Better Buildings Energy Efficiency Cost-Effectiveness Tool (v2.0)
User Guide and Instructions

Prepared for:
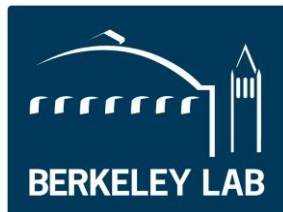
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Contents

I. Introduction

This user guide describes how to use the accompanying energy efficiency cost-effectiveness tool. The original tool was designed strictly to evaluate the cost-effectiveness of whole-home energy upgrade programs. This revision expands the tool to enable modeling of a full residential portfolio and allows a broader range of uses. This document thus includes three illustrative "use cases" (section 7) through which the user can explore this larger array of functions.

We provide three additional resources: an accompanying slide presentation, a summary of frequently asked questions and a glossary. These documents are posted with the tool at U.S. Department of Energy's Better Buildings Solution Center (http://betterbuildingssolutioncenter.energy.gov/).

A more expansive glossary of energy efficiency terms is in Appendix A of the Energy Efficiency Program Impact Evaluation Guide prepared for the State and Local Energy Efficiency (SEE) Action Network. Several trade associations and consulting firms offer training in the design of cost-effective programs. Related information is available through public-private initiatives such as the SEE Action Network. In addition, the following resources provide helpful background and discussion on the rationales, logic and practice of cost-effectiveness screening:

- National Action Plan for Energy Efficiency's guide to *Understanding Cost Effectiveness of Energy Efficiency Programs*
- Several publications of the National Efficiency Screening Project, including *Best Practices in Energy Efficiency Program Screening: How to Ensure that the Value of Energy Efficiency is Properly Accounted For* and the Resource Value Framework
- The California Public Utilities Commission's Standard Practice Manual

Before using the cost-effectiveness tool, we suggest the following preparatory steps to help you conduct your analysis in a way that best meets your needs.

- Preparatory Step 1. Understand your goals for the analysis. This will guide what types of data sources are most appropriate, which cost tests you may want to pay particular attention to, how you may design your portfolio (e.g., one-, two- or three-year cycles), and how you intend to use the results of the tool. For example, the tool can be used to design a basic portfolio of programs, to assess whether an existing portfolio remains cost-effective as efficiency measures or economic circumstances change, or to explore changes to program offerings. This user guide and a frequently asked questions (FAQs) document address these issues.
- Preparatory Step 2. Understand what data and information you have and need regarding your energy efficiency portfolio. The tool requires inputs, such as measure energy savings, lifetime of savings, costs of measures, administrative cost for implementation, etc. Your portfolio experience will be particularly useful in collecting this type of data. It will be easier to navigate through the tool if you understand in advance what you can bring to the analysis.

- Preparatory Step 3. Familiarize yourself, at least at a rudimentary level, with the theory of cost-effectiveness. To aid you in this process, the next section of this document is a brief review of cost-effectiveness analysis.

Once you have completed these preparations, you will be ready to start the cost-effectiveness analysis.

The following are the basic steps required for the cost-effectiveness analysis. Although this user guide is prepared as a stand-alone document, we recommend reviewing it in parallel with the accompanying cost-effectiveness analysis tool, as many sections may be more intuitive when viewing the actual tool.

- Step 1. Collect and enter generic/initial inputs. The first step requires entering basic information into the "Initial Inputs" tab, such as utility rates, discount rates, avoided cost inputs, and the cost tests that you are interested in calculating. These inputs are independent of the specific measures and portfolio design.
- Step 2. Specify the program types. The tool allows you to enter up to five program types in the "Program Builder" tab. The program type is defined by the types of measures, energy savings and costs. For example, one program type may include a combination of different bulbs (e.g., CFLs and LEDs) to create a residential lighting program, whereas another program may include residential heating, ventilating and air-conditioning (HVAC) measures. A third program type may include a combination of measures belonging to different categories to comprise a new home construction bundle.
- Step 3. Specify the portfolio. The "Portfolio Builder" tab allows you to define portfolio inputs (e.g., how many homes will be retrofitted over the next three years for each program type) and portfolio costs, such as administrative costs, EM&V, etc. This tab reports the portfolio budget, including the incentive and administrative budget.
- Step 4. Reporting. The "Report" tab takes all the inputs and produces a report that shows the cost-effectiveness test results for the individual programs you entered into the tool and for the overall portfolio. Here you can also conduct a sensitivity analysis. For example, is the portfolio still cost effective if the discount rates are increased?

2. Brief background on cost-effectiveness tests

Cost-effectiveness analysis calculates the costs and benefits of energy efficiency from different perspectives. Table 1 describes the five main cost tests.

Table 1. Economic Tests for Energy Efficiency Programs

Cost test		Key question answered	Summary approach
Total Resource Cost	TRC	Will the total costs of energy in the utility service territory decrease?	Comparison of program administrator and customer costs to utility resource savings
Participant Cost Test	PCT	Will the participants benefit over the measure life?	Comparison of costs and benefits of the customer installing the measure
Utility/Program Administrator Cost Test	UCT/ PACT	Will utility bills increase?	Comparison of program administrator costs to supply side resource costs
Ratepayer Impact Measure	RIM	Will utility rates increase?	Comparison of administrator costs and utility bill reductions to supply side resource costs
Societal Cost Test	SCT	Is the utility, state, or nation better off as a whole?	Comparison of society's costs of energy efficiency to resource savings and non-cash costs and benefits

Source: California Public Utilities Commission Standard Practice Manual, as summarized in "Understanding Cost-Effectiveness of Energy Efficiency Programs," a 2008 guide prepared by Snuller Price, Eric Cutter and Rebecca Ghanadan of E3 as part of the National Action Plan for Energy Efficiency

Most states with energy efficiency programs funded by utility customers use the TRC test as the primary test and typically calculate one of the "distributional" tests (PCT, UCT/PACT or RIM test) to understand the distributional impacts of energy efficiency (for example, does the investment make sense from the participant's perspective?).

Some states also use the societal cost test (SCT), which includes environmental benefits, such as benefits from reduced criteria pollutant emissions, expressed in monetary terms.

Each cost test is evaluated using a set of benefits and costs. Table 2 lists the benefit and cost components for each test.

Table 2. Costs and Benefits by Economic Test

Cost/benefit parameter	TRC	PCT	RIM	PAC	SCT
Electricity avoided costs	Benefit		Benefit	Benefit	Benefit
Natural gas avoided costs	Benefit				Benefit
Societal non-energy benefits					Benefit
Installed equipment costs	Cost	Cost			Cost
Portfolio administration costs	Cost		Cost	Cost	Cost
Utility incentives/tax credits		Benefit	Cost	Cost	
Federal incentive/tax credits	Benefit	Benefit			Benefit
Electric bill savings		Benefit	Cost		
Gas bill savings		Benefit			

Source: California Public Utilities Commission Standard Practice Manual, as summarized in "Understanding Cost-Effectiveness of Energy Efficiency Programs," a 2008 guide prepared by Snuller Price, Eric Cutter and Rebecca Ghanadan of E3 as part of the National Action Plan for Energy Efficiency

The RIM and PAC tests are typically conducted from the utility's perspective. For an electric-only utility, we do not typically include natural gas in the PAC and RIM cost tests. However, installation of electric measures with lower thermal waste can raise the consumption of natural gas for space heating or lower air conditioning demand. These interactive effects can have bill impacts on a customer and need to be captured in a PCT or alter the societal costs and benefits that could be considered under a societal cost test even from the perspective of an electric-only utility. The tool allows the user to select which resources to include in each test, as shown in the screenshot below.

Benefits Selection				
	Electricity	Natural Gas	Fuel Oil	Water
Utility's calculations	TRUE	TRUE	FALSE	FALSE
Participants perspective	TRUE	TRUE	FALSE	TRUE
Total Resource Calculations	TRUE	TRUE	TRUE	FALSE
Societal Cost Test Calculations	TRUE	TRUE	TRUE	TRUE

3. Tool summary

Key features of the current version include the following:

- Five typical program types can be specified in each sector.
- Up to 10 measures per program type can be specified.
- Up to a 30-year analysis can be conducted.
- Benefit categories include electricity, natural gas, fuel oil, and water.
- Sensitivity analysis can be conducted on key tool inputs.

- Up to a three-year horizon can be considered for portfolio planning.
- Cost-effectiveness can be calculated at the program and portfolio levels (not at measure level).
- Avoided costs can be defined on a time-of-use (TOU), summer/winter, or average basis.
- Users can use load shapes already included in the tool or enter user-defined load shapes.

The current version is limited in the following ways:

- Savings are static over time.
- The tool does not allow for "double baseline" accounting for early replacement.
- For the RIM test and PCT calculations, the tool performs simplified bill impact calculations. There is no consideration of tiers or demand charges on bill impacts.

The user is encouraged to review three companion documents to this user guide, posted with the tool at the Better Buildings Solution Center:

- Frequently Asked Questions
- Glossary
- A summary slide presentation on tool

4. Model structure and layout

The tool was developed in Microsoft Excel. The figure shows the overall model structure.

- User enters general inputs (e.g., retail sales rates, discount rates)
- User enters utility-specific avoided costs
- User defines measure level and program data
- Tool generates report with results in graphical and tabular form
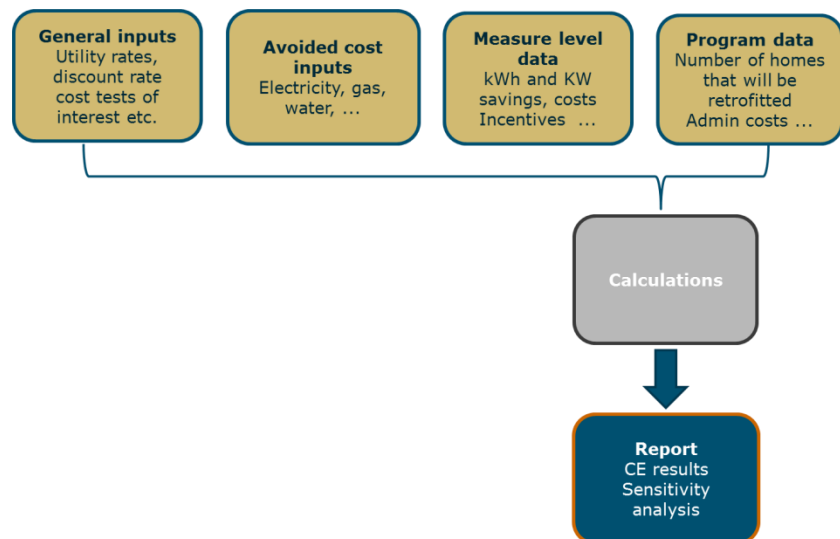
The tool workbook contains four main tabs:

- Initial (generic) inputs
- Program builder
- Portfolio builder
- Report

The tool uses the following color-coding scheme:

Color scheme:	
yellow:	User Input
blue:	Calculated Input
orange:	Dropdown Menu Input
gray:	Intermediate Calculations
green:	Final Outputs
green text boxes:	Instructions

*** The user should be careful to only include information where the cell is highlighted in yellow or orange. ***

In addition, there are numerous instructions and descriptions in green text boxes such as below to guide the user in entering information into the tool.

From the *Program Builder* tab*:*

> Define up to five program types below. Each program can have up to 10 measures.

The steps associated with each tab are described in the following sections with screenshots from the tool and instructions.

5. Four steps to using the tool

Step 1. Collect and enter generic inputs in the "Initial Inputs" tab.

The "Initial Inputs" tab requires the user to insert generic input data. This may include utility rates, discount rates, avoided cost inputs, and the cost tests that you are interested in calculating. These inputs are independent of the specific measures and program design.

Enter basic financial information into the Input column.

> Discount rates should be consistent with the utility & commission values.

> Escalation rates are the expected increases in retail rates for electricity, natural gas, fuel oil, and water.

Financial Assumptions	Input
Inflation Rate	3%
Utility Discount Rate (Nominal)	6%
Societal Discount Rate (Nominal)	3%
Participant Discount Rate (Nominal)	7%
Real Escalation Rate - Electricity	2%
Real Escalation Rate - NG	2%
Real Escalation Rate - Fuel oil	2%
Real Escalation Rate - Water	2%

The rate of inflation can be obtained from the U.S. Bureau of Economic Analysis. The value typically used for the discount rate is the weighted average cost of capital (WACC) for the utility or other supplier of

energy to the territory served by the efficiency program administrator. The utility WACC can be found in state regulatory proceedings on the utility's cost of capital — typically, general rate cases. The cost-effectiveness tool uses a *nominal* discount rate — i.e., it includes inflation. Escalation rates may be based upon long-term historical data on retail rates for electricity, gas, delivered fuels and water. Those values can be obtained directly from utilities, utility trade association surveys, the U.S. Energy Information Administration or other entities. Escalation factors should be net of inflation; that is, inflation should be removed from the rate of increase in these prices because the tool already applies a user-specified inflation rate.

Select which cost tests you want to see by selecting from the drop-down menu either a "TRUE" or "FALSE" entry. Details on the cost tests are described in the section below titled "Brief background on cost-effectiveness tests."

SPM Cost Test Selection					
	PCT	PAC	RIM	TRC	SCT
Calculate?	TRUE	TRUE	TRUE	TRUE	TRUE

Select which types of benefits should be included for each cost-effectiveness test. We have seeded the model with default and typical values. However, these will be utility- and state-specific. In the model, the tests are conducted based on the methodology described in the California Public Utilities Commission (PUC) Standard Practice Manual (SPM).[1] These tests, often with modifications, are used for evaluating energy efficiency in most jurisdictions in the U.S. For electric-only utilities, natural gas savings are not typically included in the RIM or PAC tests. In some states, such as Connecticut for example, natural gas savings are also not included in the TRC calculation. As mentioned earlier, the user may choose to include natural gas calculations for the participant's or societal perspective in the case of an electric-only utility. In the case of a dual-fuel utility, natural gas is included in all tests.

Benefits Selection				
	Electricity	Natural Gas	Fuel Oil	Water
Utility's calculations	TRUE	TRUE	FALSE	FALSE
Participants perspective	TRUE	TRUE	FALSE	TRUE
Total Resource Calculations	TRUE	TRUE	TRUE	FALSE
Societal Cost Test Calculations	TRUE	TRUE	TRUE	TRUE

Enter the utility rates for the various customer types that will participate in the program. You may enter up to five customer types.

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[1] See http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/CPUC_STANDARD_PRACTICE_MANUAL.pdf

Retail Inputs, Electric					
Customer Class 1	Residential				
TOU	Summer On Peak Rate	Summer Off Peak Rate	Winter On Peak Rate	Winter Off Peak Rate	
Rate ($/kWh)	0.15	0.15	0.15	0.15	
Customer Class 2	Commercial				
TOU	Summer On Peak Rate	Summer On Peak Rate	Winter On Peak Rate	Winter Off Peak Rate	
Rate ($/kWh)	0.15	0.15	0.15	0.15	
Customer Class 3	Customer type 3				
Annual	Flat Rate Value				
Rate ($/kWh)	0.15				
Customer Class 4	Customer type 4				
Annual	Flat Rate Value				
Rate ($/kWh)	0.15				
Customer Class 5	Customer type 5				
Summer/Winter	Summer Rate	Winter Rate			
Rate ($/kWh)	0.15	0.08			

This information is usually available on tariff sheets posted on the utility's website. The tariff sheets include seasonal and time-of-use definitions, as well as rates.

The next few screen shots are associated with defining the avoided cost inputs. The screen shot immediately below requires the user to define the seasons using dropdown options. The color of the cell will change depending on whether winter or summer is selected. Seasonal definitions are utility-specific and the user is encouraged to determine what the definitions are for their utility.

Month Number	Month	Season
1	January	Winter
2	February	Winter
3	March	Winter
4	April	Winter
5	May	Summer
6	June	Summer
7	July	Summer
8	August	Summer
9	September	Summer
10	October	Winter
11	November	Winter
12	December	Winter

Next, the user defines for winter and summer periods what hours are "off-peak" vs. "on-peak." Similar to the seasonal definitions, the colors and shade of the input will change depending on whether off-peak or on-peak inputs are selected.

TOU Hourly Definition	Winter			Summer	
Hour	Weekday	Weekend	Weekday	Weekend
1	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
2	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
3	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
4	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
5	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
6	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
7	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
8	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
9	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
10	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
11	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
12	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
13	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
14	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
15	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
16	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
17	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
18	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
19	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
20	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
21	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
22	Winter On-Peak	Winter Off-Peak	Summer On-Peak	Summer Off-Peak
23	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak
24	Winter Off-Peak	Winter Off-Peak	Summer Off-Peak	Summer Off-Peak

Next, the user enters the avoided cost information. The user first defines whether avoided cost inputs will be entered in varying degrees of granularity. The tool allows for TOU, summer/winter, or annual average definition types. TOU means that avoided costs are entered for winter on-peak and off-peak periods and summer on-peak and off-peak periods.

Avoided Cost Time Period Definition
TOU
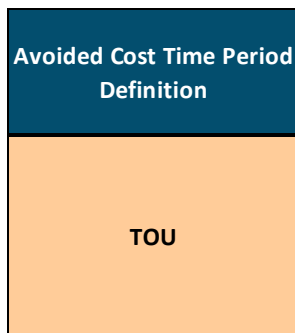
Next, the avoided cost inputs are entered for electricity, natural gas, fuel oil and water as shown in the screen shots below. The tool allows for up to 30 years of avoided cost information to be entered. Avoided costs or data to support their development and definitions of on-peak and off-peak periods can be found in a number of places, including:

- Regional or statewide modeling assumptions and projections[2]
- Energy efficiency plans or annual reports on the utilities' web sites
- Integrated resource plans on the utilities' web sites
- Modeling assumptions used by regional transmission organizations, independent system operators, or interconnection authorities for developing their own plans and market projections

The inputs in the next two screenshots represent monetized energy benefits. That is, these represent direct cost savings from energy efficiency (versus societal non-energy benefits).

Wholesale Inputs						
Annual Input	All Inputs are in Nominal Dollars					
Monetized Electricity Benefits						
Avoided Cost Time Period Definition	Generation Energy Avoided Cost	Generation Energy Avoided Cost	Generation Energy Avoided Cost	Generation Energy Avoided Cost	Additional Monetized Avoided Costs	Generation Capacity Avoided Cost	T&D Capacity Avoided Cost
TOU	Generation Avoided Cost, Summer On Peak, $/MWh	Generation Avoided Cost, Summer Off Peak, $/MWh	Generation Avoided Cost, Winter On Peak, $/MWh	Generation Avoided Cost, Winter Off Peak, $/MWh	Additional Avoided Cost ($/MWh)	Annual Capacity Value ($/kW-year)	Annual T&D Value ($/kW-year)
Present	$90	$75	$83	$70	$10	$30	$1
Average Annual Escalation	0%				0%	0%	0%

Natural Gas Avoided Cost	Fuel Oil Avoided Cost	Water Avoided Cost
Annual $/Therms	Annual $/Gallon	Annual $/Thousand Gallons
$0.86	$1.20	$0.80
0%	0%	0%

The last set of avoided cost inputs is associated with the societal cost test. These are predominantly environmental benefits. We allow for electricity, natural gas, fuel oil and water inputs in this category. Electricity societal benefits may represent, for example, the health benefits from reduced pollution.

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[2] See, for example, the Northwest Power and Conservation Council and documentation for its latest power plan. In the Northeast, consult the websites of state energy efficiency advisory councils for the latest Avoided Energy Supply Cost study.

Societal benefits, driven by inputs in Columns N through Q, are additional non-monetized benefits that count towards the Societal Cost Test.

Electricity-Societal Cost	Natural Gas-Societal Cost	Fuel Oil-Societal Cost	Water-Societal Cost
Annual $/MWh	Annual $/Therms	Annual $/Gallon	Annual $/Thousand Gallons
$0.50	$0.80	$1.00	$1.00
0%	0%	0%	0%

Step 2. Specify the program types in the "Program Builder" tab.

In this tab, you can enter up to five program types. The program type is defined by the types of measures, energy savings and costs. Programs may be designed to contain measures belonging to the same general category, such as in case of a lighting program that is created using combinations of different LED and CFL bulbs, or programs could be created by bundling different measure types, as in the case of a new home construction program.

The first section of the Program Builder requires the user to provide high-level information for the different program types that will be defined. (The name, customer type, and incentives are not defined on a measure-by-measure basis, as explained in the next set of screen shots). These inputs constitute the first three columns. The last four columns are not inputs but summaries of the detailed information entered for each program type.

"Additional Program Level Incentive" Column D represents incentives that are additional to those defined below in Columns O and P. Sensitivity analysis can only be conducted against project level incentives in Column D.

Summary of Programs						
Program Type	Customer Type	Additional Program level Incentive	Estimated Total Cost	Fed Tax, Other Incentives	Other Utility Incentive	Total Incentive
Residential Lighting (POS)	Residential	$ -	$ 130	$ -	$ 39	$ 39
Residential Appliance Rebates/(POS) Discounts	Residential	$ -	$ 1,366	$ 375	$ 39	$ 414
Refrigerator Recycling	Commercial	$ -	$ -	$ -	$ 155	$ 155
Residential HVAC/Water Heating Rebates	Customer type 4	$ -	$ 9,509	$ 1,950	$ 196	$ 2,146
New Home Construction	Customer type 5	$ -	$ 2,106	$ 60	$ -	$ 60

Next, detailed information is entered for each program type. Each program type may be defined by multiple individual measures or the user may wish to treat the combination of measures as one, as would be the case in a whole home retrofit program. In the example below, annual savings are estimated for a residential lighting program.

Below, define the characteristics of each type of program, including savings, lifetime, costs.

User can select a pre-loaded shape, or define

User can define peak savings if

Residential Lighting (POS)

Name	Number of Units	Measure Life (Years)	Annual Gross Savings Estimate/unit (Electric; kWh)	Net to Gross	Annual Net Savings Estimate/unit (Electric; kWh)	Annual Gross Savings Estimate/unit (NG; Therms)	Net to Gross	Annual Net Savings Estimate (NG; Therms)	Annual Savings Estimate (Oil; Gallons)	Annual Savings Estimate (Water; Thousand Gallons)	Incremental Measure Cost ($/Unit)	O&M Costs ($/Unit-Year)	Federal Tax or Other Incentives ($/Unit)	Utility Incentives ($/Unit)	Pre-Loaded Electric Shape Selection	Net Capacity Savings in Peak Season (overrides shape selection for capacity calculation) (kW)
CFL 15 WATT INT BARE SPIRAL 1PK	1	3.3	124	0.5	67.1	-0.7	0.5	-0.4			$ 5.03			$ 1.33	Res:Indoor_CFL_Ltg	0.03
CFL 20 WATT INT COVERED MULTI-PK	1	9.2	27	0.5	14.7	-0.7	0.5	-0.4			$ 5.41			$ 1.75	Res:Indoor_CFL_Ltg	0.00
CFL 14 WATT INT COVERED MULTI-PK	1	3.3	116	0.5	62.6	-0.7	0.5	-0.4			$ 5.56			$ 1.78	Res:Indoor_CFL_Ltg	0.02
CFL 18 WATT INT REFLECTOR AND/OR DIMMABLE MULTI-PK	1	9.2	31	0.5	16.6	-0.8	0.5	-0.4			$ 0.22			$ 1.71	Res:Indoor_CFL_Ltg	0.00
LED R-BR - 11 TO <14 WATTS	1	8.2	121	0.9	102.4	-0.7	0.9	-0.6			$ 19.02			$ 5.00	Res:Indoor_CFL_Ltg	0.02
LED A-Lamp 9 to < 10 watts	1	16.0	10	0.9	8.3	-0.2	0.9	-0.2			$ 22.04			$ 10.00	Res:Indoor_CFL_Ltg	0.00
CFL 23 WATT INT 3-WAY, SINGLE	1	9.2	20	0.7	13.9	-0.5	0.7	-0.3			$ 9.79			$ 3.00	Res:Indoor_CFL_Ltg	0.00
LED A-Lamp 10 to < 11 watts	1	6.6	63	0.9	53.7	-0.4	0.9	-0.3			$ 23.21			$ 5.00	Res:Indoor_CFL_Ltg	0.01
LED A-Lamp 13 to < 14 watts	1	16.0	14	0.9	12.0	-0.3	0.9	-0.3			$ 26.74			$ 8.48	Res:Indoor_CFL_Ltg	0.00
LED SURFACE/PENDANT/TRACK/ACCENT/RECESSED DWNLT INSTALL < 10W LED	1	20.0	1	0.7	0.5	0.0	0.7	0.0			$ 12.68			$ 1.00	Res:Indoor_CFL_Ltg	0.00
Total			526		352	-5		-3	0	0	$ 129.70	0	0	$ 39.06		

The next screen shot shows a program type in which the project "Residential Appliance Rebates/(POS) Discounts" is analyzed. The screenshot shows that each measure must be defined in terms of the number of units, measure life, gross savings of electricity and natural gas, incremental measure cost, operation and maintenance (O&M) costs and incentives.

Residential Appliance Rebates/(POS) Discounts

Name	Number of Units	Measure Life (Years)	Annual Gross Savings Estimate (Electric; kWh)	Net to Gross	Annual Net Savings Estimate (Electric; kWh)	Annual Gross Savings Estimate (NG; Therms)	Net to Gross	Annual Net Savings Estimate (NG; Therms)	Annual Savings Estimate (Oil; Gallons)	Annual Savings Estimate (Water; Thousand Gallons)	Incremental Measure Cost ($/Unit)	O&M Costs ($/Unit-Year)	Federal Tax or Other Incentives ($/Unit)	Utility Incentives ($/Unit)	Pre-Loaded Electric Shape Selection	Net Capacity Savings in Peak Season (overrides shape selection for capacity calculation) (kW)
ENERGY EFFICIENT TELEVISIONS ENERGY STAR V5.1+20% - 36"- 39"	1	7.0	68	0.1	6.8	-1.7	0.1	-0.2			$ 30.00			$ 9.50	Res:Indoor_CFL_Ltg	0.00
REFRIGERATOR: BOTTOM FREEZER WITHOUT ICE >= 16.5 CU. FT.	1	14.0	73	0.7	50.8	-2.0	0.7	-1.4			$ 145.29		$ 75.00		Res:RefgFrzr_Recyc-Conditioned	0.02
EFFICIENT VARIABLE SPEED POOL PUMP AND MOTOR - CUSTOMER	1	10.0	1169	0.6	643.0		0.6	0.0			$ 600.00		$ 100.00		Res:RefgFrzr_HighEff	0.17
REFRIGERATOR: SIDE FREEZER WITH ICE >= 23 CU. FT.	1	14.0	179	0.7	125.0	-5.4	0.7	-3.8			$ 101.87		$ 75.00		Res:RefgFrzr_Recyc-Conditioned	0.04
HI EFF CLOTHES WASHER - LEVEL 3 - MEF >= 2.4 WF <= 4.0	1	11.0	144	0.7	101.1	9.6	0.7	6.7			$ 283.59		$ 50.00		Residential_Clothes_Washer/Dryer	0.08
ENERGY EFFICIENT TELEVISIONS ENERGY STAR +35%- >50"	1	7.0	137	0.1	13.7	-3.4	0.1	-0.3			$ 60.00			$ 29.00	Res:Indoor_CFL_Ltg	0.00
REFRIGERATOR: BOTTOM FREEZER WITH ICE >= 16.5 CU. FT.	1	14.0	133	0.7	93.0	-4.9	0.7	-3.4			$ 145.29		$ 75.00		Res:RefgFrzr_Recyc-Conditioned	0.03
				1.0	0.0		1.0	0.0							None	
				1.0	0.0		1.0	0.0							None	
				1.0	0.0		1.0	0.0							None	
Total			1902		1033	-8		-2	0	0	$ 1,366.04	0	375	$ 38.50		

In addition to annual savings and costs, each measure must be defined by the load shape. The user has the option to select preloaded load shapes (see screenshot below). These load shapes correspond to 8,760 hours of annual load. The load shapes are used to determine how the annual savings are spread out in time because the avoided cost benefits depend on when the savings occur (off-peak vs. on-peak; summer vs. winter, etc.). As an example, see the screen shot below with the load shape selection column for the "Residential Appliance Rebates/(POS) Discounts" programs.

Pre-Loaded Electric Shape Selection
Res:Indoor_CFL_Ltg
Res:RefgFrzr_Recyc-Conditioned
Res:RefgFrzr_HighEff
Res:RefgFrzr_Recyc-Conditioned
Residential_Clothes_Washer/Dryer
Res:Indoor_CFL_Ltg
Res:RefgFrzr_Recyc-Conditioned
None
None
None

Although the tool contains several pre-loaded 8,760-hour load shapes (see screen shot below for example), the user can instead define 8,760-hour load shapes. For example, the user may have a simulation tool to estimate savings with a representation of hourly savings. User-defined load shapes are entered in the "Load Shape Library" tab.

If no measure is selected, the user should set the line item to "None."

See the screen shot below.

Date	Flat	Example	Res:Indoor_CFL_Ltg
1/1/2013	1.14E-04	2.30E-04	7.66E-05
1/1/2013	1.14E-04	2.26E-04	5.11E-05
1/1/2013	1.14E-04	2.34E-04	3.71E-05
1/1/2013	1.14E-04	2.38E-04	3.34E-05
1/1/2013	1.14E-04	2.36E-04	3.18E-05
1/1/2013	1.14E-04	2.28E-04	3.92E-05
1/1/2013	1.14E-04	2.74E-04	5.34E-05
1/1/2013	1.14E-04	1.82E-04	7.26E-05
1/1/2013	1.14E-04	7.75E-05	9.01E-05
1/1/2013	1.14E-04	3.79E-05	1.02E-04
1/1/2013	1.14E-04	3.68E-05	1.09E-04
1/1/2013	1.14E-04	5.92E-05	1.10E-04
1/1/2013	1.14E-04	5.92E-05	1.10E-04
1/1/2013	1.14E-04	5.92E-05	1.11E-04
1/1/2013	1.14E-04	5.92E-05	1.15E-04
1/1/2013	1.14E-04	5.92E-05	1.12E-04
1/1/2013	1.14E-04	5.92E-05	1.10E-04
1/1/2013	1.14E-04	5.92E-05	1.12E-04
1/1/2013	1.14E-04	5.92E-05	1.49E-04
1/1/2013	1.14E-04	5.92E-05	2.14E-04
1/1/2013	1.14E-04	6.71E-05	2.43E-04
1/1/2013	1.14E-04	1.15E-04	2.25E-04
1/1/2013	1.14E-04	1.63E-04	1.76E-04
1/1/2013	1.14E-04	1.94E-04	1.10E-04

The hourly values add up to 1.0 for each shape, so each hourly input for these load shapes should be considered to be the percentage of its annual use in the given hour. The tool is prepopulated with a number of load shapes for the user to select from. For instance, the screenshot above shows the hourly shapes for "flat," "example" and "Res:Indoor_CFL_Ltg" profiles. This corresponds to a shape spread out evenly across all hours, an example profile shape, and a shape corresponding to indoor CFL lighting obtained from the DEER database,[3] respectively. The "Load Shape Library" tab also has the option of entering load shapes by TOU period instead of an hourly stream for the year, as shown below.

TOU Period	Flat	Example	Res:Indoor_CFL_Ltg
Summer On-Peak	19%	26%	24%
Summer Off-Peak	23%	20%	19%
Winter On-Peak	27%	22%	31%
Winter Off-Peak	31%	33%	26%

Step 3. Specify the portfolio in the "Portfolio Builder" tab.

The "Portfolio Builder" tab allows you to define portfolio inputs, such as how many homes will be retrofitted over the next three years for each program type, and portfolio costs, such as administrative costs, evaluation, measurement and verification (EM&V), etc. This tab reports the portfolio budget, including the incentive and administrative budget.

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[3] http://www.energy.ca.gov/deer/

The screen shot below shows all the cells from the Portfolio Builder. The user must enter the number of retrofits of each program type that are forecasted to be conducted over a three-year cycle (upper frame). Next, the user must enter the costs borne by the program administrator, including administrative, marketing, direct implementation and EM&V costs. The tab shows the total budget based on these inputs.

Installation Schedule and Incentive Budget by Program Type

	Year 1	Year 2	Year 3
Residential Lighting (POS)	1		
Residential Appliance Rebates/(POS) Discounts	1		
Refrigerator Recycling	1		
Residential HVAC/Water Heating Rebates	1		
New Home Construction	1		
Incentive Budget	$ 2,813	$ -	$ -

Select number of installations planned for Years 1-3. User must select at least 1 program installation to generate portfolio & program level cost effectiveness calcs.

Per Install Overhead Costs

	Year 1	Year 2	Year 3
Residential Lighting (POS)			
Residential Appliance Rebates/(POS)			
Refrigerator Recycling			
Residential HVAC/Water Heating Rebates			
New Home Construction			

Portfolio budget values should reflect anticipated future costs for portfolio implementation.

Non-Incentive Portfolio Budget ($)

	Year 1	Year 2	Year 3
a. Administrative Costs			
b. Marketing/Outreach		$ -	$ -
c. Direct Implementation (non incentive)			
d. EM&V		$ -	$ -
Total Administration Budget	$ -	$ -	$ -
Total Variable Overhead Budget	$ -	$ -	$ -
Total Budget	$ 2,813	$ -	$ -

Step 4. Review the cost test results and perform sensitivity analysis in the "Report" tab

After you've entered the information in tabs "Initial Inputs," "Program Builder" and "Portfolio Builder," press the "Generate Initial Report" button on the "Portfolio Builder" tab.

The "Report" tab takes all the inputs and produces a report that shows the cost tests results for your programs and for the overall portfolio. Here you can also conduct a sensitivity analysis. For example, is the portfolio still cost-effective if the discount rates are increased by a certain amount?

The screenshots below illustrate what the report shows for program cost-effectiveness and overall portfolio cost-effectiveness. Some individual measures or programs entered into the tool may not be cost-effective. However, cost-effectiveness often is evaluated for the overall portfolio. Thus, the costs of less cost-effective measures and program types can be offset by more cost-effective measures and program types, provided that the overall portfolio meets the desired cost-effectiveness threshold. Note that the illustrative test results in the screenshots below are entirely calculated values and do not require any user inputs.

Program Cost Effetiveness	PCT	PAC	RIM	TRC	SCT
Residential Lighting (POS)	2.61	4.58	0.52	1.38	1.36
Residential Appliance Rebates/(POS) Discounts	1.42	24.66	0.58	0.97	1.05
Refrigerator Recycling	N/A	3.87	0.53	N/A	N/A
Residential HVAC/Water Heating Rebates	1.88	55.14	0.63	1.34	1.70
New Home Construction	0.15	N/A	0.69	0.11	0.16

Portfolio Cost Effetiveness	PCT	PAC	RIM	TRC	SCT
B/C Ratio	1.65	29.64	0.62	1.15	1.43
Total Costs	$ (13,111)	$ (428)	$ (20,436)	$ (13,111)	$ (13,111)
Total Benefits	$ 21,605	$ 12,691	$ 12,691	$ 15,076	$ 18,704
Net Benefits	$ 8,494	$ 12,263	$ (7,745)	$ 1,965	$ 5,593

The Report tab contains a tool for conducting sensitivity analysis. The screenshot below shows the inputs that can be varied in the sensitivity analysis. The user moves the slide bar (shown in grey) to alter the "initial" inputs for the sensitivity analysis. The new value resulting from the adjustment is called the "current" input. The user then selects the "Calculate Sensitivity" button.

Cost-effectiveness Sensitivity Analysis	Calculate Sensitivity	Store Current Inputs as Defaults
Discount Rates	Current Input	Default Input
Utility Discount Rate	6.1%	*6.1%*
Societal Discount Rate	3.0%	*3.0%*
Participant Discount Rate	7.0%	*7.0%*
Escalation Rates		
Retail Electricity Rate Escalator	2.0%	*2.0%*
Natural Gas Rate Escalator	2.0%	*2.0%*
Fuel Oil Rate Escalator	2.0%	*2.0%*
Water Rate Escalator	2.0%	*2.0%*
Administration Costs and Incentives		
Administration Costs	$0.0	*$ -*
Residential Lighting (POS) 'Additional Project Level Incentive'	$0.0	*$ -*
Residential Appliance Rebates/(POS) Discounts 'Additional Project Level Incentive'	$0.0	*$ -*
Refrigerator Recycling 'Additional Project Level Incentive'	$0.0	*$ -*
Residential HVAC/Water Heating Rebates 'Additional Project Level Incentive'	$0.0	*$ -*
New Home Construction 'Additional Project Level Incentive'	$0.0	*$ -*

The graph below shows the results of the sensitivity analysis. Benefits and costs for each cost test are shown for the set of "current" inputs. The user can iteratively adjust the values on the slide-bars to see what combination of inputs generates the desired cost test results.
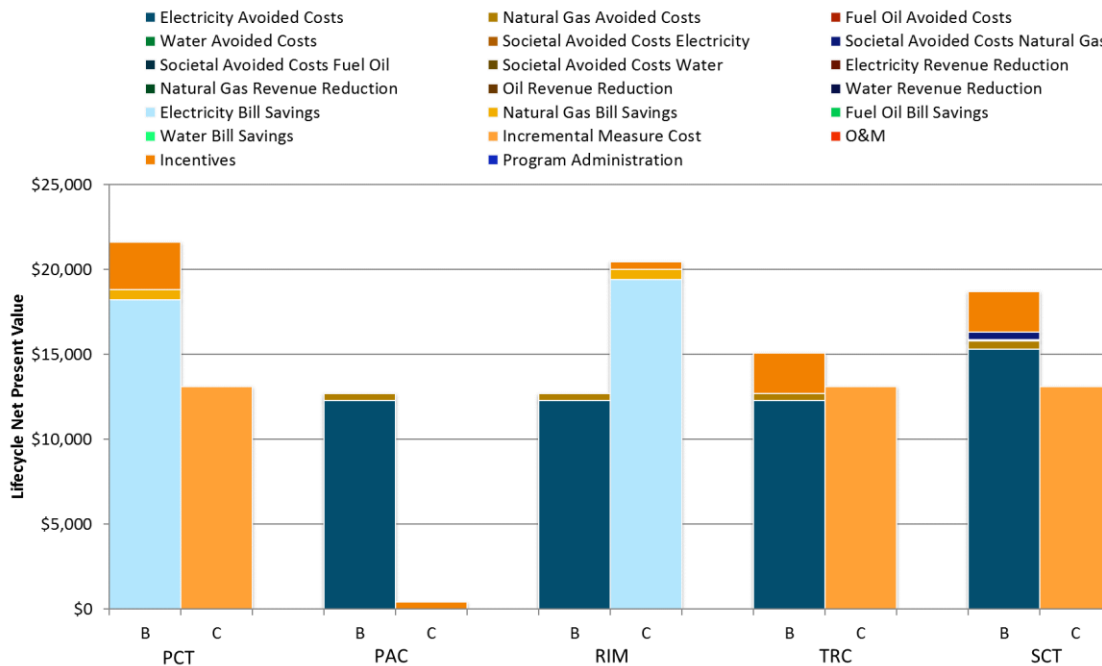
6. Other tabs

The tool contains worksheets that do not require user input and contain calculations but are necessary for tool functionality. The user must be sure not to delete these worksheets.

7. Tool applications and potential use cases

Consultation with energy efficiency program administrators helped identify several common situations that can alter the balance of costs and benefits for whole-home retrofit or home energy upgrade programs in particular. From those situations, three use cases were selected and developed for demonstrating the calculator:

- **Persistence of Low or Moderate Fuel Prices**
- **Shift from a Single-Fuel to a Multi-Fuel Program**
- **Changes in Cost-Effectiveness Screening Policy**

These use cases are designed to address cost-effectiveness issues pertaining to design, implementation, and policy context for a comprehensive home energy upgrade program. While most energy savings in a typical residential portfolio are acquired from programs targeting individual end uses, shell features or equipment, more comprehensive retrofits present unique opportunities to capture long-lasting savings across multiple end uses and fuels in a single project. These programs can reduce energy consumption

and associated emissions across an entire home for many years and avoid repeatedly returning to that home to implement individual measures on a piecemeal basis. Focusing on multiple and longer lived measures — and finding households able and willing to pay significant project costs — can be difficult and result in programs that are marginally cost-effective. To sustain these more comprehensive approaches to energy efficiency, program administrators may rely upon other programs that are highly cost-effective to achieve an overall portfolio cost-effectiveness target. The calculator therefore is designed to reflect a full residential portfolio, so that the user can employ solutions and see changes in cost-effectiveness at both the program and market sector levels.

Each use case is described in detail below.

Use Case 1: Persistence of Low or Moderate Fuel Prices

Program administrators may have assumed higher commodity prices for natural gas (and thus higher system costs for both electricity and direct use of natural gas) when planning their programs and portfolios than has turned out to be the case or is now reasonably foreseeable over the lifetime of most end uses and equipment. The persistence of low or moderate gas prices reduces avoided system costs and thus the benefits of energy efficiency programs, but also may lead program administrators to increase incentives to motivate consumers to participate in cost-effective programs in the face of longer payback times for the installed measures.

Use Case 1 addresses strategies to mitigate these impacts, including:

1. *Measure optimization* – Measures that are least cost-effective and do not enable other measures can be pared back — e.g., substitution of a less detailed and lower cost audit for a fuller, most costly one.
2. *Bundling* – Measures that are most susceptible to low or moderate gas prices can be combined or bundled with measures that are less susceptible. For example, a more efficient heating system may be coupled with a programmable thermostat as a single measure, or duct sealing may be combined with air sealing, faucet aerators and low-flow showerheads.

    In the cost-effectiveness tool, the residential lighting program with a TRC benefit-cost ratio greater than 1.0 can be paired with the residential appliances rebate program with a slightly lower TRC ratio to maintain a cost-effective portfolio.

3. *Adjustments to the residential portfolio* – For example, behavioral feedback programs can be extended to more consumers and credited with a longer measure lifetime, in keeping with the latest research findings.

The tool is able to capture the impacts of low or moderate fuel prices persisting over a period of time by allowing for analysis of the benefit-cost ratios with user inputs for natural gas and fuel oil prices. By using a low escalation rate for gas prices, the user can analyze the impact of consistently low or moderate fuel prices on net benefits of the energy efficiency portfolio.

Fuel prices can be entered in the "Initial Inputs"

 tab as shown below.

Retail Rate Projections, Non Electric				
Index	Customer Type	Marginal Natural Gas Rate ($Therms)	Marginal Fuel Oil Rate ($/gallon)	Marginal Water Rate ($/thousand gallons)
1	Residential	$0.80	$2.80	$2.20
2	Commercial	$0.90	$2.81	$2.21
3	Customer Type 3	$1.00	$2.82	$2.22
4	Customer Type 4	$1.10	$2.83	$2.23
5	Customer Type 5	$1.20	$2.84	$2.24

If low fuel prices also result in lower electricity rates, the user can enter those in the electric retail inputs. Persistence of low prices over a long time can be shown by running sensitivities in the "Report" tab by using the sliders in the model to lower the escalation for the different retail rates, as shown below.

Escalation Rates			
Retail Electricity Rate Escalator	◄	▶	2.0%
Natural Gas Rate Escalator	◄	▶	2.0%
Fuel Oil Rate Escalator	◄	▶	2.0%
Water Rate Escalator	◄	▶	2.0%

Use Case 2: Shift from a Single-Fuel to a Multi-Fuel Program

While *most spending* on home energy upgrade programs addresses electricity and natural gas,[4] *most programs* are aimed at saving either electricity or natural gas. Use Case 2 demonstrates the potential value of a dual-fuel program in which an electric efficiency program administrator partners with a natural gas efficiency program administrator to implement a suite of measures with benefits for each program and complementary value for both programs.

The tool allows for such an analysis by allowing the user to select electricity as well as natural gas components for the analysis and incorporating both the electric and natural gas impacts of a measure in the calculation of cost-effectiveness test results.

The screenshot below shows an illustrative program with measures that have electric as well as gas impacts for the participant.

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[4] https://library.cee1.org/content/cee-2015-state-efficiency-program-industry

Residential Appliance Rebates/(POS) Discounts			Measure Life	Annual Gross Savings Estimate	Net to Gross	Annual Net Savings Estimate	Annual Gross Savings Estimate	Net to Gross	Annual Net Savings Estimate
Name	Number of Units	Years	Electric; kWh		Electric; kWh	NG; Therms		NG; Therms
ENERGY EFFICIENT TELEVISIONS ENERGY STAR V5.1+20% - 36"- 39"	1	7.0	68	0.1	6.8	-1.7	0.1	-0.2
REFRIGERATOR: BOTTOM FREEZER WITHOUT ICE >= 16.5 CU. FT.	1	14.0	73	0.7	50.8	-2.0	0.7	-1.4
EFFICIENT VARIABLE SPEED POOL PUMP AND MOTOR - CUSTOMER	1	10.0	1169	0.6	643.0		0.6	0.0
REFRIGERATOR: SIDE FREEZER WITH ICE >= 23 CU. FT.	1	14.0	179	0.7	125.0	-5.4	0.7	-3.8
HI EFF CLOTHES WASHER - LEVEL 3 - MEF >= 2.4 WF <= 4.0	1	11.0	144	0.7	101.1	9.6	0.7	6.7

In this example, the "High Efficiency Clothes Washer Level 3" measure shows electric as well as gas savings. When evaluating such a measure, the tool allows for stacking of the electric as well as natural gas savings. The information could be used to analyze the impacts of a dual-fuel measure on the portfolio's cost-effectiveness.

On the flip side, the portfolio's benefit-to-cost ratio may end up being lower or higher if the implemented measures produce less waste heat and so increase gas consumption for heating or reduce electricity consumption for air conditioning.

Use Case 3: Changes in Cost-Effectiveness Screening Policy

While many states use multiple cost-effectiveness tests in order to assess programs from several economic perspectives, states tend to designate one test as the primary determinant of cost-effectiveness. The Total Resource Cost (TRC) test is the most common screening tool for U.S. energy efficiency programs. The TRC can be perceived by some as imbalanced for including all costs but only monetized system benefits. In response, a number of states implement variants of the TRC that include broader definitions of benefits or a lower discount rate. Other states have moved to the Program Administrator Cost Test (PACT). More recently, a coalition of energy efficiency experts and trade entities has encouraged a broader perspective on benefit-cost testing, including an array of system, societal and participant benefits.[5]

The cost-effectiveness tool attempts to broaden the cost-effectiveness test calculations by:

- using a PACT along with the standard TRC test, and
- using a societal cost test including a range of non-energy benefits.

The user can also consider evaluating the program on a lower benefit-to-cost ratio under the TRC test. For instance, instead of requiring the TRC ratio to be greater than 1.0, a threshold of 0.8 for cost-effectiveness could be selected if there are qualitative benefits that are not captured in the analysis.

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[5] National Efficiency Screening Project: http://www.nationalefficiencyscreening.org/