Development Support for NREL's System Advisor Model (SAM)

Cooperative Research and Development Final Report

CRADA Number: CRD-20-16998

NREL Technical Contact: Janine Keith

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-7A40-83685
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Suggested Citation
Keith, Janine. 2022. *Development Support for NREL's System Advisor Model (SAM): Cooperative Research and Development Final Report, CRADA Number CRD-20-16998.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-83685. https://www.nrel.gov/docs/fy22osti/83685.pdf.

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Cooperative Research and Development Final Report

Report Date: August 8, 2022

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Electric Power Research Institute, Inc. (EPRI)

CRADA Number: CRD-20-16998

CRADA Title: Development Support for NREL's System Advisor Model (SAM)

Responsible Technical Contact at Alliance/National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s):

Office of Energy Efficiency and Renewable Energy (EERE), Solar Energy Technologies Office (SETO)

Joint Work Statement Funding Table showing DOE commitment:

No NREL Shared Resources

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	$0.00
TOTALS	$0.00

Executive Summary of CRADA Work:

The variable nature of renewable generation, which depends on the sun shining and wind blowing for example, presents challenges for adequate and least-cost resource planning. The deployment of renewable generation assets is anticipated to increase due to various drivers, such as declining costs, favorable government policies, and increasing procurement by corporations and consumers. High levels of renewable penetration are anticipated to pose flexibility, reliability, and cost challenges to the electrical system. The development and implementation of new features into performance modeling software, such as the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM), is one way to help think through these challenges and develop appropriate strategies.

Summary of Research Results:

This CRADA consisted of implementing four features into the NREL SAM, https://sam.nrel.gov/).

(1) Improved parametric interface:

The parametric user interface in SAM is improved to enable more intuitive interpretation of the outputs and better "optimization" using the parametrics tool, including:

- Parametric output graphs to show results sorted by different parameterized inputs where possible
- The ability to create a new case matching the inputs of a row in the parametrics table
- An additional metric to quantify power exported to the grid by a system
- The ability to identify the best case based on a user-defined goal and constraints when those outputs are selected
- Additional export option that automatically transposes parametric table and adds row labels.

NREL developed and implemented the interfaces and back-end programming for these features, and the features were released in version 2021.12.02 as shown in the following screenshots.

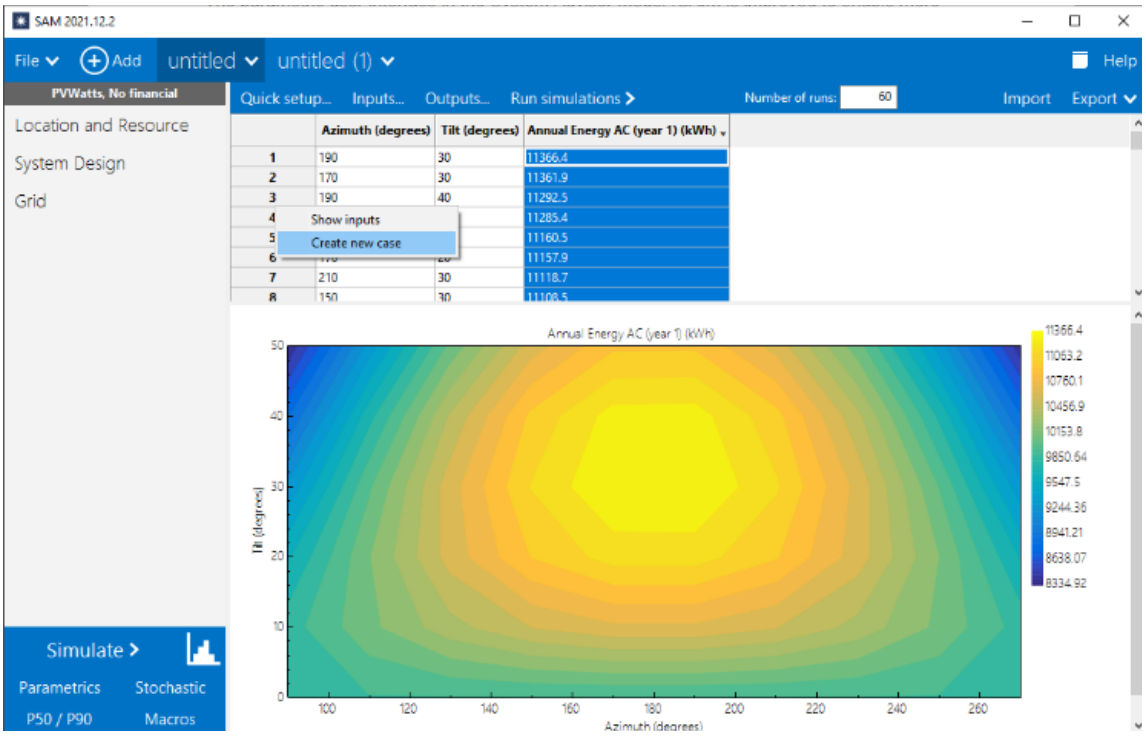


Figure 1. Parametric User Interface in SAM showing (a) output graph with Annual Energy graphed against the values of the input variables, Tilt and Azimuth (graph), (b) the ability to create a new case from a row in the parametric input table (highlighted option in pop-up box saying "Create new case"), (c) ability to sort cases by the user-selected Annual Energy output in order to identify the best case based on this user-defined "goal" (highlighted column in table with down arrow in the column header)

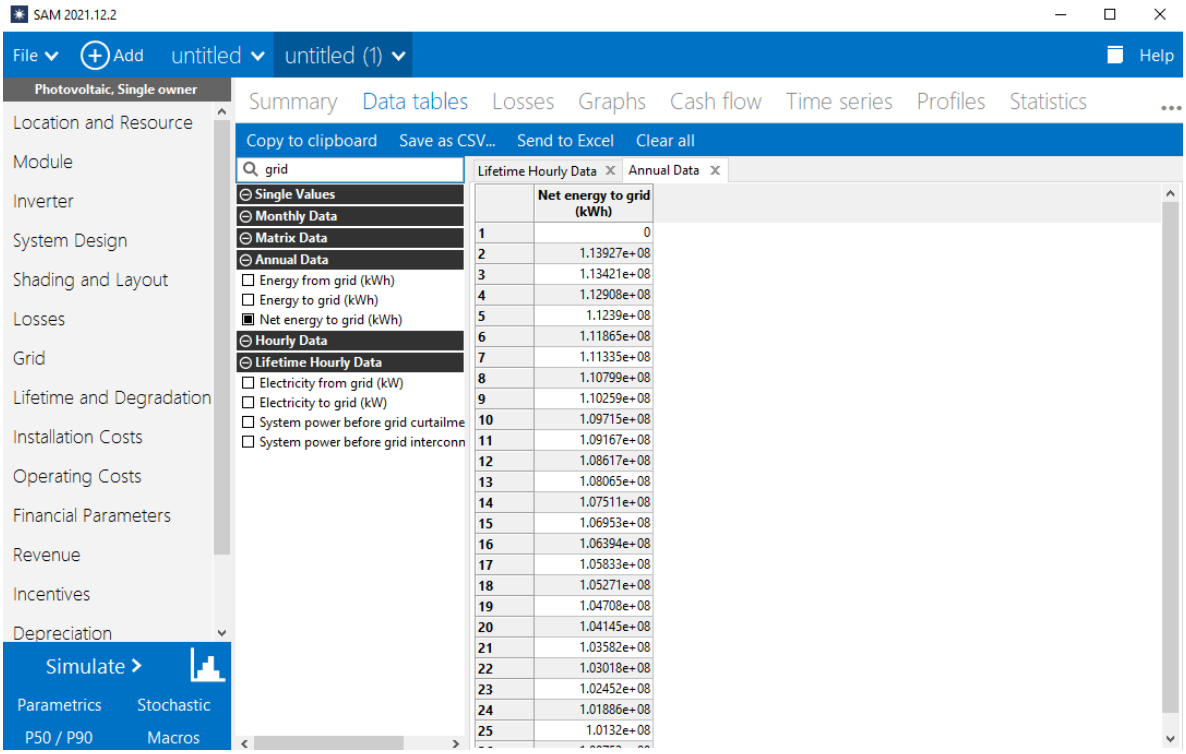
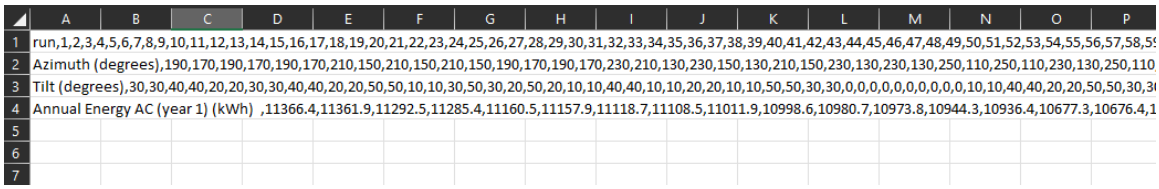


Figure 2. Output Data Tables User Interface in SAM showing the Net Energy exported to grid by a system



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	run,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,5															
2	Azimuth (degrees),190,170,190,170,190,170,210,150,210,150,210,150,190,170,190,170,230,210,130,230,150,130,210,150,230,130,230,130,250,110,250,110,230,130,250,110															
3	Tilt (degrees),30,30,40,40,20,20,30,30,40,40,20,20,50,50,10,10,30,50,30,20,50,20,10,10,40,40,10,10,20,20,10,10,50,50,30,30,0,0,0,0,0,0,0,0,0,0,0,10,10,40,40,20,20,50,50,30,3															
4	Annual Energy AC (year 1) (kWh) ,11366.4,11361.9,11292.5,11285.4,11160.5,11157.9,11118.7,11108.5,11011.9,10998.6,10980.7,10973.8,10944.3,10936.4,10677.3,10676.4,1															
5																
6																
7																

Figure 3. Data from the parametric user interface in SAM, exported to Excel using the "Export" button at the top of the screen, showing the data automatically transposed and with the rows labeled

(2) Ratcheting Demand Charges:

The capability to model ratcheting demand charges is added to the commercial behind-the-meter financial model in SAM. This allows tracking charges on a continuously rolling basis, rather than year-by-year as it currently runs. The ratcheting capability includes configuration options to apply across multiple scenarios:

- Selecting the period of previous charges from which the greater demand could be taken
- Selecting the percentage of highest demand that may be applicable from a previous month
- Selecting seasonal differences in demand ratchets
- Assigning a minimum demand value if the actual demand is lower than said minimum
- Assigning an alternate minimum demand value based on a "contracted capacity" that the user inputs.

Furthermore, additions are made to the user interface to be able to input demand ratchets, testing, validation, and help documentation.

NREL implemented these features into both the user interface and underlying utility rate calculation code within SAM with guidance from Southern Company, who has utility rates with these types of features in their territory. After some discussion, we collectively agreed that an appropriate name for these features in the user interface was "Billing Demand", describing the ratcheting demand charges. Figure 4 shows the user interface as released in SAM version 2021.12.02. The SAM implementation was validated against spreadsheet implementations of the utility rates by our partners at EPRI and Southern Company.

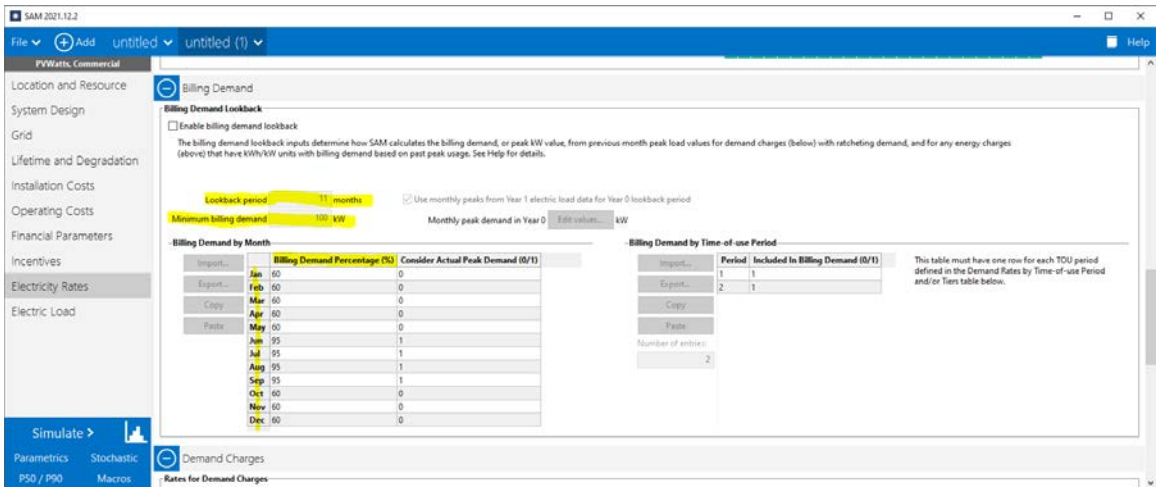


Figure 4. Billing Demand interface in the behind-the-meter Commercial financial model within SAM, highlighting the requested features outlined above

The billing demand features were also added to SAM's context-sensitive help documentation system as shown in Figure 5.

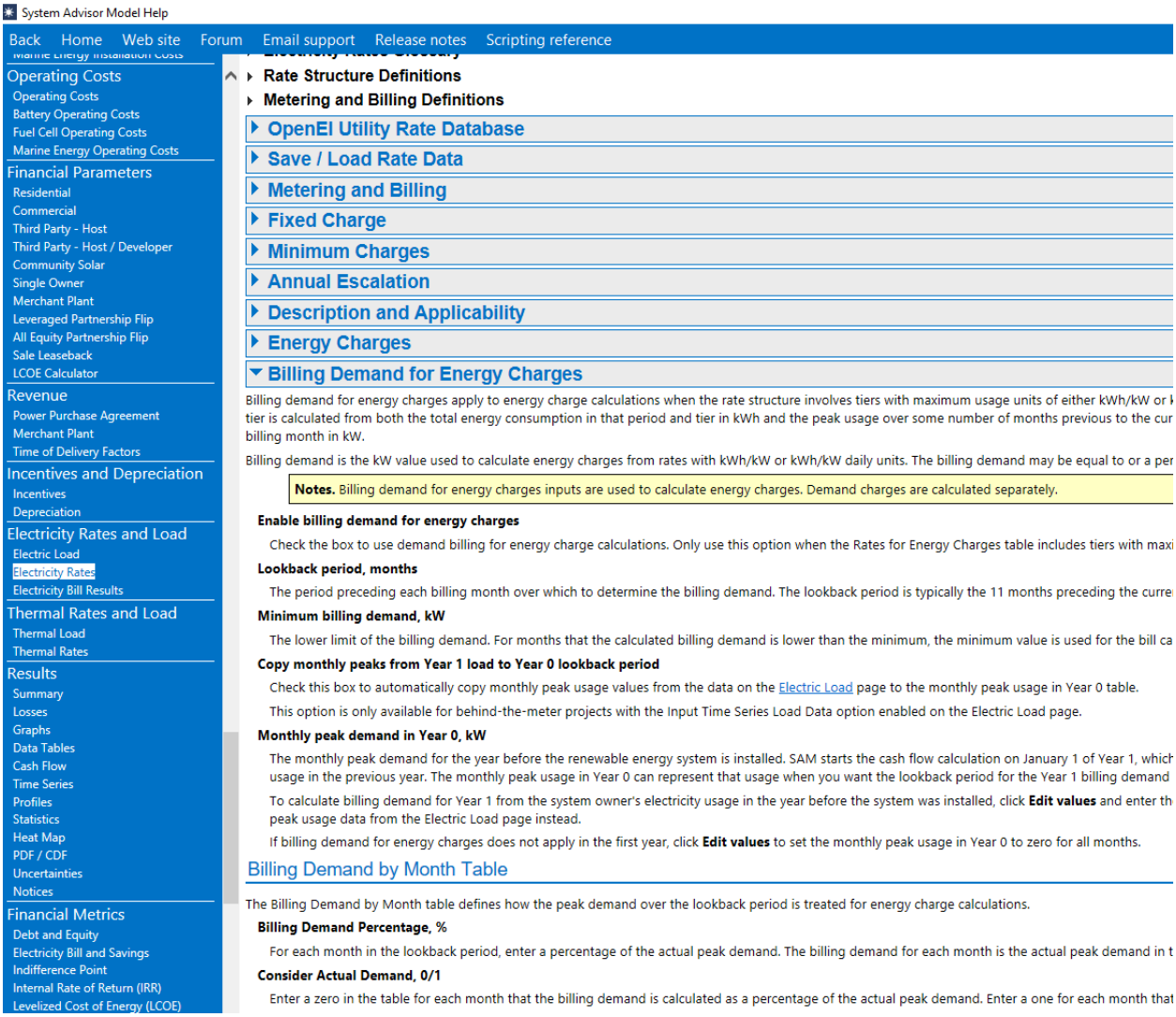


Figure 5. Detailed Help Documentation of the Billing Demand feature in SAM

(3) CapEx Table Inputs:

The ability to define CapEx as a table of $/kW inputs is added to SAM, which allows interpolation between costs as system sizes change.

We implemented this feature on the Installation Costs page of the photovoltaic models within SAM as an alternate option to the normal SAM cost inputs page. Figure 6 shows the input page as implemented and released in SAM version 2021.12.02.

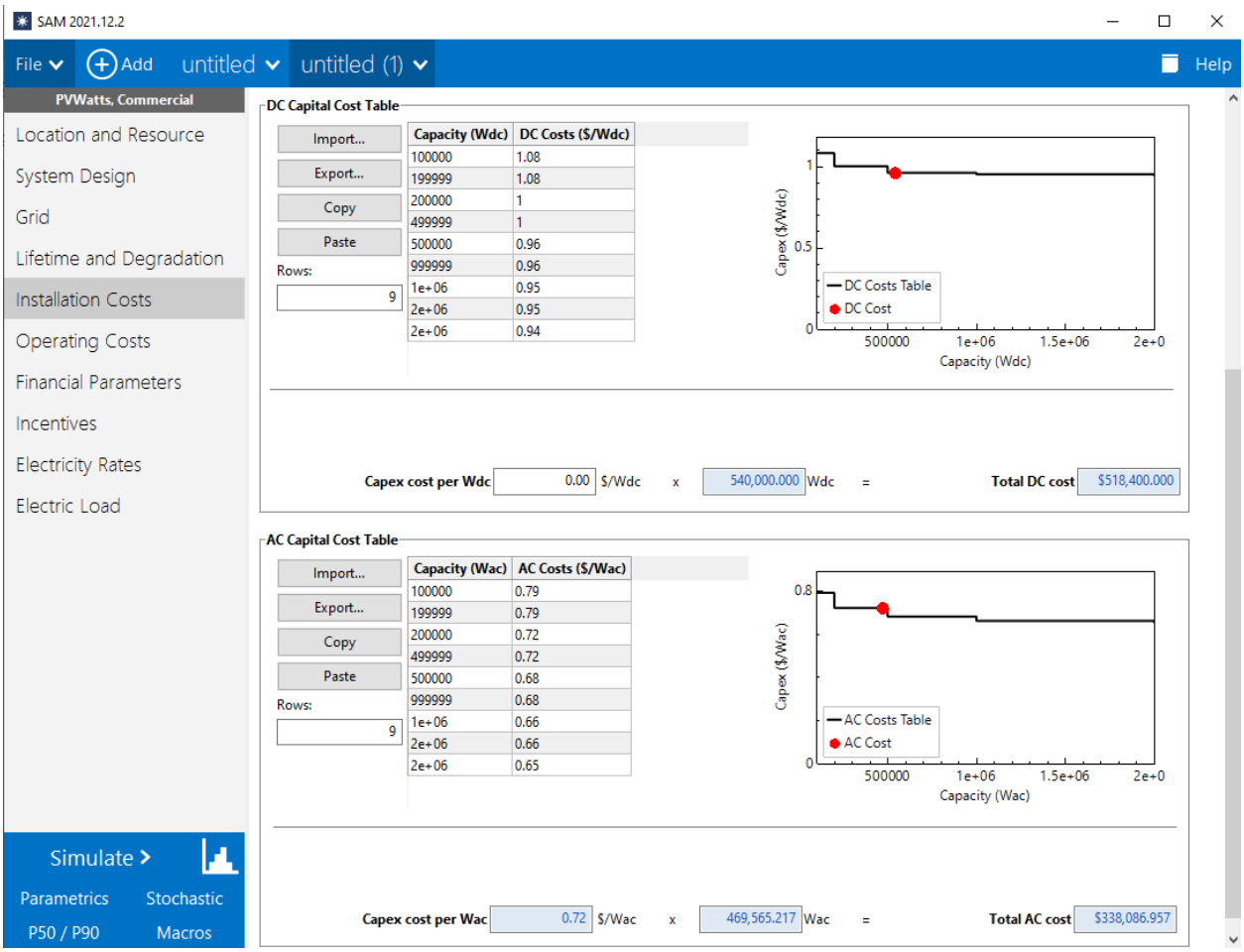


Figure 6. New user interface allowing photovoltaic costs to be input as a table of $/kW inputs for both the DC and AC side of the system

(4) PV Smoothing Algorithm:

EPRI has developed a front-of-the-meter battery model dispatch algorithm to be implemented into SAM. EPRI intends on improving the human readability of the code, better documenting it for others to understand and use the code, and posting it to an open-access code sharing website, such as github. Furthermore, a peer-reviewed journal article that describes the algorithm and results from its initial application are to be written and submitted for peer-review publication.

The code EPRI posts to github will be implemented into SAM by Contractor. The user interface is updated to reflect a dispatch option for PV smoothing with or without a user-input forecast. The performance parameters of the algorithm include defaults found in this project, but are to be adjustable by the user. Notably, this task does not fund work for developing a generalized parameter optimization.

After EPRI posted the open source code for the PV smoothing algorithm, NREL translated it into C++ for native inclusion in SAM (it was originally written in Python). NREL tested the implementation of the algorithm against a baseline test case in the Python implementation and found sufficient agreement; minor differences were found to be caused by differences in the

battery performance models used rather than any differences in the implementation of the dispatch algorithm. NREL then designed a user interface to access this new algorithm from the front-of-meter detailed photovoltaic-battery model in SAM, shown in Figure 7.

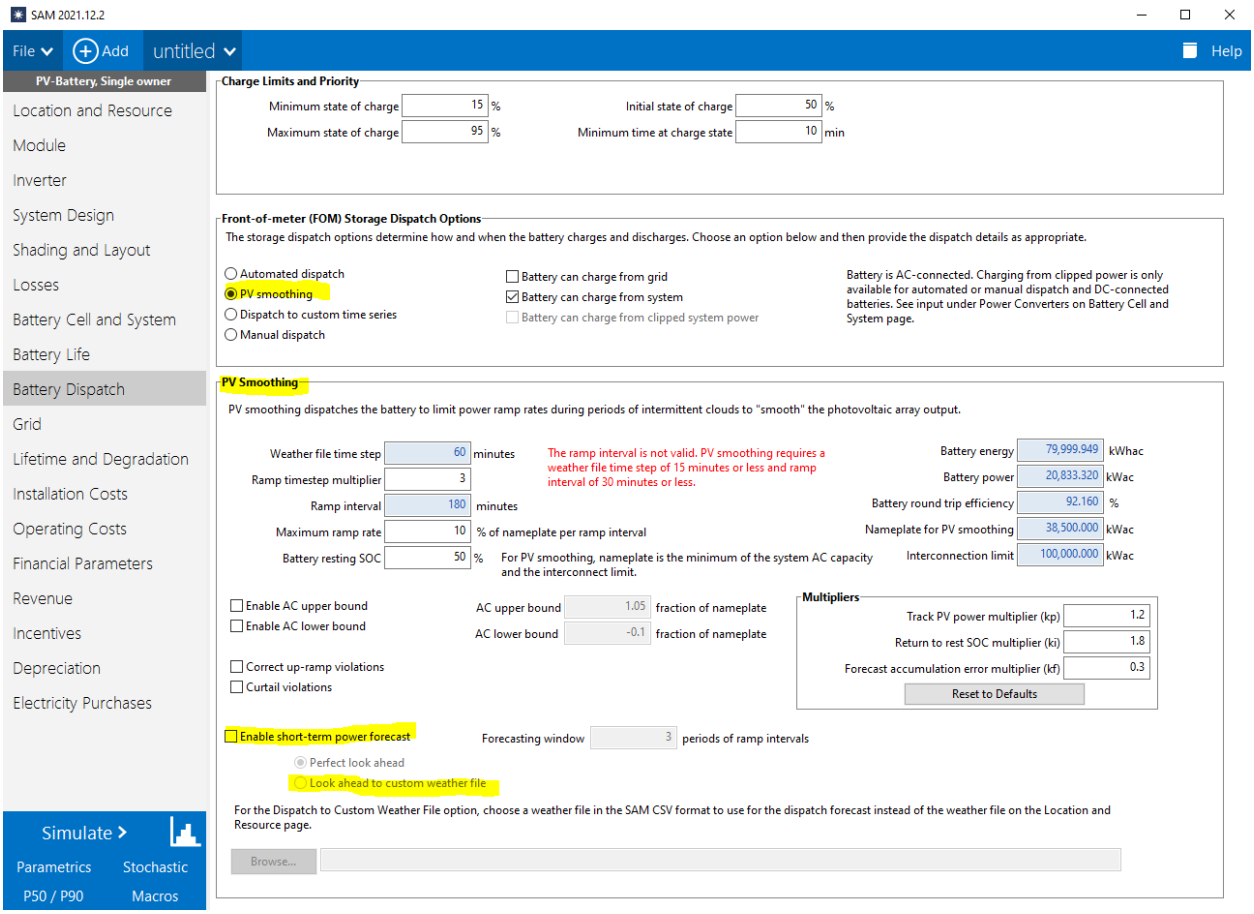


Figure 7. New SAM user interface for the PV smoothing algorithm, showing the ability to select this option within a front-of-meter photovoltaic-battery case and the ability to input an optional custom weather forecast file

Subject Inventions Listing:

None

ROI #:

None