

User Guide

Residential Solar Photovoltaic Financing Program Excel Tool

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Tool Overview

This tool is meant to help Community Choice Energy Agencies predict costs and benefits associated with offering a financing program to help residents purchase solar photovoltaic (PV) systems. Based on a variety of program and agency specifications, the model predicts the number of solar PV system purchases that will be directly caused by a financing program, and then calculates associated financial implications, greenhouse gas (GHG) emission reductions, and health impacts.

Users can visualize relationships among program design parameters by using the tool with a range of parameter values and recording the results. For example, a user might hold all input values constant and vary only agency program interest rate in order to isolate its effect on cost per ton of GHG emission reductions, or another tool output.

The tool uses an innovative modeling technique called a Technology Choice Model (TCM) to predict consumer response to a change in electricity cost. TCM incorporates both real costs and subjective consumer preferences to make predictions about consumer behavior. Predictions of consumer behavior are then used to calculate the overall impacts of a financing program.

Using the Tool

Users will interact with the Interface worksheet, which contains all of the user inputs and resulting outputs. At a minimum, users will need to enter values for the agency's energy mix, customer electricity usage, cost to the customer of electricity from the agency and solar, and some program design specifications. There are a variety of additional inputs that allow users to add further program specifications as appropriate. A detailed explanation of all available input options is included in the Interface section of this user guide.

Once the user has filled in the appropriate inputs in the tool, the Outputs section of the Interface will display a summary of model predictions. Outputs include the predicted number of homes purchasing solar PV due to the financing program's existence, as well as predicted health, environmental, and financial impacts associated with the modeled financing program. A more detailed explanation of all outputs is included under the Outputs heading in the Interface section of this user guide.

How it Works

The core of this tool is the Technology Choice Model (TCM), an economic input-output model that predicts consumer choices given a number of options with distinct costs¹. In this case, grid

¹ Kätelhön, Arne, André Bardow, and Sangwon Suh. "Stochastic Technology Choice Model for Consequential Life Cycle Assessment." *Environmental science & technology* 50.23 (2016): 12575-12583.

electricity, customer purchase of solar PV, and third party-owned (e.g. leased or power purchase agreement) solar PV are used as the purchase options. The model calculates the total costs of each option and adds uncertainty to each cost. This uncertainty represents qualitative factors that influence consumer choice, like personal preference and imperfect information flow. The model runs thousands of simulations that vary the total costs of each option based on these set uncertainties. For each simulation, the model chooses the lowest cost option for purchase. Taken together, these simulations can be used to construct a predicted market share for the three available electricity sources.

This tool modifies the cost of customer-owned solar PV based on the offered interest rate. Altering the overall electricity cost creates a new market share that is compared to a predicted baseline. The difference between the baseline and new market shares is used to calculate the number of solar PV sales that were directly caused by the financing program. This number is used to calculate the benefits associated with the program. The predicted GHG and pollutant emissions offset by sourcing electricity from solar power rather than from the CCE agency electricity supply are calculated, as well as the resulting monetary value to society of reduced GHG emissions and health impacts.

It is important to note in regard to the GHG/pollutant emission reduction predictions that this tool simply calculates them from the emission factors of the agency's current energy mix multiplied by the amount of program-caused solar generation (also incorporating transmission losses and a rebound effect). In reality, the effect of integrating solar power into the grid is more complex due to the need to provide backup power, often from natural gas.

Worksheet Details

The model's worksheets can be grouped into three categories: interface, model, and data sources.

Interface: This is the worksheet with which the user interacts to run the model.

Model: These worksheets contain the TCM portion of the tool. Worksheets in this category include:

- Model(BASE)
- Model(CCE)
- Emissions
- Interest Revenue

Data: These worksheets contain the background data that the model uses to calculate solar generation, market share, emissions, and associated impacts. They include:

- Data
- Interest Revenue

This user guide details the content and use of the Interface worksheet in Excel.

Interface

This is the main worksheet with which a user will interact. All of the model's inputs and outputs are included in this worksheet.

Inputs

Basic Information

These inputs are required to run the tool.

- **Agency:** The CCE Agency that will run the program. The model uses this information to set the baseline market share, average solar system size, cost of solar, and electricity usage. If your agency is not included in the drop-down menu, select "Other" and fill in the "Other Agency / Future Years Adjustment Inputs" section described below, in addition to the standard input fields.
- **Percent Net Revenue (%):** The percentage of electricity sales that goes to revenues.
- **Transmission losses (%):** Percentage of electricity generated that is lost during transmission from the electricity source to the consumer. The default value is set at 4.23%, representing California's average 2016 transmission losses according to the EPA.
- **Rate data:** These inputs are used to calculate both electricity prices for consumers and the electricity sales revenue foregone when customers get electricity from their solar panels instead of the CCE agency. Note that this tool was created using electricity rates estimates that included taxes and IOU fees, as found on rate comparison web pages. It is easier to calibrate if rates including those costs are entered in the fields below.
 - **Electricity price escalation rate (%/year):** The expected increase in electricity rates to customers each year. The default value is set at 2%.
 - **Average rate – most common schedule (\$/kWh):** The average electricity rate charged to most customers on their monthly bill.
 - **Average rate – CARE (\$/kWh):** The average electricity rate charged to customers in the CARE program.
 - **Average rate - other schedules (\$/kWh):** The average electricity rate charged to agency customers who are not in the above two categories.
 - **Greener product premium (%):** The additional cost charged to consumers for getting electricity from a greener mix (100% GHG-free, 100% solar, etc.) than the standard one offered by the agency.
- **Usage Data (Non-NEM accounts)**
 - **Percentage of non-CARE accounts on most common rate schedule:** The percentage of customers on the most common rate schedule, and not in the CARE program.
 - **Percentage of accounts on CARE:** The percentage of customers in the CARE program, corresponding to the CARE rate entered.
 - **Percentage of accounts on other rate schedules:** The percentage of customers who are not in either of the aforementioned categories.

- **Percentage of accounts purchasing greener electricity:** The percentage of customers who have opted up and are purchasing the agency's greener electricity offering.
- **Average electricity usage - non-CARE, non-green (kWh/month):** The average monthly usage of customers in neither the CARE nor greener product purchaser populations.
- **Average electricity usage - CARE, non-green (kWh/month):** The average monthly usage of customers in the CARE program who do not purchase the greener product.
- **Average electricity usage - non-CARE, green (kWh/month):** The average monthly usage of customers who purchase the greener product and are not in the CARE program.
- **Average electricity usage - CARE, green (kWh/month):** The average monthly usage of customers who are both in the CARE program and are purchasing greener electricity.
- **Energy mix (%):** The composition of the agency's energy mix, used to calculate anthropogenic and biogenic GHG and criteria pollutant emissions avoided when electricity is sourced from the homeowner's solar panels rather than agency supply. Unspecified power is treated as natural gas for emission calculations.

PV Financing Program Inputs

Program Details

These inputs are required or strongly recommended to customize.

- **Program administrative costs (\$/year):** All administrative and implementation costs for the program, excluding the amount provided as loans.
- **Total budget available for loans (\$):** The total budget available to be lent out in loans.
- **Existing (non-CCE) financing interest rate (%):** The average financing interest rate (customer-owned) or effective lease/PPA equivalent to an interest rate (third party-owned) that consumers can currently get on the market without the CCE agency financing program. These rates may be difficult to find or estimate, but they are just one factor in the baseline cost of customer- and third party-owned solar, and hints that they need to increase or decrease may be found during the calibration step described below.
- **CCE agency program financing interest rate (%):** The financing interest rate that the agency is thinking of offering to customers.
- **Agency's financial discount rate:** The annual rate at which future costs and benefits are devalued in the CCE agency's financial calculations.
- **Financing payback period (years):** The time period over which CCE agency financing customers or (external) third party-owned solar customers will pay back their loans.
- **NEM rate credited:** The method with which the agency provides generation credits to net energy metering customers. Choose from either flat rate or OAS (otherwise applicable rate schedule).
 - **Rate credited if "Flat rate" is chosen (\$/kWh):** The flat rate credited to NEM customers accounts for excess monthly solar electricity generation.

- **NEM bonus payments if “OAS” is chosen (\$/kWh):** The bonus payment made to NEM customers for excess monthly solar electricity generation, in addition to credits at their OAS.
- **Credit greener product price premium in NEM? (Yes/No):** Whether greener product customers with PV receive NEM credits at the premium rate for the greener product.

Additional Details

These inputs may be left as default values if desired.

- **Marketing effectiveness (%):** A way to account for the role of marketing on influencing program effectiveness. Users may input the percentage of eligible customers they expect will be aware of the program being offered. This parameter is a powerful one as it directly modifies the predicted solar uptake. The default value is 5% but higher values may be appropriate depending on planned program marketing efforts.
- **Expected default rate (%):** The percentage of financing program participants expected to default on their loans. The default value is set at 1% as an intermediate between values of 0% and 1.5% from the CA PACE Loss Reserve Program and NREL, respectively.
- **Rebound effect (%):** The increase in the amount of electricity people tend to consume once they start using solar electricity. Input a value estimate for the percentage increase in average electricity consumption after solar panels are installed. The default value is set at 3%.
- **Customers’ financial discount rate (%):** The annual rate at which future costs and benefits are devalued by the average customer. The default value is set at 6%.
- **Societal goods discount rate (%):** The annual rate at which future costs and benefits of societal benefits like health impacts and GHG reductions are devalued by society. (Used to calculate health and environmental costs/benefits that impact society.) The default value is set at 2.5%.
- **Carbon value (\$/ton CO₂e):** The monetary value ascribed to an avoided ton of CO₂e emissions. The default value is set at \$13/ton, based on the 2016 California market trading rate for CO₂ credits.
- **Health impact level:** The level (low, mid, or high) at which health impacts should be valued monetarily. Impacts will more likely be valued at a low level in sparsely populated areas, at a high level in densely populated areas, and so on. It is set at low by default.
- **Solar PV module lifetime (years):** The average number of years the solar panels are expected to last. The default value is set at 25, and the maximum allowable is 30 years.
- **Average capacity factor (%):** The average capacity factor of the installed solar panels. The default value is set at 20%.
- **Average operations & maintenance cost (\$/kW/yr):** The average annual fixed cost customers pay for maintenance per kW of solar panels. The default value is set at \$20.
- **Average percentage of usage covered by solar generation (%):** The average percentage of a customer’s typical electricity usage that is generated by their solar PV system. For example, if local homeowners generally over-size their systems to produce 105% of their monthly usage, input 105%. The default is set at 99.4%, the 2017 California average as calculated by EnergySage.

- **Local rebates (\$/W):** Any city- or county-level rebates available to at least some customers within the agency territory.
- **Percentage of accounts eligible for local rebates (%):** The percentage of accounts located in the jurisdiction offering rebates.
- **Decrease in PV cost per watt since early 2018 (%):** The tool uses an average cost per watt of solar panels recorded in February, 2018. To adjust for small price changes in future years, input the average percentage decrease in solar PV cost (\$/W) since early 2018. (To reference the default cost of solar panels used, look at cells X7:Y27 in the Model(BASE) worksheet.) To adjust for bigger changes over time, utilize the “Other” agency option. If you use that, do not input anything into this cell.

Other Agency / Future Years Adjustment Inputs

Go to this section if your agency is not listed in the drop-down “Agency” menu or if you want to use updated solar PV system size, market share, and cost data. The default values built into the tool use housing values from 2016, size and market share values from 2017, and cost values from 2018. Comments on the input field names give instructions on using them. The fields are:

- Interconnection fee (\$)
- Observed average customer-owned PV system size (kW)
- Observed average third party-owned PV system size (kW)
- Number of households suitable for buying PV (#)
- Baseline market share captured by customer-owned PV (%)
- Baseline market share captured by third party-owned PV (%)
- Average cost of a 1 kw residential solar PV system (\$)

Calibration Step

Do this step after entering all appropriate Basic Information Inputs, PV Financing Program Inputs, and if necessary, Other Agency / Future Years Adjustment Inputs. This will calibrate the tool based on the set program inputs. Before starting, make sure Workbook Calculation is set to Automatic in File > Options > Formulas.

Standard deviation (SD) for interest rates and perceived cost (%): Start adjusting this first to match predicted (row 50) to observed average PV system size (row 49). If the SD is getting very far above about 30-40%, pause and adjust the perceived cost somewhat. SD is inversely related to predicted system size but directly related to predicted market share (row 54).

Perceived cost per month (\$): Adjust this value to match predicted (row 54) to observed market share (row 53). You may need to iteratively adjust the SD and perceived cost as their results are linked. If matching the observed and predicted market shares up seems very hard, you may want to try adjusting the “Existing (non-CCE) financing interest rate” value(s).

Getting SD and perceived cost calibrated is difficult since the simulations give slightly different predictions each time you enter a value. Try to get the predicted values centered around or near the observed values.

To get a conservative range of results

1. Find the combination of SD and perceived cost that results in matching observed and predicted average PV system size and market share.
2. Record the results displayed in the Outputs box. These will be the upper bound of predicted program results.
3. Increase the SD by 5% and increase the perceived cost to again match the observed and predicted market shares (system sizes will not match).
4. Record the results again. These will be the lower bound of predicted program results.

For future use without calibration, record the SD and perceived cost values elsewhere. Recalibrate if you change any of the following inputs: Agency, Electricity Rates & Usage, Average existing (non-CCE) financing interest rate, any NEM-related inputs, Customer's Discount Rate, or the last seven Additional Details inputs.

Outputs

Uptake and Revenue Effects

- **Percentage of houses participating in agency program (%):** The percentage of households within CCE agency service territory that are predicted to participate in the agency financing program, even if they could have afforded/financed solar otherwise. Note: because this is a percentage of all houses, the value is generally very small, <1%.
- **Percentage of houses getting solar caused by program (%):** The percentage of households within CCE agency service territory that are predicted to install solar because of the financing program offered by the CCE agency, who would not have installed solar without the agency financing program.
- **Solar PV installations caused by program (#):** The number of solar PV installations caused by the CCE agency financing program.
- **Total value of loans provided (\$):** The total dollar amount of loans provided to financing program participants.
- **Program budget remaining (\$):** Remaining budget that had been reserved for loans but was not used because of lower than planned for consumer demand.
- **Revenue lost due to solar installations caused by program (\$):** The amount of electricity sales revenue foregone by the CCE agency because customers' electricity is now sourced from their program-caused solar PV systems. The lifetime solar generation in this calculation is discounted at the agency's financial discount rate.
- **Revenue from collected principal and interest (\$):** The total present value of revenue received from the financing program, as a sum of collected principal and interest. This value is discounted at the agency's financial discount rate.
- **Net revenue change due to program (\$):** The total net revenue from the program in the current year. From the present value of revenue from collected principal and interest is subtracted the present value of revenue lost due to solar installations, the loan principal, and the year's program administrative costs.

GHG and Health Effects

- **GHG emissions averted - Anthropogenic (tons CO_{2e}):** Predicted GHG emissions avoided because of the financing program from most sources in the energy mix, in tons of CO_{2e}.
- **GHG emissions averted - Biogenic (tons CO_{2e}):** Predicted GHG emissions avoided because of the financing program from biomass in the energy mix, in tons of CO_{2e}. These are not included in the calculation of emission impacts resulting from the program.
- **Cost per ton of GHG emission reductions (\$/ton CO_{2e}):** The cost to the agency per ton of CO_{2e} emissions prevented through the financing program. This number is calculated by dividing total costs by tons of CO_{2e} reduced.
- **Societal value of GHG emissions reductions (\$):** The present value of benefits from GHG emissions reductions to the general society. This value is discounted at the societal goods discount rate for the user-input solar panel lifetime.
- **Health improvements (\$):** Monetized benefits to human health resulting from the financing program. This value is discounted at the societal goods discount rate for the user-input solar panel lifetime.
- **Benefit-cost ratio:** Ratio of total calculated benefits (including program revenue and values of GHG emission reductions and health benefits) to total program costs. This is highly dependent on the amount set for the Carbon value in the Cost-Benefit Valuation section of the Inputs.