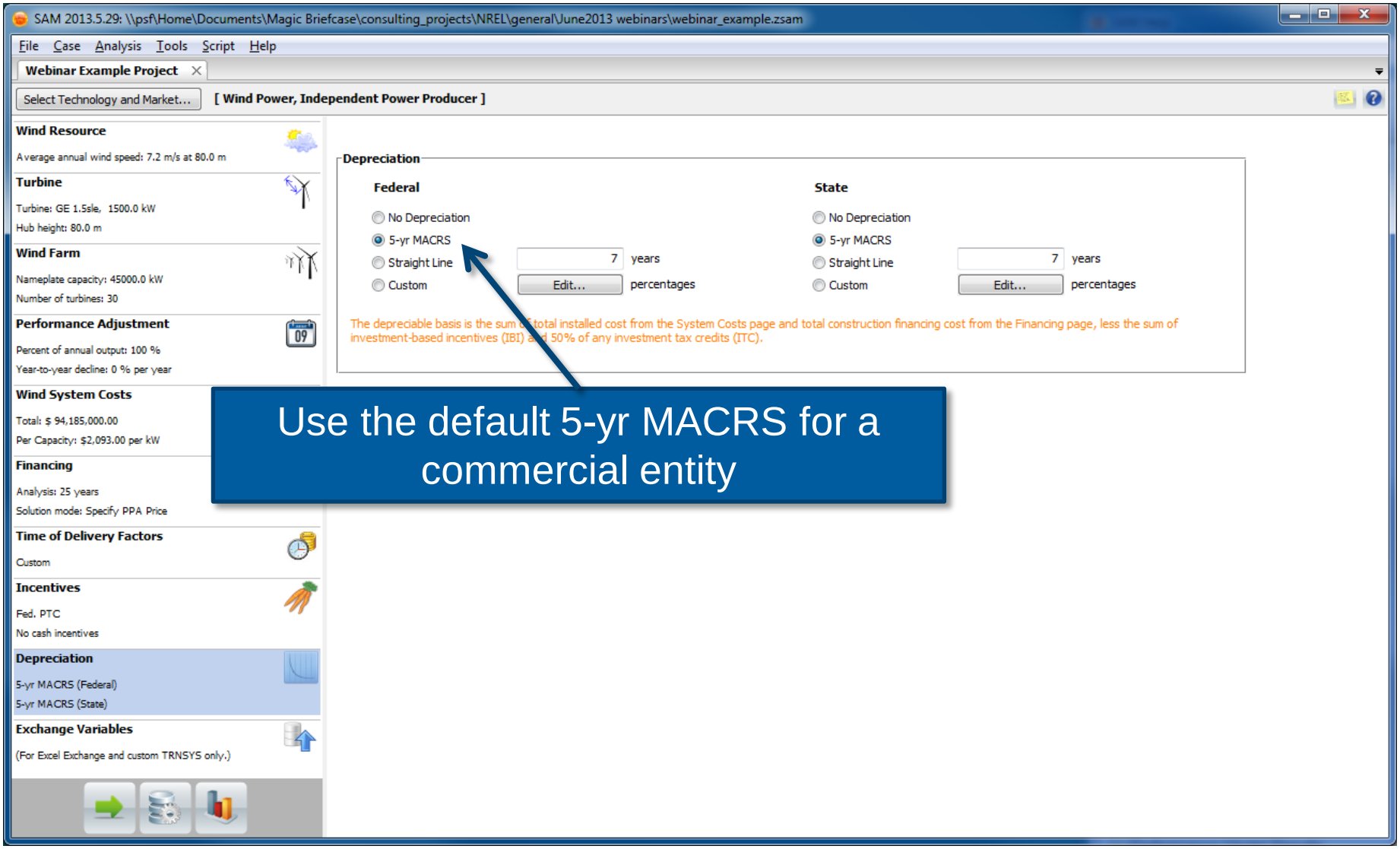


9. Incentives



Use the default value for the Federal production tax credit (PTC)

10. Depreciation



11. Run the model and review results

A complete cash flow analysis is available

SAM 2013.5.29: \\psf\Home\Documents\Magic Briefcase\consulting_projects\NREL\general\June2013 webinars\webinar_example.

File Case Analysis Tools Script Help

Webinar Example Project

Select Technology and Market... [Wind Power, Independent Power Producer]

Wind Resource
Average annual wind speed: 7.2 m/s at 80.0 m

Turbine
Turbine: GE 1.5sle, 1500.0 kW
Hub height: 80.0 m

Wind Farm
Nameplate capacity: 45000.0 kW
Number of turbines: 30

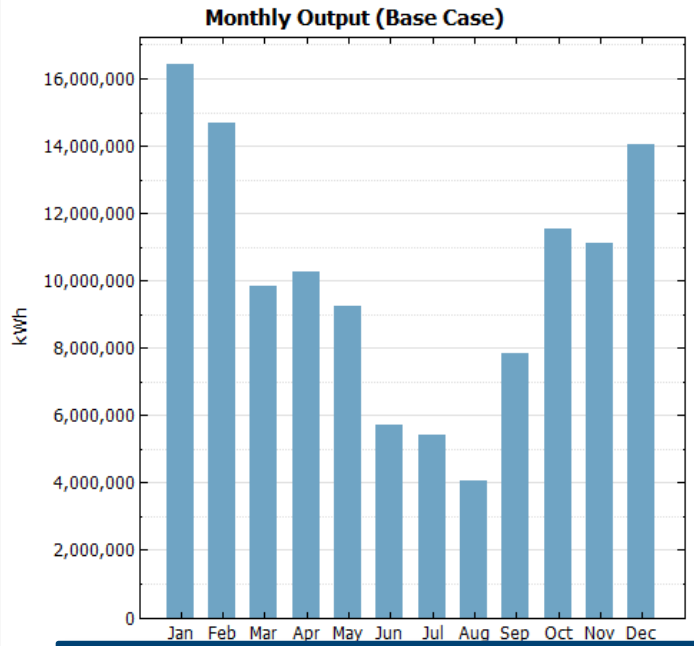
Performance Adjustment
Percent of annual output: 100 %
Year-to-year decline: 0 % per year

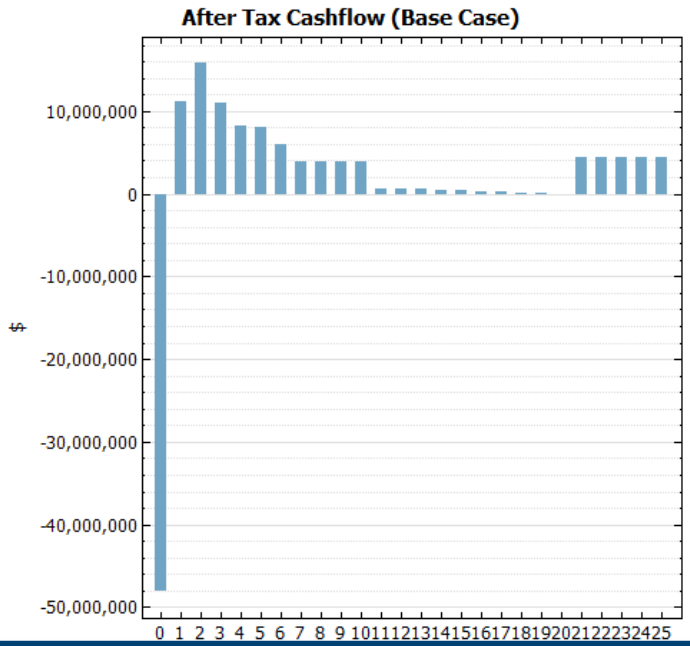
Wind System Costs
Total: $ 94,185,000.00
Per Capacity: $2,093.00 per kW

Financing

View and export data: Graphs Tables Cash Flows Time Series

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





Click Run

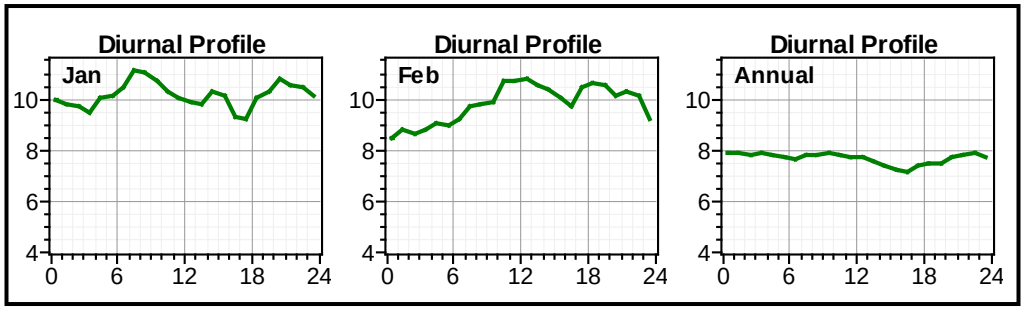
Metric	Base
Annual Energy	120,118,568 kWh
PPA price	8.00 ¢/kWh
LCOE Nominal	8.61 ¢/kWh
LCOE Real	6.95 ¢/kWh
Internal rate of return (%)	14.11 %
Minimum DSCR	1.52
Net present value ($)	$ 6,041,569.00
Calculated ppa escalation (%)	1.00 %
Calculated debt fraction (%)	50.00 %
Windfarm Capacity (MW)	45.00 MW
Capacity Factor	30.5 %
Approximate land use (m^2)	71000.0

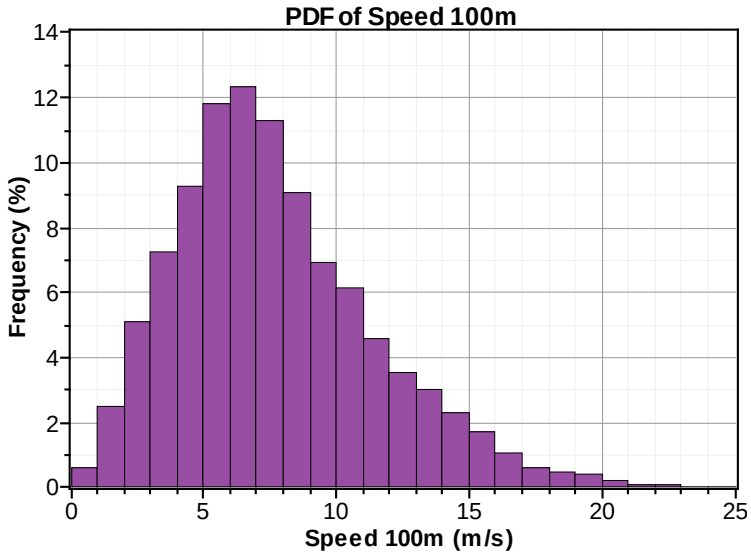
Given the assumptions, this project IRR a little over 14%, and a net present value just over $6M

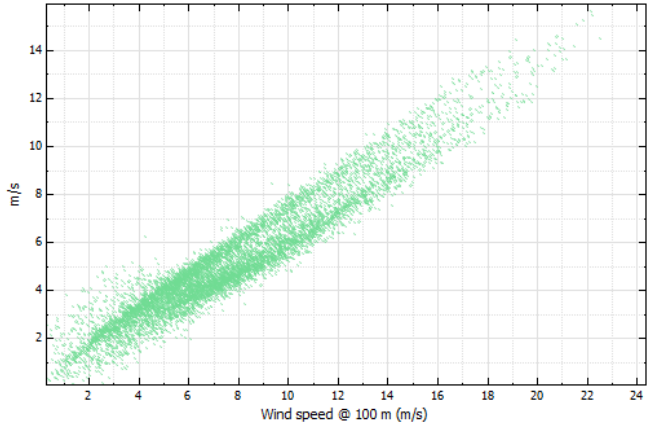
SAM Wind Analysis

Additional TOPICS

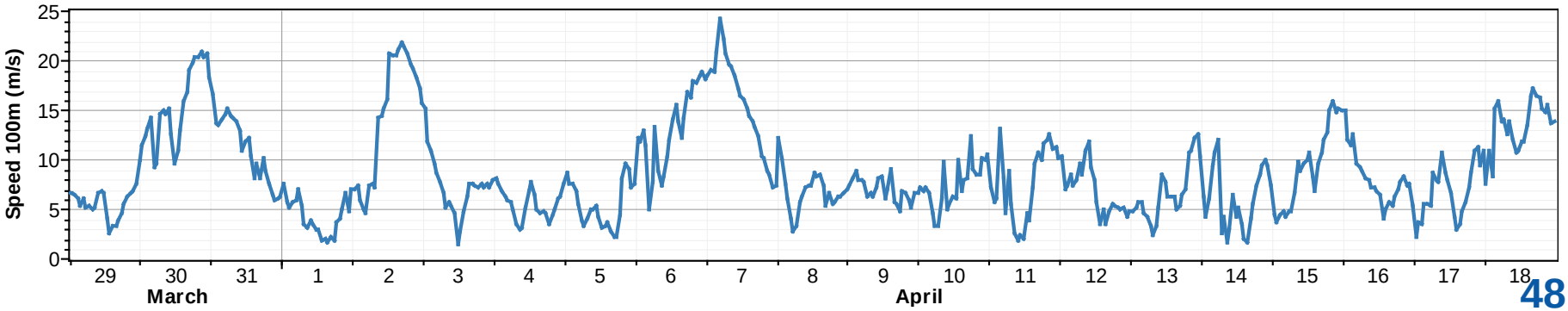
Additional Topics – Data Viewer





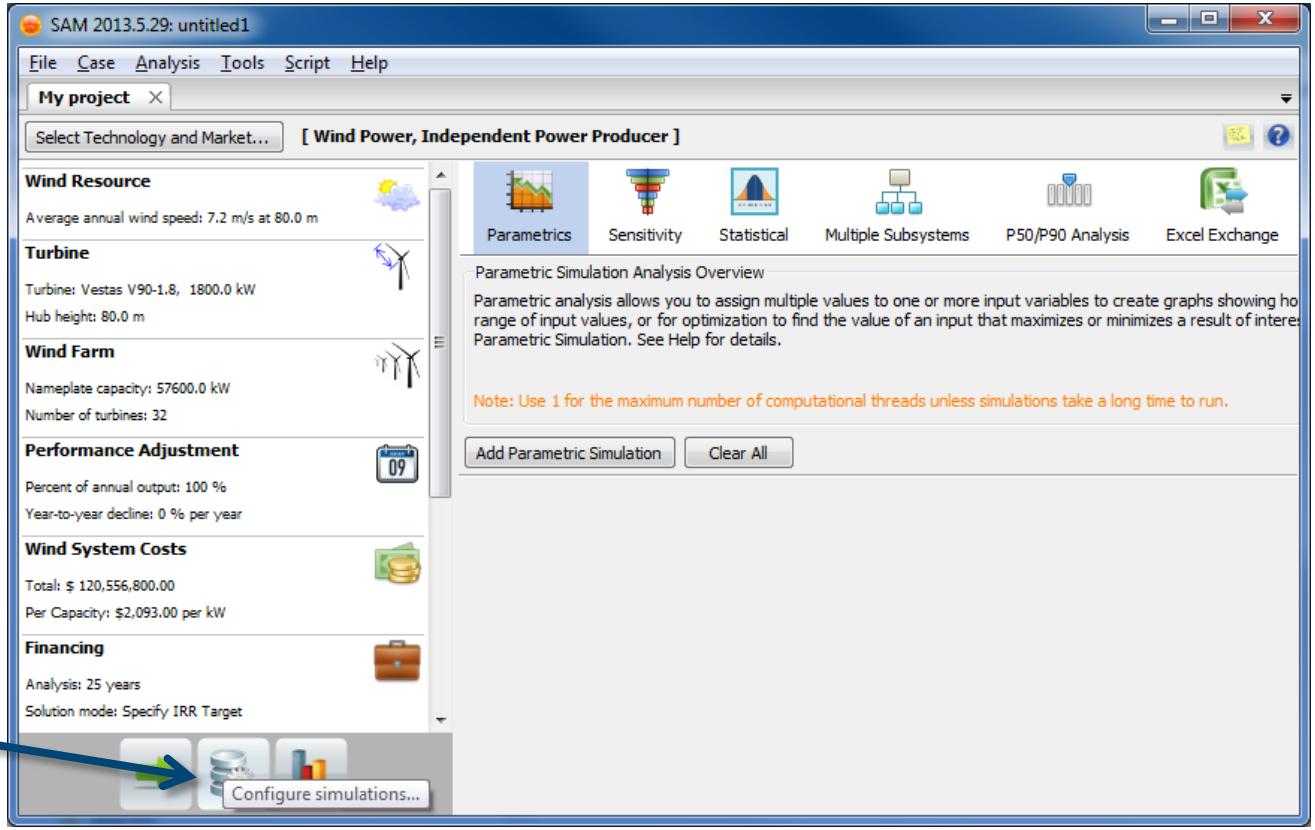


SAM comes with an hourly data viewer, which allows for many advanced views of the wind resource data. The viewer is accessed by clicking the "View hourly data..." button on the Wind Resource page



Additional Topics – Simulations

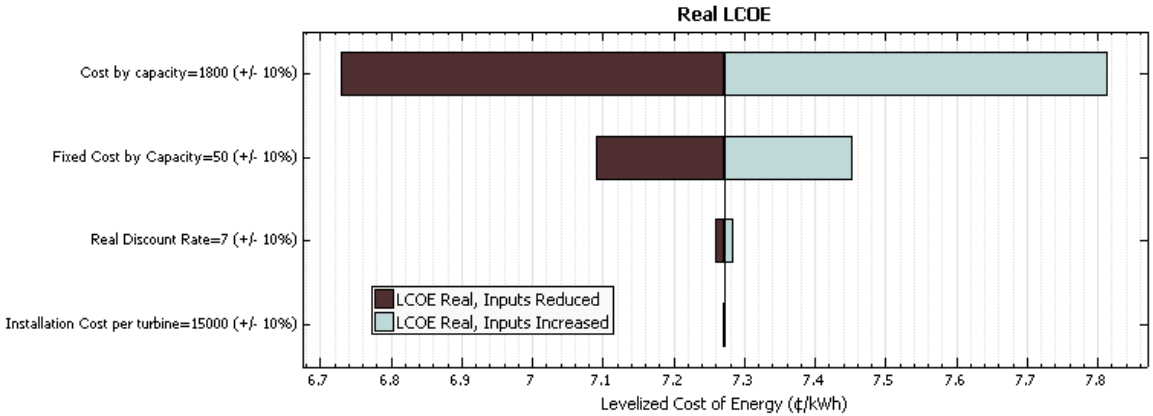
Most advanced modeling techniques are accessed through the “Analysis” menu, or the “Configure Simulations” button on the bottom left

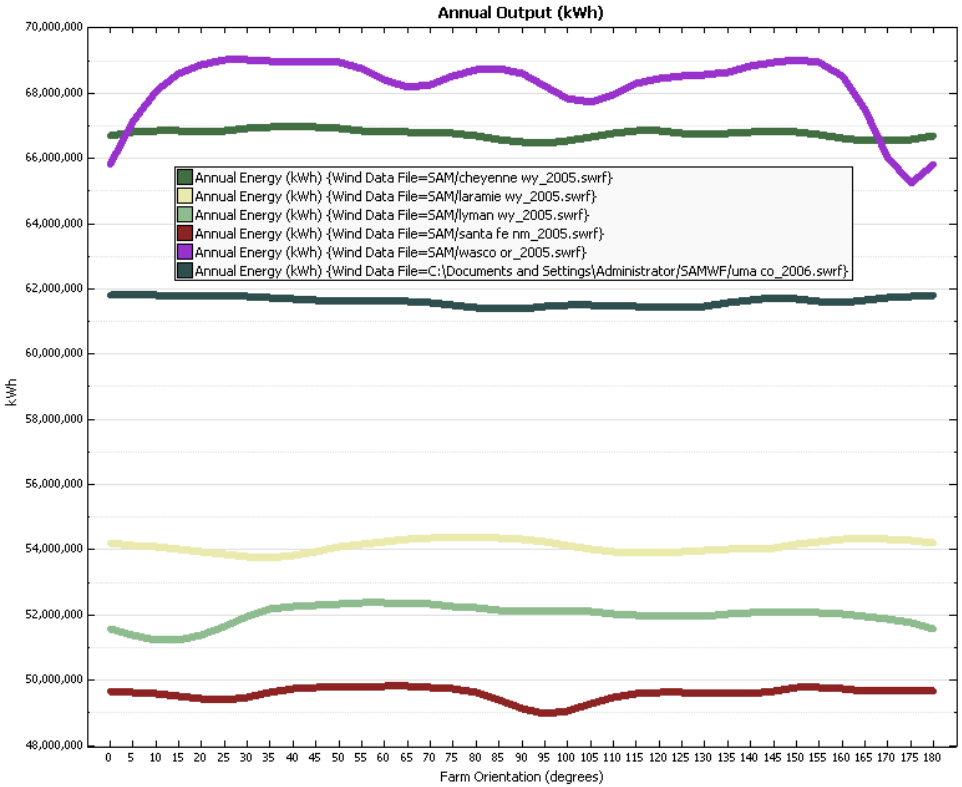


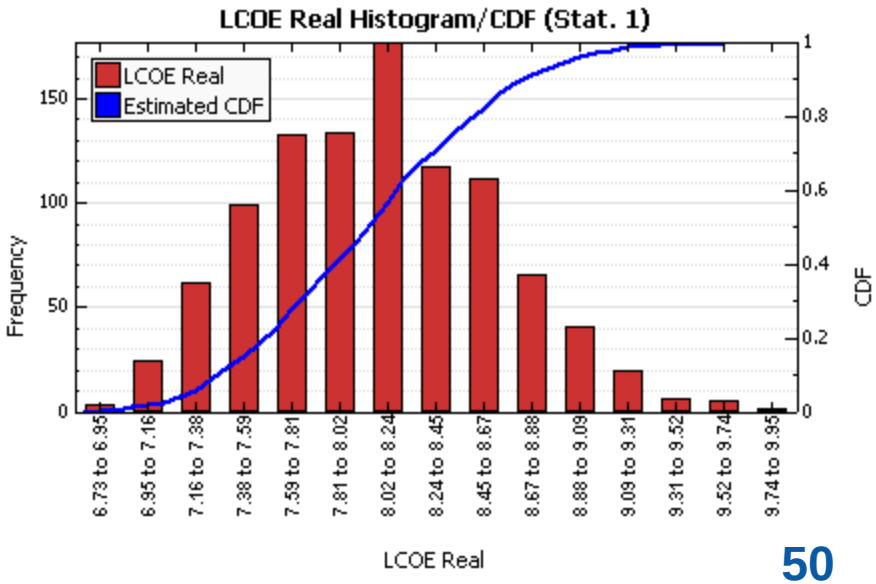
Configure Simulations button

Additional Topics - Uncertainty

Graphic outputs from uncertainty modeling in SAM







Additional Topics - Other

Excel Exchange

- Use Excel to calculate values of SAM inputs
- Set up SAM to read input values from cells in an Excel worksheet

SamUL Scripting Language

- Write a script in the SAM user interface to set values of inputs, run simulations, and read results
- Read and write data from text files
- Automate complex or repetitive analysis tasks

Software Development Kit (SDK)

- For programmers: Use the SAM API with your applications written in C/C+, Python, Java, or MATLAB
- Libraries available for Windows, OS X, and Linux
- See https://sam.nrel.gov/content/sam-simulation-core-sdk for details

Thank You!

Thank you for your time