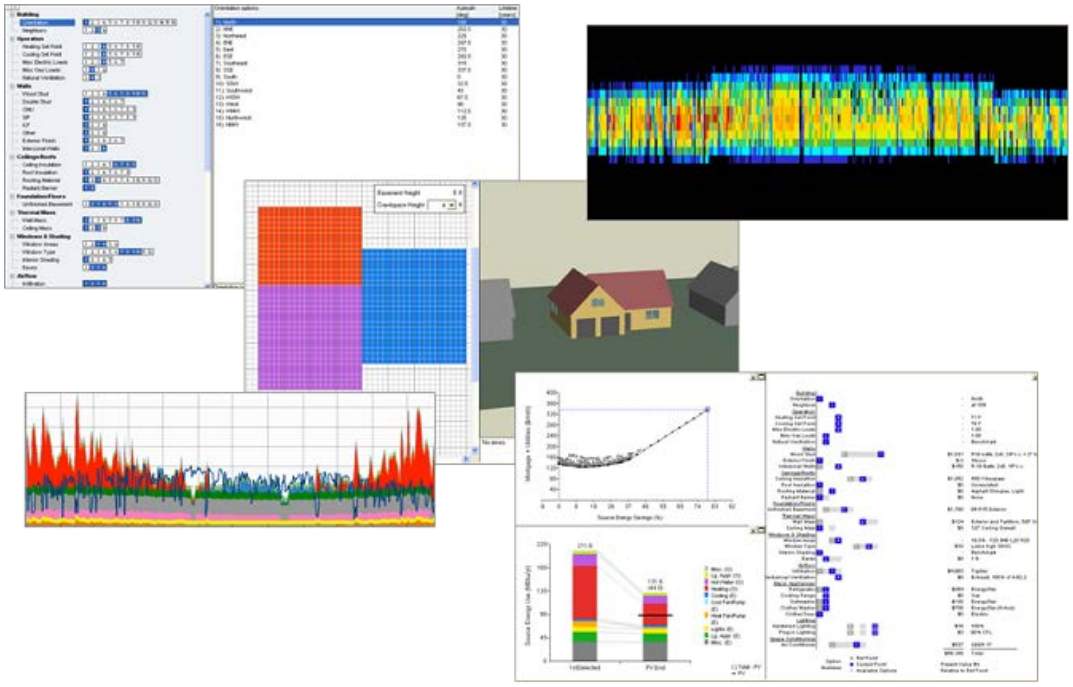
# BEopt 2.7.0.0 Help



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## Acknowledgements

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## Introduction

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- What is BEopt?
- Path to Zero Net Energy
- Search Techniques
- Special Cases

## What is BEopt?

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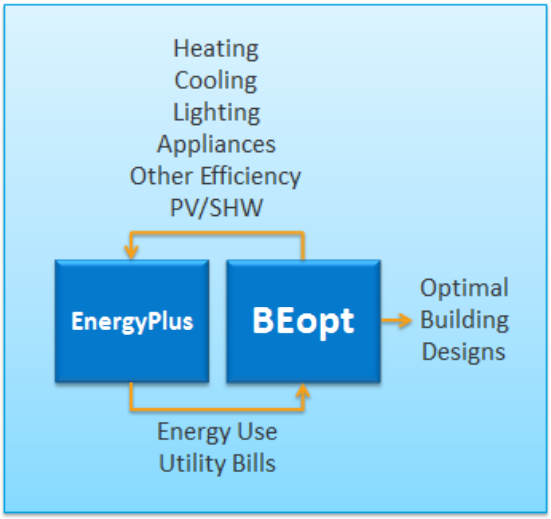
BEopt is a computer program designed to find cost-optimal building designs along the path to a zero net energy (ZNE) building. A zero net energy building produces as much energy as it uses on an annual basis, using a grid-tied, net-metered photovoltaic (PV) system and active solar. The optimal path to ZNE extends from a base case to the ZNE building through a series of energy-saving building designs with minimal energy-related costs.

In BEopt, a user selects from predefined options in various categories to specify options to be considered in the optimization. Energy savings are calculated relative to a reference. The reference can be either a user-defined reference, a climate-specific Building America Benchmark for new construction, or an Existing (w/ Min Replace) reference for retrofit. The user can also review and modify detailed information on all available options via the library management tools.

BEopt calls the EnergyPlus simulation engine and uses a sequential search technique to automate the process of identifying optimal building designs along the path to ZNE. BEopt finds these optimal designs based on discrete building options reflecting realistic construction options. BEopt handles special situations with positive or negative interactions between options in different categories.




The BEopt software includes an output screen that allows the user to navigate among different design points and retrieve detailed results regarding energy end-use and option costs in different categories. Multiple cases, based on a selected parameter such as climate, can be included in a BEopt project for comparative purposes.

Currently there are three modes of analysis: design mode, parametric mode, and optimization mode. Design mode allows the user to perform a set of building design simulations for analysis. Parametric mode allows the user to quickly perform traditional parametric analyses. Optimization mode, on the other hand, sequentially searches the available building options for the lowest cost building designs at various levels of energy savings.

## Path to Zero Net Energy

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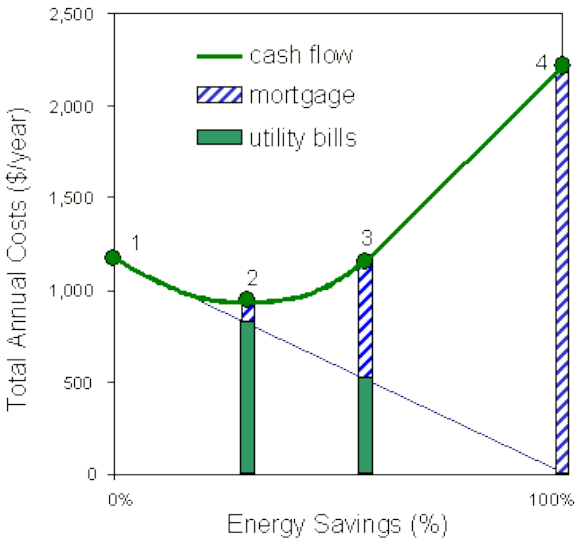
Before investing in photovoltaic technology to produce a home's energy, it is more cost-effective to first use energy efficient measures to minimize the energy that must be produced. In this way, a smaller, less expensive PV array can meet the home's energy needs. BEopt produces a graph referred to as the Path to Zero Net Energy. This Path can answer the following questions:

How much should be invested in efficiency before investing in PV?
What is the optimal configuration of energy efficiency measures?
What if only a partial reduction in energy use (from a reference case) is desired?

The following sketch illustrates the concept of a building's path to zero net energy. The path falls on a graph of the % energy savings along the x-axis, and the annualized energy costs on the y-axis. This annual cost is made up of both the energy costs each year plus the cost of energy efficiency measures that have been incorporated into the mortgage payments.




Point 1: Reference Case
The reference case is the point from which evaluating energy efficiency measures begins. The percent energy savings equals zero at this point. Also, all of the energy costs for the home are paid through the monthly utility bills.

Point 2: Minimum Annual Cost
The minimal annual cost may occur at the base case point. If not, energy efficiency measures can be implemented to decrease the annual energy costs. Some of these measures, such as the building orientation, can be implemented with no increase in initial cost. Other measures may have an initial cost but result in an overall net decrease in annual energy expenditures. Such is the case at point 2 in the above graph. Note that some energy costs are paid through the mortgage that financed the initial efficiency measures while the remaining are paid in the utility bills. Beyond point 2, additional energy can be saved but only with a net increase in annual costs.

Point 3: Take-off Point
At this point on the path, the marginal cost of saving energy equals the marginal cost of producing energy. In other words, it becomes more expensive to save the next unit of energy with an energy conservation measure than to produce that same unit of energy with on-site photovoltaics. Up to this point, all of the energy savings have come from building efficiency. From this point on, the optimal path becomes a straight line to the ZNE point. The slope of this portion of the graph equals the cost per kWh of photovoltaic electricity.

Point 4: Zero Net Energy
At the Zero Net Energy point, the building produces as much energy with photovoltaics as it consumes. While the energy costs at the reference case point are solely utility bills, the energy costs of the zero net energy point are completely covered by the mortgage payment. No utility payments are required. The total energy that must be offset includes both the electricity and the natural gas use.

Optimal Points
Optimal points are determined through a sequential search technique. It involves searching all categories (wall type, ceiling type, window glass type, HVAC type, etc.) for the most cost-effective option at each sequential point along the path to zero net energy. Starting with the reference case building, simulations are performed to evaluate all construction options available for improvement (one at a time) in the building envelope and equipment. Based on the results, the most cost-effective option is selected as an optimal point on the path and put into a new building description. The process is repeated. At each step the marginal cost of saved energy is calculated and compared with the cost of PV energy. From the point where further improvement in the building envelope or equipment has a higher marginal cost than PV, the building design is held constant and PV capacity is increased to reach the point of zero net energy.

Discrete Options
In determining the optimal combinations of building components, BEopt evaulates discrete construction options. The user can select from exact quantities and

equipment specifications. This provides final combinations of components in sizes that are actually available, rather than a solution made up of theoretical, and continuous, elements.

Near-Optimal Designs
Points that are near to the optimal path may, for reasons other than cost, provide a more desireable combination than the true optimum. BEopt identifies such combinations as well as the optimal points. This topic is discussed in greater detail under the Near Optimal Solutions section.

## Search Techniques

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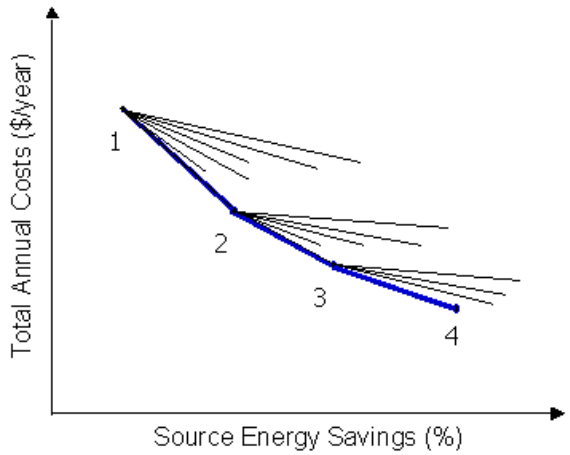
### Sequential Search

The sequential search method used by BEopt involves searching all categories (wall type, ceiling type, window glass type, HVAC type, etc.) for the most cost-effective option at each sequential point along the path to ZNE. Starting with the base case building, simulations are performed to evaluate all available options for improvement (one at a time) in the building envelope and equipment. Based on the results, the most cost-effective option is selected as an optimal point on the path and included in an updated building configuration. The process is repeated. At each step, the marginal cost of saved energy is calculated and compared with the cost of PV energy. From the point where further improvement in the building envelope or equipment has a higher marginal cost, the building design is held constant, and PV capacity is increased to reach ZNE.




In the graph above, each point represents a unique building configuration. The slope of each line extending from the points represents another possible energy efficiency measure for BEopt to evaluate. The measure with the steepest "downward" slope provides the most energy savings for the least amount of investment. From this new endpoint, the options are evaluated again to find the next optimal point. In the example above, BEopt tries all available options that could be added to the configuration at point 1. The most cost effective measure leads to a new configuration at point 2. All options are again evaluated to find the next best configuration at point 3 and so on.

## Special Cases

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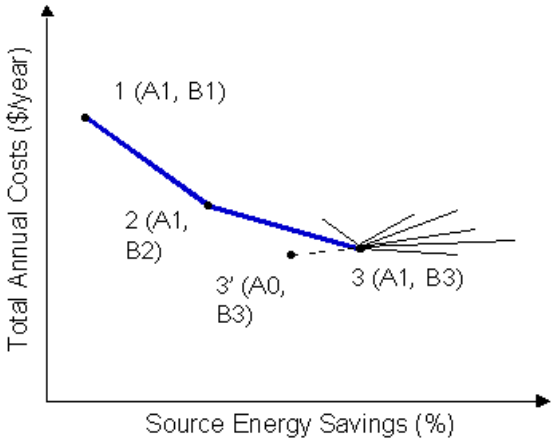
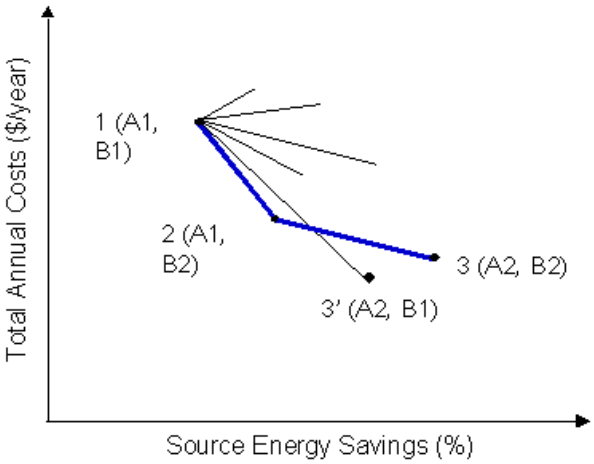
#### Special Case 1: Invest / Divest

The BEopt search technique does not assume that once an option is in the building design, it stays in. In addition to evaluating new options, each iteration evaluates the removal of options in the current building design. This can result in negative energy savings and points to the left of the current point. These backward-looking evaluations allow for the possibility that one aspect of the building (say, HVAC efficiency) may initially be improved; then when other aspects (say, envelope insulation levels) are sufficiently improved and loads reduced, it may no longer be cost optimal to have highly efficient HVAC. This phenomenon is illustrated in the following figure: starting at point 1 (A1, B1), category B is improved to point 2 (A1, B2) and again to point 3 (A1, B3). On the next iteration, an optimal point is found by looking backward to point 3' (A0, B3) where reduced investment in category A is more cost-effective than continuing with high levels of investment in categories A and B. In this case, BEopt replaces point 3 with point 3' and proceeds.



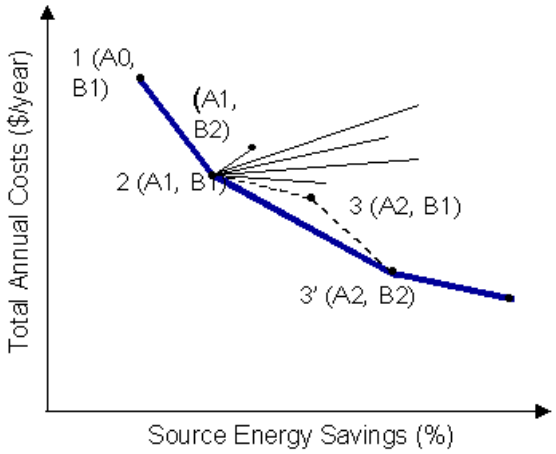

**Special Case 2: Large Steps**

BEopt also keeps track of points from previous iterations and checks to see whether they may be better than results of the current iteration. This phenomenon is illustrated in the next figure: starting at point 1 (A1, B1), a large energy-savings option (in category A) at point 3' (A2, B1) is less cost-effective than a small energy-savings option (in category B) at point 2 (A1, B2). However, when another option (say, option A2 again) is added to achieve the additional energy savings at point 3 (A2, B2), it turns out to be less cost-effective than the original large-savings option at point 3' because of negative interaction between options A2 and B2. In this case, BEopt replaces point 3 with point 3' and proceeds.




**Special Case 3: Positive Interactions**

The previous two special cases involved negative interactions between options; a third type of special case involves synergistic interactions. For example, thermal mass may facilitate passive solar heating with extra south-facing window area. This phenomenon is illustrated in the third figure: starting at point 2 (A1, B1), point (A1, B2) is rejected, while point 3 (A2, B1) is selected. But then, with option A2 in place, the performance of option B2 is so improved that the superior performance of point 3' (A2, B2) eliminates point 3.




Every special case results in an "orphaned" point as shown in the above graphs.

## Near Optimal Solutions

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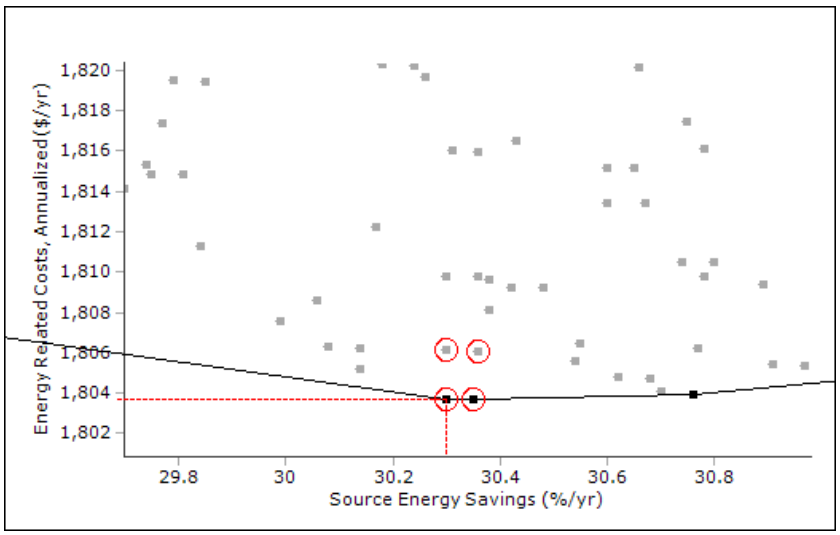
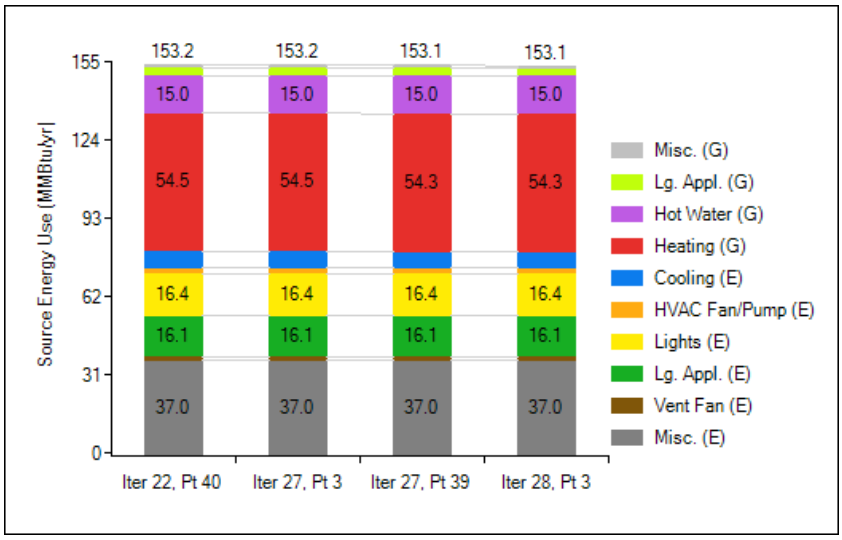
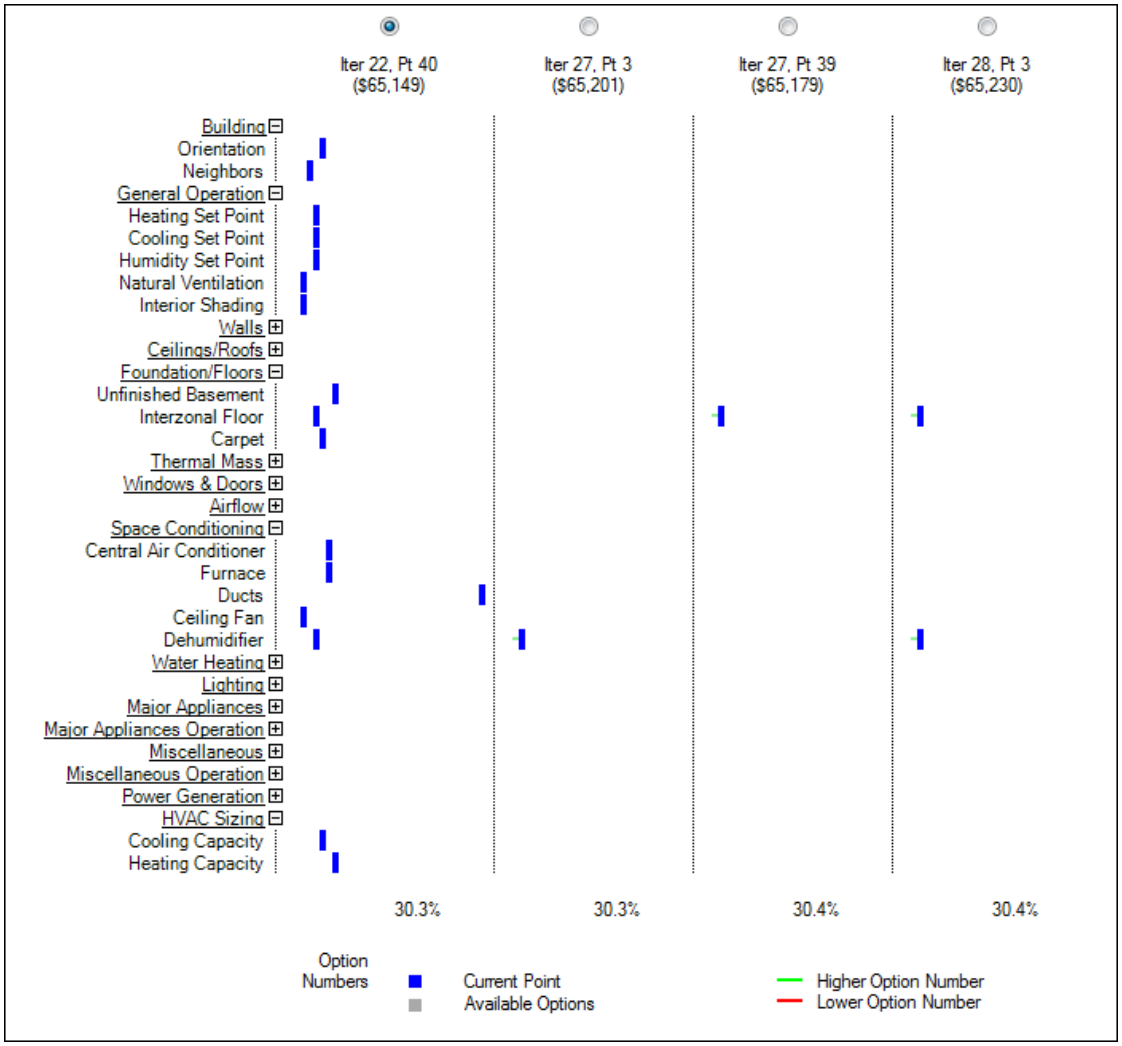
In optimization mode, BEopt will additionally find building designs that fall near, but not on, the path to zero net energy. Such points may, for reasons other than cost, provide a more desirable combination than the true optimum. Simply drag a box around the points of interest to select near neighbors on the Cost/Energy graph. The graph can be zoomed by using your mousewheel. The selected points will all be highlighted as shown below.




Results will also be displayed in both the End Use graph and Options graph on the output screen, comparing all of the selected points. As expected in the End Use graph, all of the near neighbors use approximately the same amount of energy. They may vary in how that energy use is distributed.



When evaluating the Options graph, be sure to select one of the radio buttons located above each near neighbor. This point will become the basis of comparison for all other neighboring points. As noted in the legend of the graph, green bars indicate that the neighboring point has an increased category option number relative to the selected point. A red bar represents a decreased category option number relative to the selected point. No bar indicates an exact option match to the selected point.




## Toolbars/Menus

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- BEopt Toolbar
- Case Input Toolbar
- Case Output Toolbar
- File Menu
- Screen Menu
- Case Menu
- Run Menu
- Reports Menu
- Graphs Menu
- Tools Menu
  - General Settings
  - Simulation Engine Settings
  - Cost/Energy Graph Settings
- Help menu

## BEopt Toolbar

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The BEopt toolbar provides quick access to many of BEopt's primary functions. Note that buttons on the toolbar are either invisible or inactive when their functions are not available. For example, the output button is only active when there are results to display, and the pause button is only visible while simulations are running. The menus provide access to all of BEopt's functions.

- **New Project:** Create a new BEopt project.
- **Open Project:** Open an existing BEopt project file.
- **Save Project:** Save the current BEopt project with its existing name.

**INPUT:**

The input buttons provide access to the building geometry, options, and site input screens.

- **Geometry:** Define the building's spaces and levels and explore the building rendering. See Geometry Input Screen.
- **Options:** Choose options for BEopt to consider in the analysis. See Options Input Screen.
- **Site:** Choose a location for the building, and define economic and financial parameters for the analysis. See Site Input Screen.

**OUTPUT:**

The output button is active only when there are results available for BEopt to display after running one or more simulations.

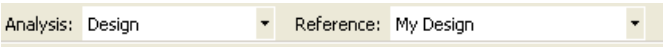
- **Output:** Displays graphs and tables of results for each case in the analysis. See Output.

**RUN:**

The Run button only appears when there are cases with no output. BEopt displays the Pause and Abort buttons only while simulations are running.

- **Run:** Start simulations when there are cases with no outputs.
- **Pause**: Pause simulations until the run button is clicked to resume.
- **Stop:** Stop simulations and discard partial results.

## Case Input Toolbar



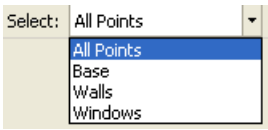

The case input toolbar is displayed whenever one of the three input screens is being viewed. The toolbar allows the user to choose the analysis mode and reference specific to the current case.

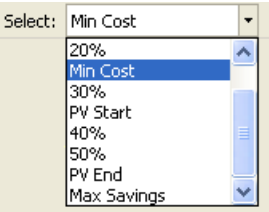
- Analysis Modes
- References

## Case Output Toolbar

The case output toolbar displayed on the upper left portion of the output screen can be used to modify and view the various results displayed. The effect of each button is described below:

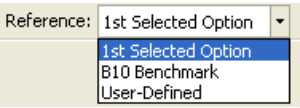
**Select:**






Use the drop down menu to select a specific point in the Cost/Energy graph. In optimization mode, points of interest (e.g. Min Cost, PV End, 30%, Max Savings) specific to the x- and y-axis metrics are available in the list, as well as all of the optimal points. For design and parametric modes, all points are available in the list.

**Reference:**

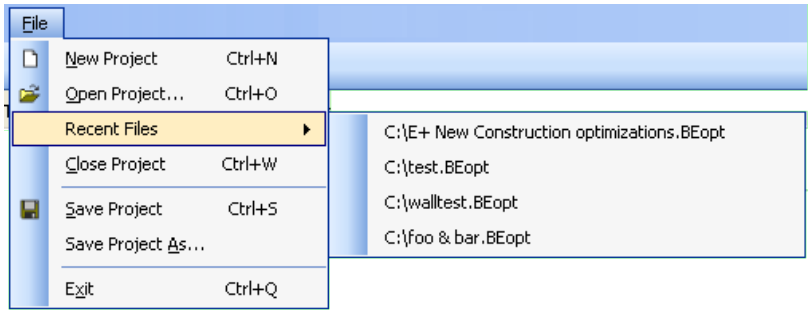



Select either a predefined reference (like the B10 Benchmark), a User-Defined reference, or the First Selected Options reference. In design mode, specific designs can be selected. For retrofit analysis, an Existing (w/ Min Replace) reference can be selected. See References for more information.

**TOOLS:**

- **Hourly Results:** Display graphs of hourly results in DView. Available data includes energy end uses, weather data, system performance, space temperatures, etc. See Hourly Results - DView.
- **Export Point:** Exports the selected point(s) in the Cost/Energy Graph to designs in a new case. This capability is particularly useful for exporting a building design from a large parametric or optimization result to perform further analysis. Note that only inputs are exported to the new case; the new case will need to be re-run to generate output.
- **Export to HPXML:** Exports the selected point in the Cost/Energy Graph to an HPXML v1.1.1 file. If in retrofit mode, two HPXML files will be produced -- one for the pre-retrofit building and one for the post-retrofit building. Only available for single-family detached buildings .

## File Menu




**New Project:** Creates a new BEopt project file with defaults and a single case.

**Open Project:** Opens an existing BEopt project file.

**Recent Files:** A list of recently used files available for loading. This menu item will not appear if there are no recent files.

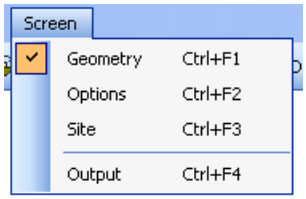
**Close Project:** Closes the current BEopt project file.

**Save Project:** Saves the current BEopt project file under the existing file name.

**Save Project As:** Allows the user to save the current BEopt project file under a new file name.

**Exit**: Exit BEopt. For modified projects, BEopt will prompt the user to save before exiting.

## Screen Menu



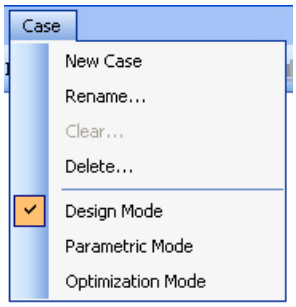

**Geometry:** Displays the geometry input screen.

**Options:** Displays the options input screen.

**Site:** Displays the site input screen.

**Output:** Displays the output screen. Only available if the current case has output.

## Case Menu




**New Case:** Creates a new BEopt case, preserving inputs of the current case, but clearing outputs.

**Rename:** Changes the name of the currently selected case.

**Clear:** Keeps the input data of the currently selected case but clears the results. Only available if the case has output.

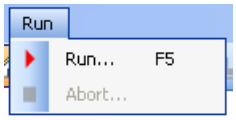
**Delete:** Deletes the currently selected case. If only one case exists in the project, it cannot be deleted.

**Design Mode**: Changes the analysis mode to design mode. If the case has output, the mode cannot be changed.

**Parametric Mode**: Changes the analysis mode to parametric mode. If the case has output, the mode cannot be changed.

**Optimization Mode:** Changes the analysis mode to optimization mode. If the case has output, the mode cannot be changed.

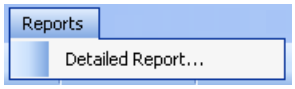
## Run Menu




**Run:** Begins the process of running energy simulations. Only available if there is a case in the project that does not have output.

**Abort:** Stops the currently running process; output data for the current case will be discarded. Only available if simulations are currently being run.

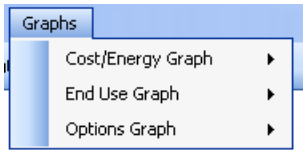
## Reports Menu




**Detailed Report**: Allows the user to generate a CSV file containing input and output data across user-specified cases. See Detailed Report for more details.

## Graphs Menu

The Graphs menu provides options for the output graphs.



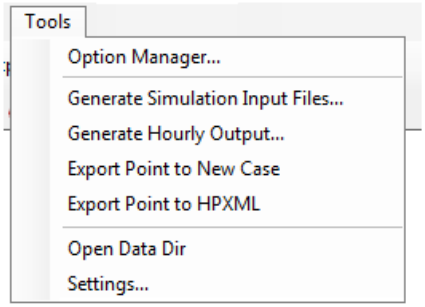

The Cost/Energy Graph refers to the graph in the upper left shown in the output screen.

The End Use Graph  refers to the bottom left graph.

The Options Graph refers to the right hand graph of selected building options.

You may also access these options by right-clicking on the individual graphs.

## Tools Menu




**Option Manager:** Opens the Option Manager, which allows the user to view and edit options and costs.

**Generation Simulation Input Files:** Generates only the simulation input files corresponding to the selected output point(s) (does not run any simulations). Only available for a case with output.

**Generate Hourly Output:** Display graphs of hourly results in DView. Available data includes energy end uses, weather data, system performance, space temperatures, etc. See Hourly Results - DView. Only available for a case with output.

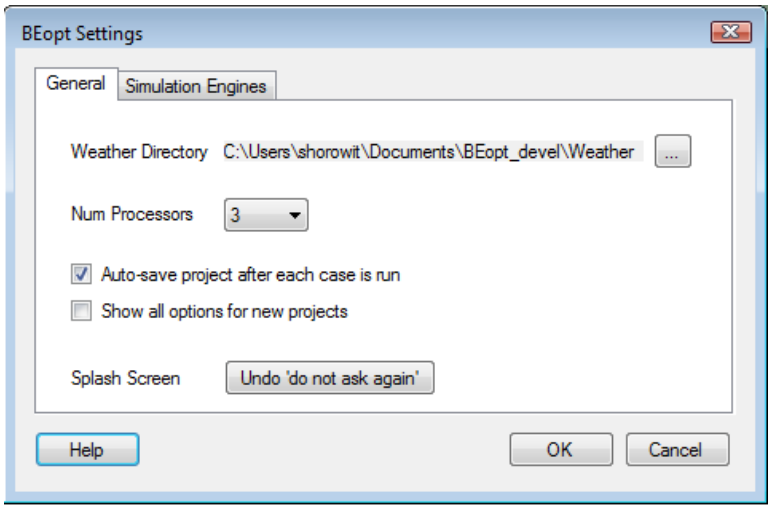
**Export Point to New Case**: Exports the selected point(s) in the Cost/Energy Graph to designs in a new case. This capability is particularly useful for exporting a building design from a large parametric or optimization result to perform further analysis. Only available for a case with output.

**Export Point to HPXML**: Exports the selected point in the Cost/Energy Graph to an HPXML file. If in retrofit mode, two HPXML files will be produced -- one for the existing building and one for the post-retrofit building. Only available for a single-family detached case with output.

**Open Data Dir**: Opens Windows Explorer at the directory where BEopt stores user data. The directory includes the user's library database (where user options and costs are housed), recent simulation input and output files, and the default weather directory.

**Settings:** Brings up the BEopt Settings Dialog. The tabs within this box allow settings to be specified for General and Simulation Engines .

## General Settings



**Weather Directory:**
Location of the weather files in EnergyPlus Weather (*.epw) format.

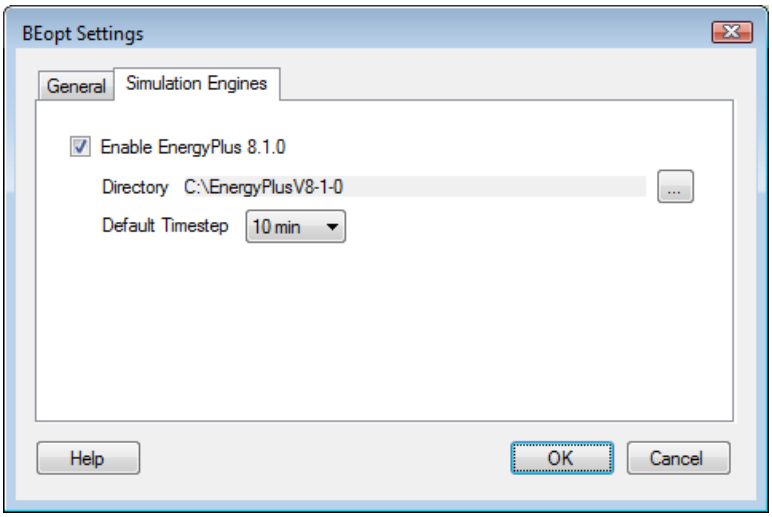
**Num Processors:**
The number of processors/cores to use when running simulations as BEopt can run multiple simulations in parallel to save time. Defaults to the number of processors on the current machine minus one (or one, for a single processor machine). The maximum value in the list is the number of processors/cores on the current machine as reported by Windows.

**Auto-save project after each case is run**
When checked, BEopt will automatically save the project file after each case's simulations are finished. This is particularly useful when running lengthy optimizations where you want to ensure the results are not lost by, e.g., a computer crash.

**Show all options for new projects**
When checked, BEopt will show every option in the Options input screen, not just those for which BEopt has cost data and deems appropriate for the situation. This will apply to any project files created after this setting has been checked. (Alternatively, this can also be toggled on/off on a per-project basis.)

**Splash Screen:**
Only shows up if the user has checked the 'Do not ask again' checkbox on the splash screen. Clicking this button allows the user to specify the project type whenever they create a new project.

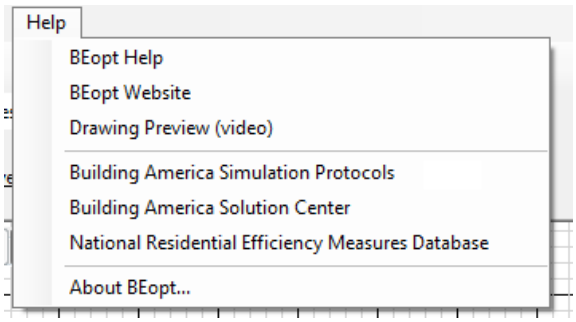
## Simulation Engines Settings




**Enable EnergyPlus:**
Allows the EnergyPlus simulation engine to be used for a case when running simulations.

The default zone timestep that EnergyPlus uses for simulations can also be specified here. Recommendations for timesteps are 10 mins or less in general; 3 mins or less for cases with Phase Phase Change Materials (PCMs). BEopt defaults to a 10 minute timestep. This default value can be overriden on a case-by-case basis from the Run dialog .

## Help Menu




**BEopt Help:** Opens this BEopt help file. Topics can be searched and displayed.

**BEopt Website**: Launches the BEopt website, which includes downloads, training videos, publications, etc.

**Drawing Preview (video):** A video preview demonstrating the range of drawing/geometry capabilities available.

**Building America Housing Simulation Protocols:** Launches the current version of the Building America Simulation Protocols document (pdf).

**Building America Solution Center**: The Building America Solution Center provides residential building professionals with access to expert information on hundreds of high-performance design and construction topics, including air sealing and insulation, HVAC components, windows, indoor air quality, and much more.

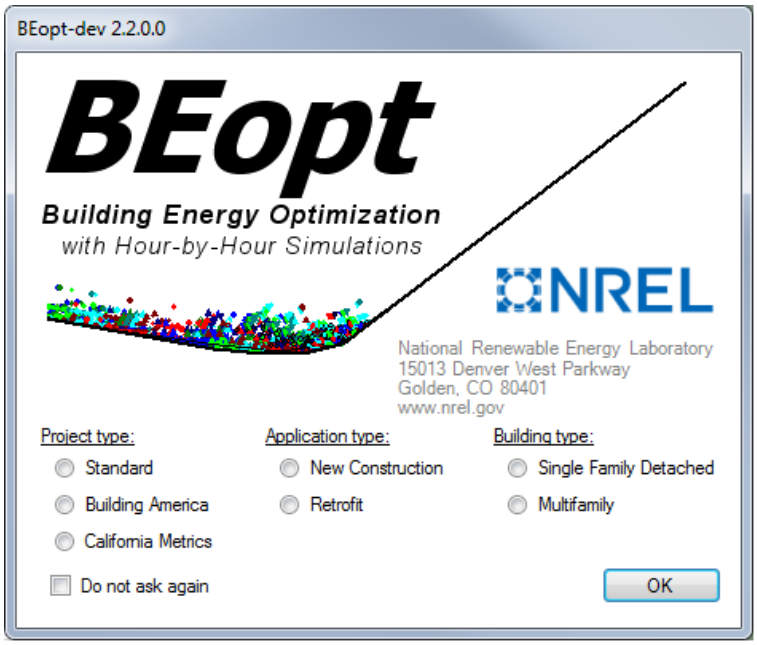
**National Residential Efficiency Measures Database**: Launches the NREMD website. This database, developed by NREL, is used as the source for costs and option properties in BEopt.

**About BEopt:** Displays the BEopt version number, credits, components, and license.

## Projects/Cases

When BEopt is launched, a new project is automatically created (with a single case inside). You can also create a new project at any time from the BEopt toolbar.

Whenever a new project is created, BEopt will prompt the user for the project type , application type, and building type:




Please click the radio button for the project type and application type of interest and choose OK. If you are only ever interested in this selection, you can click the checkbox for "Do not ask again". If at any time you change your mind, you can undo the "do not ask again" checkbox by going to General Settings.

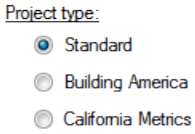
Note that a given project cannot be migrated from one project, application, or building type to another.

## Project Type

Different project types provide a tailored interface for the type of analysis being formed. If you do not know which project type to use, choose Standard.

- Standard
- Building America
- California Metrics

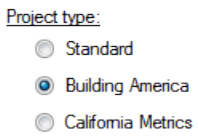
## Standard




The Standard project type has full flexibility of inputs for the user and is the default. If you do not know which project type to use, choose this one.

Even when using the Standard project type, the user can still perform Building America and California Metrics analysis without using that project type. However, certain default values are not set nor interface simplifications performed, so it is up to the user to manually choose appropriate inputs.

## Building America

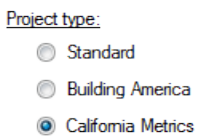



The Building America project type sets various default values and simplifies the interface specifically for analysis of projects within the DOE Building America program.

When the Building America project type is chosen, the interface is changed in the following ways:

1. The default reference for new construction is the B10 Benchmark reference.
2. The x-axis output metric for both display and optimization defaults to Adjusted Source Energy Savings for single-family detached buildings . This can be overridden on a case-by-case basis when running BEopt, or the default can be changed under Cost/Energy Graph Settings.
3. The source-to-site ratios for the different fuel types cannot be changed from the Building America defaults:
    1. Electricity: 3.365
    2. Natural Gas: 1.092
    3. Oil: 1.158
    4. Propane: 1.151
4. Weather files must be sourced from TMY3 data.

## California Metrics




The California Metrics project type sets various default values and simplifies the interface specifically for analysis of California utility cost tests, TDV energy, etc. These tests measure the cost-effectiveness of utility-sponsored energy efficiency programs, per the California Standard Practice Manual.

When the California Metrics project type is chosen, the interface is changed in the following ways:

1. Only California climate zone weather files are displayed in the EPW Location dropdown.
2. Additional inputs on the Site input screen are now available:
    1. Net-to-Gross Ratio
    2. Program Cost (Present Value)
    3. CA Climate Zone Utility
    4. CA Climate Zone Region
3. The y-axis output metric for both display and optimization defaults to Total Resource Cost Test. This can be overridden on a case-by-case basis when running BEopt, or the default can be changed under Cost/Energy Graph Settings. The full set of additional metrics that becomes available are:
    1. Total Resource Cost (TRC) Test, Net Present Value and Benefit-Cost Ratio
    2. Participant Cost Test (PCT), Net Present Value and Benefit-Cost Ratio
    3. Ratepayer Impact Measure (RIM) Test, Net Present Value and Benefit-Cost Ratio
    4. Program Administrator Cost (PAC) Test, Net Present Value and Benefit-Cost Ratio

    Note that Benefit-Cost Ratio metrics are only available for display in the Cost/Energy Graph, while the Net Present Value metrics are available for both display and optimizing over.
4. The x-axis output metric for both display and optimization defaults to TDV Energy Savings. This can be overridden on a case-by-case basis when running BEopt, or the default can be changed under Cost/Energy Graph Settings. The full set of additional metrics that becomes available are:
    1. TDV Energy Savings
    2. TDV Energy Consumption
5. The End Use graph gets an addition TDV Energy metric.
6. The marginal state income tax rate is defaulted to 9.3%.
7. The California Solar Initiative (CSI) PV rebate program is enabled by default. The program specifies a performance-based rebate of $0.03/kWh for 5 years or a capacity-based rebate of $0.20/W AC. The capacity-based incentive is enabled by default, but the user can easily switch to using the performance-based rebate (or disable the program rebates altogether).
8. Net-metered annual excess sellback rates are defaulted based on the choice of CA climate zone utility. The values, for February 2014, are:
    1. PG&E: $0.04396/kWh (source)
    2. SCE: $0.04738/kWh (source)
    3. SDG&E: $0.04680/kWh (source)
9. The user cannot enter a value greater than 40 years for the analysis period. (Avoided cost factors are only available for these years.)
10. The Site input screen defaults to the OpenEI electric utility rate (rather than a simple/flat rate).

Note that avoided costs are sourced from the 2013-2014 E3 Calculator.

## Application Type

Select one of two application types: New Construction or Retrofit.

When choosing retrofit, additional interface inputs (e.g. Retrofit Inputs, Payment Type, Cash Payment, Loan Interest Rate, Loan Period) will become available. In addition, the choice of references will change, different options may become available, labor costs specific to retrofit analysis will be used, etc.

## Building Type

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Select one of two building types: Single Family Detached or Multifamily. For single-family attached housing, select multifamily.

When choosing multifamily, additional interface inputs (e.g., drawing tool with multiple units, central metering , etc.) will become available.

## Cases

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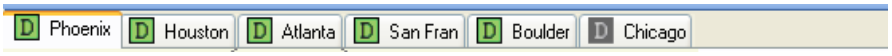


When you launch BEopt or start a new project, a new case is automatically created. Whenever only a single case exists in a project, the case tab bar (shown above) is hidden from view to simplify the interface. There is no need to ever create multiple cases within a single project; the user can always use multiple project files for different analyses. Power users may wish to group together multiple analyses (cases) within a single project.

**Cases**:
BEopt allows for the creation of multiple cases. The ability to analyze various cases is often used to evaluate building performance as a function of climate. Cases can also be used to study how building performance is affected by economic parameters, utility rates, building characteristics, or geometry.

**Case Tabs:**
BEopt displays case tabs along the top of the screen. Each case tab contains a series of input screens. To add, delete, or rename a case, right click on the case tabs. When a new case is created, it will copy all of the information (sans output) from the current selected case.

- In design mode, different designs (buildings) can be specified and simulated as a group. Design mode case tabs are marked by a D.
- In parametric mode, multiple options across multiple categories can be selected to be run with every combination. Parametric mode case tabs are marked by a P.
- In optimization mode, multiple options across multiple categories can be selected for evaluation by the optimization search technique. Optimization mode case tabs are marked with an O.

Once a case has been run, it will contain an output screen in addition to the input screens. Cases with output will have letter blocks in green, while cases without output will have letter blocks in gray.

Note that multiple Design Tabs will sometimes appear on the Options Input Screen. See Cases vs Designs for more information on the differences between them.

**View Case Input/Output Screens:**

- Left click the case tab of the desired case to view the input/output screens. To change screens, click on the appropriate screen button in the BEopt toolbar.
- Right click the case tab to view the Case Menu for additional options.

## Cases without Output

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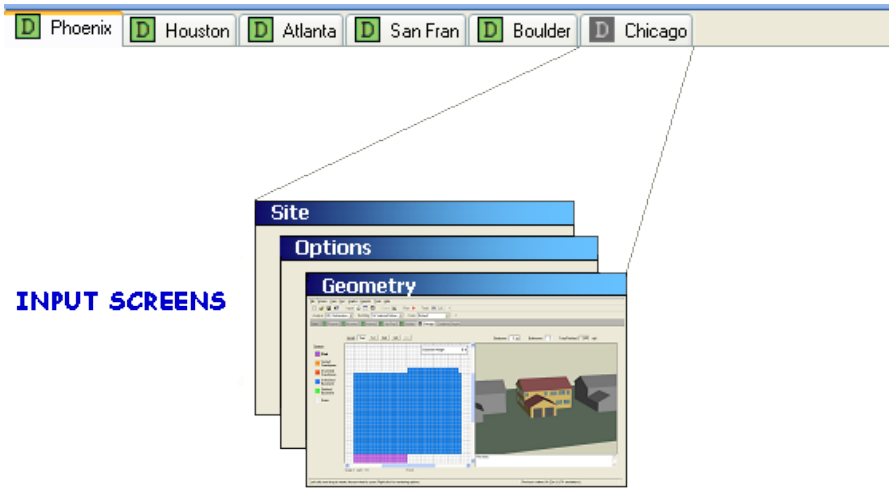
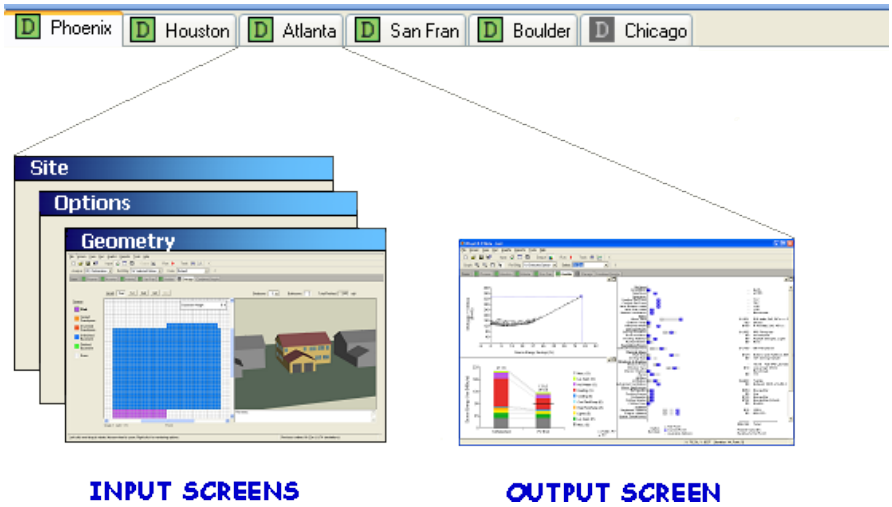
A case must first be defined before running a simulation and viewing the results. For such cases without output, only the input screens are available.



**Input Screens:**
Use the input screens to define the geometry, building options, and site/economic parameters. Any of these inputs can be changed from one case to another.

## Cases with Output

Once an optimization, parametric or design case has been run, the results can be viewed in various formats on the output screen. For these *cases with output* , either the input or output screens can be viewed for the selected case. These cases with output have their inputs disabled so as to prevent a discrepancy between the case outputs and inputs. The user has the option to clear the output from the current case or make a copy of the current case, sans output, before making input changes.




**Output Screen:**
Once the cases have been defined through the input screens, run the simulations. BEopt will automatically switch to the Output Screen to display results as the simulations occur. At any future point, click on the Output button on the BEopt toolbar to return to these results.

## Cases vs Designs

BEopt projects can include one or more cases. Across cases, anything at all can change -- geometry, selected options, economic parameters, costs, etc.

Within each case, there can also be multiple designs. Designs only show up in the Options input screen, which means that the only difference between designs is the option selection. Information specified on the Geometry input screen and Site input screen, as well as the choice of cost data, will always be used for all designs; this information is specified on the case level.

The general guidance is therefore to use multiple designs if you can (if you are only looking at different option selections given the same geometry, economics, location, etc.). If you want to change a building element that cannot be changed between two designs, then use a new case (or new project).

## Input

There are three main input screens in BEopt: the geometry, options, and site input screens.

BEopt also comes populated with a large amount of option data -- energy efficiency technologies with properties and costs -- across a broad spectrum of technology areas.

- Option Data
- Geometry Input Screen
- Options Input Screen
- Site Input Screen
- Analysis Modes
- References
- Library Management

## Option Data

- Building Group
  - Orientation Category
  - Neighbors Category
- Walls Group
  - Wood Stud Category
  - Double Wood Stud Category
  - Steel Stud Category
  - CMU Category
  - SIP Category
  - ICF Category
  - Other Category
  - Wall Sheathing Category
  - Exterior Finish Category
  - Interzonal Walls Category
- Ceilings/Roofs Group
  - Unfinished Attic Category
  - Finished Roof Category
  - Roof Material Category
  - Radiant Barrier Category
- Foundation/Floors Group
  - Slab Category
  - Finished Basement Category
  - Unfinished Basement Category
  - Crawlspace Category
  - Pier & Beam Category
  - Interzonal Floor Category
  - Carpet Category
- Thermal Mass Group
  - Floor Mass Category
  - Exterior Wall Mass Category
  - Partition Wall Mass Category
  - Ceiling Mass Category
- Windows & Doors Group
  - Window Areas Category
  - Windows Category
  - Interior Shading Category
  - Door Area Category
  - Doors Category
  - Eaves Category
  - Overhangs Category
- Airflow Group
  - Air Leakage Category
  - Mechanical Ventilation Category
  - Natural Ventilation Category
- Space Conditioning Group
  - Central Air Conditioner Category
  - Room Air Conditioner Category
  - Furnace Category
  - Boiler Category
  - Electric Baseboard Category
  - Air Source Heat Pump Category
  - Mini-Split Heat Pump Category
  - Ground Source Heat Pump Category
  - Ducts Category
  - Ceiling Fan Category
  - Dehumidifier Category
- Space Conditioning Schedules Group
  - Cooling Set Point Category
  - Heating Set Point Category
  - Humidity Set Point Category
- Water Heating Group
  - Water Heater Category
  - Distribution Category
  - Central Water Heater Category
  - Central Distribution Category
  - Solar Water Heating Category
  - Solar Water Heating Azimuth Category
  - Solar Water Heating Tilt Category
- Lighting Group
  - Lighting Category
- Appliances & Fixtures Group
  - Refrigerator Category
  - Cooking Range Category
  - Dishwasher Category
  - Clothes Washer Category

    - Clothes Dryer Category
    - Hot Water Fixtures Category
- Appliances & Fixtures Schedules Group
    - Refrigerator Schedule Category
    - Cooking Range Schedule Category
    - Clothes Dryer Schedule Category
- Miscellaneous Group
    - Plug Loads Category
    - Extra Refrigerator Category
    - Freezer Category
    - Pool Heater Category
    - Pool Pump Category
    - Hot Tub/Spa Heater Category
    - Hot Tub/Spa Pump Category
    - Well Pump Category
    - Gas Fireplace Category
    - Gas Grill Category
    - Gas Lighting Category
- Miscellaneous Schedules Group
    - Plug Loads Schedule Category
    - Extra Refrigerator Schedule Category
    - Freezer Schedule Category
    - Pool Heater Schedule Category
    - Pool Pump Schedule Category
    - Hot Tub/Spa Heater Schedule Category
    - Hot Tub/Spa Pump Schedule Category
    - Well Pump Schedule Category
    - Gas Fireplace Schedule Category
    - Gas Grill Schedule Category
    - Gas Lighting Schedule Category
- Power Generation Group
    - PV System Category
    - PV Azimuth Category
    - PV Tilt Category


## Building Group

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- Orientation Category
- Neighbors Category


## Orientation Category

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Orientation is defined as the direction faced by the front of the house (azimuth = degrees, clockwise from South).

**Properties**

- Azimuth [degrees]: The house's azimuth is measured clockwise from due south (when viewed from above).

**Options**

- North
- NNE
- Northeast
- ENE
- East
- ESE
- Southeast
- SSE
- South
- SSW
- Southwest
- WSW
- West
- WNW
- Northwest
- NNW

## Neighbors Category

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For shading and wind sheltering. Neighboring houses are placed to the left, right, front, and/or back of the BEopt house and are assumed to have the same geometry and orientation as the BEopt house. The option values correspond to the minimum perpendicular distance between the BEopt house and the neighboring house (not including eaves).

**Properties**

- Left Neighbor Offset [ft]: The minimum distance between the simulated house and the neighboring house to the left (not including eaves). A value of zero indicates no neighbors.
- Right Neighbor Offset [ft]: The minimum distance between the simulated house and the neighboring house to the right (not including eaves). A value of zero indicates no neighbors.
- Back Neighbor Offset [ft]: The minimum distance between the simulated house and the neighboring house to the back (not including eaves). A value of zero indicates no neighbors.
- Front Neighbor Offset [ft]: The minimum distance between the simulated house and the neighboring house to the front (not including eaves). A value of zero indicates no neighbors.

**Options**

- None
- Left/Right at 20ft
- Left/Right at 15ft
- Left/Right at 10ft
- Left/Right at 15ft, Front/Back at 80ft
- Left, at 15ft
- Right, at 15ft
- Front, at 15ft
- Back, at 15ft

## Walls Group

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- Wood Stud Category
- Double Wood Stud Category
- Steel Stud Category
- CMU Category
- SIP Category
- ICF Category
- Other Category
- Wall Sheathing Category
- Exterior Finish Category
- Interzonal Walls Category


## Wood Stud Category

---

Wood stud walls are standard wood stud framed walls with cavity insulation.
When batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5' 2x6 cavity), R-values reflect this effect.

Grade of batt installation quality (1, 2, or 3) is described in RESNET's "2006 Mortgage Industry National Home Energy Rating Systems Standards."

**Properties**

- Cavity Insulation Type: The type of insulation used in the wall cavity.
- Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Cavity Insulation Installed R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Installed cavity R-value refers to the R-value of the cavity insulation as installed and not the overall R-value of the assembly. If batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), use an R-value that accounts for this effect (see HUD Mobile Home Construction and Safety Standards 3280.509 for reference).
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Cavity Depth [in]: Depth of the stud cavity.
- Insulation Fills Cavity: Specifies whether the cavity insulation completely fills the depth of the wall cavity.
- Framing Factor [frac]: The fraction of a wall assembly that is comprised of structural framing.
- Framing Spacing [in]: The on-center spacing between framing in a wall assembly.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of OSB sheathing, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- Uninsulated, 2x4, 16 in o.c.
- Uninsulated, 2x6, 24 in o.c.
- R-7 Fiberglass Batt, 2x4, 16 in o.c.
- R-11 Fiberglass Batt, 2x4, 16 in o.c.
- R-13 Fiberglass Batt, 2x4, 16 in o.c.
- R-15 Fiberglass Batt, 2x4, 16 in o.c.
- R-19 Fiberglass Batt, 2x6, 24 in o.c.
- R-21 Fiberglass Batt, 2x6, 24 in o.c.

- R-13 Cellulose, 2x4, 16 in o.c.
- R-13 Cellulose, 2x4, 16 in o.c., Grade 2
- R-13 Cellulose, 2x4, 16 in o.c., Grade 3
- R-19 Cellulose, 2x6, 24 in o.c.
- R-13 Fiberglass, 2x4, 16 in o.c.
- R-19 Fiberglass, 2x6, 24 in o.c.
- R-23 Closed Cell Spray Foam, 2x4, 16 in o.c.
- R-36 Closed Cell Spray Foam, 2x6, 24 in o.c.
- R-13 Open Cell Spray Foam, 2x4, 16 in o.c.
- R-20 Open Cell Spray Foam, 2x6, 24 in o.c.

## Double Wood Stud Category

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Double wood stud walls are built from two parallel wood stud walls. Both stud walls and the space between them are filled with continuous insulation.

**Properties**

- Cavity Insulation Type: The type of insulation used in the wall cavity.
- Nominal Cavity Insulation R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal cavity R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Stud Depth [in]: Depth of the studs. The total cavity depth of the double stud wall = (2 x stud depth) + gap depth.
- Gap Depth [in]: Depth of the gap between walls. The total cavity depth of the double stud wall = (2 x stud depth) + gap depth.
- Framing Factor [frac]: The fraction of a wall assembly that is comprised of structural framing for the individual (inner and outer) stud walls.
- Framing Spacing [in]: The on-center spacing between framing in a wall assembly.
- Staggered Studs: Indicates that the double studs are aligned in a staggered fashion (as opposed to being centered).

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: The calculated assmebly R-values account for the thermal break effect of the gap between the individual stud walls. They also include inside and outside air films, 1/2 in. of OSB sheathing, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- R-33 Fiberglass Batt, Gr-1, 2x4 Centered, 24 in o.c.
- R-33 Fiberglass Batt, Gr-1, 2x4 Staggered, 24 in o.c.
- R-39 Fiberglass Batt, Gr-1, 2x4 Centered, 24 in o.c.
- R-39 Fiberglass Batt, Gr-1, 2x4 Staggered, 24 in o.c.
- R-45 Fiberglass Batt, Gr-1, 2x4 Centered, 24 in o.c.
- R-45 Fiberglass Batt, Gr-1, 2x4 Staggered, 24 in o.c.
- R-33 Cellulose, Gr-1, 2x4 Centered, 24 in o.c.
- R-33 Cellulose, Gr-1, 2x4 Staggered, 24 in o.c.
- R-39 Cellulose, Gr-1, 2x4 Centered, 24 in o.c.
- R-39 Cellulose, Gr-1, 2x4 Staggered, 24 in o.c.
- R-45 Cellulose, Gr-1, 2x4 Centered, 24 in o.c.
- R-45 Cellulose, Gr-1, 2x4 Staggered, 24 in o.c.
- R-33 Fiberglass, Gr-1, 2x4 Centered, 24 in o.c.
- R-33 Fiberglass, Gr-1, 2x4 Staggered, 24 in o.c.
- R-39 Fiberglass, Gr-1, 2x4 Centered, 24 in o.c.
- R-39 Fiberglass, Gr-1, 2x4 Staggered, 24 in o.c.
- R-45 Fiberglass, Gr-1, 2x4 Centered, 24 in o.c.
- R-45 Fiberglass, Gr-1, 2x4 Staggered, 24 in o.c.

## Steel Stud Category

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Steel stud walls are standard steel framed walls with cavity insulation.

Grade of batt installation quality (1, 2, or 3) is described in RESNET's "2006 Mortgage Industry National Home Energy Rating Systems Standards."

**Properties**

- Cavity Insulation Type: The type of insulation used in the wall cavity.
- Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Cavity Depth [in]: Depth of the stud cavity.
- Insulation Fills Cavity: Specifies whether the cavity insulation completely fills the depth of the wall cavity.
- Framing Factor [frac]: The fraction of a wall assembly that is comprised of structural framing.
- Framing Spacing [in]: The on-center spacing between framing in a wall assembly.

Correction Factor: The parallel path correction factor, as specified in Table C402.1.4.1 of the 2015 IECC as well as ASHRAE Standard 90.1, is used to determine the thermal resistance of wall assemblies containing metal framing.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of OSB sheathing, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- Uninsulated, 2x4, 16 in o.c.
- Uninsulated, 2x6, 24 in o.c.
- R-11 Fiberglass Batt, 2x4, 16 in o.c.
- R-13 Fiberglass Batt, 2x4, 16 in o.c.
- R-15 Fiberglass Batt, 2x4, 16 in o.c.
- R-19 Fiberglass Batt, 2x6, 24 in o.c.
- R-21 Fiberglass Batt, 2x6, 24 in o.c.
- R-25 Fiberglass Batt, 2x8, 24 in o.c.
- R-13 Cellulose, 2x4, 16 in o.c.
- R-13 Cellulose, 2x4, 16 in o.c., Grade 2
- R-13 Cellulose, 2x4, 16 in o.c., Grade 3
- R-19 Cellulose, 2x6, 24 in o.c.
- R-13 Fiberglass, 2x4, 16 in o.c.
- R-19 Fiberglass, 2x6, 24 in o.c.

## CMU Category

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A concrete masonry unit (CMU) -- also called concrete block, cement block, besser block and foundation block -- is a large rectangular brick used in construction.

Interior furring (optional) may be used to place insulation or simply to provide an air cavity behind drywall.

**Properties**

- Masonry Type: A description of the masonry type for the CMU wall.
- CMU Block Thickness [in]: Thickness of the CMU portion of the wall.
- CMU Conductivity [Btu-in/h-ft^2-R]: Overall conductivity of the finished CMU block.
- CMU Density [lb/ft^3]: The density of the finished CMU block.
- Framing Factor [frac]: Total fraction of wall that is framing for windows or doors.
- Furring Insulation Type: The type of insulation filling the furring cavity.
- Furring Insulation R-value [h-ft^2-R/Btu]: R-value of the insulation filling the furring cavity.
- Furring Cavity Depth [in]: The depth of the interior furring cavity. A value of zero indicates no furring on the wall.
- Furring Stud Spacing [in]: Spacing of studs in the furring.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- 6-in Concrete Filled
- 6-in Concrete Filled, R-10 XPS
- 6-in Concrete Filled, R-12 Polyiso
- 6-in Concrete Filled, R-13 Closed Cell Spray Foam
- 6-in Concrete Filled, R-19 Fiberglass Batt, 2x6, 24 in o.c.
- 6-in Hollow
- 6-in Hollow, R-10 XPS
- 6-in Hollow, R-12 Polyiso
- 6-in Hollow, R-13 Closed Cell Spray Foam
- 6-in Hollow, R-19 Fiberglass Batt, 2x6, 24 in o.c.
- 8-in Hollow
- 8-in Hollow, R-10 XPS
- 8-in Hollow, R-12 Polyiso
- 8-in Hollow, R-13 Closed Cell Spray Foam
- 8-in Hollow, R-19 Fiberglass Batt, 2x6, 24 in o.c.
- 12-in Hollow
- 12-in Hollow, R-10 XPS
- 12-in Hollow, R-12 Polyiso
- 12-in Hollow, R-13 Closed Cell Spray Foam
- 12-in Hollow, R-19 Fiberglass Batt, 2x6, 24 in o.c.
- 6-in Perlite Filled
- 6-in Perlite Filled, R-10 XPS
- 6-in Perlite Filled, R-12 Polyiso
- 6-in Perlite Filled, R-13 Closed Cell Spray Foam
- 6-in Perlite Filled, R-19 Fiberglass Batt, 2x6, 24 in o.c.

## SIP Category

Structural insulated panels, SIPs, are a composite building material. They consist of an insulating layer of rigid core sandwiched between two layers of structural board.

**Properties**

- Nominal Insulation R-value [h-ft^2-R/Btu]: R-value of the insulating core of the SIP.
- Insulation Thickness [in]: Thickness of the insulating core of the SIP.
- Framing Factor [frac]: Total fraction of wall that is framing for windows or doors.
- Interior Sheathing Type: The interior sheathing type of the SIP wall.
- Interior Sheathing Thickness [in]: The thickness of the interior sheathing.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of OSB sheathing, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- 3.6 in EPS Core, OSB int.
- 5.6 in EPS Core, OSB int.
- 7.4 in EPS Core, OSB int.
- 9.4 in EPS Core, OSB int.
- 3.6 in EPS Core, Gypsum int.
- 5.6 in EPS Core, Gypsum int.
- 7.4 in EPS Core, Gypsum int.
- 9.4 in EPS Core, Gypsum int.

## ICF Category

Insulating concrete forms (ICFs) are rigid plastic foam forms that hold concrete in place during curing and remain in place afterwards to serve as thermal insulation for concrete walls.

**Properties**

- Nominal Insulation R-value [h-ft^2-R/Btu]: R-value of each insulating layer of the form.
- Insulation Thickness [in]: Thickness of each insulating layer of the form.
- Concrete Thickness [in]: The thickness of the concrete core of the ICF.
- Framing Factor [frac]: Fraction of wall that is framing for windows or doors.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- 2" EPS, 4" Concrete, 2" EPS
- 2" EPS, 8" Concrete, 2" EPS
- 2" EPS, 12" Concrete, 2" EPS

## Other Category

Other walls allow generic exterior walls to be defined. Users can specify the properties of material layers that make up the wall.

T-mass walls are 2' of EPS with 3' of concrete on either side.

The listed properties (including layer thicknesses) for the ORNL options are effective properties for equivalent wall models (based on J. Kosny, E. Kossecka, S. Carpenter, T. Forrest, "Modeling Two-and-Three Dimensional Heat Transfer Through Composite Wall and Roof Assemblies in Transient Energy Simulation Programs" ASHRAE research project - 1145-TRP March 2001).

**Properties**

- Num Layers [#]: Integer number of layers in wall.
- Thickness 1 [in]: Thickness of the outside layer.
- Thickness 2 [in]: Thickness of the second layer.
- Thickness 3 [in]: Thickness of the third layer.
- Thickness 4 [in]: Thickness of the fourth layer.
- Thickness 5 [in]: Thickness of the fifth layer.
- Conductivity 1 [Btu-in/h-ft^2-R]: Conductivity of the outside layer.
- Conductivity 2 [Btu-in/h-ft^2-R]: Conductivity of the second layer.
- Conductivity 3 [Btu-in/h-ft^2-R]: Conductivity of the third layer.
- Conductivity 4 [Btu-in/h-ft^2-R]: Conductivity of the fourth layer.

- Conductivity 5 [Btu-in/h-ft^2-R]: Conductivity of the fifth layer.
- Density 1 [lb/ft^3]: Density of the outside layer.
- Density 2 [lb/ft^3]: Density of the second layer.
- Density 3 [lb/ft^3]: Density of the third layer.
- Density 4 [lb/ft^3]: Density of the fourth layer.
- Density 5 [lb/ft^3]: Density of the fifth layer.
- Specific Heat 1 [Btu/lb-R]: Specific heat of the outside layer.
- Specific Heat 2 [Btu/lb-R]: Specific heat of the second layer.
- Specific Heat 3 [Btu/lb-R]: Specific heat of the third layer.
- Specific Heat 4 [Btu/lb-R]: Specific heat of the fourth layer.
- Specific Heat 5 [Btu/lb-R]: Specific heat of the fifth layer.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of drywall, and vinyl siding.

**Options**

- None
- T-Mass Wall w/ Metal Ties (ORNL)
- T-Mass Wall w/ Plastic Ties (ORNL)
- 10" Grid ICF (ORNL)
- Superinsulated

## Wall Sheathing Category

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Wall sheathing options can be applied on top of any exterior wall (e.g. Wood Stud, CMU, etc.).

**Properties**

- Has OSB: Specifies if the walls have a layer of structural shear OSB sheathing; alternatively, the wall may have other means to handle the shear load on the wall such as cross-bracing.
- Continuous Insulation Type: The type of continuous insulation in the wall assembly.
- Continuous Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the continuous insulation and not the overall R-value of the assembly.
- Continuous Insulation Thickness [in]: The thickness of the continuous insulation.

**Options**

- None
- OSB
- R-5 XPS
- R-10 XPS
- R-15 XPS
- R-6 Polyiso
- R-12 Polyiso
- OSB, R-5 XPS
- OSB, R-10 XPS
- OSB, R-15 XPS
- OSB, R-6 Polyiso
- OSB, R-12 Polyiso

## Exterior Finish Category

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Absorptivity is the fraction of solar energy absorbed by the exterior finish. Emissivity refers to how effectively a material radiates heat away from the surface.

Actual costs for options in this category can vary significantly for non-energy reasons. For optimizations, it may be advisable to use user-specified net energy-related costs (or zero costs for all options).

**Properties**

- Siding Type: The type of siding or cladding use in a wall assembly (e.g., wood or aluminum).
- Solar Absorptivity: The property that determines the fraction of the incident radiation that is absorbed.
- Conductivity [Btu-in/h-ft^2-R]: Conductivity of the exterior finish assembly.
- Density [lb/ft^3]: Density of the exterior finish assembly.
- Specific Heat [Btu/lb-R]: Specific heat of the exterior finish assembly.
- Thickness [in]: Thickness of the exterior finish assembly.
- Emissivity: The property that determines the fraction of the incident radiation that is absorbed.

**Calculated Values**

- R-value [h-ft^2-R/Btu]

**Options**

- Stucco, Medium/Dark
- Brick, Light
- Brick, Medium/Dark
- Wood, Light
- Wood, Medium/Dark
- Aluminum, Light
- Aluminum, Medium/Dark
- Vinyl, Light
- Vinyl, Medium/Dark
- Fiber-Cement, Light
- Fiber-Cement, Medium/Dark
- No Absorptivity

## Interzonal Walls Category

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Interzonal walls are interior walls that separate two spaces that are not both conditioned. Examples include:

Walls between living space and the garage
Walls between cathedral/finished attic and unfinished attic
Walls between finished basement and unfinished basement

The construction is assumed to be wood stud. When batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), R-values reflect this effect.

Grade of batt installation quality (1, 2, or 3) is described in RESNET's "2006 Mortgage Industry National Home Energy Rating Systems Standards."

**Properties**

- Cavity Insulation Type: The type of insulation used in the cavity.
- Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal cavity R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Cavity Insulation Installed R-Value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Installed cavity R-value refers to the R-value of the cavity insulation as installed and not the overall R-value of the assembly. If batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), use an R-value that accounts for this effect (see HUD Mobile Home Construction and Safety Standards 3280.509 for reference).
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Cavity Depth [in]: Depth of the stud cavity (e.g. 3.5" for 2x4 studs)
- Insulation Fills Cavity: Specifies whether the cavity insulation completely fills the depth of the wall cavity. When the insulation does not completely fill the cavity, air film resistances inside the cavity are added to the insulation Rvalue.
- Framing Factor [frac]: The fraction of a wall assembly that is comprised of structural framing.
- Framing Spacing [in]: The on-center spacing between framing in a wall assembly.
- Continous Insulation Type: The type of continuous insulation used in the interzonal wall.
- Continuous Insulation Nominal R-value [h-ft^2-R/Btu]: R-value of any rigid insulation on the wall. Insulation is assumed to be placed on the unconditioned side of the wall.
- Continuous Insulation Thickness [in]: The thickness of the rigid insulation layer.

**Calculated Values**

- R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films and 1/2 in. of drywall.

**Options**

- None
- Uninsulated, 2x4, 16 in o.c.
- Uninsulated, 2x6, 24 in o.c.
- R-7 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- R-11 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- R-15 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
- R-21 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
- R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c., R-5 XPS
- R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c., R-6 Polyiso
- R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c., R-5 XPS
- R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c., R-6 Polyiso
- R-13 Cellulose, Gr-1, 2x4, 16 in o.c.
- R-13 Cellulose, Gr-1, 2x4, 16 in o.c., Grade 2
- R-13 Cellulose, Gr-1, 2x4, 16 in o.c., Grade 3
- R-19 Cellulose, Gr-1, 2x6, 24 in o.c.
- R-13 Fiberglass, Gr-1, 2x4, 16 in o.c.
- R-19 Fiberglass, Gr-1, 2x6, 24 in o.c.
- R-23 Closed Cell Spray Foam, Gr-1, 2x4, 16 in o.c.
- R-36 Closed Cell Spray Foam, Gr-1, 2x6, 24 in o.c.
- R-13 Open Cell Spray Foam, Gr-1, 2x4, 16 in o.c.

- R-20 Open Cell Spray Foam, Gr-1, 2x6, 24 in o.c.
- Superinsulated

## Ceilings/Roofs Group

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- Unfinished Attic Category
- Finished Roof Category
- Roof Material Category
- Radiant Barrier Category

## Unfinished Attic Category

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Attic space that is not directly conditioned. Insulation can be on the attic floor (the ceiling of the space below) or at the roof plane. Options can also specify whether the attic is vented or not.

**Properties**

- Ceiling Insulation Type: The type of insulation (e.g., cellulose or expanded polystyrene foam) used in a particular measure.
- Ceiling Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the filled insulation and not the overall R-value of the assembly.
- Ceiling Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Ceiling Insulation Thickness [in]: The thickness in inches of insulation required to obtain a certain R-value.
- Ceiling Framing Factor [frac]: The framing factor of the ceiling.
- Ceiling Framing Spacing [in]: The on-center spacing between framing in the ceiling assembly.
- Ceiling Joist Thickness [in]: Thickness of joists in the ceiling.
- Roof Insulation Type: The type of insulation used to insulate the roof plane.
- Roof Insulation Nominal R-value [h-ft^2-R/Btu]: R-value of insulation placed between rafters or joists. Use an R-value of 0 for no insulation.
- Roof Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Roof Insulation Thickness [in]: Thickness of roof insulation.
- Roof Framing Factor [frac]: Fraction of roof that is made up of framing elements.
- Roof Framing Spacing [in]: The on-center spacing between framing in the roof assembly.
- Roof Framing Thickness [in]: Thickness of roof framing.
- Roof Continuous Insulation Type: The type of continuous insulation on the roof.
- Roof Continuous Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the continuous insulation.
- Roof Continuous Insulation Thickness [in]: Thickness of rigid insulation added to the roof.
- SLA: Ratio of the effective leakage area (infiltration and/or ventilation) in the unfinished attic to the total floor area of the attic.

**Calculated Values**

- Ceiling R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films and 1/2 in. of drywall.
- Roof R-Assembly [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films and 3/4 in. of wood sheathing.
- Roof Taper Factor [frac]: Roof Taper Factor displays the derating of ceiling insulation R-value caused by the roof perimeter tapering effect at eaves depth of 0, 1, and 2 feet. It is calculated based on geometry screen inputs, accounting for the non-linear increase in U-value with reduced insulation thickness. For example, with an original ceiling insulation R-value of 61.3 and a displayed Roof Taper Factor value of 0.85, a derated (effective, overall) ceiling insulation R-value of 0.85*61.3 will be used in simulations.

**Options**

- None
- Uninsulated, Vented
- Ceiling R-7 Fiberglass, Gr-1, Vented
- Ceiling R-13 Fiberglass, Gr-1, Vented
- Ceiling R-19 Fiberglass, Gr-1, Vented
- Ceiling R-30 Fiberglass, Gr-1, Vented
- Ceiling R-38 Fiberglass, Gr-1, Vented
- Ceiling R-49 Fiberglass, Gr-1, Vented
- Ceiling R-60 Fiberglass, Gr-1, Vented
- Ceiling R-7 Cellulose, Gr-1, Vented
- Ceiling R-13 Cellulose, Gr-1, Vented
- Ceiling R-13 Cellulose, Gr-1, Roof R-49 Closed Cell Spray Foam, Gr-1, Unvented
- Ceiling R-19 Cellulose, Gr-1, Vented
- Ceiling R-30 Cellulose, Gr-1, Vented
- Ceiling R-38 Cellulose, Gr-1, Vented
- Ceiling R-49 Cellulose, Gr-1, Vented
- Ceiling R-60 Cellulose, Gr-1, Vented
- Ceiling R-30 Fiberglass Batt, Gr-1, Vented
- Ceiling R-38 Fiberglass Batt, Gr-1, Vented
- Ceiling R-49 Fiberglass Batt, Gr-1, Vented
- Ceiling R-30 Closed Cell Spray Foam, Gr-1, Vented
- Ceiling R-38 Closed Cell Spray Foam, Gr-1, Vented
- Ceiling R-49 Closed Cell Spray Foam, Gr-1, Vented

Ceiling R-60 Closed Cell Spray Foam, Gr-1, Vented
- Ceiling R-30 Open Cell Spray Foam, Gr-1, Vented
- Ceiling R-38 Open Cell Spray Foam, Gr-1, Vented
- Ceiling R-49 Open Cell Spray Foam, Gr-1, Vented
- Ceiling R-60 Open Cell Spray Foam, Gr-1, Vented
- Roof R-19 Fiberglass Batt, Gr-1, Unvented
- Roof R-30 Fiberglass Batt, Gr-1, Unvented
- Roof R-38 Fiberglass Batt, Gr-1, Unvented
- Roof R-38 Fiberglass Batt, R-24 Polyiso, Gr-1, Unvented
- Roof R-38 Fiberglass Batt, R-25 XPS, Gr-1, Unvented
- Roof R-30 Closed Cell Spray Foam, Gr-1, Unvented
- Roof R-38 Closed Cell Spray Foam, Gr-1, Unvented
- Roof R-49 Closed Cell Spray Foam, Gr-1, Unvented
- Roof R-60 Closed Cell Spray Foam, Gr-1, Unvented
- Roof R-30 Open Cell Spray Foam, Gr-1, Unvented
- Roof R-38 Open Cell Spray Foam, Gr-1, Unvented
- Roof R-49 Open Cell Spray Foam, Gr-1, Unvented
- Roof R-60 Open Cell Spray Foam, Gr-1, Unvented
- Roof R-27.5 SIP, Unvented
- Roof R-37.5 SIP, Unvented
- Roof R-47.5 SIP, Unvented
- Superinsulated

## Finished Roof Category

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Finished attic roof or vaulted ceiling. Options are for insulation levels at the roof plane. When batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), R-values reflect this effect.

R30C/R38C differ from R30/R38 in that they are higher density batts intended to fit between rafters for cathedral ceilings.

**Properties**

- Cavity Insulation Type: The type of insulation installed in the roof.
- Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal cavity R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Cavity Insulation Installed R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Installed cavity R-value refers to the R-value of the cavity insulation as installed and not the overall R-value of the assembly. If batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), use an R-value that accounts for this effect (see HUD Mobile Home Construction and Safety Standards 3280.509 for reference).
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Cavity Depth [in]: Thickness of roof framing.
- Insulation Fills Cavity: Specifies whether the cavity insulation completely fills the depth of the cavity. When the insulation does not completely fill the cavity, air film resistances inside the cavity are added to the insulation Rvalue.
- Framing Factor [frac]: The framing factor of the finished roof.
- Framing Spacing [in]: The on-center spacing between framing in the roof assembly.
- Continuous Insulation Type: The type of continuous insulation.
- Continuous Insulation Nominal R-Value [h-ft^2-R/Btu]: R-value of rigid insulation placed on the exterior of the roof.
- Continuous Insulation Thickness [in]: Thickness of rigid insulation added to the roof.

**Calculated Values**

- R-value [h-ft^2-R/Btu]: Assembly R-values include inside and outside air films, 1/2 in. of drywall, and 3/4 in. of wood sheathing.

**Options**

- None
- Uninsulated, 2x4
- Uninsulated, 2x6
- Uninsulated, 2x8
- Uninsulated, 2x10
- Uninsulated, 2x12
- Uninsulated, 2x10, R-15 XPS
- R-13 Fiberglass Batt, Gr-1, 2x4
- R-19 Fiberglass Batt, Gr-1, 2x6
- R-19 Fiberglass Batt, Gr-1, 2x8
- R-19 Fiberglass Batt, Gr-1, 2x10
- R-30C Fiberglass Batt, Gr-1, 2x8
- R-30C Fiberglass Batt, Gr-1, 2x10
- R-30 Fiberglass Batt, Gr-1, 2x10
- R-30 Fiberglass Batt, Gr-1, 2x12
- R-38 Fiberglass Batt, Gr-1, 2x10
- R-38 Fiberglass Batt, Gr-1, 2x12
- R-38 Fiberglass Batt, Gr-1, 2x14
- R-38C Fiberglass Batt, Gr-1, 2x10

- R-38C Fiberglass Batt, Gr-1, 2x12
- R-38C Fiberglass Batt, Gr-1, 2x10, R-24 Polyiso
- R-38C Fiberglass Batt, Gr-1, 2x10, R-25 XPS
- R-30 + R-19 Fiberglass Batt, Gr-1
- R-13 Fiberglass, Gr-1, 2x4
- R-13 Fiberglass, Gr-1, 2x4, R-15 XPS
- R-19 Fiberglass, Gr-1, 2x6
- R-30 Fiberglass, Gr-1, 2x8
- R-38 Fiberglass, Gr-1, 2x10
- R-49 Fiberglass, Gr-1, 2x12
- R-36 Closed Cell Spray Foam, Gr-1, 2x6
- R-47 Closed Cell Spray Foam, Gr-1, 2x8
- R-60 Closed Cell Spray Foam, Gr-1, 2x10
- R-20 Open Cell Spray Foam, Gr-1, 2x6
- R-26 Open Cell Spray Foam, Gr-1, 2x8
- R-33 Open Cell Spray Foam, Gr-1, 2x10
- R-27.5 SIPs
- R-37.5 SIPs
- R-47.5 SIPs
- Superinsulated

## Roof Material Category

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Absorptivity is the fraction of solar energy absorbed by the roofing material. Emissivity refers to how effectively a material radiates heat away from the surface.

Actual costs for options in this category can vary significantly for non-energy reasons. For optimizations, it may be advisable to use user-specified net energy-related costs (or zero costs for all options).

**Properties**

- Description: Material description used by Manual J sizing calculations.
- Color: Color description used by Manual J sizing calculations.
- Absorptivity: The solar radiation absorptance of the outside roof surface, specified as a value between 0 and 1.
- Emissivity: Infrared emissivity of the outside surface of the roof. Used to determine IR radiation leaving the roof surface and IR radiation from the sky, ground, and other surfaces absorbed by the roof surface.

**Options**

- Asphalt Shingles, Dark
- Asphalt Shingles, Medium
- Asphalt Shingles, Light
- Asphalt Shingles, White or cool colors
- Tile, Dark
- Tile, Medium (Mottled, Terra Cotta, Buff)
- Tile, Light
- Tile, White
- Metal, Dark
- Metal, Medium
- Metal, Light
- Metal, White
- Galvanized Steel
- No Absorptivity

## Radiant Barrier Category

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Radiant barriers are layers of reflective material used to reduce heat transfer between the attic roof and the ceiling insulation and ductwork (if present). Radiant barriers are not included in cathedral ceiling constructions.

**Properties**

- Has Radiant Barrier

**Options**

- None
- Double-Sided, Foil

## Foundation/Floors Group

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- Slab Category
- Finished Basement Category
- Unfinished Basement Category
- Crawlspace Category

- Pier & Beam Category
- Interzonal Floor Category
- Carpet Category

## Slab Category

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The configurations for slab insulation refer to:
Perimeter - placed horizontally, below the perimeter of the slab
Gap - placed vertically between the edge of the slab and the foundation wall
Exterior - placed vertically on the exterior of the foundation wall
Whole slab - placed horizontally below the entire slab area

**Properties**

- Insulation Type: The type of slab insulation.
- Perimeter Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the perimeter insulation. Perimeter insulation is placed horizontally below the perimeter of the slab.
- Perimeter Insulation Width [ft]: The distance from the perimeter of the house where the perimeter insulation ends.
- Whole Slab Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the whole slab insulation. Whole slab insulation is placed horizontally below the entire slab.
- Gap Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the gap insulation. Gap insulation is placed vertically between the edge of the slab and the foundation wall.
- Exterior Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the exterior insulation. Exterior insulation is placed vertically on the exterior of the foundation wall.
- Exterior Insulation Depth [ft]: The depth of the exterior foundation insulation.
- Mass Thickness [in]: Thickness of the slab foundation mass.
- Mass Conductivity [Btu-in/h-ft^2-R]: Conductivity of the slab foundation mass.
- Mass Density [lb/ft^3]: Density of the slab foundation mass.
- Mass Specific Heat [Btu/lb-R]: Specific heat of the slab foundation mass.

**Calculated Values**

- Bare Perimeter Conductance [Btu/hr-ft-F]: Perimeter conductances are calculated based on Winkelmann's Underground Surfaces article (Jan 2003).
- Carpet Perimeter Conductance [Btu/hr-ft-F]: Perimeter conductances are calculated based on Winkelmann's Underground Surfaces article (Jan 2003).

**Options**

- None
- Uninsulated
- 2ft R5 Perimeter, R5 Gap XPS
- 2ft R10 Perimeter, R5 Gap XPS
- 2ft R10 Perimeter, R10 Gap XPS
- 4ft R5 Perimeter, R5 Gap XPS
- 4ft R10 Perimeter, R5 Gap XPS
- 4ft R10 Perimeter, R10 Gap XPS
- 2ft R5 Exterior XPS
- 2ft R10 Exterior XPS
- 4ft R5 Exterior XPS
- 4ft R10 Exterior XPS
- 4ft R15 Exterior XPS
- 4ft R20 Exterior XPS
- Whole Slab R10, R5 Gap XPS
- Whole Slab R10, R10 Gap XPS
- Whole Slab R20, R5 Gap XPS
- Whole Slab R20, R10 Gap XPS
- Whole Slab R30, R10 Gap XPS
- Whole Slab R40, R10 Gap XPS
- Superinsulated

## Finished Basement Category

---

Finished basement (with direct conditioning supplied by the house's heating and/or cooling systems). Insulation (interior or exterior) at perimeter basement walls. Partial height insulation is positioned at the top of the basement wall.

**Properties**

- Insulation Height [ft]: The insulation height on the basement wall.
- Cavity Insulation Type: The type of cavity insulation on the wall.
- Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: R-value of cavity insulation placed on the finished basement wall, either interior or exterior.
- Cavity Insulation Installed R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Installed cavity R-value refers to the R-value of the cavity insulation as installed and not the overall R-value of the assembly. If batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), use an R-value that accounts for this effect (see HUD Mobile Home Construction and Safety Standards 3280.509 for reference).
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and

0% for Grade 1.
- Cavity Depth [in]: Depth of the stud cavity.
- Insulation Fills Cavity: Specifies whether the cavity insulation completely fills the depth of the wall cavity.
- Framing Factor [frac]: The percentage of a basement wall assembly that is comprised of structural framing.
- Framing Spacing [in]: The on-center spacing between framing in the basement wall assembly.
- Continuous Insulation Type: The type of continuous insulation on the wall.
- Continuous Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal continuous R-value refers to the R-value of the continuous insulation and not the overall R-value of the assembly.
- Continuous Insulation Thickness [in]: The thickness of the continuous insulation.
- Ceiling Framing Factor [frac]: Fraction of ceiling that is framing.
- Ceiling Framing Spacing [in]: The on-center spacing between framing in the basement ceiling assembly.
- Ceiling Joist Height [in]: Height of the joist member.
- Rim Joist Insulation R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Rim joist insulation R-value refers to the R-value of the insulation and not the overall R-value of the assembly.
- Constant ACH [1/hr]: Constant air exchange rate, in Air Changes per Hour (ACH), for the finished basement.

**Calculated Values**

- Wall R-value [h-ft^2-R/Btu]: The assembly R-value includes an inside air film and 1/2 in. of drywall, but does not include the concrete foundation wall.
- Perimeter Conductance [Btu/hr-ft-F]: Perimeter conductances are calculated based on Winkelmann's Underground Surfaces article (Jan 2003).

**Options**

- None
- Uninsulated
- Half Wall R-5 XPS
- Half Wall R-10 XPS
- Whole Wall R-5 XPS
- Whole Wall R-10 XPS
- Whole Wall R-15 XPS
- Whole Wall R-20 XPS
- Whole Wall R-11 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- Whole Wall R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- Whole Wall R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
- Whole Wall R-21 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
- Whole Wall R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c., R-5 XPS
- Whole Wall R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c., R-10 XPS
- Superinsulated

## Unfinished Basement Category

---

Unfinished basement. Insulation (interior or exterior) at perimeter basement walls, or at the ceiling. Partial height wall insulation is positioned at the top of the basement wall. Even if the basement has airflow registers, the registers are assumed to be closed.

**Properties**

- Wall Insulation Height [ft]: The insulation height on the basement wall.
- Wall Cavity Insulation Type: The type of insulation in the wall cavity.
- Wall Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Wall Cavity Insulation Installed R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Installed cavity R-value refers to the R-value of the cavity insulation as installed and not the overall R-value of the assembly. If batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5" 2x6 cavity), use an R-value that accounts for this effect (see HUD Mobile Home Construction and Safety Standards 3280.509 for reference).
- Wall Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Wall Cavity Depth [in]: Depth of the stud cavity.
- Wall Insulation Fills Cavity: Specifies whether the cavity insulation completely fills the depth of the wall cavity.
- Wall Framing Factor [frac]: The percentage of a basement wall assembly that is comprised of structural framing.
- Wall Framing Spacing [in]: The on-center spacing between framing in the basement wall assembly.
- Wall Continuous Insulation Type: The type of continuous wall insulation.
- Wall Continuous Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the continuous insulation and not the overall R-value of the assembly.
- Wall Continuous Insulation Thickness [in]: The thickness of the continuous insulation.
- Ceiling Cavity Insulation Type: The type of insulation in the ceiling cavity.
- Ceiling Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Ceiling Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Ceiling Framing Factor [frac]: Fraction of ceiling that is framing.
- Ceiling Framing Spacing [in]: The on-center spacing between framing in the basement ceiling assembly.

- Ceiling Joist Height [in]: Height of the joist member.
- Rim Joist Insulation R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Rim joist insulation R-value refers to the R-value of the insulation and not the overall R-value of the assembly.
- Constant ACH [1/hr]: Constant air exchange rate, in Air Changes per Hour (ACH), for the unfinished basement. A value of 0.10 ACH or greater is recommended for modeling Heat Pump Water Heaters in unfinished basements.

**Calculated Values**

- Ceiling R-value [h-ft^2-R/Btu]: Assembly R-values include film coefficients, but do NOT include carpet (added in the Carpet category) or floor mass (added in the Floor Mass category).
- Wall R-value [h-ft^2-R/Btu]: The assembly R-value includes an inside air film and 1/2 in. of drywall, but does not include the concrete foundation wall.
- Perimeter Conductance [Btu/hr-ft-F]: Perimeter conductances are calculated based on Winkelmann's Underground Surfaces article (Jan 2003).

**Options**

- None
- Uninsulated
- Half Wall R-5 XPS
- Half Wall R-10 XPS
- Half Wall R-6 Polyiso
- Half Wall R-12 Polyiso
- Whole Wall R-5 XPS
- Whole Wall R-10 XPS
- Whole Wall R-15 XPS
- Whole Wall R-20 XPS
- Whole Wall R-6 Polyiso
- Whole Wall R-12 Polyiso
- Whole Wall R-18 Polyiso
- Whole Wall R-11 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- Whole Wall R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.
- Whole Wall R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
- Whole Wall R-21 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
- Whole Wall R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c., R-5 XPS
- Whole Wall R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c., R-10 XPS
- Ceiling R-13 Fiberglass Batt, Gr-1
- Ceiling R-19 Fiberglass Batt, Gr-1
- Ceiling R-30 Fiberglass Batt, Gr-1
- Ceiling R-13 Closed Cell Spray Foam, Gr-1
- Ceiling R-19 Closed Cell Spray Foam, Gr-1
- Ceiling R-30 Closed Cell Spray Foam, Gr-1
- Ceiling R-13 Open Cell Spray Foam, Gr-1
- Ceiling R-19 Open Cell Spray Foam, Gr-1
- Ceiling R-30 Open Cell Spray Foam, Gr-1
- Superinsulated

## Crawlspace Category

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Insulation at perimeter crawlspace walls, or at the ceiling. Options can also specify whether the crawlspace is vented or not.

**Properties**

- Wall Continuous Insulation Type: Type of insulation on the crawlspace wall.
- Wall Continuous Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal R-value refers to the R-value of the continuous insulation and not the overall R-value of the assembly.
- Ceiling Cavity Insulation Type: The type of insulation in the ceiling cavity.
- Ceiling Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the ceiling cavity insulation.
- Ceiling Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Ceiling Framing Factor [frac]: Fraction of ceiling that is framing.
- Ceiling Framing Spacing [in]: The on-center spacing between framing in the crawlspace ceiling assembly.
- Ceiling Joist Height [in]: Height of the joist member.
- Rim Joist Insulation R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Rim joist insulation R-value refers to the R-value of the insulation and not the overall R-value of the assembly.
- Constant ACH [1/hr]: Constant air exchange rate, in Air Changes per Hour (ACH), for the crawlspace.

**Calculated Values**

- Ceiling R-value [h-ft^2-R/Btu]: Assembly R-values include film coefficients, but do NOT include carpet (added in the Carpet category) or floor mass (added in the Floor Mass category).
- Perimeter Conductance [Btu/hr-ft-F]: Perimeter conductances are calculated based on Winkelmann's Underground Surfaces article (Jan 2003).

**Options**

None
- Uninsulated, Vented
- Uninsulated, Unvented
- Wall R-5 XPS, Unvented
- Wall R-10 XPS, Unvented
- Wall R-15 XPS, Unvented
- Wall R-20 XPS, Unvented
- Wall R-6 Polyiso, Unvented
- Wall R-12 Polyiso, Unvented
- Wall R-18 Polyiso, Unvented
- Wall R-11 Fiberglass Batt, Unvented
- Wall R-13 Fiberglass Batt, Unvented
- Wall R-19 Fiberglass Batt, Unvented
- Wall R-21 Fiberglass Batt, Unvented
- Wall R-13 Closed Cell Spray Foam, Unvented
- Wall R-19 Closed Cell Spray Foam, Unvented
- Wall R-13 Open Cell Spray Foam, Unvented
- Wall R-19 Open Cell Spray Foam, Unvented
- Ceiling R-13 Fiberglass Batt, Gr-1, Vented
- Ceiling R-19 Fiberglass Batt, Gr-1, Vented
- Ceiling R-30 Fiberglass Batt, Gr-1, Vented
- Ceiling R-13 Closed Cell Spray Foam, Gr-1, Vented
- Ceiling R-19 Closed Cell Spray Foam, Gr-1, Vented
- Ceiling R-30 Closed Cell Spray Foam, Gr-1, Vented
- Ceiling R-13 Open Cell Spray Foam, Gr-1, Vented
- Ceiling R-19 Open Cell Spray Foam, Gr-1, Vented
- Ceiling R-30 Open Cell Spray Foam, Gr-1, Vented
- Superinsulated

## Pier & Beam Category

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Pier & Beam (sometimes called Post & Beam) foundation. Insulation can be placed above the open crawlspace.

**Properties**

- Ceiling Cavity Insulation Type: The type of insulation in the ceiling cavity.
- Ceiling Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: The nominal R-value of the ceiling cavity insulation.
- Ceiling Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Ceiling Framing Factor [frac]: Fraction of ceiling that is framing.
- Ceiling Framing Spacing [in]: The on-center spacing between framing in the pier & beam ceiling assembly.
- Ceiling Joist Height [in]: Height of the joist member.
- Constant ACH [1/hr]: Constant air exchange rate, in Air Changes per Hour (ACH), for the pier & beam foundation.

**Calculated Values**

- Floor R-value [h-ft^2-R/Btu]: Assembly R-values include film coefficients, but do NOT include carpet (added in the Carpet category) or floor mass (added in the Floor Mass category).

**Options**

- None
- Uninsulated
- Ceiling R-13 Fiberglass Batt, Gr-1
- Ceiling R-19 Fiberglass Batt, Gr-1
- Ceiling R-30 Fiberglass Batt, Gr-1
- Ceiling R-38 Fiberglass Batt, Gr-1
- Ceiling R-13 Closed Cell Spray Foam, Gr-1
- Ceiling R-19 Closed Cell Spray Foam, Gr-1
- Ceiling R-30 Closed Cell Spray Foam, Gr-1
- Ceiling R-38 Closed Cell Spray Foam, Gr-1
- Ceiling R-13 Open Cell Spray Foam, Gr-1
- Ceiling R-19 Open Cell Spray Foam, Gr-1
- Ceiling R-30 Open Cell Spray Foam, Gr-1
- Ceiling R-38 Open Cell Spray Foam, Gr-1
- Superinsulated

## Interzonal Floor Category

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Interzonal floors exist when conditioned space is over an inset garage or cantilevered over the exterior environment.

**Properties**

- Cavity Insulation Type: The type of insulation in the floor cavity.

Cavity Insulation Nominal R-value [h-ft^2-R/Btu]: Insulation levels are specified by R-value. R-value is a measure of insulation's ability to resist heat traveling through it. The higher the R-value the better the thermal performance of the insulation. Nominal cavity R-value refers to the R-value of the cavity insulation and not the overall R-value of the assembly.
- Cavity Install Grade: Installation grade as defined by RESNET standard. 5% of the cavity is considered missing insulation for Grade 3, 2% for Grade 2, and 0% for Grade 1.
- Framing Factor [frac]: The fraction of a wall assembly that is comprised of structural framing.
- Framing Spacing [in]: The on-center spacing between framing in the floor assembly.

**Calculated Values**

- R-value [h-ft^2-R/Btu]: Assembly R-values include film coefficients, but do NOT include carpet (added in the Carpet category) or floor mass (added in the Floor Mass category).

**Options**

- None
- Uninsulated
- R-13 Fiberglass Batt, Gr-1
- R-19 Fiberglass Batt, Gr-1
- R-30 Fiberglass Batt, Gr-1
- R-38 Fiberglass Batt, Gr-1
- R-13 Fiberglass, Gr-1
- R-19 Fiberglass, Gr-1
- R-30 Fiberglass, Gr-1
- R-38 Fiberglass, Gr-1
- R-13 Cellulose, Gr-1
- R-19 Cellulose, Gr-1
- R-30 Cellulose, Gr-1
- R-38 Cellulose, Gr-1
- R-23 Closed Cell Spray Foam, Gr-1
- R-36 Closed Cell Spray Foam, Gr-1
- R-13 Open Cell Spray Foam, Gr-1
- R-20 Open Cell Spray Foam, Gr-1
- Superinsulated

## Carpet Category

---

Fraction of the above-grade floor surfaces in conditioned spaces which are carpeted, affecting the thermal resistance of the floor and thermal coupling to the room air.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Floor Carpet Fraction: Defines the fraction of a floor which is covered by carpet.
- Carpet Pad R-value [h-ft^2-R/Btu]: The combined R-Value of the carpet and the pad.

**Options**

- 0% Carpet
- 20% Carpet
- 40% Carpet
- 60% Carpet
- 80% Carpet
- 100% Carpet

## Thermal Mass Group

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- Floor Mass Category
- Exterior Wall Mass Category
- Partition Wall Mass Category
- Ceiling Mass Category

## Floor Mass Category

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Top layer (other than carpet) of floors in conditioned spaces, with the exception of foundation slabs.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Thickness [in]: Thickness of the floor mass.
- Conductivity [Btu-in/h-ft^2-R]: Conductivity of the floor mass.
- Density [lb/ft^3]: Density of the floor mass.

- Specific Heat [Btu/lb-R]: Specific heat of the floor mass.

**Calculated Values**

- Capacitance [Btu/F-sqft]: The thermal capacitance of the floor mass.

**Options**

- None
- Wood Surface
- 2 in. Gypsum Concrete

## Exterior Wall Mass Category

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Specify the properties and thickness of up to two layers of drywall, drywall impregnated with PCM (Phase Change Material), or another PCM/thermal mass application on the interior surface of the exterior walls.

PCM modeling does not currently include the effects of sub cooling or hysteresis. Some PCM properties are effective values to account for combinations of PCMs with other materials or non-uniform thickness in some PCM encapsulations.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Num Layers [#]: Integer number of layers of exterior wall mass.
- Thickness 1 [in]: Thickness of the layer.
- Thickness 2 [in]: Thickness of the second layer.
- Density 1 [lb/ft^3]: Density of the layer.
- Density 2 [lb/ft^3]: Density of the second layer.
- Specific Heat 1 [Btu/lb-F]: Specific heat of the layer.
- Specific Heat 2 [Btu/lb-F]: Specific heat of the second layer.
- Conductivity 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material.
- Conductivity 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material, for the second layer.
- Conductivity, Liquid 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its liquid phase.
- Conductivity, Liquid 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its liquid phase, for the second layer.
- Conductivity, Solid 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its solid phase.
- Conductivity, Solid 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its solid phase, for the second layer.
- Melting Temperature 1 [F]: Mid-point temperature of the total phase change range at which the PCM melts.
- Melting Temperature 2 [F]: Mid-point temperature of the total phase change range at which the PCM melts, for the second layer.
- Melting Temperature Range 1 [F]: Temperature range around the phase change temperature required for the PCM to fully melt/solidify.
- Melting Temperature Range 2 [F]: Temperature range around the phase change temperature required for the PCM to fully melt/solidify, for the second layer.
- Latent Heat 1 [Btu/lb]: Heat required to change phase (from solid to liquid, liquid to solid, etc.).
- Latent Heat 2 [Btu/lb]: Heat required to change phase (from solid to liquid, liquid to solid, etc.), for the second layer.

**Calculated Values**

- Sensible Capacity 1 [Btu/F-ft^2]: Heat required to increase temperature of 1lbm of material/construction element by 1F.
- Sensible Capacity 2 [Btu/F-ft^2]: Heat required to increase temperature of 1lbm of material/construction element by 1F for the second layer.
- Latent Capacity 1 [Btu/ft^2]: Heat required to complete change phase.
- Latent Capacity 2 [Btu/ft^2]: Heat required to complete change phase for the second layer.

**Options**

- None
- 1/2 in. Drywall
- 5/8 in. Drywall
- 2 x 1/2 in. Drywall
- 2 x 5/8 in. Drywall
- PCM Drywall
- Drywall / PCM Mat

## Partition Wall Mass Category

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Specify the properties, thickness and area of up to two layers of drywall, drywall impregnated with PCM (Phase Change Material), or another PCM/thermal mass application for interzonal walls and partition walls.

PCM modeling does not currently include the effects of sub cooling or hysteresis. Some PCM properties are effective values to account for combinations of PCMs with other materials or non-uniform thickness in some PCM encapsulations.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Fraction of Floor Area: Ratio of exposed partition wall area to total conditioned floor area and accounts for the area of both sides of partition walls.
- Num Layers [#]: Integer number of layers of partition wall mass.

- Thickness 1 [in]: Thickness of the layer.
- Thickness 2 [in]: Thickness of the second layer.
- Density 1 [lb/ft^3]: Density of the layer.
- Density 2 [lb/ft^3]: Density of the second layer.
- Specific Heat 1 [Btu/lb-F]: Specific heat of the layer.
- Specific Heat 2 [Btu/lb-F]: Specific heat of the second layer.
- Conductivity 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material.
- Conductivity 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material, for the second layer.
- Conductivity, Liquid 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its liquid phase.
- Conductivity, Liquid 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its liquid phase, for the second layer.
- Conductivity, Solid 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its solid phase.
- Conductivity, Solid 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its solid phase, for the second layer.
- Melting Temperature 1 [F]: Mid-point temperature of the total phase change range at which the PCM melts.
- Melting Temperature 2 [F]: Mid-point temperature of the total phase change range at which the PCM melts, for the second layer.
- Melting Temperature Range 1 [F]: Temperature range around the phase change temperature required for the PCM to fully melt/solidify.
- Melting Temperature Range 2 [F]: Temperature range around the phase change temperature required for the PCM to fully melt/solidify, for the second layer.
- Latent Heat 1 [Btu/lb]: Heat required to change phase (from solid to liquid, liquid to solid, etc.).
- Latent Heat 2 [Btu/lb]: Heat required to change phase (from solid to liquid, liquid to solid, etc.), for the second layer.

**Calculated Values**

- Area [sqft]: The total exposed area of partition walls (including both sides).
- Sensible Capacity 1 [Btu/F-ft^2]: Heat required to increase temperature of 1lbm of material/construction element by 1F.
- Sensible Capacity 2 [Btu/F-ft^2]: Heat required to increase temperature of 1lbm of material/construction element by 1F for the second layer.
- Latent Capacity 1 [Btu/ft^2]: Heat required to complete change phase.
- Latent Capacity 2 [Btu/ft^2]: Heat required to complete change phase for the second layer.

**Options**

- None
- 1/2 in. Drywall
- 5/8 in. Drywall
- 2 x 1/2 in. Drywall
- 2 x 5/8 in. Drywall
- PCM Drywall
- Drywall / PCM Mat
- Light Adiabatic

## Ceiling Mass Category

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Specify the properties and thickness of up to two layers of drywall, drywall impregnated with PCM (Phase Change Material), or another PCM/thermal mass application on the interior surface of: ceilings below attics, cathedral/vaulted ceilings, and ceiling below upper/lower floors.

PCM modeling does not currently include the effects of sub cooling or hysteresis. Some PCM properties are effective values to account for combinations of PCMs with other materials or non-uniform thickness in some PCM encapsulations.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Num Layers [#]: Integer number of layers of ceiling mass.
- Thickness 1 [in]: Thickness of the layer.
- Thickness 2 [in]: Thickness of the second layer.
- Density 1 [lb/ft^3]: Density of the layer.
- Density 2 [lb/ft^3]: Density of the second layer.
- Specific Heat 1 [Btu/lb-F]: Specific heat of the layer.
- Specific Heat 2 [Btu/lb-F]: Specific heat of the second layer.
- Conductivity 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material.
- Conductivity 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material, for the second layer.
- Conductivity, Liquid 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its liquid phase.
- Conductivity, Liquid 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its liquid phase, for the second layer.
- Conductivity, Solid 1 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its solid phase.
- Conductivity, Solid 2 [Btu-in/h-ft^2-F]: Thermal conductivity of the material in its solid phase, for the second layer.
- Melting Temperature 1 [F]: Mid-point temperature of the total phase change range at which the PCM melts.
- Melting Temperature 2 [F]: Mid-point temperature of the total phase change range at which the PCM melts, for the second layer.
- Melting Temperature Range 1 [F]: Temperature range around the phase change temperature required for the PCM to fully melt/solidify.
- Melting Temperature Range 2 [F]: Temperature range around the phase change temperature required for the PCM to fully melt/solidify, for the second layer.
- Latent Heat 1 [Btu/lb]: Heat required to change phase (from solid to liquid, liquid to solid, etc.).
- Latent Heat 2 [Btu/lb]: Heat required to change phase (from solid to liquid, liquid to solid, etc.), for the second layer.

**Calculated Values**

- Sensible Capacity 1 [Btu/F-ft^2]: Heat required to increase temperature of 1lbm of material/construction element by 1F.
- Sensible Capacity 2 [Btu/F-ft^2]: Heat required to increase temperature of 1lbm of material/construction element by 1F for the second layer.
- Latent Capacity 1 [Btu/ft^2]: Heat required to complete change phase.
- Latent Capacity 2 [Btu/ft^2]: Heat required to complete change phase for the second layer.

**Options**

- None
- 1/2 in. Drywall
- 5/8 in. Drywall
- 2 x 1/2 in. Drywall
- 2 x 5/8 in. Drywall
- PCM Drywall
- Drywall / PCM Mat

## Windows & Doors Group

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- Window Areas Category
- Windows Category
- Interior Shading Category
- Door Area Category
- Doors Category
- Eaves Category
- Overhangs Category

## Window Areas Category

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Window Area options can be specified as:
1) Window areas as a fraction of each facade's exterior wall area,
2) Total window area as a fraction of exterior wall area, followed by the fractional distribution of window areas for the facades, or
3) Absolute window areas (sqft) for each facade.
Window areas include both glazing and frame. Window areas (and net wall areas) are multiplied times the costs (per square foot) specified in the Window Type and Walls categories.

Perimeter/Area ratios are used to adjust the U-values and SHGCs based on frame and glazing areas for various types and sizes of window assembly.

**Properties**

- Window Area Fraction of Wall Area: Ratio of total window area to exterior wall area of living space.
- Front Fraction of Total Window Area: The ratio of window area facing front to total window area.
- Back Fraction of Total Window Area: The ratio of window area facing back to total window area.
- Left Fraction of Total Window Area: The ratio of window area facing left to total window area.
- Right Fraction of Total Window Area: The ratio of window area facing right to total window area.
- Front Area [ft^2]: The total window area facing front.
- Back Area [ft^2]: The total window area facing back.
- Left Area [ft^2]: The total window area facing left.
- Right Area [ft^2]: The total window area facing right.
- Front Window to Wall Ratio
- Back Window to Wall Ratio
- Left Window to Wall Ratio
- Right Window to Wall Ratio
- Front Perimeter/Area Ratio [1/ft]: Perimeter/Area ratio (1/ft) represents the type(s) and size(s) of window units to be used on each facade. Perimeter includes all frame elements (1 additional segment in a slider). Typical values for standard sizes are: 24" x 59" casement = 1.41; 47" x 59" slider = 1.12; 47" x 59" picture (fixed) = 0.92; 39" x 79" sliding door = 0.92. For a combination of types on one facade, calculate (total perimeter)/(total area). Perimeter/Area ratio is used to adjust the U-value and SHGC based on frame and glazing areas for various types of window assembly.
- Back Perimeter/Area Ratio [1/ft]: Perimeter/Area ratio (1/ft) represents the type(s) and size(s) of window units to be used on each facade. Perimeter includes all frame elements (1 additional segment in a slider). Typical values for standard sizes are: 24" x 59" casement = 1.41; 47" x 59" slider = 1.12; 47" x 59" picture (fixed) = 0.92; 39" x 79" sliding door = 0.92. For a combination of types on one facade, calculate (total perimeter)/(total area). Perimeter/Area ratio is used to adjust the U-value and SHGC based on frame and glazing areas for various types of window assembly.
- Left Perimeter/Area Ratio [1/ft]: Perimeter/Area ratio (1/ft) represents the type(s) and size(s) of window units to be used on each facade. Perimeter includes all frame elements (1 additional segment in a slider). Typical values for standard sizes are: 24" x 59" casement = 1.41; 47" x 59" slider = 1.12; 47" x 59" picture (fixed) = 0.92; 39" x 79" sliding door = 0.92. For a combination of types on one facade, calculate (total perimeter)/(total area). Perimeter/Area ratio is used to adjust the U-value and SHGC based on frame and glazing areas for various types of window assembly.
- Right Perimeter/Area Ratio [1/ft]: Perimeter/Area ratio (1/ft) represents the type(s) and size(s) of window units to be used on each facade. Perimeter includes all frame elements (1 additional segment in a slider). Typical values for standard sizes are: 24" x 59" casement = 1.41; 47" x 59" slider = 1.12; 47" x 59" picture (fixed) = 0.92; 39" x 79" sliding door = 0.92. For a combination of types on one facade, calculate (total perimeter)/(total area). Perimeter/Area ratio is used to adjust the U-value and SHGC based on frame and glazing areas for various types of window assembly.

**Calculated Values**

- Total Window Area [sqft]: The total window area (including frames) in the building.
- FBLR Window Areas [sqft]: The window areas (including frames) for the front, back, left, and right (FBLR) facades of the building.
- FBLR WWRs: The window to wall ratios (WWRs) for the front, back, left, and right (FBLR) facades of the building.
- Total WWR & FBLR Distribution: The total window to wall ratio (WWR) for the building followed by the fraction of this window area on the front, back, left, and right (FBLR) facades of the building.
- FBLR Perimeter/Area Ratios [1/ft]: The window perimeter/area ratios for the front, back, left, and right (FBLR) facades of the building.

**Options**

- None
- F18 B18 L18 R18
- F15 B15 L15 R15
- F15 B15 L0 R0
- F12 B12 L12 R12
- F10 B30 L10 R10
- 18% F25 B25 L25 R25
- 18% F20 B40 L20 R20
- 15% F25 B25 L25 R25
- 15% F20 B40 L20 R20
- 50sqft, all facades

## Windows Category

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The type of window for each facade on the house. Options can define facade-specific window types or a single window type for the building.

U-values and SHGCs listed here are NFRC ratings for standard-size, single casement windows. Other window types and sizes may be represented using Perimeter/Area Ratio as explained in the Window Areas category

3-pane windows may include 2 layers of glass and a suspended film.

Argon-filled windows may not be available at higher altitudes (above approximately 3500 feet), due to issues with atmospheric pressure differences between the installation and manufacturer's locations.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Panes: Number of panes of glazing in a window or skylight system.
- U-Value [Btu/h-ft^2-R]: The heat transfer coefficient of the windows.
- SHGC: The ratio of solar heat gain through a glazing system compared to that of an unobstructed opening.
- Frame Material: The material comprising the frame of a glazing system.
- Front Frame Material: The material comprising the frame of a glazing system for front facing windows.
- Back Frame Material: The material comprising the frame of a glazing system for back facing windows.
- Left Frame Material: The material comprising the frame of a glazing system for left facing windows.
- Right Frame Material: The material comprising the frame of a glazing system for right facing windows.
- Front U-Value [Btu/h-ft^2-R]: The heat transfer coefficient of front facing windows.
- Back U-Value [Btu/h-ft^2-R]: The heat transfer coefficient of back facing windows.
- Left U-Value [Btu/h-ft^2-R]: The heat transfer coefficient of left facing windows.
- Right U-Value [Btu/h-ft^2-R]: The heat transfer coefficient of right facing windows.
- Front SHGC: The ratio of solar heat gain through a glazing system compared to that of an unobstructed opening for front facing windows.
- Back SHGC: The ratio of solar heat gain through a glazing system compared to that of an unobstructed opening for back facing windows.
- Left SHGC: The ratio of solar heat gain through a glazing system compared to that of an unobstructed opening for left facing windows.
- Right SHGC: The ratio of solar heat gain through a glazing system compared to that of an unobstructed opening for right facing windows.

**Options**

- Clear, Single, Metal
- Clear, Single, Non-metal
- Clear, Double, Metal, Air
- Clear, Double, Thermal-Break, Air
- Clear, Double, Non-metal, Air
- Low-E, Double, Non-metal, Air, H-Gain
- Low-E, Double, Non-metal, Air, M-Gain
- Low-E, Double, Non-metal, Air, L-Gain
- Low-E, Double, Non-metal, Arg, H-Gain
- Low-E, Double, Non-metal, Arg, M-Gain
- Low-E, Double, Non-metal, Arg, L-Gain
- Low-E, Double, Insulated, Air, H-Gain
- Low-E, Double, Insulated, Air, M-Gain
- Low-E, Double, Insulated, Air, L-Gain
- Low-E, Double, Insulated, Arg, H-Gain
- Low-E, Double, Insulated, Arg, M-Gain
- Low-E, Double, Insulated, Arg, L-Gain
- Low-E, Triple, Non-metal, Air, H-Gain
- Low-E, Triple, Non-metal, Air, L-Gain
- Low-E, Triple, Non-metal, Arg, H-Gain
- Low-E, Triple, Non-metal, Arg, L-Gain
- Low-E, Triple, Insulated, Air, H-Gain
- Low-E, Triple, Insulated, Air, L-Gain
- Low-E, Triple, Insulated, Arg, H-Gain
- Low-E, Triple, Insulated, Arg, L-Gain
- Back Windows = High-SHGC
- Superinsulated, Opaque

## Interior Shading Category

Solar gains through windows are modified by the Interior Shading multipliers (a multiplier of 1.0 indicates no reduction in solar gain).

The schedule for interior shading is specified based on the heating and cooling season logic defined in the Building America House Simulation Protocols, with cooling taking precedence for any month that has both heating and cooling availability. Alternatively, the user can specify the heating/cooling shade seasons for which the shade multipliers apply.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Heating Shade Multiplier: Interior shading multiplier for heating season. 1.0 indicates no reduction in solar gain, 0.85 indicates 15% reduction, etc.
- Cooling Shade Multiplier: Interior shading multiplier for cooling season. 1.0 indicates no reduction in solar gain, 0.85 indicates 15% reduction, etc.
- Cooling Shade Schedule [0/1]: The months of the year for which the cooling shade multiplier should apply (using a value of 1 for each month). Any month not set as cooling will use the heating shade multiplier. Note that the specification of cooling shade months is only used for shade multipliers, it does not dictate when the heating or cooling HVAC systems are running.

**Options**

- None
- Summer = 0.7, Winter = 0.7
- Summer = 0.6, Winter = 0.7
- Summer = 0.5, Winter = 0.7
- Summer = 0.7, Winter = 0.95
- Summer = 0.5, Winter = 0.95
- Apr-Sep = 0.5, Oct-Mar = 0.95

## Door Area Category

The amount of opaque door area. Door glazing area should be included in the Window Areas category.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Area [ft^2/unit]: The amount of opaque door area, whose material is described in the Door category. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- 20 ft^2
- 30 ft^2
- 40 ft^2

## Doors Category

The type of opaque exterior door.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- U-Value [Btu/h-R-ft^2]: The heat transfer coefficient of a material or assembly, the U-value is the inverse of R-value. It is calculated for a total window, skylight, or entry door assembly.
- Operation: This describes the way an entry door opens.

**Options**

- Wood
- Steel
- Fiberglass

## Eaves Category

Eaves extend from the edges of both the main house and garage roofs.

**Properties**

- Depth [ft]: Depth of eaves' horizontal extension.

**Options**

- None
- 1 ft
- 2 ft
- 3 ft

## Overhangs Category

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Overhangs are horizontal shading surfaces positioned relative to each window. Overhangs can be specified both per story and per facade, and are characterized by a depth, vertical offset, and width extension. Any potential overlap of overhangs between pairs of windows (based on the width extension specified) will not be costed.

**Properties**

- Depth [ft]: Depth of the overhang. The distance from the wall surface in the direction normal to the wall surface.
- Offset [ft]: Height of the overhangs above windows, relative to the top of the window framing.
- Width Extension [ft]: Length that the overhang extends beyond the window width, relative to the outside of the window framing. Refers to the extended width on each side of the window (i.e. the total overhang width will be the window width plus two times the overhang width extension). Note that any potential overlap of overhangs between pairs of windows will not be costed.
- First Story, Front: Specifies the presence of overhangs on front windows on the first story.
- First Story, Back: Specifies the presence of overhangs on back windows on the first story.
- First Story, Left: Specifies the presence of overhangs on left windows on the first story.
- First Story, Right: Specifies the presence of overhangs on right windows on the first story.
- Second Story, Front: Specifies the presence of overhangs on front windows on the second story.
- Second Story, Back: Specifies the presence of overhangs on back windows on the second story.
- Second Story, Left: Specifies the presence of overhangs on left windows on the second story.
- Second Story, Right: Specifies the presence of overhangs on right windows on the second story.
- Third Story, Front: Specifies the presence of overhangs on front windows on the third story.
- Third Story, Back: Specifies the presence of overhangs on back windows on the third story.
- Third Story, Left: Specifies the presence of overhangs on left windows on the third story.
- Third Story, Right: Specifies the presence of overhangs on right windows on the third story.
- Fourth Story, Front: Specifies the presence of overhangs on front windows on the fourth story.
- Fourth Story, Back: Specifies the presence of overhangs on back windows on the fourth story.
- Fourth Story, Left: Specifies the presence of overhangs on left windows on the fourth story.
- Fourth Story, Right: Specifies the presence of overhangs on right windows on the fourth story.
- Fifth Story, Front: Specifies the presence of overhangs on front windows on the fifth story.
- Fifth Story, Back: Specifies the presence of overhangs on back windows on the fifth story.
- Fifth Story, Left: Specifies the presence of overhangs on left windows on the fifth story.
- Fifth Story, Right: Specifies the presence of overhangs on right windows on the fifth story.
- Sixth Story, Front: Specifies the presence of overhangs on front windows on the sixth story.
- Sixth Story, Back: Specifies the presence of overhangs on back windows on the sixth story.
- Sixth Story, Left: Specifies the presence of overhangs on left windows on the sixth story.
- Sixth Story, Right: Specifies the presence of overhangs on right windows on the sixth story.

**Options**

- None
- 2ft, All Stories, All Windows
- 2ft, First Story, All Windows
- 2ft, First Story, Front Windows
- 2ft, First Story, Back Windows
- 2ft, First Story, Left Windows
- 2ft, First Story, Right Windows

## Airflow Group

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- Air Leakage Category
- Mechanical Ventilation Category
- Natural Ventilation Category

## Air Leakage Category

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For the above-grade living space (including finished attic), air leakage is specified either by ACH50 (air changes per hour at 50 Pascal), or constant annual average ACH (air changes per hour). BEopt uses the AIM-2 method to determine hourly, weather-dependent infiltration flow rates.

In addition to above-grade living space, options here also specify the garage air leakage. All other spaces (e.g. crawlspace, finished/unfinished basement, unfinished attic) have their leakage/ventilation specified in their respective categories.

For multifamily buildings, the air leakage is specified for the entire building. The building's effective leakage area is then apportioned to each unit according to the unit's exposed exterior wall area.

**Properties**

- Above-Grade Living Space ACH50 [1/hr]: Air exchange rate, in Air Changes per Hour at 50 Pascals (ACH50), for above-grade living space (including finished

attic).

- Above-Grade Living Space Constant ACH [1/hr]: Air exchange rate, in natural Air Changes per Hour (ACH), for the living space. Using this variable will override the AIM-2 calculation method with a constant air exchange rate.
- Garage ACH50 [1/hr]: Air exchange rate, in Air Changes per Hour at 50 Pascals (ACH50), for the garage.
- Shelter Coefficient: The local shelter coefficient (AIM-2 infiltration model) accounts for nearby buildings, trees and obstructions. 1.00 - No obstructions or local shielding 0.90 - Light local shielding with few obstructions within two building heights 0.70 - Local shielding with many large obstructions within two building heights 0.50 - Heavily shielded, many large obstructions within one building height 0.30 - Complete shielding with large buildings immediately adjacent auto - Chooses an appropriate value based on the presence of neighbors, the neighbor offset, and the building height.

**Calculated Values**

- Leakage Estimate: 'Typical' and 'Efficient' levels of ACH50 are estimated for the specified building age, climate, and size, based on a statistical analysis of the housing stock by Chan et al. [LBNL Report No. 5966E, 2012]. The 'Efficient' estimate applies to homes that have already participated in an energy efficiency program.
- Above-Grade Living Space ACHn [1/hr]: Air exchange rate, in natural Air Changes per Hour, for the above-grade living space (including finished attic).
- Above-Grade Living Space ELA [sqft]: The area of a theoretical hole in the building envelope that would leak as much as all of the building's actual holes at a pressure difference of 4 Pa.
- Above-Grade Living Space SLA [frac]: Ratio of the effective leakage area (infiltration and/or ventilation) in the above-grade living space to the total floor area of the above-grade living space (including finished attic).

**Options**

- None
- 25 ACH50
- 20 ACH50
- 15 ACH50
- 10 ACH50
- 8 ACH50
- 7 ACH50
- 7 ACH50, 0.5 Shelter Coefficient
- 6 ACH50
- 5 ACH50
- 4 ACH50
- 3 ACH50
- 2 ACH50
- 1 ACH50
- Constant 0.1 ACH

## Mechanical Ventilation Category

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Mechanical ventilation is specified as a fraction of ASHRAE Standard 62.2 ventilation:
CFM = 0.01xFFA + (#BR+1)x7.5 (2010 Standard)
CFM = 0.03xFFA + (#BR+1)x7.5 (2013 Standard)
where FFA = Finished Floor Area and #BR = Number of Bedrooms.

For existing buildings, ASHRAE 62.2 also allows for infiltration credit (not included in the total cfm displayed above). For default options, simulations include infiltration credit. For user options, simulations may or may not include infiltration credit.

ERV (energy recovery ventilation) efficiency refers to the total (sensible + latent) energy recovered. HRV (heating energy ventilation) refers to sensible-only energy recovered.

In addition to the ventilation specified here, BEopt includes a kitchen range hood and spot ventilation fan in each bathroom. The flow rates of the kitchen and bathroom fans are 100 cfm and 50 cfm, respectively, and their efficiency is 0.3 W/cfm. The kitchen range hood operates 60 min/ day (6-7pm) and each bathroom fan operates 60 min/day (7-8 am). Clothes dryer exhaust can be specified in the Clothes Dryer category.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Ventilation Type: Ventilation strategy used (none, exhaust, or balanced.)
- Fraction of ASHRAE 62.2 [frac]: Fraction of the ventilation rate (including any infiltration credit) specified by ASHRAE 62.2 that is desired in the building.
- ASHRAE 62.2 Standard: Specifies which version (year) of the ASHRAE 62.2 Standard should be used.
- Fan Power [W/cfm]: Fan power per delivered airflow rate for each fan providing whole house ventilation. If the house uses a balanced ventilation system there is assumed to be two fans operating at this efficiency; otherwise one fan is assumed.
- Recovery Type: The recovery type (e.g. Heating for HRVs, Energy for ERVs) for balanced mechanical ventilation systems.
- Total Recovery Efficiency: The net total energy (sensible plus latent, also called enthalpy) recovered by the supply airstream adjusted by electric consumption, case heat loss or heat gain, air leakage and airflow mass imbalance between the two airstreams, as a percent of the potential total energy that could be recovered plus the exhaust fan energy. Values for some products can be found at the Home Ventilating Institute (hvi.org).
- Sensible Recovery Efficiency: The net sensible energy recovered by the supply airstream as adjusted by electric consumption, case heat loss or heat gain, air leakage, airflow mass imbalance between the two airstreams and the energy used for defrost (when running the Very Low Temperature Test), as a percent of the potential sensible energy that could be recovered plus the exhaust fan energy. Values for some products can be found at the Home Ventilating Institute (hvi.org).
- Allow Infiltration Credit: Defines whether the infiltration credit allowed per the 2010 or 2013 ASHRAE 62.2 Standards will be included in the calculation of the mechanical ventilation rate. If True, the infiltration credit will apply: - to Single-Family Detached homes in New Construction/Retrofit modes for 2013 ASHRAE 62.2 - to Single-Family Detached or Multi-Family homes in Retrofit mode for 2010 ASHRAE 62.2

**Calculated Values**

- Flow Rate [cfm/unit]: Rated flow capacity of the mechanical ventilation system, using equations specified by ASHRAE 62.2, excluding any infiltration credit. For multifamily buildings, the value is the average across all of the units.
- Total Power [W/unit]: The total electrical power of the mechanical ventilation system. For multifamily buildings, the value is the average across all of the units.
- Number of Fans [#/unit]: The assumed number of fans for the mechanical ventilation system. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- Exhaust, 2010 ASHRAE 62.2
- Exhaust, 2013 ASHRAE 62.2
- Exhaust, 50% of 2010 ASHRAE 62.2
- Supply, 2010 ASHRAE 62.2
- HRV, 60%, 2010 ASHRAE 62.2
- HRV, 70%, 2010 ASHRAE 62.2
- ERV, 72%, 2010 ASHRAE 62.2

## Natural Ventilation Category

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Natural ventilation through opening windows in the house. It is assumed that occupants will open windows when the humidity ratio and relative humidity of the air outside are less than the specified maximum values and when operating within the seasons and days specified by each option. Windows will be closed if the inside air temperature drops below the specified offsets from the heating or cooling setpoint or if natural ventilation cannot meet the cooling load when the inside temperature is above the cooling setpoint.

If no heating and/or cooling setpoint is selected, values of 71F and 76F, respectively, will be used for purposes of defining natural ventilation operation.

Note that natural ventilation will not occur during the vacation periods defined by the Building America House Simulation Protocols.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number Weekdays: Number of weekdays in the week that natural ventilation can occur.
- Number Weekend Days: Number of weekend days in the week that natural ventilation can occur.
- Fraction Window Area Openable [frac]: Specifies the fraction of total window area in the home that can be opened (e.g. typical sliding windows can be opened to half of their area).
- Fraction of Openable Windows Open [frac]: Specifies the fraction of the total openable window area in the building that is opened for ventilation.
- Heating Season Setpoint Offset [degrees F]: The temperature offset below the hourly cooling setpoint, to which the living space is allowed to cool during months that are only in the heating season (as defined by the 2010 Building America House Simulation Protocols).
- Cooling Season Setpoint Offset [degrees F]: The temperature offset above the hourly heating setpoint, to which the living space is allowed to cool during months that are only in the cooling season (as defined by the 2010 Building America House Simulation Protocols).
- Overlap Season Setpoint Offset [degrees F]: The temperature offset above the maximum heating setpoint, to which the living space is allowed to cool during months that are in both the heating season and cooling season (as defined by the 2010 Building America House Simulation Protocols).
- Heating Season: True if windows are allowed to be opened during months that are only in the heating season (as defined by the 2010 Building America House Simulation Protocols).
- Cooling Season: True if windows are allowed to be opened during months that are only in the cooling season (as defined by the 2010 Building America House Simulation Protocols).
- Overlap Season: True if windows are allowed to be opened during months that are in both the heating season and cooling season (as defined by the 2010 Building America House Simulation Protocols).
- Max OA Humidity Ratio [frac]: Outdoor air humidity ratio above which windows will not open for natural ventilation.
- Max OA Relative Humidity [frac]: Outdoor air relative humidity (0-1) above which windows will not open for natural ventilation.

**Calculated Values**

- Days: The days of the week for which natural ventilation is allowed.

**Options**

- None
- Year-Round, 3 days/wk
- Year-Round, 7 days/wk
- Cooling Months Only, 7 days/wk

## Space Conditioning Group

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- Central Air Conditioner Category
- Room Air Conditioner Category
- Furnace Category
- Boiler Category
- Electric Baseboard Category
- Air Source Heat Pump Category
- Mini-Split Heat Pump Category
- Ground Source Heat Pump Category

- Ducts Category
- Ceiling Fan Category
- Dehumidifier Category

## Central Air Conditioner Category

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Most residential central air conditioners are called "split-systems" because they have an outdoor component with a condenser and compressor and an indoor component with an evaporator coil. Central air conditioners provide cooling through a duct system.

SEER (Seasonal Energy Efficiency Ratio) is an estimate of how efficiently a cooling system will operate over an entire season. SEER values shown are nominal rated values; actual performance will vary depending on climate.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation. The auto-sized result is then rounded up to a discrete size for costing purposes. If a unit requires larger than a 5-ton air conditioner, multiple air conditioners will be used for costing.

High SEER air-conditioners tend to decrease in efficiency as the rated capacity increases. This trend has been included for the SEER 18, SEER 21, and SEER 24.5 options using manufacturer data but can be modified by creating a User-Defined option. EER multipliers are applied to the rated EER for 1.5, 2, 3, 4, and 5 ton air-conditioners. The BEopt auto-sized result is used to interpolate between multipliers. For units larger than 5 tons, 2 equally sized units are assumed when adjusting the EER.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Speeds: Number of speeds of the compressor.
- Rated SEER [Btu/W-h]: Seasonal Energy Efficiency Ratio (SEER) is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. Procedures to test SEER are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- Installed SEER [Btu/W-h]: The installed Seasonal Energy Efficiency Ratio (SEER) of the air conditioner, which can be used to account for performance derating or degradation relative to the rated value. SEER is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. Procedures to test SEER are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- EER [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB).
- EER 2 [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB) for the second speed.
- EER 3 [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB) for the third speed.
- EER 4 [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB) for the fourth speed.
- Rated SHR: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity.
- Rated SHR 2: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity for the second speed.
- Rated SHR 3: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity for the third speed.
- Rated SHR 4: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity for the fourth speed.
- Capacity Ratio: Capacity at first compressor speed divided by rated capacity.
- Capacity Ratio 2: Capacity at second compressor speed divided by rated capacity.
- Capacity Ratio 3: Capacity at third compressor speed divided by rated capacity.
- Capacity Ratio 4: Capacity at fourth compressor speed divided by rated capacity.
- Fan Speed Ratio: Fan speed at first compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fan Speed Ratio 2: Fan speed at second compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fan Speed Ratio 3: Fan speed at third compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fan Speed Ratio 4: Fan speed at fourth compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Rated Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the indoor fan under conditions prescribed by AHRI Standard 210/240 for SEER testing
- Installed Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the indoor fan for the maximum fan speed under actual operating conditions
- Condenser Type: For evaporatively cooled units, the performance curves are a function of outdoor wetbulb (not drybulb) and entering wetbulb.
- Crankcase [kW]: Capacity of the crankcase heater for the compressor. To simulate without a crankcase heater, set to zero.
- Crankcase Max Temp [degrees F]: Outdoor dry-bulb temperature above which compressor crankcase heating is disabled.
- 1.5 Ton EER Capacity Derate: EER multiplier for 1.5 ton air-conditioners. This variable can be used to account for a degradation in efficiency for larger units and is applied to the AC_CoolingEER value(s) based on BEopt auto-sizing results.
- 2 Ton EER Capacity Derate: EER multiplier for 2 ton air-conditioners. This variable can be used to account for a degradation in efficiency for larger units and is applied to the AC_CoolingEER value(s) based on BEopt auto-sizing results.
- 3 Ton EER Capacity Derate: EER multiplier for 3 ton air-conditioners. This variable can be used to account for a degradation in efficiency for larger units and is applied to the AC_CoolingEER value(s) based on BEopt auto-sizing results.
- 4 Ton EER Capacity Derate: EER multiplier for 4 ton air-conditioners. This variable can be used to account for a degradation in efficiency for larger units and is applied to the AC_CoolingEER value(s) based on BEopt auto-sizing results.
- 5 Ton EER Capacity Derate: EER multiplier for 5 ton air-conditioners. This variable can be used to account for a degradation in efficiency for larger units and is applied to the AC_CoolingEER value(s) based on BEopt auto-sizing results.

**Calculated Values**

- Compressor: Number of speeds of the compressor.
- Cycling [frac]: The cycling degradation coefficient (c_d).

**Options**

- None
- SEER 8
- SEER 10
- SEER 13
- SEER 14
- SEER 15
- SEER 16
- SEER 16 (2 Stage)
- SEER 17
- SEER 18
- SEER 21
- SEER 24.5
- Ideal AC

## Room Air Conditioner Category

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A room air conditioner is an encased assembly designed as a single unit for mounting in a window or through the wall for the purpose of delivering conditioned air to an enclosed space. Room air conditioners do not use a duct system.

Options are assumed to condition the entire building unless they are denoted as, e.g., "30% Conditioned".

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- EER [Btu/W-h]: This is a measure of the instantaneous energy efficiency of cooling equipment. EER is the steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btu/h divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btu/h per watt (Btu/W-h). Procedures to test EER for central equipment are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B. For room air conditioners the procedures are defined in the American National Standard (ANS) Z234.1-1972, Room Air Conditioners, Sections 4, 5, 6.1, and 6.5, and in the American Society of Heating, Refrigerating and Air Conditioning in Engineers (ASHRAE) Standard 16-69.
- Rated SHR: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity.
- Airflow [cfm/ton]
- Energy Multiplier [frac]: Room air conditioners are modeled as conditioning the entire finished floor area. This multiplier can be used to adjust the cooling energy use to account for, e.g., when the system does not condition the entire living space.

**Options**

- None
- EER 8.5
- EER 9.8
- EER 10.7
- EER 8.5, 30% Conditioned
- EER 9.8, 30% Conditioned
- EER 10.7, 30% Conditioned
- EER 8.5, 20% Conditioned
- EER 9.8, 20% Conditioned
- EER 10.7, 20% Conditioned

## Furnace Category

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Furnaces are the most commonly used residential heating system in the United States. Running most often on gas, but sometimes on oil, propane, or electricity, furnaces deliver their heat through a duct system.

AFUE (Annual Fuel Utilization Efficiency) is an estimate of heating equipment efficiency, represented as a percentage. AFUE values shown are nominal rated values; actual performance will vary depending on climate.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation. The auto-sized result is then rounded up to a discrete size for costing purposes. If a unit requires larger than a 120 kBtu/hr furnace, multiple furnaces will be used for costing.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Fuel Type: Type of fuel used for heating. Typically either natural gas, electricity, propane, or fuel oil.
- Rated AFUE [Btu/Btu]: The Annual Fuel Utilization Efficiency (AFUE) is the measure of seasonal or annual efficiency of a furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls. Procedures to test AFUE are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix N to Subpart B.

Installed AFUE [Btu/Btu]: The installed Annual Fuel Utilization Efficiency (AFUE) of the furnace, which can be used to account for performance derating or degradation relative to the rated value. AFUE is the measure of seasonal or annual efficiency of a furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls. Procedures to test AFUE are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix N to Subpart B.

- Max Supply Temp [degrees F]: Maximum supply air temperature.
- Installed Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the indoor fan for the maximum fan speed under actual operating conditions. Note: This value will only be used if the building does not have a central cooling system with its own fan power specified.
- Has Open Flue: Specifies whether the furnace has an associated flue that is not closed. The presence of a flue affects BEopt's air leakage model.

**Options**

- None
- Electric, 100% AFUE
- Gas, 60% AFUE
- Gas, 64% AFUE
- Gas, 68% AFUE
- Gas, 72% AFUE
- Gas, 76% AFUE
- Gas, 78% AFUE
- Gas, 80% AFUE
- Gas, 90% AFUE
- Gas, 92.5% AFUE
- Gas, 95% AFUE
- Gas, 96% AFUE
- Gas, 98% AFUE
- Oil, 72% AFUE
- Oil, 76% AFUE
- Oil, 78% AFUE
- Oil, 80% AFUE
- Oil, 85% AFUE
- Oil, 90% AFUE
- Oil, 94% AFUE
- Oil, 95% AFUE
- Oil, 96% AFUE
- Propane, 60% AFUE
- Propane, 64% AFUE
- Propane, 68% AFUE
- Propane, 72% AFUE
- Propane, 76% AFUE
- Propane, 78% AFUE
- Propane, 80% AFUE
- Propane, 82% AFUE
- Propane, 90% AFUE
- Propane, 92% AFUE
- Propane, 94% AFUE
- Propane, 96% AFUE

## Boiler Category

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A boiler heats your home by burning gas, propane, or oil to heat water or steam that circulates through baseboards. Boilers do not use a duct system.

AFUE (Annual Fuel Utilization Efficiency) is an estimate of heating equipment efficiency, represented as a percentage. AFUE values shown are nominal rated values; actual performance will vary depending on climate.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation. The auto-sized result is then rounded up to a discrete size for costing purposes. If a unit requires larger than a 120 kBtu/hr boiler, multiple boilers will be used for costing.

For condensing boilers, the default control has no Outdoor Air Temperature Reset. User can go to the Option Editor and switch on the reset control with user defined reset temperature bounds.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Fuel Type: Type of fuel used for heating. Typically either natural gas, electricity, propane, or fuel oil.
- System Type: The system type of the boiler.
- Rated AFUE [Btu/Btu]: The Annual Fuel Utilization Efficiency (AFUE) is the measure of seasonal or annual efficiency of a furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls. Procedures to test AFUE are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix N to Subpart B.
- Installed AFUE [Btu/Btu]: The installed Annual Fuel Utilization Efficiency (AFUE) of the boiler, which can be used to account for performance derating or degradation relative to the rated value. AFUE is the measure of seasonal or annual efficiency of a furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and

occupant controls. Procedures to test AFUE are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix N to Subpart B.
- Design Temperature [F]: Temperature of the outlet water.
- Outside Air Reset Enabled: Outside Air Reset Enabled on Hot Water Supply Temperature
- Low Outside Air Temp [degrees F]: Low Outside Air Temperature
- Hot Water Supply Temp Low Outside Air [degrees F]: Hot Water Supply Temperature Corresponding to Low Outside Air Temperature
- High Outside Air Temp [degrees F]: High Outside Air Temperature
- Hot Water Supply Temp High Outside Air [degrees F]: Hot Water Supply Temperature Corresponding to High Outside Air Temperature
- Has Open Flue: Specifies whether the boiler has an associated flue that is not closed. The presence of a flue affects BEopt's air leakage model.

**Calculated Values**

- HIR [Btu/Btu]: The heating input ratio for the boiler.

**Options**

- None
- Electric, Hot Water, 100% AFUE
- Gas, Hot Water, Forced Draft, 72% AFUE
- Gas, Hot Water, Forced Draft, 76% AFUE
- Gas, Hot Water, Forced Draft, 80% AFUE
- Gas, Hot Water, Forced Draft, 82% AFUE
- Gas, Hot Water, Forced Draft, 85% AFUE
- Gas, Hot Water, Condensing, 95% AFUE, OAT Reset
- Gas, Hot Water, Condensing, 96% AFUE
- Gas, Hot Water, Condensing, 98% AFUE
- Oil, Hot Water, Forced Draft, 72% AFUE
- Oil, Hot Water, Forced Draft, 76% AFUE
- Oil, Hot Water, Forced Draft, 80% AFUE
- Oil, Hot Water, Forced Draft, 82% AFUE
- Oil, Hot Water, Forced Draft, 84% AFUE
- Oil, Hot Water, Forced Draft, 85% AFUE
- Oil, Hot Water, Forced Draft, 87% AFUE
- Oil, Hot Water, Condensing, 90% AFUE
- Oil, Hot Water, Condensing, 95% AFUE
- Oil, Hot Water, Condensing, 96% AFUE
- Propane, Hot Water, Forced Draft, 72% AFUE
- Propane, Hot Water, Forced Draft, 76% AFUE
- Propane, Hot Water, Forced Draft, 80% AFUE
- Propane, Hot Water, Forced Draft, 82% AFUE
- Propane, Hot Water, Forced Draft, 85% AFUE
- Propane, Hot Water, Condensing, 96% AFUE

## Electric Baseboard Category

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Electric baseboard systems have electric heating elements installed in longitudinal panels, usually along the baseboards of exterior walls. Electric baseboard heating does not use a duct system.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Efficiency [Btu/Btu]: The efficiency of the electric baseboard.

**Options**

- None
- 100% Efficiency

## Air Source Heat Pump Category

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Heat pumps provide both heating and cooling in one integrated system. Air source heat pumps, often used in moderate climates, use the difference between outdoor and indoor air temperatures to cool and heat. Air source heat pumps provide heating and cooling through a duct system.

SEER (Seasonal Energy Efficiency Ratio) and HSPF (Heating and Seasonal Performance Factor) are estimates of the efficiency of the heat pump's cooling and heating. SEER and HSPF values shown are nominal rated values; actual performance will vary depending on climate.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation. The auto-sized result is then rounded up to a discrete size for costing purposes. If a unit requires larger than a 5-ton heat pump, multiple heat pumps will be used for costing.

High SEER/HSPF heat pumps tend to decrease in efficiency as the rated capacity increases. This trend has been included for the SEER 18/HSPF 9.3, SEER 19/HSPF 9.5, and SEER 22/HSPF 10.0 options using manufacturer data but can be modified by creating a User-Defined option. EER and COP multipliers are applied to the rated EER for 1.5, 2, 3, 4, and 5 ton heat pumps. The BEopt auto-sized result is used to interpolate between multipliers. For units larger than 5 tons, 2 equally sized units are assumed when adjusting the EER and COP.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Speeds: Number of speeds of the compressor.
- Rated SEER [Btu/W-h]: Seasonal Energy Efficiency Ratio (SEER) is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. Procedures to test SEER are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- Installed SEER [Btu/W-h]: The installed Seasonal Energy Efficiency Ratio (SEER) of the heat pump, which can be used to account for performance derating or degradation relative to the rated value. SEER is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. Procedures to test SEER are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- Rated HSPF [Btu/W-h]: The Heating Seasonal Performance Factor (HSPF) is a measure of a heat pump's energy efficiency over one heating season. It represents the total heating output of a heat pump (including supplementary electric heat) during the normal heating season (in Btu) as compared to the total electricity consumed (in watt-hours) during the same period. Procedures to test HSPF are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- Installed HSPF [Btu/W-h]: The installed Heating Seasonal Performance Factor (HSPF) of the heat pump, which can be used to account for performance derating or degradation relative to the rated value. HSPF is a measure of a heat pump's energy efficiency over one heating season. It represents the total heating output of a heat pump (including supplementary electric heat) during the normal heating season (in Btu) as compared to the total electricity consumed (in watt-hours) during the same period. Procedures to test HSPF are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- EER [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB).
- EER 2 [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB) for the second speed.
- EER 3 [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB) for the third speed.
- EER 4 [kBtu/kWh]: EER (net) from the A test (95 ODB/80 EDB/67 EWB) for the fourth speed.
- COP [Wh/Wh]: COP (net) at 47 ODB/70 EDB/60 EWB (AHRI rated conditions).
- COP 2 [Wh/Wh]: COP (net) at 47 ODB/70 EDB/60 EWB (AHRI rated conditions) for the second speed.
- COP 3 [Wh/Wh]: COP (net) at 47 ODB/70 EDB/60 EWB (AHRI rated conditions) for the third speed.
- COP 4 [Wh/Wh]: COP (net) at 47 ODB/70 EDB/60 EWB (AHRI rated conditions) for the fourth speed.
- Rated SHR: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity.
- Rated SHR 2: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity for the second speed.
- Rated SHR 3: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity for the third speed.
- Rated SHR 4: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity for the fourth speed.
- Capacity Ratio: Capacity at first compressor speed divided by rated capacity.
- Capacity Ratio 2: Capacity at second compressor speed divided by rated capacity.
- Capacity Ratio 3: Capacity at third compressor speed divided by rated capacity.
- Capacity Ratio 4: Capacity at fourth compressor speed divided by rated capacity.
- Fanspeed Ratio Cooling: Cooling fan speed at first compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Cooling 2: Cooling fan speed at second compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Cooling 3: Cooling fan speed at third compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Cooling 4: Cooling fan speed at fourth compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Heating: Heating fan speed at first compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Heating 2: Heating fan speed at second compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Heating 3: Heating fan speed at third compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Fanspeed Ratio Heating 4: Heating fan speed at fourth compressor speed divided by fan speed at the compressor speed for which Capacity Ratio = 1.0 (typically speed 2 for 2-speed units and speed 3 for variable-speed units).
- Rated Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the indoor fan under conditions prescribed by AHRI Standard 210/240 for SEER/HSPF testing
- Installed Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the indoor fan for the maximum fan speed under actual operating conditions
- Condenser Type: For evaporatively cooled units, the performance curves are a function of outdoor wetbulb (not drybulb) and entering wetbulb.
- Min Temp [degrees F]: Outdoor dry-bulb temperature below which compressor turns off
- Crankcase [kW]: Capacity of the crankcase heater for the compressor. To simulate without a crankcase heater, set to zero.
- Crankcase Max Temp [degrees F]: Outdoor dry-bulb temperature above which compressor crankcase heating is disabled.
- 1.5 Ton EER Capacity Derate: EER multiplier for 1.5 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_CoolingEER value(s) based on BEopt auto-sizing results.
- 2 Ton EER Capacity Derate: EER multiplier for 2 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_CoolingEER value(s) based on BEopt auto-sizing results.
- 3 Ton EER Capacity Derate: EER multiplier for 3 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_CoolingEER value(s) based on BEopt auto-sizing results.
- 4 Ton EER Capacity Derate: EER multiplier for 4 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_CoolingEER value(s) based on BEopt auto-sizing results.
- 5 Ton EER Capacity Derate: EER multiplier for 5 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is

applied to the HP_CoolingEER value(s) based on BEopt auto-sizing results.
- 1.5 Ton COP Capacity Derate: COP multipliers for 1.5 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_HeatingCOP value(s) based on BEopt auto-sizing results.
- 2 Ton COP Capacity Derate: COP multipliers for 2 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_HeatingCOP value(s) based on BEopt auto-sizing results.
- 3 Ton COP Capacity Derate: COP multipliers for 3 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_HeatingCOP value(s) based on BEopt auto-sizing results.
- 4 Ton COP Capacity Derate: COP multipliers for 4 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_HeatingCOP value(s) based on BEopt auto-sizing results.
- 5 Ton COP Capacity Derate: COP multipliers for 5 ton heat pumps. This variable can be used to account for a degradation in efficiency for larger units and is applied to the HP_HeatingCOP value(s) based on BEopt auto-sizing results.
- Size For Max Load: If set to True, the BEopt autosizing algorithm will use the maximum of the heating and cooling loads to set the heat pump capacity, based on the heating/cooling capacities under design conditions. If set to False, the regular BEopt autosizing algorithm will be used, which uses the cooling load to set the heat pump capacity, with up to 1.3x oversizing allowed for variable-speed equipment in colder climates when the heating load exceeds the cooling load (per ACCA Manual S).

**Calculated Values**

- Compressor: Number of speeds of the compressor.
- Cooling Cycling [frac]: The cycling degradation coefficient (c_d) for cooling.
- Heating Cycling [frac]: The cycling degradation coefficient (c_d) for heating.

**Options**

- None
- SEER 8, 6.0 HSPF
- SEER 10, 6.2 HSPF
- SEER 13, 7.7 HSPF
- SEER 14, 8.2 HSPF
- SEER 15, 8.5 HSPF
- SEER 16, 8.6 HSPF
- SEER 17, 8.7 HSPF
- SEER 18, 9.3 HSPF
- SEER 19, 9.5 HSPF
- SEER 22, 10 HSPF

## Mini-Split Heat Pump Category

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Heat pumps provide both heating and cooling in one integrated system. Mini-split heat pumps are also called ductless heat pumps, multi-split, or variable refrigerant flow (VRF) heat pump systems. Like air source heat pumps, they have two main components: an outdoor compressor/condenser and an indoor air-handling unit. The indoor and outdoor units are linked via conduit that houses the refrigerant and power cables. Mini-split heat pumps do not use a duct system.

The following inputs for this model are available in, or can be derived from, NEEP's Cold Climate Air-Source Heat Pump Specification Listing spreadsheet: Rated SEER, Rated HSPF, Heating Capacity Offset, Minimum Heating Capacity [frac], Maximum Heating Capacity [frac], Heating Capacity Retention Fraction/Temperature, and Pan Heater Power. These properties are related and one should not be changed without changing the others. In general, the remaining inputs related to airflow, SHR, etc. can be left at their default values.

All BEopt options are modeled as variable-speed systems. Note that efficiency and retention of heating capacity at colder temperatures is highly related to system size; therefore, the system size (nominal cooling capacity) is included in each option name.

Options are assumed to condition the entire building unless they are denoted as, e.g., "30% Conditioned". Options in the Electric Baseboard category may also be selected to allow supplemental heating.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Rated SEER [Btu/W-h]: Seasonal Energy Efficiency Ratio (SEER) is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. Procedures to test SEER are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B.
- Minimum Cooling Capacity [frac]: Minimum cooling capacity as a fraction of the nominal cooling capacity at rated conditions.
- Maximum Cooling Capacity [frac]: Maximum cooling capacity as a fraction of the nominal cooling capacity at rated conditions.
- Rated SHR: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity.
- Minimum Cooling Airflow [cfm/ton]: Minimum cooling cfm divided by the nominal rated cooling capacity
- Maximum Cooling Airflow [cfm/ton]: Maximum cooling cfm divided by the nominal rated cooling capacity
- Rated HSPF [Btu/W-h]: The Heating Seasonal Performance Factor (HSPF) is a measure of a heat pump's energy efficiency over one heating season. It represents the total heating output of a heat pump (including supplementary electric heat) during the normal heating season (in Btu) as compared to the total electricity consumed (in watt-hours) during the same period. Procedures to test HSPF are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B. For units with an integrated pan heater, this should be the Rated HSPF of an equivalent unit without a pan heater, which typically reduces the Rated HSPF by 0.1-1.0 points.
- Heating Capacity Offset [Btu/h]: The difference between the nominal rated heating capacity and the nominal rated cooling capacity. The heating capacity is calculated by adding this value to the cooling capacity.
- Minimum Heating Capacity [frac]: Minimum heating capacity as a fraction of nominal heating capacity at rated conditions. Can be derived from NEEP's Cold Climate Air-Source Heat Pump Specification Listing spreadsheet.
- Maximum Heating Capacity [frac]: Maximum heating capacity as a fraction of nominal heating capacity at rated conditions. Can be derived from NEEP's Cold

Climate Air-Source Heat Pump Specification Listing spreadsheet.

- Minimum Heating Airflow [cfm/ton]: Minimum heating cfm divided by the nominal rated heating capacity
- Maximum Heating Airflow [cfm/ton]: Maximum heating cfm divided by the nominal rated heating capacity
- Heating Capacity Retention Fraction [frac]: The maximum heating capacity at X degrees F divided by the maximum heating capacity at 47 degrees F. The value for X is input in the "Heating Capacity Retention Temperature [F]" field. Can be derived from NEEP's Cold Climate Air-Source Heat Pump Specification Listing spreadsheet. BEopt uses a linear relationship between this point and the rating point to determine maximum heating capacity as a function of outdoor temperature.
- Heating Capacity Retention Temperature [F]: The outdoor drybulb temperature at which the heating capacity retention fraction is defined.
- Pan Heater [W/unit]: MSHPs designed for use in cold climates often include a pan heater in the outdoor unit as an optional or integrated accessory, to prevent ice build up from damaging the coil. This field specifies the power of the pan heater included in each outdoor unit. Pan heaters are assumed to operate when the compressor is running and the outdoor drybulb is less than 32 degrees F. Note that the pan heater typically reduces the Rated HSPF by 0.1–1.0 points; units with integrated pan heaters should use the Rated HSPF input of an equivalent unit without a pan heater. This input is available in NEEP's Cold Climate Air-Source Heat Pump Specification Listing spreadsheet. It is assumed that a new outdoor unit is needed every 1.5 tons (nominal cooling capacity).
- Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the fan.
- Size For Max Load: If set to True, the BEopt autosizing algorithm will use the maximum of the heating and cooling loads to set the heat pump capacity, based on the heating/cooling capacities under design conditions. If set to False, the regular BEopt autosizing algorithm will be used, which uses the cooling load to set the heat pump capacity, with up to 1.3x oversizing allowed for variable-speed equipment in colder climates when the heating load exceeds the cooling load (per ACCA Manual S).
- Energy Multiplier [frac]: Mini-split heat pumps are modeled as conditioning the entire finished floor area. This multiplier can be used to adjust the heating/cooling energy use to account for, e.g., when the system does not condition the entire living space.

**Calculated Values**

- Cooling Cycling [frac]: The cycling degradation coefficient (c_d) for cooling.
- Heating Cycling [frac]: The cycling degradation coefficient (c_d) for heating.

**Options**

- None
- A - 9 kBtuh/unit - SEER 14.5, 8.2 HSPF
- A - 12 kBtuh/unit - SEER 14.5, 8.2 HSPF
- A - 15 kBtuh/unit - SEER 14.5, 8.2 HSPF
- B - 9 kBtuh/unit - SEER 19, 9.8 HSPF
- B - 12 kBtuh/unit - SEER 18, 9.6 HSPF
- B - 15 kBtuh/unit - SEER 17, 9.4 HSPF
- C - 9 kBtuh/unit - SEER 26, 10.7 HSPF
- C - 12 kBtuh/unit - SEER 23, 10.5 HSPF
- C - 15 kBtuh/unit - SEER 20, 10.3 HSPF
- D - 9 kBtuh/unit - SEER 30, 13.5 HSPF
- D - 12 kBtuh/unit - SEER 26, 12.5 HSPF
- D - 15 kBtuh/unit - SEER 22, 12 HSPF
- E - 9 kBtuh/unit - SEER 33, 14.2 HSPF
- E - 12 kBtuh/unit - SEER 29.3, 14 HSPF
- E - 15 kBtuh/unit - SEER 25.3, 13.4 HSPF
- E - 12 kBtuh/unit - SEER 29.3, 14 HSPF, Size for max load
- B - 12 kBtuh/unit - SEER 18, 9.6 HSPF, 70% Conditioned

## Ground Source Heat Pump Category

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Heat pumps provide both heating and cooling in one integrated system. Ground source heat pumps (sometimes called geothermal heat pumps), are similar to air source heat pumps, but use the ground instead of outside air to provide heating and cooling. Ground source heat pumps provide heating and cooling through a duct system.

All BEopt options are modeled with vertical bore field configuration.

For new construction or for autosizing within retrofit analysis, a calculation consistent with ACCA's Manual J 8th Edition is performed to auto-size the equipment for the annual simulation. The auto-sized result is then rounded up to a discrete size for costing purposes. If a unit requires larger than a 5-ton heat pump, multiple heat pumps will be used for costing.

BEopt auto adjusts ground heat exchanger pumping power, and indoor fan power (using a default efficiency consistent with air source heat pumps).

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- COP [W/W]: User can use AHRI/ ASHRAE ISO 13556-1 rated EER value and convert it to EIR here. System will auto adjust based on AHRI rated condition and estimated user input pump head and estimated total AHU & duct static pressure drop of 1.0 inch w.g. (Default system internal static pressure drop 0.5 in.w.g with external duct system at 0 in.w.g, and condenser coil water pressure drop of 11 feet at rated condition, there may be slight variance between system to system, estimated is average value). Also note: In EnergyPlus, fan and pumping power and their motor heat into air or fluid stream are both counted separately, so the fan and pump power above cannot be zeroed out.
- EER [Btu/W-h]: This is a measure of the instantaneous energy efficiency of cooling equipment. EER is the steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btu/h divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btu/h per watt (Btu/W-h). Procedures to test EER for central equipment are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix M to Subpart B. For room air conditioners the procedures are defined in the American National Standard (ANS) Z234.1-1972, Room Air Conditioners, Sections 4, 5, 6.1, and 6.5, and in the American Society of Heating, Refrigerating and Air Conditioning in Engineers (ASHRAE) Standard 16-69.
- Heat Exchanger Type: Vertical bore is the only available option currently.

- Ground Conductivity [Btu/h-ft-R]: For vertical bore Field: There are three ways to estimate the thermal conductivity and diffusivity of the soil or rock into which the GHEX are installed: 1. best guess of what the formation contains for areas where geology is very consistent with depth. 2. averaging the thermal conductivity and diffusivity based on depth. Information can be obtained from county geologic maps, drill logs from water well or other drilled excavations. 3. Formation Thermal Conductivity (FTC) test. For Horizonal Trench: soil thermal conductivity and diffusivity vary with soil water contents. But the values are normally averaged between the wilting point and the field capacity of the soil. Refer to GSHP design guideline. Default to 0.75, value between 0.2 to 1.
- Grout Conductivity [Btu/h-ft-R]: Grout thermal conductivity, default to 0.8 (thermally enhanced grout), value between 0.2 to 1. Grout is used to enhance heat transfer between the pipe and the ground. Use thermally enhanced grout can effectively reduce the heat exchanger size. Common grout is Bentonite based.
- Bore Configuration: Different types of vertical bore configuration results in different G-functions which captures the thermal response of a bore field.
- Number of Bore Holes: Number of vertical bores, autosized
- Bore Depth [ft]: Vertical well bore depth typically range from 150 to 300 feet deep. Beopt default to autosize.
- Bore Spacing [ft]: Bore holes are typically spaced 15 to 20 feet apart, default to 20 feet.
- Bore Diameter [in]: Bore hole diameter, default to 5.0 inch
- Nominal Pipe Size [in]: Pipe norminal size 3/4" or 1", DR 11 HDPE is used as default.
- Ground Diffusivity [ft^2/h]: A measure of thermal inertia, the ground diffusivity is the thermal conductivity divided by density and specific heat capacity
- Heat Exchanger Fluid Type: Fluid type
- Fraction Glycol [frac]: Fraction of glycol, 0 indicates water.
- Ground Loop Design Delta Temp [F]: Ground loop design temperature difference, default to 10°F.
- Pump Head [ft of water]: Default pump head, default to 45 feet of water column
- U Tube Leg Separation [in]: U-tube leg spacing, default to 2.9 inch.
- Heat Exchanger U Tube Spacing Type: U-tube shank spacing type, default to Type B, for 5" bore, this is equivalent to 0.966 inch shank spacing. Type C is the type where the U tube legs are farthest apart.
- Rated SHR: The sensible heat ratio (ratio of the sensible portion of the load to the total load) at the nominal rated capacity.
- Supply Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm) of the indoor fan

**Calculated Values**

- HX Bore [ft/ton]: With proper (auto) ground heat exchanger sizing, thermally enhanced grout or high ground thermal conductivity will result in less heat exchanger bore length (bore depth times number of bores) with similar energy savings, but reduced first cost and annual energy related cash flow. Note that bore length is the larger value required between heating and cooling. Increased GSHP efficiency will result in decreasing bore length needed for cooling and increasing bore length needed for heating; at some efficiency level, the two trends can intersect, causing a discontinuity in the displayed bore length trend.

**Options**

- None
- EER 16.6, COP 3.6, Low-k soil, Std grout
- EER 18.2, COP 3.7, Low-k soil, Std grout
- EER 19.4, COP 3.8, Low-k soil, Std grout
- EER 20.2, COP 4.2, Low-k soil, Std grout
- EER 16.6, COP 3.6, Low-k soil, Enh grout
- EER 18.2, COP 3.7, Low-k soil, Enh grout
- EER 19.4, COP 3.8, Low-k soil, Enh grout
- EER 20.2, COP 4.2, Low-k soil, Enh grout
- EER 16.6, COP 3.6, High-k soil, Enh grout
- EER 18.2, COP 3.7, High-k soil, Enh grout
- EER 19.4, COP 3.8, High-k soil, Enh grout
- EER 20.2, COP 4.2, High-k soil, Enh grout

## Ducts Category

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The location of the ducts can be user-specified or automatically determined based on the types of spaces in the building (e.g., basements) according to the Building America House Simulation Protocols.

The displayed R-Value is for ducts in unconditioned spaces. The displayed Leakage Fraction is total leakage (supply + return), including any air handler leakage, as a fraction of total air handler airflow.

The displayed surface areas are for the supply and return sides, respectively. User options can specify these areas as a fraction of Building America Benchmark's duct surface area, which varies based on number of stories and finished floor area.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Total Leakage: The total amount of air flow leakage expressed as a fraction of the total air flow rate.
- Supply Leakage Fraction of Total: The amount of air flow leakage leaking out from the supply duct expressed as a fraction of the total duct leakage.
- Return Leakage Fraction of Total: The amount of air flow leakage leaking into the return duct expressed as a fraction of the total duct leakage.
- Supply Air Handler Leakage Fraction of Total: The amount of air flow leakage leaking out from the supply-side of the air handler expressed as a fraction of the total duct leakage.
- Return Air Handler Leakage Fraction of Total: The amount of air flow leakage leaking out from the return-side of the air handler expressed as a fraction of the total duct leakage.
- Leakage to Outside at 25Pa [cfm/100 ft^2 Finished Floor]: Normalized leakage to the outside when tested at a pressure differential of 25 Pascals (0.1 inches w.g.) across the system. The following assumptions are made for modeling: supply and return duct average operating pressures are both 25 Pa; 67% of the specified leakage is on the supply side, 33% on the return side; includes air handler (AH) leakage of 2.5% of AH flow rate; 20% of AH leakage is on the supply side, 80% on the return side. These assumptions are based on 2013 RESNET Standards (Appendix A) and ASHRAE Standard 152-2004.
- Insulation Nominal R-Value [h-ft^2-R/Btu]: The nominal R-value for duct insulation. The actual R-values used for the simulation are calculated from the nominal R-value based on "True R-Values of Round Residential Ductwork" by Palmiter & Kruse (2006).
- Location: The space with the primary location of ducts. Specifying Living, FinishedBasement or FinishedAttic results in ducts in conditioned space. Specifying

Auto uses the following priority of spaces to determine the location, loosely based on the Building America House Simulation Protocols: FinishedBasement, UnfinishedBasement, Crawlspace, PierBeam, UnfinishedAttic, Garage, FinishedAttic, Living. For multifamily buildings, the 'auto' duct location algorithm is applied to each unit individually. For a unit to have ducts in an unconditioned space, the unit must be adjacent to that space. Use 'Living' to represent ducts in conditioned plenum space (and increase the Wall Height on the Geometry Screen to account for floor-to-floor heights that include plenums).

- Location Fraction: Fraction of supply ducts in the space specified by Duct Location; the remainder of supply ducts will be located in above-grade conditioned space. Use 'Auto' for the Building America House Simulation Protocols values: - One-story homes: 1.0 - Two-story or higher homes: 0.65
- Supply Surface Area Multiplier: Values specify a fraction of the Building America Benchmark supply duct surface area. The Building America Benchmark supply duct surface area is defined as: - One-story homes: 0.27 x (Finished Floor Area) - Two-story or higher homes: 0.20 x (Finished Floor Area) Duct surface area is used to calculate conduction losses and does not affect leakage.
- Return Surface Area Multiplier: Values specify a fraction of the Building America Benchmark return duct surface area. The Building America Benchmark return duct surface area is defined as: - One-story homes: 0.05 x (# Returns) x (Finished Floor Area), with a maximum of 0.25 x (Finished Floor Area) - Two-story or higher homes: 0.04 x (# Returns) x (Finished Floor Area), with a maximum of 0.19 x (Finished Floor Area) Duct surface area is used to calculate conduction losses and does not affect leakage.
- Number of Returns: The number of duct returns. This affects the amount of return duct surface area for conduction losses. Use 'Auto' for the Building America House Simulation Protocols values: - Detached homes: 1 + Number of stories (finished basement and finished attic count as a story) - Attached homes: 0
- Distribution System Efficiency: A system efficiency factor, not included in manufacturer's equipment performance ratings for heating and cooling equipment, that adjusts for the energy losses associated with the delivery of energy from the equipment to the source of the load, such as energy losses associated with heat transfer across duct or piping walls and air leakage to or from forced air distribution systems.

**Calculated Values**

- Location: The primary location of the ducts. For multifamily buildings, this is a list of the unique duct locations for the units in the buildings.
- Supply Area [sqft/unit]: The supply duct surface area, calculated based on the finished floor area. For multifamily buildings, the value is averaged across all of the units.
- Return Area [sqft/unit]: The return duct surface area, calculated based on the finished floor area and the number of duct returns. For multifamily buildings, the value is averaged across all of the units.
- Supply/Return Actual R-Values [h-ft^2-R/Btu]: The actual R-values of the ducts are calculated from the nominal R-value based on "True R-Values of Round Residential Ductwork" by Palmiter & Kruse (2006).

**Options**

- None
- 30% Leakage, Uninsulated
- 30% Leakage, R-4
- 30% Leakage, R-6
- 30% Leakage, R-8
- 20% Leakage, Uninsulated
- 20% Leakage, R-4
- 20% Leakage, R-6
- 20% Leakage, R-8
- 15% Leakage, Uninsulated
- 15% Leakage, R-4
- 15% Leakage, R-6
- 15% Leakage, R-8
- 10% Leakage, Uninsulated
- 10% Leakage, R-4
- 10% Leakage, R-6
- 10% Leakage, R-8
- 7.5% Leakage, Uninsulated
- 7.5% Leakage, R-4
- 7.5% Leakage, R-6
- 7.5% Leakage, R-8
- 8 CFM25 per 100ft2, Uninsulated
- 8 CFM25 per 100ft2, R-4
- 8 CFM25 per 100ft2, R-6
- 8 CFM25 per 100ft2, R-8
- 4 CFM25 per 100ft2, Uninsulated
- 4 CFM25 per 100ft2, R-4
- 4 CFM25 per 100ft2, R-6
- 4 CFM25 per 100ft2, R-8
- In Finished Space
- * 15% Leakage, R-6, 50% Surface Area, 1 return
- 0.8 DSE
- 0.9 DSE

## Ceiling Fan Category

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BEopt calculates ceiling fan electrical power use and possible cooling energy reductions.

Options specifications:
1) number of fans -- either absolute or based on coverage, where 100% equals one ceiling fan per 300 square feet of floor area
2) efficiency -- either standard or efficient, where efficient reduces power by 50%
3) occupancy control -- either typical or "smart", where "smart" assumes occupants only use the fans when needed and fan energy is reduced by 50%
4) cooling set point offset -- equivalent thermal comfort with cooling setpoints up to 4 F higher, if adequate ceiling fan coverage

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Coverage [frac]: Fraction of house conditioned by fans where # of fans = (above-grade finished floor area)(% coverage)/300.
- Specified Number [#/unit]: Total number of fans - instead of specifying the number of fans via % coverage, this value directly specifies the number of fans. For multifamily buildings, the value is the average across all of the units.
- Power [W]: Power consumption per fan assuming it runs at medium speed.
- Control: "Typical" indicates half of the fans will be on whenever the interior temperature is above the cooling set point; "Smart" indicates 50% of the energy consumption of "Typical."
- Use Benchmark Energy: Use the energy value specified in the BA Benchmark: 77.3 + 0.0403 x FFA kWh/yr, where FFA is Finished Floor Area
- Cooling Setpoint Offset [degrees F]: Increase in cooling set point due to fan usage.

**Calculated Values**

- Fans [#/unit]: The number of ceiling fans. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- National Average
- Standard Efficiency
- High Efficiency
- Premium Efficiency
- Standard Efficiency, 2 Fans
- Standard Efficiency, 3 Fans
- Standard Efficiency, 4 Fans
- Standard Efficiency, 5 Fans
- Standard Efficiency, 50% Coverage
- Premium Efficiency, 50% Coverage, Smart
- Standard Efficiency, 100% Coverage, Smart, 4 Deg F
- Premium Efficiency, 100% Coverage, Smart, 4 Deg F

## Dehumidifier Category

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Whole-house, direct-expansion dehumidifier. Removes moisture from the living space to meet the relative humidity setpoint. Dehumidifier water removal rates can be determined by BEopt or entered by the user. This option is not intended to model point-source dehumidification equipment, such as basement dehumidifiers.

Note that any dehumidification energy will appear in the Electric Cooling end use.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Energy Factor [L/kWh]: The energy efficiency of dehumidifiers is measured by its energy factor, in liters of water removed per kilowatt-hour (kWh) of energy consumed or L/kWh. Rated energy factor is at inlet condition of 80 deg-F DB and 60% RH. If 'Auto' is entered, BEopt will use ENERGY STAR criteria to determine the energy factor.
- Water Removal Rate [Pints/day]: Dehumidifier rated water removal rate measured in pints per day at an inlet condition of 80°F DB/60%RH. Typically determined by two factors: the size of the space that needs to be dehumidified and the conditions that exist in the space before dehumidification. If 'Auto' is entered, BEopt will use building inputs and climatic information to size the dehumidifier.
- Air Flow Rate [cfm]: The dehumidifier rated air flow rate in CFM. If 'Auto' is entered, BEopt will determine the air flow using the rated water removal rate.
- Configuration: The configuration of the dehumidifier. Only affects costing. If 'auto' is selected, dehumidifiers larger than 70 pints/day will be ducted.

**Options**

- None
- Autosized, Standalone
- Autosized, Ducted
- 25 pints/day, Standalone
- 30 pints/day, Standalone
- 45 pints/day, Standalone
- 65 pints/day, Standalone
- 70 pints/day, Ducted
- 90 pints/day, Ducted
- 110 pints/day, Ducted
- 150 pints/day, Ducted

## Space Conditioning Schedules Group

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- Cooling Set Point Category
- Heating Set Point Category
- Humidity Set Point Category

## Cooling Set Point Category

Options specify 24-hour profiles and separate schedules for weekdays and weekends.

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen.

**Properties**

- Is Programmable Thermostat: Specifies whether there is a programmable thermostat.
- Constant Setpoint [degrees F]: Constant cooling setpoint for every hour. If 'auto' is specified, a variable setpoint schedule will be used based on Residential Energy Consumption Survey (RECS) 2009 data for the location's heating degree days.
- Schedule [degrees F]: Cooling setpoint schedule
- DR Schedule [degrees F]: The cooling set point schedule for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.

**Calculated Values**

- Weekday Setup [hours]: The hours of temperature setup for the weekdays.
- Weekend Setup [hours]: The hours of temperature setup for the weekends.

**Options**

- None
- 69 F
- 70 F
- 71 F
- 72 F
- 73 F
- 74 F
- 75 F
- 76 F
- 77 F
- 78 F
- 79 F
- 80 F
- 76 F w/ Setup 85 F (wkday)
- 76 F w/ Setup 81 F
- Demand Response, 76 F w/ Direct Load Control
- Demand Response, 76 F w/ Direct Load Control and Precooling

## Heating Set Point Category

Options specify 24-hour profiles and separate schedules for weekdays and weekends.

**Properties**

- Is Programmable Thermostat: Specifies whether there is a programmable thermostat.
- Constant Setpoint [degrees F]: Constant heating setpoint for every hour. If 'auto' is specified, a variable setpoint schedule will be used based on Residential Energy Consumption Survey (RECS) 2009 data for the location's cooling degree days.
- Schedule [degrees F]: Heating setpoint schedule.

**Calculated Values**

- Weekday Setback [hours]: The hours of temperature setback for the weekdays.
- Weekend Setback [hours]: The hours of temperature setback for the weekends.

**Options**

- None
- 63 F
- 64 F
- 65 F
- 66 F
- 67 F
- 68 F
- 69 F
- 70 F
- 71 F
- 72 F
- 73 F
- 74 F
- 75 F
- 71 F w/ Setback 65 F
- 71 F w/ Setback 65 F (wkdy)

## Humidity Set Point Category

Humidity set point is only used when a dehumidifier has been included. The humidity set point is applied only to the living zone and is constant for the entire year.

**Properties**

- Annual Relative Humidity Setpoint [frac]: The annual relative humidity setpoint.

**Options**

- None
- 45% RH
- 50% RH
- 55% RH
- 60% RH
- 65% RH

## Water Heating Group

- Water Heater Category
- Distribution Category
- Central Water Heater Category
- Central Distribution Category
- Solar Water Heating Category
- Solar Water Heating Azimuth Category
- Solar Water Heating Tilt Category

## Water Heater Category

The HPWH options are based on generic models illustrating different performance levels possible with HPWH technology. Details of compressor efficiency, control logic, etc. are available via the Options Editor. For HPWH performance evaluation results, see Sparn B, Hudon K, Christensen D. 'Laboratory Performance Evaluation of Residential Integrated Heat Pump Water Heaters.' NREL/TP-5500-52635. September 2011.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Type: Water heater type.
- Fuel Type: Type of fuel used for heating. Typically either natural gas, electricity, propane, or fuel oil.
- Volume [gal]: Nominal tank volume. For multifamily buildings, the value is the average across all of the units. A value of 'auto' will autosize the water heater based on the Building America House Simulation Protocols.
- Rated Energy Factor: For Water Heaters, Energy Factor is the ratio of useful energy output from the water heater to the total amount of energy delivered to the water heater. The higher the EF is, the more efficient the water heater. Procedures to test the EF of water heaters are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix E to Subpart B.
- Installed Energy Factor: The installed Energy Factor (EF) of the water heater, which can be used to account for performance derating or degradation relative to the rated value. Energy Factor is the ratio of useful energy output from the water heater to the total amount of energy delivered to the water heater. The higher the EF is, the more efficient the water heater. Procedures to test the EF of water heaters are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix E to Subpart B. For heat pump water heaters, this input is only used for calculating RESNET's Energy Rating Index (ERI).
- Recovery Efficiency [frac]: For Water Heaters, the recovery efficiency is the ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater. Test procedures to test recovery efficiency are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix E to Subpart B. This information can often be found in the AHRI Certification Directory or on the EnergyStar website.
- Cycling Derate [frac]: Annual energy derate for cycling inefficiencies -- accounts for the impacts of thermal cycling and small hot water draws on the heat exchanger that are not currently reflected in the Energy Factor test procedure. CEC's 2008 Title24 implemented a 8% derate for tankless water heaters.
- First Hour Rating [gal]: A measure of the capability of a water heater to meet peak demands.
- Input-Electric [kW]: The maximum energy input rating of an electric water heater.
- Input-Fuel [kBtu/h]: The maximum energy input rating of a gas, propane, or fuel oil water heater.
- Forced Draft Fan Power [W]: On cycle electric power draw from the forced draft fan motor.
- Parasitic Electric Power [W]: Off cycle electric power draw for controls, etc.
- Location: The code-word for the location of the water heater. Use 'Auto' for the Building America House Simulation Protocols location: - Hot-Humid & Hot-Dry BA zones: Attached garage if one exists, otherwise in conditioned space - Other BA zones: Basement if one exists, otherwise in conditioned space
- Setpoint [degrees F]: Water heater setpoint temperature. For electric water heaters, both top and bottom setpoints will use this temperature.
- HPWH Min Ambient Temp [degrees F]: The minimum ambient temperature at which the HPWH compressor will operate
- HPWH Max Ambient Temp [degrees F]: The maximum ambient temperature at which the HPWH compressor will operate
- HPWH Compressor Input [kW]: Input power of HPWH compressor at rated conditions
- HPWH COP: COP of HPWH compressor at rated conditions. This is the gross COP of the compressor, defined as the ratio of compressor power to heating capacity (it does not include fan power or any auxiliary power).
- HPWH Rated SHR: Sensible Heat Ratio (ratio of the sensible portion of the load to the total load) of the heat pump water heater's evaporator at rated conditions. This is the net SHR of the evaporator and includes the effects of fan heat.
- HPWH Airflow Rate [cfm]: Air flow rate of the the heat pump water heater.
- HPWH Fan Power [W/cfm]: Fan power (in W) per delivered airflow rate (in cfm)
- HPWH Parasitics [W]: Parasitic electricity consumption of the heat pump water heater.
- HPWH Tank UA [Btu/h-R]: The overall UA of the tank (HPWH only).

- HPWH Interaction Factor: Specifies how much the HPWH space conditioning impact interacts with the building's HVAC equipment. This can be used to account for, e.g., the situation where a HPWH is in a closet and only a portion of the HPWH's space cooling affects the HVAC system.
- HPWH Temperature Depression [degrees F]: The reduction in ambient air temperature in the space where the water heater is located. This variable can be used to simulate the impact the HPWH has on its own performance when installing in a confined space such as a utility closet.
- HPWH Ducting: Specifies where the HPWH pulls air from/exhausts to. The HPWH can currently only be ducted outside of the home, not to different zones within the home.
- Has Open Flue: Specifies whether the water heater has an associated flue that is not closed. The presence of a flue affects BEopt's air leakage model.

**Calculated Values**

- Energy Factor: For water heaters, Energy Factor is the ratio of useful energy output from the water heater to the total amount of energy delivered to the water heater. For multifamily buildings, the value is averaged across all of the units.
- Tank Volume [gal/unit]: Nominal volume of the water heater tank. For multifamily buildings, the value is the average across all of the units.
- Location: The location of the water heater.
- Unmet Showers [%/unit]: % Unmet Showers is an estimate of the percent of annual showering time with water leaving the HPWH below 110 deg F. The value shown uses the Benchmark shower flow rate (2.25 gpm). This metric is meant to assist users in selecting HPWH options that maintain an acceptable level of hot water delivery. It is a function of HPWH tank volume, setpoint, climate, and number of bedrooms; and it assumes the HPWH is in conditioned space. This metric does not account for the effect that some BEopt options (e.g. low-flow fixtures, demand recirc. or clothes washer options) might have on hot water draw volume or mixed water temperature. The metric is sensitive to the timing of hot water use and thus real world values will vary considerably from one set of occupants to the next. The % Unmet Showers metric is only available for 50 or 80 gal HPWHs. For multifamily buildings, the value is averaged across all of the units.

**Options**

- None
- Electric Benchmark
- Electric Standard
- Electric Premium
- Electric Tankless
- Gas Benchmark
- Gas Standard
- Gas Premium
- Gas Premium, Condensing
- Gas Tankless
- Gas Tankless, Condensing
- Oil Standard
- Oil Premium
- Propane Standard
- Propane Premium
- Propane Premium, Condensing
- Propane Tankless
- HPWH, 50 gal
- HPWH, 50 gal, 140 F
- HPWH, 50 gal, Exhaust Ducting
- HPWH, 50 gal, In Confined Space
- HPWH, 80 gal
- Ideal Water Heater

## Distribution Category

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Hot water distribution systems impact the volume of hot water from the water heater required to meet the delivered hot water loads at the fixtures, internal heat gains to the building, and possibly recirculation pump energy (based on Table 18 in the 2009 Building America Benchmark).

Insulated options assume the pipe is completely insulated and that there are no gaps along the pipe or at elbows and tees. Timer recirculation control assumes 16 hours of daily pump operation from 6am to 10pm. Demand recirculation controls assume push button control at all non-appliance fixtures with 100% ideal control (button pushed for every draw event, no false signals, and immediate use of hot water when it arrives at the fixture). User options not covered by the BA Benchmark House Simulation Protocols will be modeled as the Benchmark distribution system.

Recirculation pump energy will appear in the Hot Water end use.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Pipe Material: The plumbing material.
- Pipe Layout: The plumbing layout of the hot water distribution system. Trunk and branch uses a main trunk line to supply various branch take-offs to specific fixtures. In the home run layout, all fixtures are fed from dedicated piping that runs directly from central manifolds.
- Pipe Location: The primary location of the pipes. Interior implies that the pipes are in the living space, finished attic, or basement. Any other space is considered Exterior.
- Recirculation Type: The type of hot water recirculation control, if any. Timer recirculation control assumes 16 hours of daily pump operation from 6am to 10pm. Demand recirculation controls assume push button control at all non-appliance fixtures with 100% ideal control (button pushed for every draw event, no false signals, and immediate use of hot water when it arrives at the fixture).
- Insulation Nominal R-Value [h-ft^2-R/Btu]: The nominal R-value for hot water pipe insulation.
- Pipe Length [ft]: The total length of DHW pipes in the home. This is only used for costing purposes. If 'auto' is selected, the an equation from DEG's "Documentation of Hot Water Distribution Systems in 60 Calif Production Homes" will be used: 366 + 0.1322*(FFA-2432) + 86*(N_bathrooms-2.85)

**Options**

- None
- Uninsulated, TrunkBranch, Copper
- Uninsulated, TrunkBranch, PEX
- Uninsulated, HomeRun, PEX
- R-2, TrunkBranch, Copper
- R-2, TrunkBranch, PEX
- R-2, HomeRun, PEX
- R-2, TrunkBranch, Copper, Timer
- R-2, TrunkBranch, PEX, Timer
- R-2, TrunkBranch, Copper, Demand
- R-2, TrunkBranch, PEX, Demand
- R-5, TrunkBranch, Copper, Timer
- R-5, TrunkBranch, PEX, Timer

## Central Water Heater Category

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A central water heater serves all of the units in a multifamily building.

If a central water heater is selected, please also choose an appropriate option in the Central Distribution category.

**Properties**

- Type: Water heater type.
- Fuel Type: Type of fuel used for heating. Typically either natural gas, electricity, propane, or fuel oil.
- Volume [gal]: Nominal tank volume. A value of 'auto' will autosize the tank volume based on the ASHRAE Simplified Method (Chapter 50, 2011 HVAC Applications).
- Thermal Efficiency: The thermal efficiency is the ratio of the heat transferred to the water flowing through the water heater to the amount of energy consumed by the water heater as measured during the thermal efficiency test procedure prescribed in 10 CFR Part 431 Subpart G. For electric water heaters, the thermal efficiency is always 0.98.
- Standby Loss-Electric [%/hr]: Standby loss means the average hourly energy required to maintain the stored water temperature. For electric water heaters, standby loss is expressed as a percentage (per hour) of the heat content of the stored water. A value of 'auto' will use the equations for the maximum standby loss allowed by the federal standard. FElectric storage water heaters: 0.30 + 27/Vm (%/hr), where Vm is the measured tank volume.
- Standby Loss-Fuel [Btu/h]: Standby loss means the average hourly energy required to maintain the stored water temperature. For fuel-fired water heaters, standby loss is expressed in Btu/h based on a 70 deg-F temperature differential between stored water and the ambient temperature. A value of 'auto' will use the equations for the maximum standby loss allowed by the federal standard. Fuel-fired water heaters: Q/800 + 110(Vr)1/2 (Btu/hr), where Q is the rated input capacity in Btu/hr and Vr is the rated tank volume in gallons. It is assumed that central water heaters have an integral flue damper and all of the tank losses go to the space where the water heater is installed.
- Input-Electric [kW]: The maximum energy input rating of an electric water heater. A value of 'auto' will autosize the input capacity based on the ASHRAE Simplified Method (Chapter 50, 2011 HVAC Applications).
- Input-Fuel [kBtu/h]: The maximum energy input rating of a gas, propane, or fuel oil water heater. A value of 'auto' will autosize the input capacity based on the ASHRAE Simplified Method (Chapter 50, 2011 HVAC Applications).
- Location: The code-word for the location of the water heater. Use 'Auto' for the Building America House Simulation Protocols location: - Hot-Humid & Hot-Dry BA zones: Attached garage if one exists, otherwise in conditioned space - Other BA zones: Basement if one exists, otherwise in conditioned space If the water heater is located in conditioned space, it will be located in the first unit, although the tank losses will not affect the unit's temperature. This is the recommended workaround for central water heaters located in mechanical rooms.
- Setpoint [degrees F]: Water heater setpoint temperature. For electric water heaters, both top and bottom setpoints will use this temperature.
- Forced Draft Fan Power [W]: On-cycle electric power draw for the forced draft fan motor (watts).
- Parasitic Electric Power [W]: Off-cycle electric power draw for controls, etc. (watts).
- Ratio of Output Capacity to Volume [kBtu/h-gal]: The ratio of output capacity to tank storage volume. Used when autosizing the input capacity and tank volume. The default value of 1.41 kBtu/h-gal corresponds to a "Peak Minutes" value of 20 minutes from the ASHRAE simplified sizing method (Tables 8 and 9A from 2011 Handbook of HVAC Applications, Ch. 50), which was a typical value seen in California multi-family projects.
- Has Open Flue: Specifies whether the water heater has an associated flue that is not closed. The presence of a flue affects BEopt's air leakage model.

**Calculated Values**

- Tank Volume [gal]: Nominal tank volume.
- Input Capacity [kBtu/h]: The maximum energy input rating of the water heater.
- Standby Loss [Btu/hr]: Standby loss means the average hourly energy required to maintain the stored water temperature.

**Options**

- None
- Electric, Standard
- Gas, Natural Draft
- Gas, Forced Draft
- Gas, Condensing
- Propane, Natural Draft
- Propane, Forced Draft
- Propane, Condensing

## Central Distribution Category

---

Specifies the hot water distribution associated with the central water heater for a multifamily building.

Default option names include R-values 1) for the supply recirculation loop, 2) for the return recirculation loop, and 3) for the branch of each multifamily unit, respectively.

If a central distribution option is selected, please also choose an appropriate option in the Central Water Heater category.

Recirculation pump energy will appear in the Hot Water end use.

**Properties**

- Pipe Material: The plumbing material.
- Branch Pipe Layout: The plumbing layout of the hot water distribution system within each unit. Trunk and branch uses a main trunk line to supply various branch take-offs to specific fixtures. In the home run layout, all fixtures are fed from dedicated piping that runs directly from central manifolds.
- Branch Pipe Location: The primary location of the pipes for each unit. Interior implies that the pipes are in the living space, finished attic, or basement. Any other space is considered Exterior.
- Recirculation Type: The type of hot water recirculation control, if any. Timer recirculation control assumes 16 hours of daily pump operation from 6am to 10pm. Demand recirculation controls assume push button control at all non-appliance fixtures with 100% ideal control (button pushed for every draw event, no false signals, and immediate use of hot water when it arrives at the fixture).
- Recirculation Loop Location: Location of the recirculation supply and return pipes. 'Living' should be selected to simulate pipes in a plenum that is thermally coupled to living space.
- Recirculation Loop Living Story: For recirculation loops located in conitioned living space (i.e. plenums), this is the story on which the loop is located. Pipe losses will be distributed to all units on this story, based on the floor area of each unit on the story.
- Supply Pipe Insulation Nominal R-Value [h-ft^2-F/Btu]: The nominal R-value for insulation on recirculation supply pipes.
- Return Pipe Insulation Nominal R-Value [h-ft^2-F/Btu]: The nominal R-value for insulation on recirculation return pipes
- Branch Pipe Insulation Nominal R-Value [h-ft^2-F/Btu]: The nominal R-value for insulation on pipes located within units.
- Pipe Insulation R-Value Derate: A 30% derate was found to be typical in "Validation of a Hot Water Distribution Model Using Laboratory & Field Data" (Backman and Hoeschele 2013).
- Supply Pipe Diameter [in]: The nominal inside diameter of the supply side recirculation loop pipes. Used to calculate pipe head losses for pump sizing and to derive pipe insulation thickness. Select 'auto' to use the equation from the California ACM Reference Manual.
- Return Pipe Diameter [in]: The nominal inside diameter of the return side recirculation loop pipes. Used to calculate pipe head losses for pump sizing and to derive pipe insulation thickness.
- Supply Pipe Length [ft]: The length of the supply side recirculation loop pipes. Used for costing, to calculate pipe head losses for pump sizing, and to model pipe thermal losses. Select 'auto' to use the equation from the California ACM Reference Manual.
- Return Pipe Length [ft]: The length of the return side recirculation loop pipes. Used for costing, to calculate pipe head losses for pump sizing, and to model pipe thermal losses. Select 'auto' to use the equation from the California ACM Reference Manual.
- Branch Pipe Length [ft]: The length of DHW pipes serving each unit. This is only used for costing purposes. If 'auto' is selected, the equation from DEG's "Documentation of Hot Water Distribution Systems in 60 Calif Production Homes" will be used: 366 + 0.1322*(FFA-2432) + 86*(N_bathrooms-2.85)
- Recirculation Pump Flow Rate [gpm]: The volumetric flow rate for the central DHW recirculation loop pump. A value of 'auto' will size the pump using Eq. 9 from 2011 ASHRAE Handbook of HVAC Applications, p50.7, assuming an allowable temperature drop of 5 deg-F at the farthest branch.
- Recirculation Pump Timer Control Schedule: Schedule for timer control of the recirculation pump.

**Calculated Values**

- Supply/Return Pipe Diameters [in]: The nominal inside diameter of the supply and return side recirculation loop pipes. Used to calculate pipe head losses for pump sizing and to derive pipe insulation thickness.
- Supply/Return Pipe Lengths [ft]: The length of the supply and return side recirculation loop pipes. Used for costing, to calculate pipe head losses for pump sizing, and to model pipe thermal losses.
- Recirc Pump Flow Rate [gpm]: The volumetric flow rate for the central DHW recirculation loop pump.

**Options**

- None
- R-0/0/0, Copper, Continuous
- R-6/4/0, Copper, Continuous
- R-6/4/0, Copper, Demand
- R-6/4/0, Copper, Timer
- R-6/4/2, Copper, Continuous
- R-6/4/5, Copper, Continuous

## Solar Water Heating Category

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Solar water heating systems provide pre-heated water to a conventional water heater specified in the Water heating / Water heater category.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Collector Area [ft^2/unit]: Area of the collector array for each unit of the building.
- FRta: Optical gain coefficient in Hottel-Whillier-Bliss (HWB) equation.
- FRUL [Btu/hr-ft^2-F]: Thermal loss coefficient in the Hottel-Whillier-Bliss (HWB) equation.
- IAM: The incident angle modifier coefficient.
- Tank Storage Volume [gal]: The volume of the solar storage tank. If set to 'auto', the tank storage volume will be 1.5 gal for every ft^2 of collector area.
- Tank R-Value [hr-ft^2-F/Btu]: The insulation level of the solar storage tank.
- Fluid Type: The solar system's heat transfer fluid.
- Heat Exchanger Effectiveness: Heat exchanger effectiveness, where the effectiveness e, is defined as e = (Tcold-out - Tcold-in) / (Thot-in - Tcold-in).

- Pump Power [W/ft^2]: Total pump energy consumption in Watts per sqft of collector area.

**Calculated Values**

- Total Collector Area [ft^2]: The total collector area for the building. For multifamily buildings, this is the collector area per unit multiplied by the number of units.
- Total Pump Power [W]: Total pump energy consumption.
- Tank Storage Volume [gal]: The volume of the solar storage tank.

**Options**

- None
- 40 sqft/unit
- 64 sqft/unit

## Solar Water Heating Azimuth Category

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Options of type 'Relative' imply degrees relative to the Orientation of the front of the house (e.g. house azimuth + 90 degrees), while options of type 'Absolute' imply the actual azimuth (e.g. 90 degrees). An absolute azimuth of 0 degrees is south-facing.

**Properties**

- Azimuth Type: Relative azimuth angle is measured clockwise from the front of the house. Absolute azimuth angle is measured clockwise from due south.
- Azimuth [degrees]: The azimuth angle is measured clockwise, based on the azimuth type specified.

**Options**

- Back Roof
- Front Roof
- Left Roof
- Right Roof
- West
- Southwest
- South
- Southeast
- East

## Solar Water Heating Tilt Category

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Options of type Pitch imply degrees relative to the roof pitch (e.g. roof pitch + 10 degrees), options of type Absolute imply the actual tilt (e.g. 40 degrees), and options of type Latitude imply degrees relative to the location's latitude (e.g. Phoenix latitude + 15 degrees). An absolute tilt of 0 degrees is horizontal and an absolute tilt of 90 degrees is vertical.

If a building has multiple roofs with different pitches, the pitch of the top roof will be used for options of type Pitch.

**Properties**

- Tilt Type: Type of tilt angle referenced.
- Tilt [degrees]: Angle of tilt specific to the tilt type.

**Calculated Values**

- Tilt [deg]: The absolute angle of tilt.

**Options**

- Roof Pitch
- 0 degrees
- 10 degrees
- 20 degrees
- 30 degrees
- 40 degrees
- 50 degrees
- 60 degrees
- 70 degrees
- 80 degrees
- 90 degrees
- Latitude - 15 degrees
- Latitude
- Latitude + 15 degrees

## Lighting Group

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- Lighting Category

## Lighting Category

Lighting options are specified in terms of fractions of compact fluorescent (CFL), light-emitting-diodes (LED), and linear fluorescent (LFL) lamps; with the remaining percentage being incandescent. Options can also be defined in terms of hardwired and plugin lighting.

Displayed lifetimes are calculated based on the fractions of lamp technologies and the household average daily lamp usage.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Hardwired Fraction CFL: Fraction of all hardwired lamps (interior, garage, and exterior) that are compact fluorescent. Hardwired lighting not specified as CFL, LED, or LFL is assumed to be incandescent.
- Hardwired Fraction LED: Fraction of all hardwired lamps (interior, garage, and exterior) that are LED. Hardwired lighting not specified as CFL, LED, or LFL is assumed to be incandescent.
- Hardwired Fraction LFL: Fraction of all hardwired lamps (interior, garage, and exterior) that are linear fluorescent. Hardwired lighting not specified as CFL, LED, or LFL is assumed to be incandescent.
- Plugin Fraction CFL: Fraction of all plugin lamps that are compact fluorescent. Plugin lighting not specified as CFL, LED, or LFL is assumed to be incandescent.
- Plugin Fraction LED: Fraction of all plugin lamps that are LED. Plugin lighting not specified as CFL, LED, or LFL is assumed to be incandescent.
- Plugin Fraction LFL: Fraction of all plugin lamps that are linear fluorescent. Plugin lighting not specified as CFL, LED, or LFL is assumed to be incandescent.
- Incandescent Efficacy [lm/W]: The ratio of light output from an incandescent lamp to the electric power it consumes.
- CFL Efficacy [lm/W]: The ratio of light output from a CFL lamp to the electric power it consumes.
- LED Efficacy [lm/W]: The ratio of light output from a LED lamp to the electric power it consumes.
- LFL Efficacy [lm/W]: The ratio of light output from a LFL lamp to the electric power it consumes.
- Annual Interior Energy [kWh/unit/yr]: Total interior annual lighting energy (excludes garage). For multifamily buildings, the value is the average across all of the units.
- Annual Garage Energy [kWh/unit/yr]: Total garage annual lighting energy. For multifamily buildings, the value is the average across all of the units.
- Annual Exterior Energy [kWh/unit/yr]: Total exterior annual lighting energy. For multifamily buildings, the value is the average across all of the units.
- Corridor LPD [W/ft^2]: The lighting power density (W/ft^2 of corridor floor area) for a multifamily building. The lights are assumed to be on continuously throughout the year.
- Interior Qualifying Light Fixtures [frac]: This input is only used for calculating RESNET's Energy Rating Index (ERI). The ratio of the interior Qualifying Light Fixtures to all interior light fixtures in Qualifying Light Fixture Locations. A Qualifying Light Fixture is a light fixture located in a Qualifying Light Fixture Location that contains lamps (i.e. light bulbs) with an average luminous efficacy equal to or greater than 50 lumens/watt or a light fixture that is controlled by a photocell (outdoor fixtures) or by a motion sensor (indoor fixtures). Qualifying Light Fixture Locations are those light fixtures located in kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, bedrooms, garage, utility rooms, home offices, and all outdoor fixtures mounted on a building or pole. This excludes plug-in lamps, closets, unfinished basements, and landscape lighting.
- Garage Qualifying Light Fixtures [frac]: This input is only used for calculating RESNET's Energy Rating Index (ERI). Fraction of garage fixtures that are Qualifying Light Fixtures. A Qualifying Light Fixture is a light fixture located in a Qualifying Light Fixture Location that contains lamps (i.e. light bulbs) with an average luminous efficacy equal to or greater than 50 lumens/watt or a light fixture that is controlled by a photocell (outdoor fixtures) or by a motion sensor (indoor fixtures). Qualifying Light Fixture Locations are those light fixtures located in kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, bedrooms, garage, utility rooms, home offices, and all outdoor fixtures mounted on a building or pole. This excludes plug-in lamps, closets, unfinished basements, and landscape lighting.
- Exterior Qualifying Light Fixtures [frac]: This input is only used for calculating RESNET's Energy Rating Index (ERI). Fraction of exterior fixtures that are Qualifying Light Fixtures. A Qualifying Light Fixture is a light fixture located in a Qualifying Light Fixture Location that contains lamps (i.e. light bulbs) with an average luminous efficacy equal to or greater than 50 lumens/watt or a light fixture that is controlled by a photocell (outdoor fixtures) or by a motion sensor (indoor fixtures). Qualifying Light Fixture Locations are those light fixtures located in kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, bedrooms, garage, utility rooms, home offices, and all outdoor fixtures mounted on a building or pole. This excludes plug-in lamps, closets, unfinished basements, and landscape lighting.

**Calculated Values**

- Annual Elec [kWh/unit/yr]: Total lighting electricity usage for the building. For multifamily buildings, the value is averaged across all of the units.
- Hardwired Fractions [CFL, LED, LFL, Inc]: Fractions of all hardwired lamps (interior, garage, and exterior) that are compact fluorescent, light-emitting-diode, linear fluorescent, and incandescent.
- Plugin Fractions [CFL, LED, LFL, Inc]: Fractions of all plugin lamps that are compact fluorescent, light-emitting-diode, linear fluorescent, and incandescent.

**Options**

- None
- 100% Incandescent
- 20% CFL Hardwired, 34% CFL Plugin
- 34% CFL Hardwired, 34% CFL Plugin
- 40% CFL Hardwired, 34% CFL Plugin
- 60% CFL Hardwired, 34% CFL Plugin
- 80% CFL Hardwired, 34% CFL Plugin
- 100% CFL Hardwired, 34% CFL Plugin
- 20% LED Hardwired, 34% CFL Plugin
- 40% LED Hardwired, 34% CFL Plugin
- 60% LED Hardwired, 34% CFL Plugin
- 80% LED Hardwired, 34% CFL Plugin
- 100% LED Hardwired, 34% CFL Plugin
- 20% CFL
- 40% CFL
- 60% CFL
- 80% CFL

- 100% CFL
- 20% LED
- 40% LED
- 60% LED
- 80% LED
- 100% LED
- 100% LED, Low Efficacy
- 1200 kWh/yr

## Appliances & Fixtures Group

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- Refrigerator Category
- Cooking Range Category
- Dishwasher Category
- Clothes Washer Category
- Clothes Dryer Category
- Hot Water Fixtures Category

## Refrigerator Category

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For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Configuration: The configuration of the refrigerator.
- Volume [ft^3]: The total storage volume of a refrigerator or freezer.
- Adjusted Volume [ft^3]: For refrigerators, AV is calculated: AV = 1.63 x Total Refrigerator Volume. For refrigerator-freezers, AV is calculated: AV= Fresh Volume + 1.63 x Total Freezer Volume.
- Rated Annual Consumption [kWh/yr]: The EnergyGuide rated annual energy consumption for a refrigerator.
- Has Ice Dispenser: The feature of a refrigerator to provide through-the-door ice.
- Defrost: The defrost type of the refrigerator.
- Occupancy Energy Multiplier: Appliance energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Elec Use [kWh/yr]: Total electric usage of the refrigerator.

**Options**

- None
- Side freezer., EF = 4.4
- Side freezer, EF = 6.5
- Side freezer, EF = 10.8
- Side freezer, EF = 13.8
- Side freezer, EF = 15.7
- Side freezer, EF = 19.6
- Side freezer, EF = 19.8
- Side freezer, EF = 20.6
- Side freezer, EF = 20.6, DR control
- Bottom freezer, EF = 4.5
- Bottom freezer, EF = 6.7
- Bottom freezer, EF = 10.2
- Bottom freezer, EF = 13.6
- Bottom freezer, EF = 15.9
- Bottom freezer, EF = 19.8
- Bottom freezer, EF = 20.1
- Bottom freezer, EF = 21.3
- Top freezer, EF = 4.4
- Top freezer, EF = 6.9
- Top freezer, EF = 10.5
- Top freezer, EF = 14.1
- Top freezer, EF = 15.9
- Top freezer, EF = 17.6
- Top freezer, EF = 17.6, 95% Usage
- Top freezer, EF = 17.6, 105% Usage
- Top freezer, EF = 19.9
- Top freezer, EF = 20.4
- Top freezer, EF = 21.9

## Cooking Range Category

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For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Fuel Type: Type of fuel used for heating.
- Cooktop Energy Factor: Cooktop energy factor determined by DOE test procedures for cooking appliances (DOE 1997).
- Oven Energy Factor: Oven energy factor determined by DOE test procedures for cooking appliances (DOE 1997).
- Induction Range: Specifies whether the range uses induction cooking. Induction cooking heats a cooking vessel by magnetic induction, instead of by thermal conduction from a flame or an electrical heating element.
- Convection Oven: Specifies whether the cooking range has a convection oven. A convection oven (also known as a fan-assisted oven or simply a fan oven) is an oven that has fans to circulate air around food.
- Has Electronic Ignition: For gas cooking ranges with electronic ignition, an extra (40 + 13.3x(#BR)) kWh/yr of electricity will be included.
- Occupancy Energy Multiplier: Appliance energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Elec Use [kWh/unit/yr]: Total electric usage of the cooking range. For multifamily buildings, the value is averaged across all of the units.
- Gas Use [therms/unit/yr]: Total gas usage of the cooking range. For multifamily buildings, the value is averaged across all of the units.

**Options**

- None
- Electric
- Electric, 80% Usage
- Electric, 120% Usage
- Electric, Induction
- Gas
- Gas, 80% Usage
- Gas, 120% Usage
- Propane
- Propane, 80% Usage
- Propane, 120% Usage

## Dishwasher Category

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'Rated Annual Consumption' is the annual energy used by the dishwasher, under test conditions, from the EnergyGuide label.

For dishwasher with boost heating elements, the dishwasher water heating depends on the water heater set point.

In the case where all hot water is heated internally (dishwashers with cold-water connection only), energy consumption for dishwasher water heating depends on mains water temperature and is location-dependent, and the impact on water heater energy consumption is zero.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Place Settings [#]: The number of place settings for the unit. Data obtained from manufacturer's literature.
- Rated Annual Consumption [kWh]: The annual energy consumed by the dishwasher, as rated, obtained from the EnergyGuide label. This includes both the appliance electricity consumption and the energy required for water heating.
- Water Usage [Gal/cycle]: This is the amount of water used to run the dishwasher for one cycle.
- Cold Water Inlet Only: Does the dishwasher use a cold water connection only. Input obtained from manufacturer's literature.
- Internal Heater Adjustment: Does the system use an internal electric heater to adjust water temperature? Input obtained from manufacturer's literature.
- Cold Water Conn Use Per Cycle [gal/cycle]: Volume of water per cycle used if there is only a cold water inlet connection, for the dishwasher. Input obtained from manufacturer's literature.
- Energy Guide Date: Energy Guide test date.
- Energy Guide Annual Gas Cost [$/yr]: Annual cost of gas, as rated. Obtained from the EnergyGuide label.
- Occupancy Energy Multiplier: Appliance energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- Occupancy Hot Water Multiplier: Appliance hot water use is multiplied by this factor to account for occupancy usage that differs from the national average. This should generally be equal to the Occupancy Energy Multiplier.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Elec Use [kWh/unit/yr]: Total electricity consumption of the dishwasher assuming a water heater setpoint of 125 deg-F. This does not include the water heater energy consumption. For multifamily buildings, the value is the average across all of the units.
- Hot Water Volume [gal/unit/day]: The volume of hot water required by the dishwasher assuming a water heater setpoint of 125 deg-F. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- 318 Rated kWh
- 318 Rated kWh, 80% Usage
- 318 Rated kWh, 120% Usage

- 290 Rated kWh
- 290 Rated kWh, 80% Usage
- 290 Rated kWh, 120% Usage
- 290 Rated kWh, DR control

## Clothes Washer Category

---

Options of varying energy, water use, and water removal efficiency are available for washers. Cold Only options refer to operating the clothes washer with cold water.

The Modified Energy Factor is a measure of energy efficiency that considers the energy used by the washer, the energy used to heat the water, and the energy used to run the dryer.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Modified Energy Factor [ft^3/kWh-cycle]: The Modified Energy Factor (MEF) is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D. The higher the value, the more efficient the clothes washer is. Procedures to test MEF are defined by the Department of Energy (DOE) in 10 Code of Federal Regulations Part 430, Appendix J to Subpart B.
- Rated Annual Consumption [kWh]: The annual energy consumed by the clothes washer, as rated, obtained from the EnergyGuide label. This includes both the appliance electricity consumption and the energy required for water heating.
- Annual Cost with Gas DHW [$]: The annual cost of using the system under test conditions. Input is obtained from the EnergyGuide label.
- Test Date [year]: Input obtained from EnergyGuide labels. The new E-guide labels state that the test was performed under the 2004 DOE procedure, otherwise use year < 2004.
- Drum Volume [ft^3]: Volume of the washer drum. Obtained from the EnergyStar website or the manufacturer's literature.
- Use Cold Cycle Only: The washer is operated using only the cold cycle.
- Thermostatic Control: The clothes washer uses hot and cold water inlet valves to control temperature (varies hot water volume to control wash temperature). Use this option for machines that use hot and cold inlet valves to control wash water temperature or machines that use both inlet valves AND internal electric heaters to control temperature of the wash water. Input obtained from the manufacturer's literature.
- Has Internal Heater Adjustment: The washer uses an internal electric heater to adjust the temperature of wash water. Use this option for washers that have hot and cold water connections but use an internal electric heater to adjust the wash water temperature. Obtain the input from the manufacturer's literature.
- Has Water Level Fill Sensor: The washer has a vertical axis and water level fill sensor. Input obtained from the manufacturer's literature.
- Occupancy Energy Multiplier: Appliance energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- Occupancy Hot Water Multiplier: Appliance hot water use is multiplied by this factor to account for occupancy usage that differs from the national average. This should generally be equal to the Occupancy Energy Multiplier.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Elec Use [kWh/unit/yr]: Total electricity consumption of the clothes washer assuming a water heater setpoint of 125 deg-F. This does not include the water heater energy consumption. For multifamily buildings, the value is the average across all of the units.
- Total Water Volume [gal/unit/day]: The volume of total (hot and cold) water required by the clothes washer assuming a water heater setpoint of 125 deg-F. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- Standard
- Standard, 80% Usage
- Standard, 120% Usage
- Standard, Cold Only
- EnergyStar
- EnergyStar, 80% Usage
- EnergyStar, 120% Usage
- EnergyStar, DR control
- EnergyStar, Cold Only

## Clothes Dryer Category

---

Clothes dryer energy consumption depends on the characteristics of both the dryer (moisture removal efficiency) and the washer (remaining moisture in clothes).

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Fuel Type: Type of fuel used for drying.
- Energy Factor [lb/kWh]: The Energy Factor, for electric or gas systems.
- Assumed Gas Electric Split [frac]: For gas dryers, the Assumed Energy Use Ratio is (Electric Energy / (Gas Energy + Electric Energy)).
- Exhaust [cfm]: Rated flow capacity of the clothes dryer exhaust. This fan is assumed to run 60 min/day between 11am and 12pm.
- Auto Termination: Instead of only having a timer that terminates the dry cycle after a certain time interval selected by the consumer, many new clothes dryers offer an automatic termination setting. Auto termination controls the length of the drying cycle, using temperature sensors and/or moisture sensors to terminate

the cycle when the clothes are dry.
- Occupancy Energy Multiplier: Appliance energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Options**

- None
- Electric
- Electric, 80% Usage
- Electric, 120% Usage
- Electric, DR control
- Electric, Premium
- Electric, Heat Pump, Ventless
- Gas
- Gas, 80% Usage
- Gas, 120% Usage
- Gas, Premium
- Propane
- Propane, 80% Usage
- Propane, 120% Usage

## Hot Water Fixtures Category

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Hot Water Fixtures usage not specified for appliances in the Appliance group. Option values specify a fraction of the national average (Building America Benchmark) hot water consumption, where a "0.50" option would have half the use and a "2.00" option would have double.

Hot water loads are calculated from the sum of delivered hot (110 deg-F) water consumption for:
Sinks: Water Usage [gal/day] = 12.5 + 4.16x(#BR)
Showers: Water Usage [gal/day] = 14 + 4.67x(#BR)
Bath: Water Usage [gal/day] = 3.5 + 1.17x(#BR)
where #BR = Number of Bedrooms

These values do not include hot water consumption due to distribution systems specified in the Water Heating / Distribution category.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Sink Multiplier [frac]: Values specify a fraction of the national average (Building America Benchmark) sink water use, where a "0.50" option would have half the use and a "2.00" option would have double.
- Shower Multiplier [frac]: Values specify a fraction of the national average (Building America Benchmark) shower water use, where a "0.50" option would have half the use and a "2.00" option would have double.
- Bath Multiplier [frac]: Values specify a fraction of the national average (Building America Benchmark) bath water use, where a "0.50" option would have half the use and a "2.00" option would have double.
- Low Flow Fixtures: Specifies whether the plumbing fixtures are low-flow -- i.e., all showers and faucets < 2.0 gpm.

**Calculated Values**

- Sink Volume [gal/unit/day]: The volume of delivered hot (110 deg-F) water associated with sinks. For multifamily buildings, the value is averaged across all of the units.
- Shower Volume [gal/unit/day]: The volume of delivered hot (110 deg-F) water associated with showers. For multifamily buildings, the value is averaged across all of the units.
- Bath Volume [gal/unit/day]: The volume of delivered hot (110 deg-F) water associated with baths. For multifamily buildings, the value is averaged across all of the units.

**Options**

- None
- 2.00
- 1.00
- 0.50

## Appliances & Fixtures Schedules Group

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- Refrigerator Schedule Category
- Cooking Range Schedule Category
- Clothes Dryer Schedule Category

## Refrigerator Schedule Category

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If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, automatic shift to evening hours

## Cooking Range Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard

## Clothes Dryer Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, manual shift to non-peak hours
- Demand Response, manual shift to evening hours
- Demand Response, automatic shift to evening hours

## Miscellaneous Group

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- Plug Loads Category
- Extra Refrigerator Category
- Freezer Category
- Pool Heater Category
- Pool Pump Category
- Hot Tub/Spa Heater Category
- Hot Tub/Spa Pump Category
- Well Pump Category
- Gas Fireplace Category
- Gas Grill Category
- Gas Lighting Category

## Plug Loads Category

---

Plug loads include all loads not explicitly defined in the Appliances & Fixtures group or Miscellaneous group, such as kitchen appliances and electronics. Option values specify a fraction of the national average (Building America Benchmark) energy use, where the '0.50' option has half the use and the '2.00' option has double.

Plug loads are calculated as:
Annual electric use [kWh/yr] = 1108.1 + 180.2x(#BR) + 0.278x(FFA)
where #BR = Number of Bedrooms and FFA = Finished Floor Area (in sqft)

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Multiplier [frac]: Values specify a fraction of the national average (Building America Benchmark) energy use, where the "0.50" option has half the use and the "2.00" option has double.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/unit/yr]: Total electricity use of other electric loads not specified elsewhere. For multifamily buildings, the value is averaged across all of the units.

**Options**

- None
- 4.00
- 2.00
- 1.50
- 1.00
- 0.75
- 0.50
- 0.25
- Ideal Load

## Extra Refrigerator Category

---

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Extra Refrigerators [#/unit]: Number of extra refrigerators. A fractional number can be used to represent a community of houses where some houses have the technology and some do not. For multifamily buildings, the value is the average across all of the units.
- Configuration: The configuration of the refrigerator.
- Volume [ft^3]: The total storage volume of a refrigerator or freezer.
- Adjusted Volume [ft^3]: For refrigerators, AV is calculated: AV = 1.63 x Total Refrigerator Volume. For refrigerator-freezers, AV is calculated: AV= Fresh Volume + 1.63 x Total Freezer Volume.
- Rated Annual Energy Consumption [kWh/yr]: The EnergyGuide rated annual energy consumption for a refrigerator.
- Has Ice Dispenser: The feature of a refrigerator to provide through-the-door ice.
- Defrost: The defrost type of the refrigerator.
- Occupancy Energy Multiplier: Unit energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/unit/yr]: Total electric usage of the extra refrigerators. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- Side freezer, EF = 4.4
- Side freezer, EF = 6.5
- Side freezer, EF = 10.8
- Side freezer, EF = 13.8
- Side freezer, EF = 15.7
- Side freezer, EF = 19.6
- Side freezer, EF = 19.8
- Side freezer, EF = 20.6
- Side freezer, EF = 20.6, DR control
- Bottom freezer, EF = 4.5
- Bottom freezer, EF = 6.7
- Bottom freezer, EF = 10.2
- Bottom freezer, EF = 13.6
- Bottom freezer, EF = 15.9
- Bottom freezer, EF = 19.8
- Bottom freezer, EF = 20.1

- Bottom freezer, EF = 21.3
- Top freezer, EF = 4.4
- Top freezer, EF = 6.9
- Top freezer, EF = 6.9, National Average
- Top freezer, EF = 10.5
- Top freezer, EF = 14.1
- Top freezer, EF = 15.9
- Top freezer, EF = 17.6
- Top freezer, EF = 19.9
- Top freezer, EF = 20.4
- Top freezer, EF = 21.9

## Freezer Category

---

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Freezers [#/unit]: Number of freezers. A fractional number can be used to represent a community of houses where some houses have the technology and some do not. For multifamily buildings, the value is the average across all of the units.
- Configuration: The configuration of the freezer.
- Volume [ft^3]: The total storage volume of a freezer.
- Adjusted Volume [ft^3]: For freezers, adjusted volume (AV) is calculated: AV = 1.73 x Total Freezer Volume.
- Rated Annual Energy Consumption [kWh/yr]: The EnergyGuide rated annual energy consumption for a freezer.
- Defrost: The defrost type of the freezer.
- Occupancy Energy Multiplier: Unit energy use is multiplied by this factor to account for occupancy usage that differs from the national average.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/unit/yr]: Total electric usage of the freezers. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- Upright, EF = 6
- Upright, EF = 9
- Upright, EF = 12
- Upright, EF = 12, National Average
- Upright, EF = 16
- Upright, EF = 18
- Upright, EF = 20
- Upright, EF = 20, DR control
- Chest, EF = 10
- Chest, EF = 13
- Chest, EF = 18
- Chest, EF = 24
- Chest, EF = 27
- Chest, EF = 29

## Pool Heater Category

---

For multifamily buildings, the pool is assumed to be shared by all units of the building.

**Properties**

- Number of Electric Pool Heaters [#]: Number of electric heaters. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Number of Gas Pool Heaters [#]: Number of gas heaters. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Energy Multiplier: For each unit, sets the annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/yr]: Total electricity use of the pool heater.
- Annual Gas Use [therms/yr]: Total gas use of the pool heater.

**Options**

- None
- National Average
- Electric
- Gas

## Pool Pump Category

---

For multifamily buildings, the pool is assumed to be shared by all units of the building.

**Properties**

- Number of Pool Pumps [#]: Number of pool pumps. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Energy Multiplier: For each unit, sets the annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/yr]: Total electricity use of the pool pump.

**Options**

- None
- National Average
- Typical Efficiency
- Typical Efficiency, DR control

## Hot Tub/Spa Heater Category

---

For multifamily buildings, the hot tub is assumed to be shared by all units of the building.

**Properties**

- Number of Electric Hot Tub Heaters [#]: Number of electric hot tub heaters. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Number of Gas Hot Tub Heaters [#]: Number of gas hot tub heaters. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Energy Multiplier: For each unit, sets the annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/yr]: Total electricity use of the hot tub/spa heater.
- Annual Gas Use [therms/unit/yr]: Total gas use of the hot tub/spa heaters. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- National Average
- Electric
- Gas

## Hot Tub/Spa Pump Category

---

For multifamily buildings, the hot tub is assumed to be shared by all units of the building.

**Properties**

- Number of Hot Tub Pumps [#]: Number of hot tub pumps. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Energy Multiplier: For each unit, sets the annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/yr]: Total electricity use of the hot tub/spa pump.

**Options**

- None
- National Average
- Typical Efficiency

## Well Pump Category

---

For multifamily buildings, the well pump is assumed to be shared by all units of the building.

**Properties**

- Number of Well Pumps [#]: Number of well pumps. A fractional number can be used to represent a community of houses where some houses have the technology and some do not.
- Energy Multiplier: For each unit, sets the item's energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- DR Automatic Control: Specifies whether the technology has Demand Response (DR) automatic controls. DR schedules can be defined that require technologies with DR automatic controls.

**Calculated Values**

- Annual Elec Use [kWh/yr]: Total electricity use of the well pump.

**Options**

- None
- National Average
- Typical Efficiency
- High Efficiency
- High Efficiency, DR control

## Gas Fireplace Category

---

This gas use will be automatically converted to electricity for all-electric houses, to preserve total site miscellaneous energy use.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Gas Fireplaces [#/unit]: Number of gas fireplaces. A fractional number can be used to represent a community of houses where some houses have the technology and some do not. For multifamily buildings, the value is the average across all of the units.
- Energy Multiplier: For each unit, sets the annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.
- Has Open Chimney: Specifies whether the gas fireplace has an associated chimney that is not closed (e.g., with tight-fitting dampers). The presence of a chimney affects BEopt's air leakage model.

**Calculated Values**

- Annual Gas Use [therms/unit/yr]: Total gas use of the gas fireplaces. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- National Average
- Gas Fireplace

## Gas Grill Category

---

This gas use will be automatically converted to electricity for all-electric houses, to preserve total site miscellaneous energy use.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Gas Grills [#/unit]: Number of gas grills. A fractional number can be used to represent a community of houses where some houses have the technology and some do not. For multifamily buildings, the value is the average across all of the units.
- Energy Multiplier: For each unit, sets the annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.

**Calculated Values**

- Annual Gas Use [therms/unit/yr]: Total gas use of the gas grills. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- National Average
- Gas Grill

## Gas Lighting Category

---

This gas use will be automatically converted to electricity for all-electric houses, to preserve total site miscellaneous energy use.

For multifamily buildings, the selected option(s) apply to each unit.

**Properties**

- Number of Gas Lighting [#/unit]: Number of gas lighting. A fractional number can be used to represent a community of houses where some houses have the technology and some do not. For multifamily buildings, the value is the average across all of the units.
- Energy Multiplier: For each unit, sets the item's annual energy use equal to the national average (Building America Benchmark) energy use times this multiplier.
- Scale Energy Use: If true, scales the energy use relative to a 3-bedrom, 1920 sqft house using the following equation: Fscale = (0.5 + 0.25 x Nbr/3 + 0.25 x FFA/1920) where Nbr is the number of bedrooms and FFA is the finished floor area.

**Calculated Values**

- Annual Gas Use [therms/unit/yr]: Total gas use of the gas lighting. For multifamily buildings, the value is the average across all of the units.

**Options**

- None
- National Average
- Gas Lighting

## Miscellaneous Schedules Group

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- Plug Loads Schedule Category
- Extra Refrigerator Schedule Category
- Freezer Schedule Category
- Pool Heater Schedule Category
- Pool Pump Schedule Category
- Hot Tub/Spa Heater Schedule Category
- Hot Tub/Spa Pump Schedule Category
- Well Pump Schedule Category
- Gas Fireplace Schedule Category
- Gas Grill Schedule Category
- Gas Lighting Schedule Category

## Plug Loads Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, manual shift to non-peak hours

## Extra Refrigerator Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, automatic shift to evening hours

## Freezer Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, automatic shift to evening hours

## Pool Heater Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard

## Pool Pump Schedule Category

---

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, automatic shift to evening hours

## Hot Tub/Spa Heater Schedule Category

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, manual shift to evening hours

## Hot Tub/Spa Pump Schedule Category

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, manual shift to evening hours

## Well Pump Schedule Category

If a demand response (DR) option is selected, be sure to enable Demand Response Signals on the site screen. If a demand response option with automatic DR Control is selected, be sure to select an appliance with DR Automatic Control enabled.

**Properties**

- Schedule: The annual schedule for the technology.
- DR Schedule: The annual schedule for the technology for houses that employ demand response (DR). The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Penetration Rate: The fraction of homes in the analysis that employ demand response (DR) for this technology, either via occupant behavior or controls. The actual schedule for a demand response event will combine the non-DR and DR schedules using the penetration rate.
- DR Control: Specifies whether the Demand Response (DR) shift is manual (occupant) or automatic (DR automatic controls). Automatic schedules apply only to options with DR automatic controls while manual schedules apply to all options.

**Options**

- Standard
- Demand Response, automatic shift to adjacent hours

## Gas Fireplace Schedule Category

**Properties**

- Schedule: The annual schedule for the technology.

**Options**

- Standard

## Gas Grill Schedule Category

**Properties**

- Schedule: The annual schedule for the technology.

**Options**

- Standard

## Gas Lighting Schedule Category

---

**Properties**

- Schedule: The annual schedule for the technology.

**Options**

- Standard

## Power Generation Group

---

- PV System Category
- PV Azimuth Category
- PV Tilt Category

## PV System Category

---

PV options are in kW DC.

Displayed costs excluded any incentives, which are specified on the Site input screen.

For multifamily buildings, the PV system is assumed to be shared by all units of the building and energy production is allocated to each unit based on finished floor area.

**Properties**

- Size [kW]: Size (power) of the photovoltaic array in kW DC. For multifamily buildings, the value is the total across all of the units.
- Module Type: Type of module to use for the PV simulation. The module type will have secondary effects due to temperature, etc.
- System Losses [frac]: Difference between theoretical module-level and actual PV system performance due to wiring resistance losses, dust, module mismatch, etc. This value does not include the inverter performance.
- Inverter Efficiency [frac]: The efficiency of the inverter

**Options**

- None
- 0.5 kW
- 1.0 kW
- 1.5 kW
- 2.0 kW
- 2.5 kW
- 3.0 kW
- 3.5 kW
- 4.0 kW
- 4.5 kW
- 5.0 kW
- 5.5 kW
- 6.0 kW
- 6.5 kW
- 7.0 kW
- 7.5 kW
- 8.0 kW
- 8.5 kW
- 9.0 kW
- 9.5 kW
- 10.0 kW
- 10.5 kW
- 11.0 kW
- 11.5 kW
- 12.0 kW

## PV Azimuth Category

---

Options of type 'Relative' imply degrees relative to the Orientation of the front of the house (e.g. house azimuth + 90 degrees), while options of type 'Absolute' imply

the actual azimuth (e.g. 90 degrees). An absolute azimuth of 0 degrees is south-facing.

**Properties**

- Azimuth Type: Relative azimuth angle is measured clockwise from the front of the house. Absolute azimuth angle is measured clockwise from due south.
- Azimuth [degrees]: The azimuth angle is measured clockwise, based on the azimuth type specified.

**Options**

- Back Roof
- Front Roof
- Left Roof
- Right Roof
- West
- Southwest
- South
- Southeast
- East

## PV Tilt Category

---

Options of type Pitch imply degrees relative to the roof pitch (e.g. roof pitch + 10 degrees), options of type Absolute imply the actual tilt (e.g. 40 degrees), and options of type Latitude imply degrees relative to the location's latitude (e.g. Phoenix latitude + 15 degrees). An absolute tilt of 0 degrees is horizontal and an absolute tilt of 90 degrees is vertical.

If a building has multiple roofs with different pitches, the pitch of the top roof will be used for options of type Pitch.

**Properties**

- Tilt Type: Type of tilt angle referenced.
- Tilt [degrees]: Angle of the tilt, specific to the type of tilt.

**Calculated Values**

- Tilt [deg]: The absolute angle of tilt.

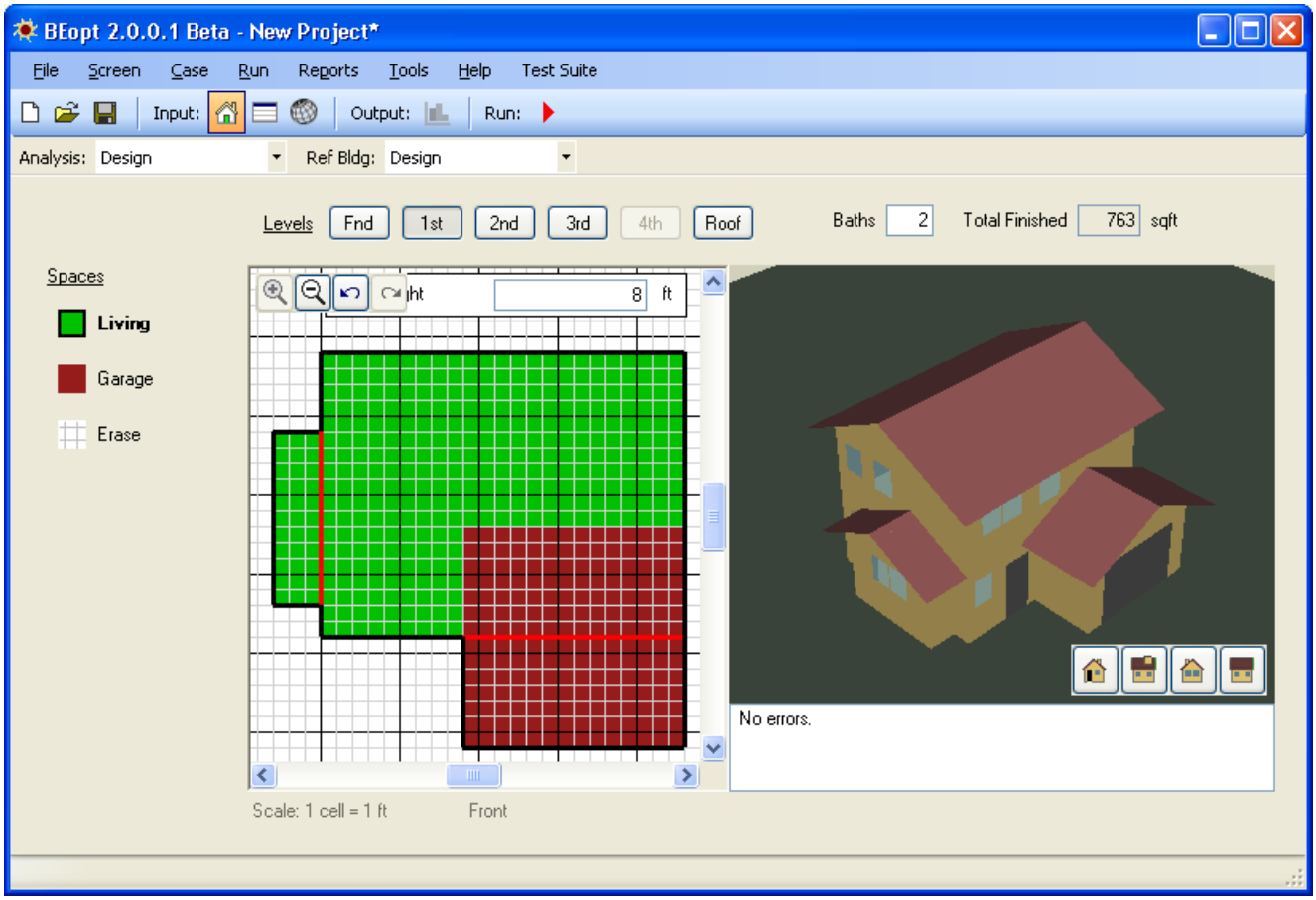
**Options**

- Roof, Pitch
- 0 degrees
- 10 degrees
- 20 degrees
- 30 degrees
- 40 degrees
- 50 degrees
- 60 degrees
- 70 degrees
- 80 degrees
- 90 degrees
- Latitude - 15 degrees
- Latitude
- Latitude + 15 degrees

## Geometry Input Screen

---

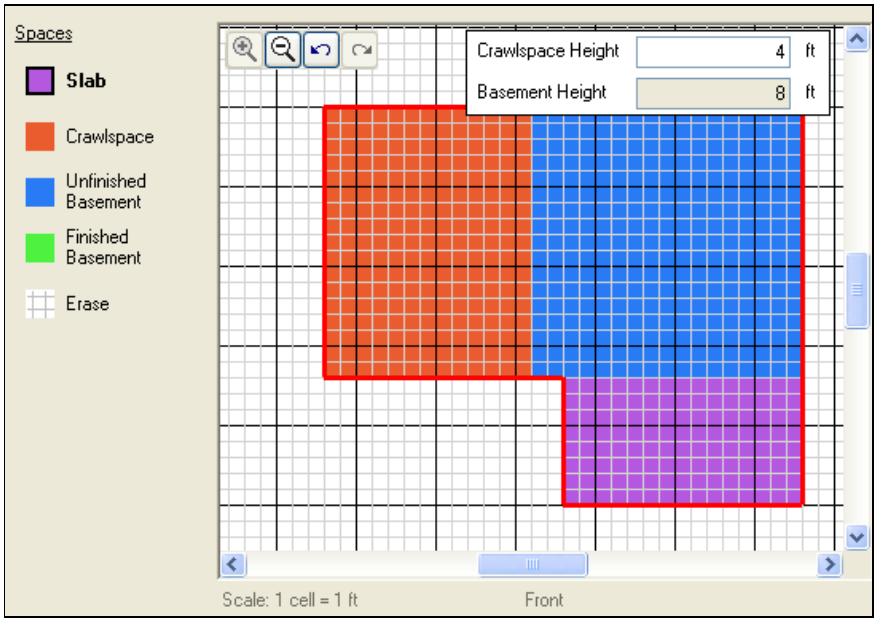

- Drawing Area
  - Space Types
  - Building Characteristics
- Rendering Area
  - Errors Pane
- General Inputs
- Multifamily Inputs
- Preview (video)




To view the geometry input screen, click the geometry button on the BEopt toolbar.

## Drawing Area

The drawing area provides a grid where the user can draw the floor plan of a building using the palette of different space types.




**Getting Started**

1. Choose Space Type:
   - Click space type on the left
2. Draw:

Erase:
- Click space type Erase on the left
- Click and drag to erase

Other:

- Click and drag to draw
- (Or double-click to fill an area)

- Right-click for a menu
- Middle click-and-drag to pan

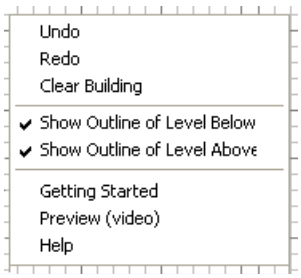
3. Change Level:
   - Click level button at the top
   - (Or use mouse wheel)

**Drawing Tips**

- To start a drawing, click a space type and use your mouse in the drawing area to define the geometry for that space.
- The rendering area displays a three-dimensional representation of the entire building as you draw.
- To erase part or all of a space from the drawing, click Erase and use your mouse pointer as an eraser or double-click the space.
- To clear the entire level (or building), right-click the drawing and select the appropriate option from the shortcut menu.
- When you finish drawing the spaces for a level, click a level button or use your mouse wheel to move to the next level and draw spaces for that level.
- A red outline indicates spaces in the next level up. A black outline indicates spaces in the next level down.
- Double-click to fill an outline with a space type.
- While drawing a space, if the mouse hits the border of the drawing area, the drawing will automatically pan to provide more drawing room.
- The drawing area can be zoomed out to 1 cell = 2 ft if there is not enough space to fit the building. Drawing still occurs at the 1 ft resolution.
- Undo/Redo buttons are available if you make a mistake or want to go back to a previous state.

### Right-Click Menu

Another feature of the drawing area is the menu accessed by right-clicking on the drawing area.




**Undo:** Go back to the previous drawing state; you can undo up to 5 times. Note that undo only refers to the drawn spaces, not the building characteristics.

**Redo:** Redo a previously undone change; you can redo up to 5 times. Note that redo only refers to the drawn spaces, not the building characteristics.

**Clear Building:** Erases all spaces drawn for the entire building.

**Show Outline of Level Below:** Toggles on/off the display of the outline of the spaces from the level below the current level.

**Show Outline of Level Above:** Toggles on/off the display of the outline of the spaces from the level above the current level.

**Getting Started:** Opens the Getting Started help documentation.

**Preview (video):** Launches a video showcasing the flexibility of BEopt's geometry input.

**Help:** Opens the Geometry Input Screen help documentation.

**Drawing Automation**

Drawing automation automatically adds or removes spaces as necessary in order to generate a complete building without errors. The approach attempts to be 'conservative' where possible - the goal is to make minimal changes, leaving the building as intact as possible. The user can then proceed incrementally.

For example, if living space is drawn on the 1st level, BEopt will automatically add a foundation space below and an attic space above the living space. Likewise, if the user erases living space on the 1st level, the foundation space below it will also be removed. While BEopt tries to be smart about adding/removing spaces, it is impossible to always know what the user might want; therefore, it is recommended that the user check all levels of their building to ensure that correct spaces were defined.

## Space Types

---

BEopt displays a different set of space types for each level.

**Foundation Level**

- **Slab:** Concrete slab foundation below living space and/or garage.
- **Crawlspace:** Crawlspace that can have vents to allow natural airflow. Insulation can be placed in the crawlspace ceiling or along the exterior walls. Can be conditioned.
- **Pier & Beam** : Pier & Beam (sometimes called Post & Beam) foundation. Cannot be mixed with other foundation types. Insulation can be placed above the open crawlspace.
- **Unfinished Basement:** Basement space without direct supply of heating or cooling. Insulation can be placed along the exterior walls (for indirect conditioning) or in the basement ceiling.

- **Finished Basement:** Basement space with direct heating or cooling. Insulation is placed along the exterior walls.

**1st Level**

- **Living:** Space with direct heating and cooling. This includes living rooms, kitchens, bedrooms, bathrooms, etc.
- **Garage:** Unconditioned garage space. Must have a slab foundation.
- **Corridor:** Conditioned space that leads to different units in a multi-family building. (Only available for multi-family buildings)

**2nd, 3rd, 4th, 5th, and 6th Levels**

- **Living:** Space with direct heating and cooling. This includes living rooms, kitchens, bedrooms, bathrooms, etc. (Not available on 6th Level)
- **Corridor:** Enclosed conditioned space that leads to different units in a multifamily building. (Only available for multifamily buildings ; Not available on 6th Level)
- **Open to Below:** Extension of the space below (creating, for example, a 2-story space). Does not increase the total finished floor area. (Not available on 6th Level)
- **Unfinished Attic:** Attic space without direct supply of heating or cooling. Can have vents to allow natural airflow. Insulation can be placed on the attic floor or at the roof/walls.
- **Finished Attic:** Attic living space with direct heating and cooling. Insulation is placed at the walls and roof.
- **Vaulted Ceiling:** When above conditioned space, insulation is at the roof; otherwise uninsulated. Does not increase the total finished floor area.
- **Garage Roof**: Uninsulated roof above garage. (Only available on 2nd Level)
- **Porch Roof (Pitched):** Shading surface pitched like the roof. If a porch roof is attached to another roof (e.g., attic or vaulted ceiling), it will be extended based on eave options; otherwise, it will not.
- **Flat Roof / Deck:** Horizontal shading/roof surface. Cantilevered portions of decks will cause shading. Deck over space below will function as a flat roof (but without option-based eaves).

**All Levels**

- **Erase:** Erase building geometry.

## Building Characteristics

As the user draws spaces, appropriate inputs for the drawn spaces appear in the upper right hand corner of the drawing area. These inputs are as follows:

**Basement Height:**

Basement Height 8 ft

Appears when any basement space is drawn on the foundation level. Currently the basement height is restricted to 8 feet.

**Crawlspace Height:**

Crawlspace Height 4 ft

Appears when any crawlspace is drawn on the foundation level. The crawlspace height can be set between 1.5 and 5 feet.

**Pier & Beam Height**:

Pier & Beam Height 3 ft

Appears when pier & beam foundation is drawn on the foundation level. The pier & beam height can be set between 0.5 and 8 feet.

**Wall Height:**

Wall Height 8 ft

Appears on any level with living space, garage or "open to below" space types. Wall Height is level specific, and can vary from level to level. The wall height on the first level has a minimum of 8 feet while the wall height of above levels has a minimum of 2 feet.

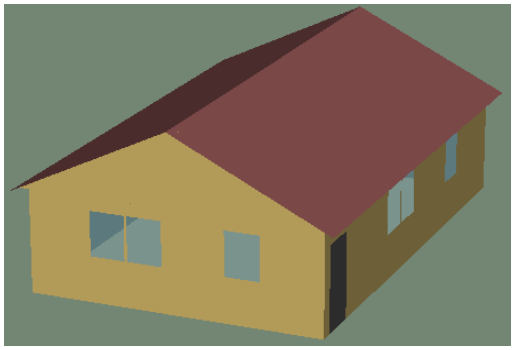
For multifamily buildings, the wall height can be increased to account for plenum space. For example, if a building has a 8-foot floor-to-ceiling height and a 2-foot conditioned plenum, the wall height entered in BEopt should be 10 feet.

**Roof Type:**

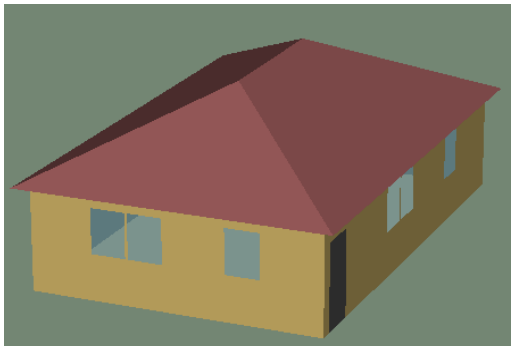
Roof Type Gable

Gable
Hip

Appears on any level where a roof space is drawn. Available roof types are Gable and Hip. Roof Type is level specific, and can vary from level to level.

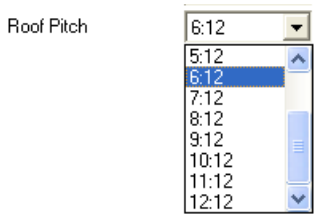


Gable Roof



Hip Roof

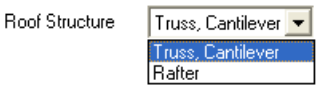
**Roof Pitch:**




Appears on any level where a roof space is drawn. A range of roof pitches are available. Roof Pitch is level specific, and can vary from level to level.

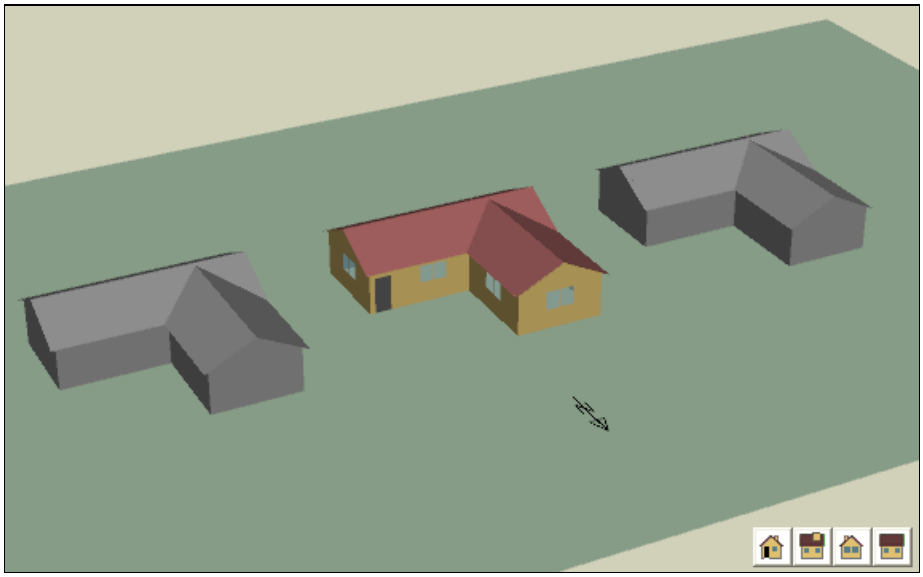
Note: If you want a flat roof, this is drawn using the Flat Roof space type and not selected via this dropdown.

**Roof Structure:**




Appears on any level where a roof space is drawn. Two possible roof structures are available, Cantilever Truss and Rafter. Roof Structure is level specific, and can vary from level to level. The choice of roof structure 1) impacts the vertical position of the eaves for shading and 2) can affect heat transfer through insulated attic floors based on the amount of insulation that can be installed at the perimeter of the attic (cantilever roofs can accommodate more insulation at the perimeter of the attic).

## Rendering Area

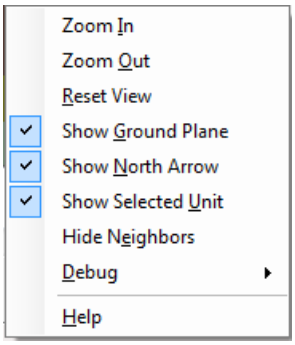


As spaces are created in the drawing area, the rendering area gives instant feedback in the form of a three-dimensional model. The user can explore the model by rotating the rendering (left-click + drag) and by zooming in and out (mouse wheel up/down). The four buttons at the bottom-right of the rendering area are also available for quickly viewing elevation renderings from all four sides of the house.

NOTE: When more than one option is selected on the Options Input Screen in a category that affects the rendering, BEopt renders the building using the lowest numbered selected option for each category. (In Design Mode, BEopt renders the first design in the case.)

### Right-Click Menu

Additional rendering capabilities can be accessed through the right-click menu of the rendering area. These capabilities are as follows:




**Zoom In:** Has the same effect as mouse wheel up. This capability is necessary for mice without wheels.

**Zoom Out:** Has the same effect as mouse wheel down. This capability is necessary for mice without wheels.

**Reset View:** Shows the rendering in the default isometric view.

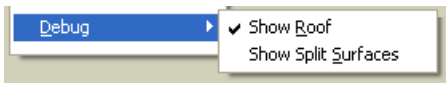
**Show Ground Plane**: Shows a surface on the ground level to help differentiate above-grade surfaces from below-grade surfaces.

**Show North Arrow:** Renders an arrow at ground level that points North.

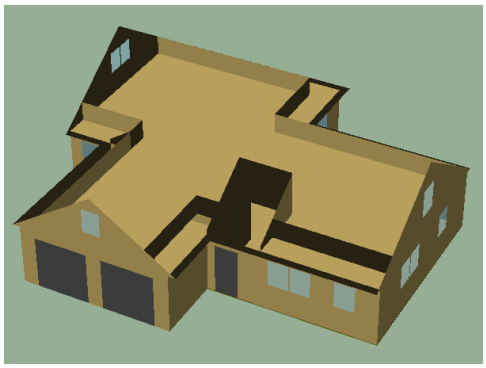
**Show Selected Unit** : Highlight the selected multi-family unit in the building rendering. Only available for multifamily buildings .

**Hide Neighbors:** When the rendered building (see NOTE above) has neighbors, selecting "Hide Neighbors" will remove any neighbor buildings from the rendering. This will NOT affect the simulation.

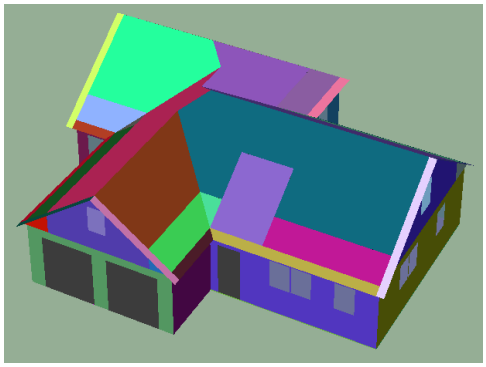
**Debug:** Several options for checking and verifying building geometry.




**Show Roof:** When unchecked, BEopt hides roof surfaces to expose wall surfaces below the roof.

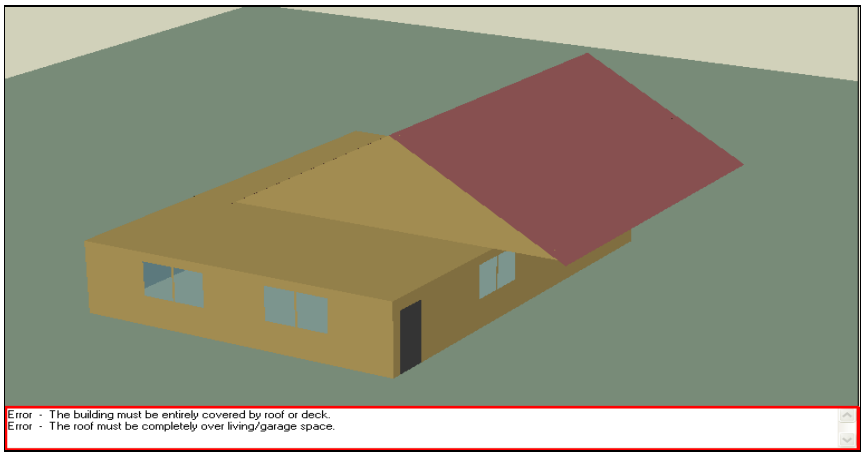


**Show Split Surfaces:** When checked, BEopt assigns random colors to all of the opaque surfaces to show each individual surface that is modeled. Each surface is distinct based on the spaces on either sides.



**Help:** Opens the Geometry Input Screen help documentation.

## Errors Pane




If BEopt detects that there are problems with the building drawing, error and/or warning messages will appear in the pane below the rendering area. If drawing automation is enabled, the possibility of errors should be greatly reduced.

The possible errors/warnings are listed below:

**Error - The building has no foundation area.**
This error will appear until the user has drawn a space on the foundation level.

**Error - The building has no above-grade finished floor area.**
The building must have living space or finished attic space.

**Error - The building cannot have attic or living space above a roof.**
Roof spaces must be the highest spaces drawn for any given grid area.

**Error - The garage cannot be on top of a crawlspace or basement.**
The garage may not have a basement or crawlspace foundation.

**Error - Multistory space (e.g. Open to Below and Vaulted Ceiling) must be completely above other space.**
Multistory spaces reference the space drawn below them. This error will appear if there is no space drawn directly below the multistory space.

**Error - The building's entire foundation must be covered by living/garage space.**

**Error - The building's first story must be entirely over a foundation.**

**Error - The building must be entirely covered by roof or deck.**

**Error - The building cannot be covered by porch roof.**
Porch roofs are intended only as shading surfaces. The building may be covered by any other roof space.

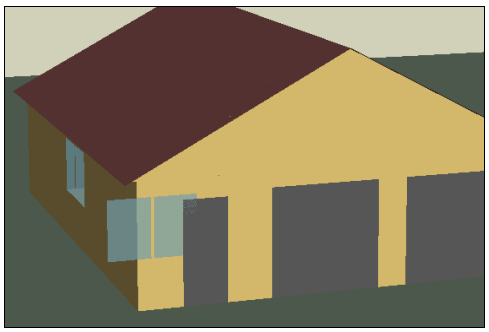
**Error - The roof must be completely over living/garage space.**

**Error - The garage roof must be completely over garage space.**

**Error - Open to Below space cannot be covering the garage.**

**Error - BEopt cannot currently handle multi-family units that are entirely basement.**

**Warning - Rendering indicates potential problem fitting window area onto wall.**
This warning indicates that the selected window area option does not fit on the wall area as the building has been drawn. It's likely that simulations will still be successful.



**Warning - Garages should typically be covered by garage roof.**

## General Inputs

Aside from the building geometry, the user can also specify:

- Age of home (Retrofit only)
- Number of bedrooms - impacts occupancy levels (e.g. miscellaneous electric loads)
- Number of bathrooms - impacts occupancy levels (e.g. hot water consumption); can include fractional bathrooms (e.g. 1.5)

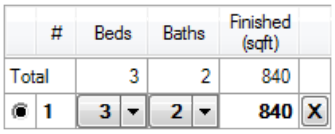
The total finished floor area, in sqft, is also displayed here.

For multifamily buildings, the beds/baths specification and total finished floor area display are provided for each unit. A total for the building is also included.

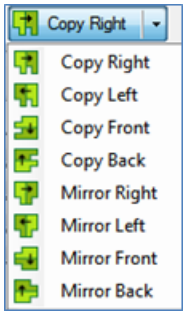
## Multifamily Inputs

In addition to BEopt's existing drawing capabilities, new drawing and display features facilitate user input of multiunit buildings including duplexes, townhouses and apartment buildings. Dwelling unit geometry can be drawn in detail.

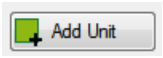
As a user begins to draw, Unit 1 is created (similar to single-family detached mode).




A copy (or mirrored copy) of the selected unit can be placed at the far edge of the building:




Alternatively, a new unit (that is not a copy) can be added and then drawn:

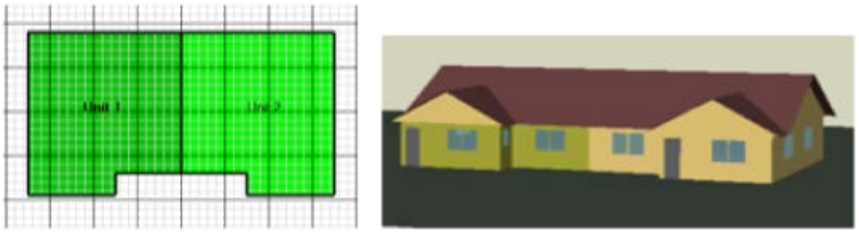



Characteristics are displayed for multiple units. The number of bedrooms/bathrooms can be assigned for each unit. Building totals are displayed at the top. Units can be deleted by clicking the X button next to the unit.

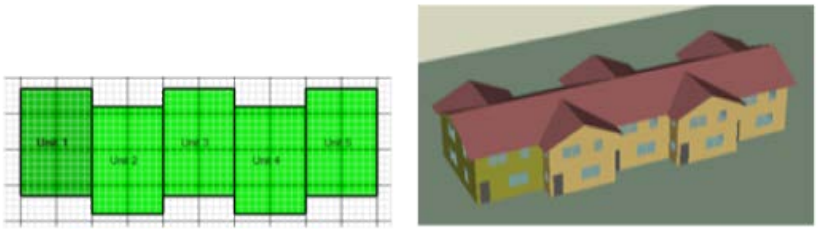
**Sample buildings**

Here are some sample mutlifamily buildings that can be drawn.

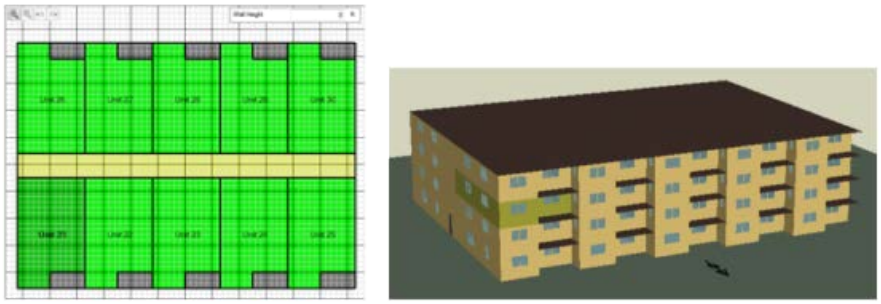
- Duplex:



- 2-story townhouse:



- Apartment (interior corridor):



## General Inputs

Aside from the building geometry, the user can also specify:

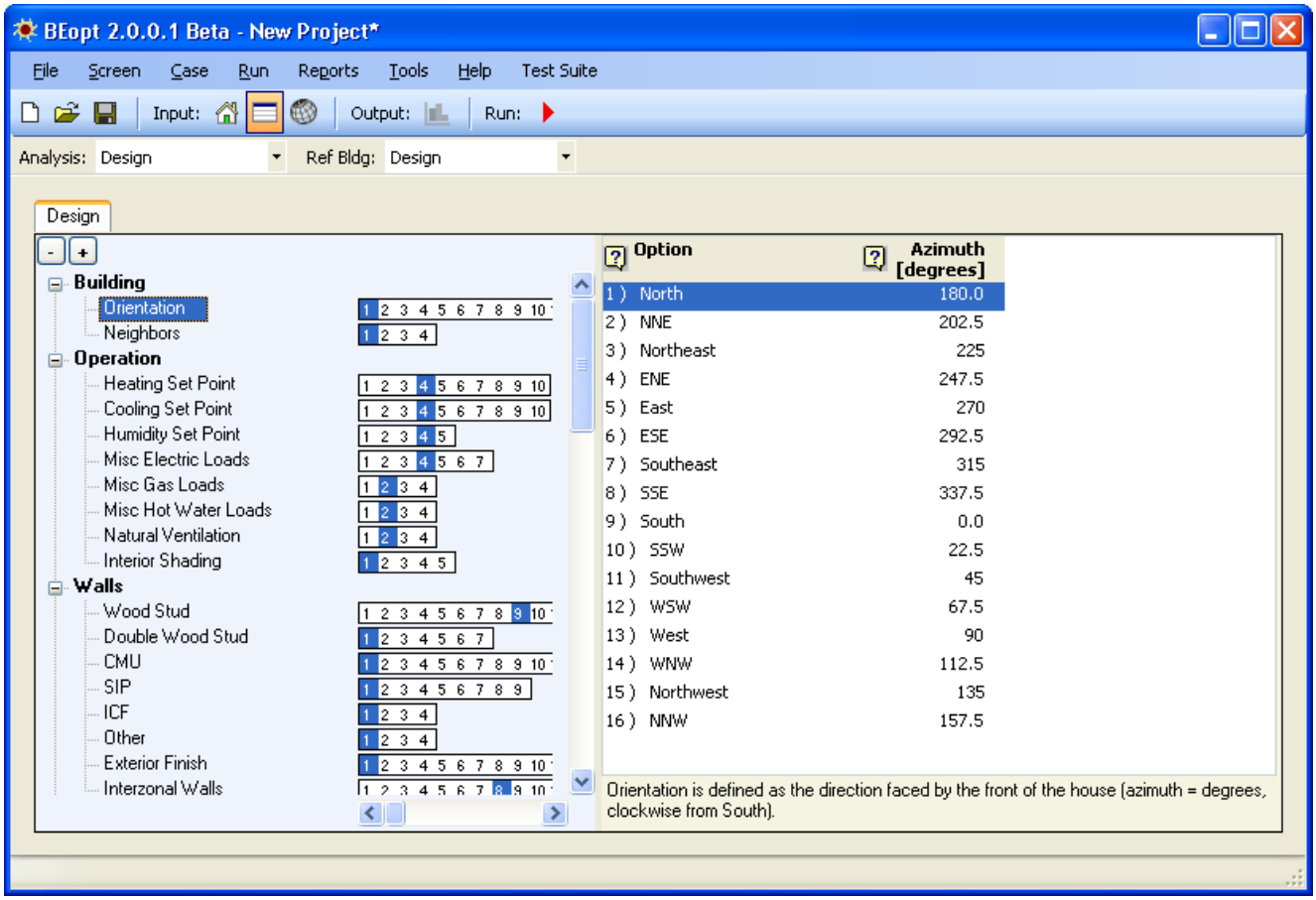
- Age of home (Retrofit only)
- Number of bedrooms - impacts occupancy levels (e.g. miscellaneous electric loads)
- Number of bathrooms - impacts occupancy levels (e.g. hot water consumption); can include fractional bathrooms (e.g. 1.5)

The total finished floor area, in sqft, is also displayed here.

For multifamily buildings, the beds/baths specification and total finished floor area display are provided for each unit. A total for the building is also included.

## Options Input Screen

- Design Tabs
- Option Categories
- Option Summary Matrix
- Available Options
- HVAC Sizing
- Retrofit Inputs




The Options input screen allows the user to select options to be evaluated. Some categories will only be displayed if they are a part of the building geometry. For example, if a building sits entirely on a slab, basement and crawlspace categories will not be visible.

To view the Options input screen, click the Options button on the BEopt toolbar. Select the options that BEopt should consider in the analysis.

## Design Tabs

Each case will display one or more tabs on the Options input screen depending on the situation the user is in. Within each tab, the user can select from the available options in each category.

See the Cases vs Designs section for help on understanding the difference between case tabs and design tabs.

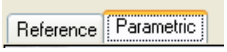
**Design Mode**

In design mode, BEopt will default to a tab called MyDesign. The user can create, rename, or delete designs by right-clicking on the appropriate design tab. Only a single option can be selected in each category for these designs.

When the reference is set to be one of the user's designs, it will not display as a separate tab; but when the reference is set to anything else, an additional tab called Reference will be displayed where the user can view (and sometimes select) the options that make up the reference.

**Parametric Mode**

In parametric mode, BEopt will show a tab called Parametric where multiple options can be selected across multiple categories. A Reference tab will also be displayed where the user can view (and sometimes select) the options that make up the reference.




**Optimization Mode**

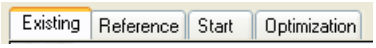
In optimization mode, BEopt will show a tab called Optimization where multiple options can be selected across multiple categories. A Reference tab will also be displayed where the user can view (and sometimes select) the options that make up the reference.

Finally, a Start tab is displayed to show the options that make up the starting point of the optimization search technique. It is currently set to the first selected option

in each category and cannot be changed.

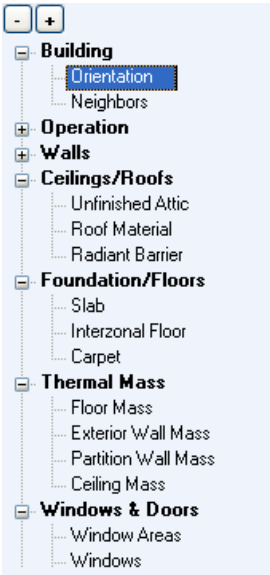
**Retrofit Analysis**

When performing retrofit analysis, an additional tab called Existing will always appear at the beginning. This is where the user specifies the single option in each category that describes the existing building.




On all other tabs, if replace at "wear out" is selected, the options for the existing tab are combined with the options of the current tab to calculate energy and costs over the analysis period. Note that both the available and selected options in a given category can change if the user chooses a different option for the existing building.

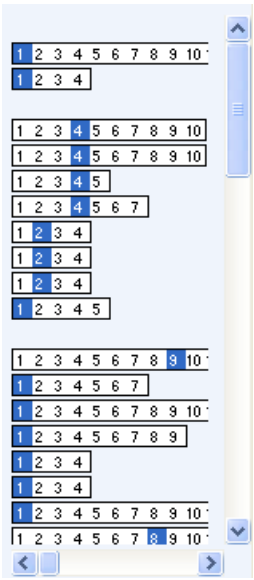
## Groups and Categories




Options are organized into groups (building, operation, walls, etc.) and categories (orientation, neighbors, windows, etc.).

By clicking on a category, the available options within that category will be displayed in the Available Options list to the right.

## Option Summary Matrix



The summary matrix of options shows all of the currently selected options in each category. The matrix provides the user with a snapshot of all their selected options as a secondary check that they selected options as intended.

Note that hovering over the option numbers in the matrix will display the option name in a tooltip.

## Available Options

| Option | Compressor | Cycling [frac] | Cost [$] | Cost [$/kBtuh] | Lifetime [Years] |
|---|---|---|---|---|---|
| 1 ) None | | | | | |
| 2 ) SEER 13 | 1 Stage | 0.05 | $411.00 | $64.16 | 19 |
| 3 ) SEER 14 | 1 Stage | 0.05 | $411.00 | $73.80 | 19 |
| 4 ) SEER 15 | 1 Stage | 0.07 | $411.00 | $83.43 | 19 |
| 5 ) SEER 16 | 1 Stage | 0.13 | $411.00 | $93.07 | 19 |
| 6 ) SEER 16 (2 Stage) | 2 Stage | 0.10 | $411.00 | $93.07 | 19 |
| 7 ) SEER 17 | 2 Stage | 0.11 | $411.00 | $102.70 | 19 |
| 8 ) SEER 18 | 2 Stage | 0.10 | $411.00 | $112.34 | 19 |
| 9 ) SEER 21 | 2 Stage | 0.07 | $411.00 | $141.24 | 19 |
| 10 ) SEER 24.5 | Var. Speed | 0.25 | $411.00 | $174.96 | 19 |

Clicking on a category name or the summary matrix shows a list of available options and pertinent option data including their properties and cost/lifetime information, as shown above. One or more options can be selected by the user depending on the specified analysis mode.

By default, BEopt will only display options in each category that are deemed appropriate and have cost information. For example, BEopt will not display a SEER 10 air conditioner for new construction because it does not meet the federal minimum standard. Likewise, BEopt will not display options that insulate 2x6 walls for retrofit if the pre-retrofit home is specified as having a 2x4 wall. In categories where not all options are being displayed, BEopt will show the following message below the category:

> BEopt is currently only showing options deemed appropriate and for which costs exist. You can show additional options.

Clicking on the link will show all options in the category -- any new options displayed will have an exclamation point next to them to denote that they do not have costs and should only be used for energy simulation purposes. These new options can be again hidden by clicking on the new link that appears in the message below the category:

> BEopt is currently showing all options, not just those deemed appropriate and for which costs exist. You can hide these additional options.

Display columns can either be property values or calculations. Calculations can be based on the building location and geometry in addition to the option's properties, and will update accordingly if the building location or geometry is changed.

Hovering over the question mark icons will display additional details about the column being displayed.

Costs displayed for each option include both material costs and labor costs, where labor costs are specific to the situation (e.g. installing an AC in new construction, installing an AC in retrofit, replacing an AC in retrofit, etc). Costs are aggregated as much as possible by unit cost (e.g. $ + $/kBtuh), whereas the actual costs in the library may be more disaggregated. The costs displayed reflect the values for material cost multiplier and labor cost multiplier, but do not include any incentives or rebates.

There is also a menu available via right-clicking on the grid:

> Option Manager...
> Choose Columns ...

**Option Manager**: Opens the Option Manager, which allows the user to view and edit options and costs.

**Choose Columns**: Allows the user to customize the columns that are displayed. You can choose 'Show All' to show all possible columns, or 'Reset to Default' to revert to the columns that BEopt displays by default.

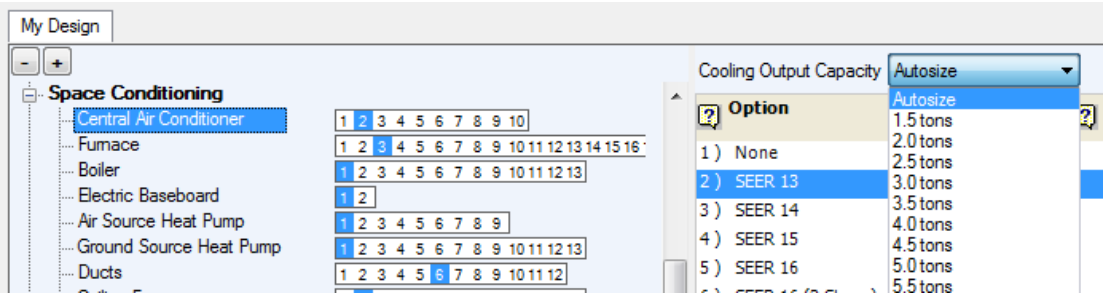
**Retrofit Analysis**

When evaluating retrofits, additional inputs are available to the user (e.g., to dictate whether measures are evaluated today or when the existing component naturally wears out and requires replacement). See the Retrofit Inputs section for further details on how inputs are handled for retrofit analysis.

In addition, note that post-retrofit designs can have their available and selected options change in a given category as a result of the user selecting a different option for the existing building. BEopt defaults to selecting the same option in the post-retrofit design as in the existing building if possible (i.e. the do-nothing situation). If not possible, the minimum replace option is selected.

## HVAC Sizing

For heating/cooling space conditioning categories (e.g. Central Air Conditioner, Furnace, Boiler, etc.), BEopt provides the user with various ways to size the equipment. For equipment that provides cooling, a Cooling Output Capacity dropdown appears. For equipment that provides heating, a Heating Output Capacity dropdown appears. For equipment that provides both, a Cooling/Heating Output Capacity dropdown and a Supplemental Heating Output Capacity dropdown appears.

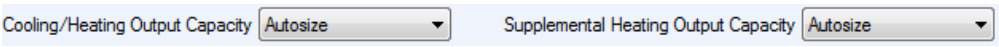



If you know the size of the equipment you want to simulate, choose the size in the dropdown. Note that while some equipment (e.g., combustion furnaces) are marketed in terms of input capacity, the output capacity is the value that should be entered into BEopt.

If instead you choose 'Autosize', BEopt will automatically determine the size based on calculations consistent with ACCA Manual J sizing; the autosized results will appear at the bottom of the Options Graph. The Autosize choice allows there to be a potential HVAC downsizing cost benefit for more efficient designs.

For design cases, a HVAC capacity selection can be made specific to each design.

For equipment that provides both heating and cooling (e.g. heat pumps), the cooling and heating output capacities of the heat pump are set equal and entered as a single value, and a separate supplemental (resistance) heating output capacity is also entered.




**Retrofit Analysis**

See Retrofit Inputs for additional inputs that are available for retrofit analysis .

**Multifamily Analysis**

For multifamily buildings with individual systems, 'Autosize' will size the heating and cooling systems for each unit individually. The capacities shown on the Output Screen are an average across all units.

## Retrofit Inputs

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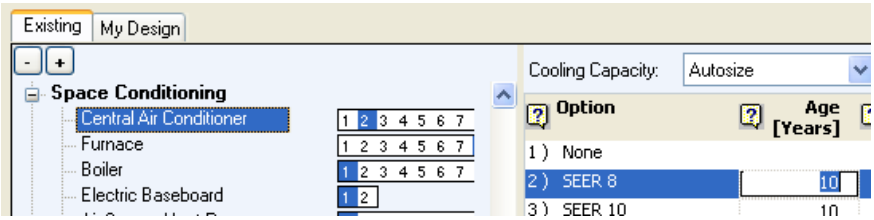
When performing retrofit analysis, additional information is available on the Options input screen.

**Existing Tab**

A tab called Existing will be visible where the user can specify the options that make up the existing building by selecting a single option in each category.

For categories of technologies that wear out, the age of the existing technology can also be specified. The age defaults to half of the technology's lifetime.

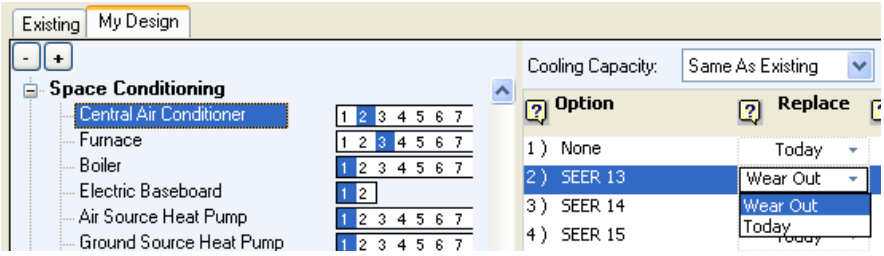



This input is used to calculate the remaining life of the existing component, and will be used to determine when future replacements of the existing component occur for any post-retrofit measures that are replaced at wear-out.

The process for specifying heating/cooling capacities for the existing building is described under HVAC Sizing.

**Other Tabs**

All other tabs, including references, build on the existing building. For categories of options that wear out, the user can specify whether options are replaced today or at wear-out (or either, in Parametric and Optimization modes). If replace at "wear out" is selected, the options for the existing tab are combined with the options of the current tab to calculate energy and costs over the analysis period.

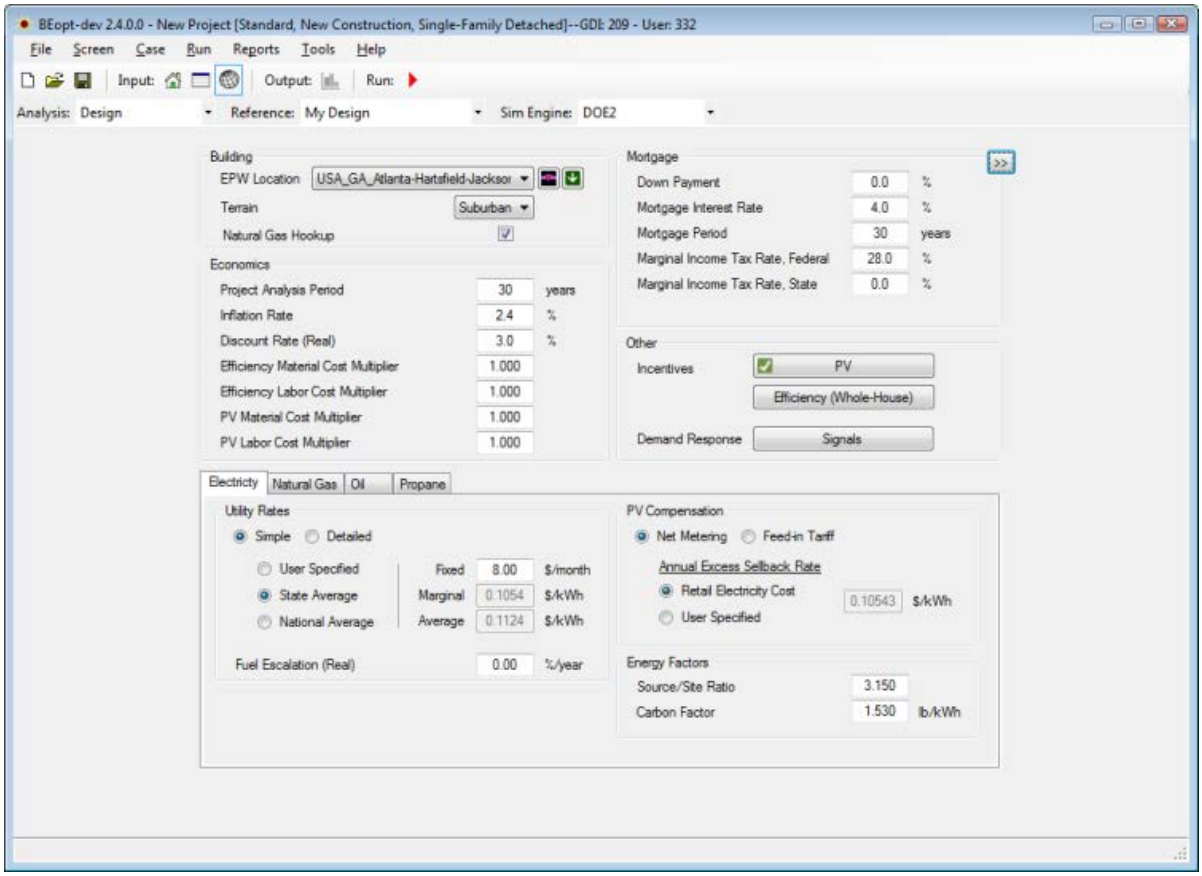



Note that available and selected options displayed in a given category depend on the option selected for the existing building. BEopt defaults to selecting the same option as the option in the existing building if possible (i.e. the do-nothing situation), except when the minimum replace option is selected.

The process for specifying heating/cooling capacities is described under HVAC Sizing, with the exception of any additional choice available in the dropdowns: "Same as Existing". When this choice is made, a fixed equipment capacity will be used that is identical to the capacity in the existing building (which may be autosized). If the Autosize choice is selected, the equipment will be autosized whenever there is a replacement of the equipment; the replacement timing is dependent on the choice of Replace (Today or Wear Out) and the age of the existing equipment.

## Site Input Screen

To view the site input screen, click the site button on the BEopt toolbar.




The following site parameters can be defined. Note that some parameters will change based on the choice of project type.

Building

- EPW Location
- Terrain
- Natural Gas Hookup (New Construction)

Economics

- Project Analysis Period
- Inflation Rate
- Discount Rate (Real)
- Efficiency Material Cost Multiplier
- Efficiency Labor Cost Multiplier
- PV Material Cost Multiplier
- PV Labor Cost Multiplier

Mortgage

- Down Payment (New Construction)
- Mortgage Interest Rate (New Construction)
- Mortgage Period (New Construction)
- Payment Type (Retrofit)
- Cash Payment (Retrofit)
- Loan Interest Rate (Retrofit)
- Loan Period (Retrofit)

Other

- PV Incentives
- Efficiency Incentives (Whole-House)
- Demand Response Signals

California Metrics

- Net-to-Gross Ratio (California Metrics)
- Program Cost (Present Value) (California Metrics)
- CA Climate Zone Utility (California Metrics)
- CA Climate Zone Region (California Metrics)

Utility Rates

- Electric Utility Rates
- Non-Electric Utility Rates
- Fuel Escalation (Real)
- Centrally Metered (Multifamily)
- Net Metering
- Feed-in Tariff
- PV Monthly Grid Connection Fee
- Source / Site Ratio
- Carbon Factor

Project Info

- Marginal Income Tax Rate, Federal
- Marginal Income Tax Rate, State

## Building

- EPW Location
- Terrain
- Natural Gas Hookup (New Construction)

## EPW Location

**INPUT:**
Use the drop-down menu to specify the building location.

Clicking on the graph button launches a separate window where you can visualize the hourly weather data.

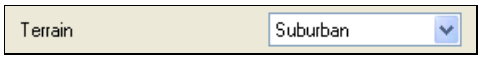
Clicking on the down arrow button allows you to quickly download one or more EPW weather files from the EnergyPlus website. Note: this button is not visible if using the California Metrics project type, as all available CA weather files are shipped with BEopt.

**EFFECT IN CALCULATION:**
The location identifies the weather file that will be used for both the building energy simulation and the photovoltaic and solar hot water heating simulations.

**DEFAULT VALUE:**
USA_GA_Atlanta-Hartsfield-Jackson.Intl.AP.722190_TMY3.epw
(CZ01RV2.epw for California Metrics project type)

**MORE INFORMATION:**
Click the graph icon to visualize the hourly data in DView. Click the down arrow to bring up a popup window where one or multiple EPW weather files can be quickly downloaded from the EnergyPlus Weather File Download Area.

## Terrain



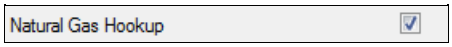

**INPUT:**
Use the drop-down menu to specify the building's terrain environment.

**EFFECT IN CALCULATION:**
Used by simulation engines to modify the local free stream wind speed to account for ground roughness at the weather station. Ultimately affects the wind speed at the building and the resulting air infiltration.

**DEFAULT VALUE:**
Suburban

**MORE INFORMATION:**
See the Wind Speed Profile Coefficients table in ASHRAE Fundamentals 2005 or the EnergyPlus Engineering Reference documentation.

## Natural Gas Hookup (New Construction)




This input will only show up for New Construction analysis.

**INPUT:**
When unchecked, the B10 Benchmark reference will be an all-electric building. Otherwise, it will be a mixed fuel building.

**DEFAULT VALUE:**
Checked

## Economics

- Project Analysis Period
- Inflation Rate
- Discount Rate (Real)
- Material Cost Multiplier
- Labor Cost Multiplier

## Project Analysis Period

| Project Analysis Period | 30 | years |
|---|---|---|

**INPUT:**
Enter the analysis period for the project.

**EFFECT IN CALCULATION:**
This value is used in calculating the cash flows and various economic metrics.

**DEFAULT VALUE:**
30 years

**MORE INFORMATION:**

## Inflation Rate

| Inflation Rate | 3.0 | % |
|---|---|---|

**INPUT:**
Enter the inflation rate.

**EFFECT IN CALCULATION:** This value is used to properly inflate costs (e.g. option replacement costs and utility bill payments) over the project analysis period.

**DEFAULT VALUE:**
3.0%

**MORE INFORMATION:**

## Discount Rate (Real)

| Discount Rate (Real) | 3.0 | % |
|---|---|---|

**INPUT:**
Enter the real discount rate (excluding inflation).

**EFFECT IN CALCULATION:** This value is used in calculating the cost of cash flows over the project analysis period for various economic metrics.

**DEFAULT VALUE:**
3.0%

**MORE INFORMATION:**
The nominal discount rate = (1 + real discount rate) * (1 + inflation rate) - 1.

## Efficiency Material Cost Multiplier

| Efficiency Material Cost Multiplier | 1.000 |
|---|---|

**INPUT:**
This value allows the user to modify the material cost of all efficiency options (including Solar DHW).

**EFFECT IN CALCULATION:**
All options' material costs across all efficiency categories are multiplied by this value.

**DEFAULT VALUE:**
1.000

**MORE INFORMATION:**

## Efficiency Labor Cost Multiplier

| Efficiency Labor Cost Multiplier | 1.000 |
|---|---|

**INPUT:**
This value allows the user to modify the labor cost of all efficiency options (including Solar DHW).

**EFFECT IN CALCULATION:**
All options' labor costs across all efficiency categories are multiplied by this value.

**DEFAULT VALUE:**
1.000

**MORE INFORMATION:**

## PV Material Cost Multiplier

| PV Material Cost Multiplier | 1.000 |
|---|---|

**INPUT:**
This value allows the user to modify the material cost of all PV options.

**EFFECT IN CALCULATION:**
All PV options' material costs are multiplied by this value.

**DEFAULT VALUE:**
1.000

**MORE INFORMATION:**

## Efficiency Labor Cost Multiplier

| PV Labor Cost Multiplier | 1.000 |
|---|---|

**INPUT:**
This value allows the user to modify the labor cost of all PV options.

**EFFECT IN CALCULATION:**
All PV options' labor costs are multiplied by this value.

**DEFAULT VALUE:**
1.000

**MORE INFORMATION:**

## Mortgage

- Down Payment (New Construction)
- Mortgage Interest Rate (New Construction)
- Mortgage Period (New Construction)
- Payment Type (Retrofit)
- Cash Payment (Retrofit)
- Loan Interest Rate (Retrofit)
- Loan Period (Retrofit)
- Marginal Income Tax Rate, Federal
- Marginal Income Tax Rate, State

## Down Payment (New Construction)

| Down Payment | 0.0 | % |
|---|---|---|

This input will only show up for New Construction analysis.

**INPUT:**
Enter the mortgage down payment, i.e. the initial upfront cash payment, as a percentage of the purchase price.

**EFFECT IN CALCULATION:**
In the cash flows, this payment is considered upfront rather than rolled into the mortgage payments.

**DEFAULT VALUE:**
0.0%

**MORE INFORMATION:**
If 100% is entered, the entire purchase is done upfront in cash and there are no mortgage payments.

## Mortgage Interest Rate (New Construction)

| Mortgage Interest Rate | 7.0 | % |
|---|---|---|

This input will only show up for New Construction analysis.

**INPUT:**
Enter the mortgage rate.

**EFFECT IN CALCULATION:**
The mortgage rate is used in calculating the annual cost of energy efficiency measures and solar equipment. The mortgage rate will be compounded monthly when calculating annual cash flows.

**DEFAULT VALUE:**
7.0%

**MORE INFORMATION:**
For historical national average mortgage rates, go to the Mortgage Information Service Website. At this site, you can view data for 30 and 15 year fixed rate mortgages.

## Mortgage Period (New Construction)

Mortgage Period 30 years

This input will only show up for New Construction analysis.

**INPUT:**
End of the term of the mortgage.

**EFFECT IN CALCULATION:**
This value is used in calculating the mortgage portion of the energy related costs.

**DEFAULT VALUE:**
30 years

**MORE INFORMATION:**

## Payment Type (Retrofit)

Type ◉ Tax Deductible Loan ○ Loan ○ Cash

This input will only show up for Retrofit analysis.

**INPUT:**
The type of payments made for the retrofit improvements to the house. The choices are Tax Deductible Loan, Loan, or Cash.

**EFFECT IN CALCULATION:**
A tax deductible loan (e.g., a home equity loan or home equity line of credit) will use the marginal income tax rates to calculate tax deductions. Loans and tax deductible loans will incur annual loan payments; the cash option assumes 100% of the retrofit is paid upfront via cash.

**DEFAULT VALUE:**
Tax Deductible Loan

**MORE INFORMATION:**

## Cash Payment (Retrofit)

Cash Payment 0.0 %

This input will only show up for Retrofit analysis. If the Cash Payment Type is chosen, the input will be disabled and set to 100%.

**INPUT:**
Enter the cash payment, i.e. the initial upfront payment, as a percentage of the retrofit cost.

**EFFECT IN CALCULATION:**
In the cash flows, this payment is considered upfront rather than rolled into the loan payments.

**DEFAULT VALUE:**
0.0%

**MORE INFORMATION:**

## Loan Interest Rate (Retrofit)

Loan Interest Rate 7.0 %

This input will only show up for Retrofit analysis. If the Cash Payment Type is chosen, the input will be disabled.

**INPUT:**
Enter the loan interest rate.

**EFFECT IN CALCULATION:**
The loan rate is used in calculating the annual cost of energy efficiency measures and solar equipment. The rate will be compounded monthly when calculating annual cash flows. Loans are only calculated for retrofit measures that are replaced today; retrofit measures replaced in the future (i.e. at natural wear-out) will be paid in cash.

**DEFAULT VALUE:**
7.0%

**MORE INFORMATION:**

## Loan Period (Retrofit)

| Loan Period | 5 | years |
|---|---|---|

This input will only show up for Retrofit analysis. If the Cash Payment Type is chosen, the input will be disabled.

**INPUT:**
End of the term of the loan.

**EFFECT IN CALCULATION:**
This value is used in calculating the loan portion of the energy related costs. Loans are only calculated for retrofit measures that are replaced today; retrofit measures replaced in the future (i.e. at natural wear-out) will be paid in cash.

**DEFAULT VALUE:**
5 years

**MORE INFORMATION:**

## Marginal Income Tax Rate, Federal

| Marginal Income Tax Rate, Federal | 28.0 | % |
|---|---|---|

This input will only show up for New Construction analysis.

**INPUT:**
Enter the federal tax rate for the homeowner's highest level of income.

**EFFECT IN CALCULATION:**
This tax rate is used in conjunction with the state marginal income tax rate to calculate annual tax deductions based on the interest portion of mortgage payments or tax deductible retrofit loans.

**DEFAULT VALUE:**
28.0%

**MORE INFORMATION:**
Using a rate of 28% assumes that an individual homeowner's income exceeded $85,650 ($142,700 for married couples filing jointly) in 2012. To view the marginal tax rates for other income levels, see the rate schedule at the IRS website.

The effective tax rate used to calculate tax deductions is (federal tax rate + state tax rate * (1 - federal tax rate)). This takes into account the fact that you can deduct state income tax payments on a federal tax return if you itemize deductions.

## Marginal Income Tax Rate, State

| Marginal Income Tax Rate, State | 0.0 | % |
|---|---|---|

This input will only show up for New Construction analysis.

**INPUT:**
Enter the state tax rate for the homeowner's highest level of income.

**EFFECT IN CALCULATION:**
This tax rate is used in conjunction with the federal marginal income tax rate to calculate annual tax deductions based on the interest portion of mortgage payments or tax deductible retrofit loans.

**DEFAULT VALUE:**
0.0%
(9.3% for California Metrics project type)

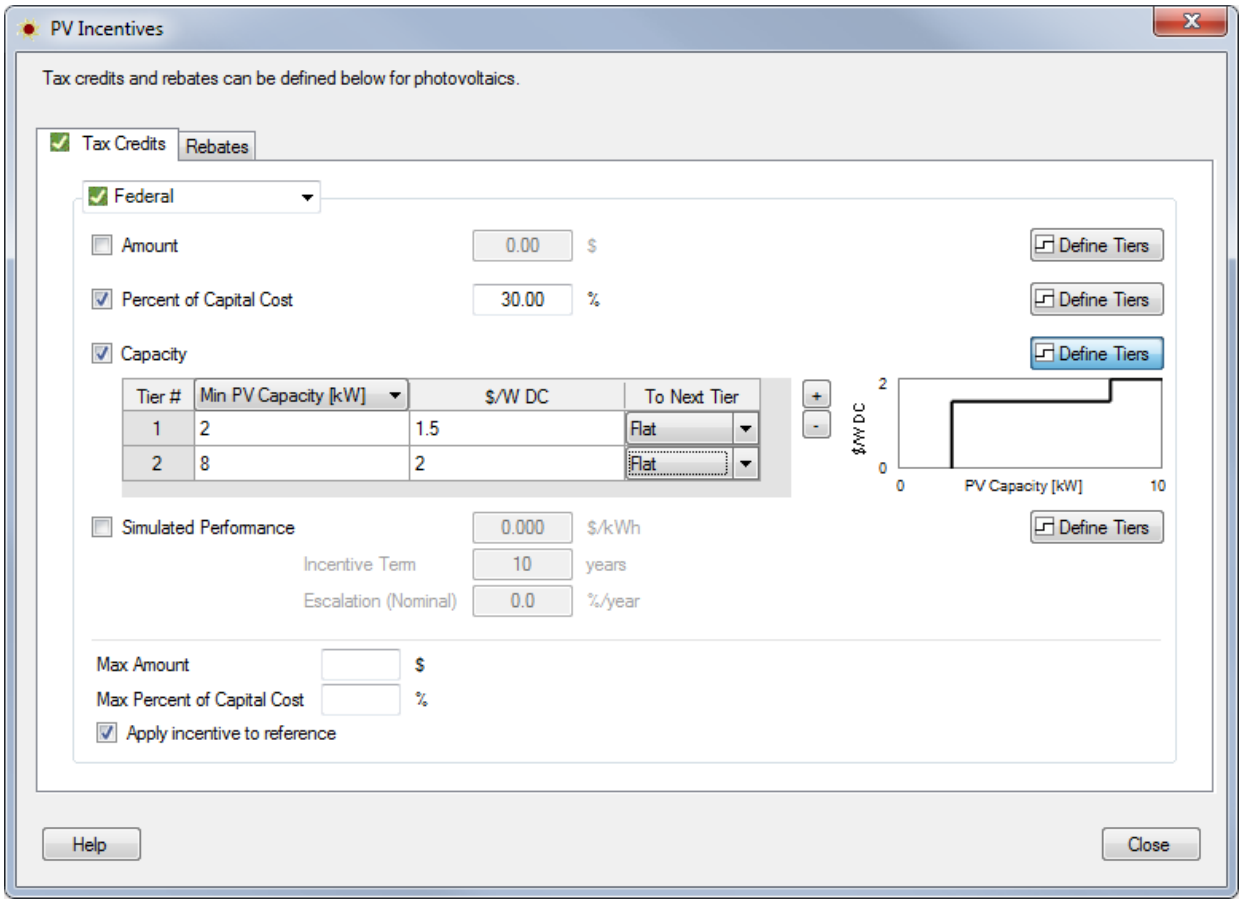
**MORE INFORMATION:**
The effective tax rate used to calculate tax deductions is (federal tax rate + state tax rate * (1 - federal tax rate)). This takes into account the fact that you can deduct state income tax payments on a federal tax return if you itemize deductions.

## Other

- PV Incentives
- Efficiency Incentives
- Demand Response Signals

# PV Incentives

Clicking on the above button launches a window where you can specify PV incentives. These PV incentives can, for example, be tied to the performance (energy production) of the PV system.




The PV incentives dialog allows the user to define tax credits and rebates for different entities (e.g. federal, state, utility). The incentive can then be specified in a number of ways:

- Amount - a fixed incentive amount.
- Percent of Capital Cost - the incentive is a percentage of the capital cost incurred for the PV system.
- Capacity - the incentive is defined as a dollar per capacity (kW DC) of the PV system.
- Simulated Performance - the incentive is defined as a dollar per unit of energy produced for the given fuel type. In this case, the incentive can be repeated over multiple years including a nominal escalation rate.

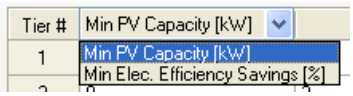
By clicking the checkbox next to the incentive type, incentives can be enabled or disabled. If multiple incentives are enabled, they will be added together.

A maximum value (specified in $ or percent of capital cost) can be entered to cap the maximum incentive amount (e.g. a maximum rebate of $2000 from the utility). In addition, the user can specify whether the incentive should be applied to the reference.

Finally, any incentive type can be specified in a tiered approach by clicking the Define Tiers button and entering information about each tier. New tiers can be added or removed by clicking the + or - buttons. The graph to the right will dynamically update based on the information entered in the table. In the example above, a tax credit based on Capacity will be given as follows:

- Starting at 2 kW DC, $1.50 for each kW installed.
- Starting at 8 kW DC, $2.00 for each kW installed.

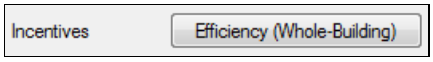
Tiers can be defined either based on capacity ("Min PV Capacity [kW]") or linked to the efficiency of the building ("Min Elec. Efficiency Savings [%]") by choosing the appropriate dropdown item from the tier table's column header.




Anytime an incentive is defined and enabled, green checkboxes will be displayed in the relevant places (including the Site Input Screen) to show that there are incentives that will be used in the analysis.

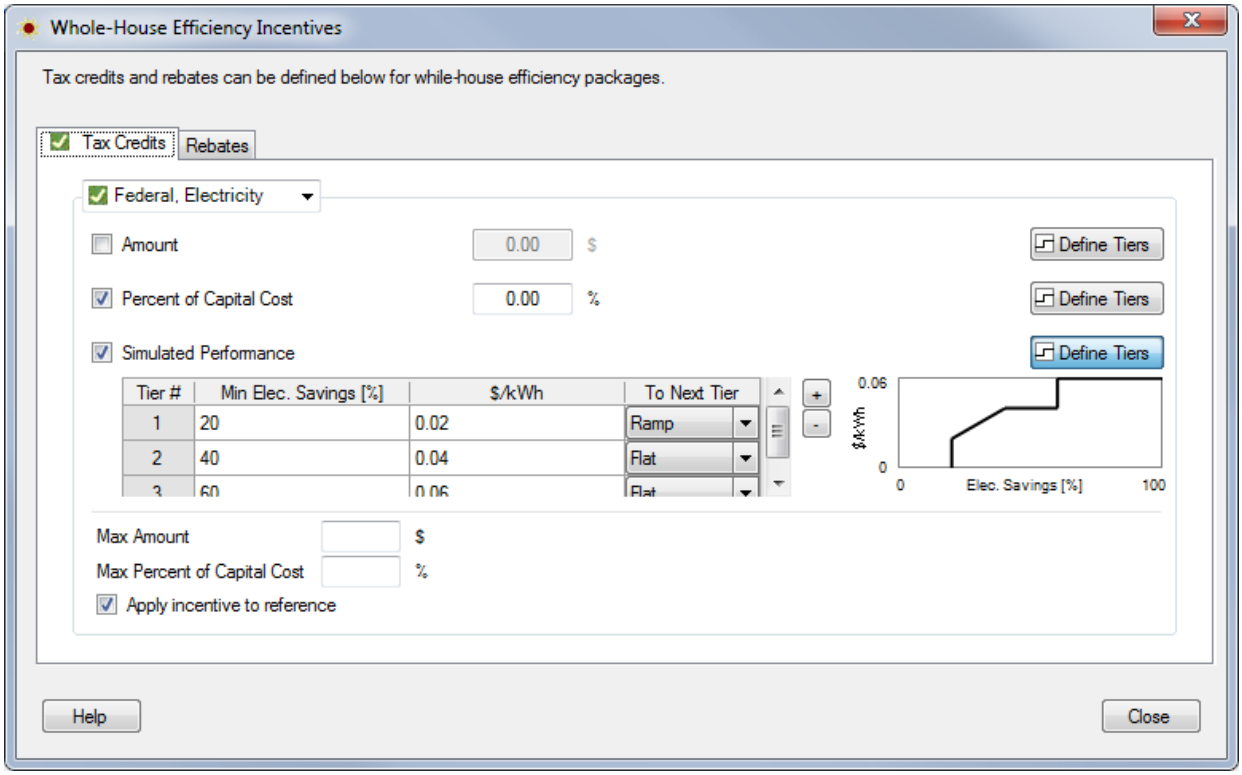
For incentives based on simulated performance, first year energy production (rather than life-cycle energy production) will be used.

## Efficiency Incentives (Whole-Building)




Clicking on the above button launches a window where you can specify whole-building efficiency incentives. These whole-building efficiency incentives can, for example, be tied to the performance (energy savings) of the home. The structure of the incentives is largely borrowed from the PV Incentives dialog.

Note: We recognize that there are many energy efficiency incentive programs that are defined on a measure-by-measure basis rather than a whole-building approach. We hope to include capabilities to accommodate these types of programs in the future.




The efficiency incentives dialog allows the user to define tax credits and rebates for different combinations of entity (e.g. federal, state, utility) and fuel type. The incentive can then be specified in a number of ways:

- Amount - a fixed incentive amount.
- Percent of Capital Cost - the incentive is a percentage of the capital cost incurred for the efficiency measure or package.
- Simulated Performance - the incentive is defined as a dollar per unit of energy saved for the given fuel type.

By clicking the checkbox next to the incentive type, incentives can be enabled or disabled. If multiple incentives are enabled, they will be added together.

A maximum value (specified in $ or percent of capital cost) can be entered to cap the maximum incentive amount (e.g. a maximum rebate of $2000 from the electric utility). In addition, the user can specify whether the incentive should be applied to the reference.

Finally, any incentive type can be specified in a tiered approach by clicking the Define Tiers button and entering information about each tier. New tiers can be added or removed by clicking the + or - buttons. The graph to the right will dynamically update based on the information entered in the table. In the example above, a tax credit based on Simulated Performance will be given as follows:

- Starting at 20% whole-building electricity savings, 2 cents for each kWh saved.
- Between 20% and 40% whole-building electricity savings, 2-4 cents for each kWh saved, linearly interpolating between.
- Starting at 40% whole-building electricity savings, 4 cents for each kWh saved.
- Starting at 60% whole-building electricity savings, 6 cents for each kWh saved.

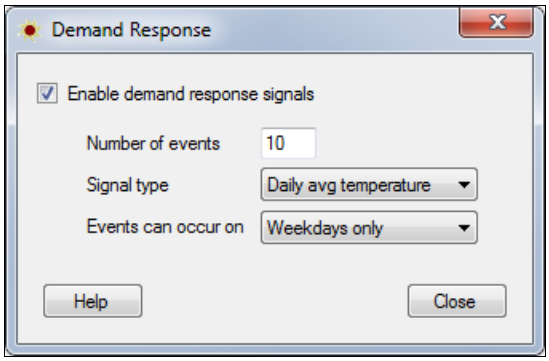
Anytime an incentive is defined and enabled, green checkboxes will be displayed in the relevant places (including the Site Input Screen) to show that there are incentives that will be used in the analysis.

For incentives based on simulated performance, first year energy savings (rather than life-cycle energy savings) will be used.

## Demand Response Signals

Clicking on the above button launches a window where you can specify demand response (DR) signals/events. Based on the occurrence of demand response

signals/events, options with demand response capabilities defined will respond by using shifted consumption patterns/schedules.




**Enable demand response signals**: Toggles on or off the definition of demand response signals/events. If enabled, the DR signals will only impact BEopt results if options are defined and selected that include demand response capabilities.

**Number of events**: The number of DR event days that will occur in the year. The value must be between 1 and 365.

**Signal type**: The occurrence of DR events can be defined based on daily avg temperature or daily max temperature. When a California climate zone weather file (e.g. CZ01RV2.epw) is specified as the EPW Location, daily avg TDV and daily max TDV are also available. BEopt will automatically calculate the DR event days for which the signal type is greatest.

**Events can occur on**: Specifies whether DR events can occur on any day, weekdays only, or weekends only. Some utilities, for example, may only see critical peak loads when outdoor temperatures are high and on weekdays (e.g., when additional commercial loads are occurring).

## California Metrics

- Net-to-Gross Ratio (California Metrics)
- Program Cost (Present Value) (California Metrics)
- CA Climate Zone Utility (California Metrics)
- CA Climate Zone Region (California Metrics)

## Net-to-Gross Ratio (California Metrics)

| | | |
|---|---|---|
| Net-to-Gross Ratio | 100.0 | % |

This input will only show up when a California climate zone weather file (e.g. CZ01RV2.epw) is specified as the EPW Location.

**INPUT:**
Enter the net-to-gross ratio for the utility-sponsored energy efficiency program.

**EFFECT IN CALCULATION:**
Net-to-gross ratios are used in the calculation of California's Total Resource Cost Test.

**DEFAULT VALUE:**
90.0%

**MORE INFORMATION:**
Net-to-gross ratios are important in determining the actual energy savings attributable to a particular program, as distinct from energy efficiency occurring naturally (in the absence of a program). The net-to-gross ratio equals the net program load impact divided by the gross program load impact. This factor is applied to gross program savings to determine the program's net impact. Adapted from the California Public Utilities Commission Website: http://docs.cpuc.ca.gov/published/Final_decision/11474-13.htm

## Program Cost (Present Value) (California Metrics)

| | | |
|---|---|---|
| Program Cost (Present Value) | 0 | $/home |

This input will only show up when a California climate zone weather file (e.g. CZ01RV2.epw) is specified as the EPW Location.

**INPUT:**

**DEFAULT VALUE:**

Enter the net present value of per-home program administration program costs for the utility-sponsored energy efficiency program.

**EFFECT IN CALCULATION:**
Program costs are used in the calculation of California's Program Administrator Cost Test.

$100/home

**MORE INFORMATION:**

## CA Climate Zone Utility (California Metrics)

Utility ◉ SCE ○ SDG&E

This input will only show up when a California climate zone weather file (e.g. CZ01RV2.epw) is specified as the EPW Location.

**INPUT:**
Select the utility within the California climate zone for the utility-sponsored energy efficiency program.

**EFFECT IN CALCULATION:**
When calculating California metrics, some climate zones have multiple utilities that service that zone, each with its own set of avoided cost factors. The choice of utility will dictate which avoided cost factors to use. Avoided costs are used in the calculation of the Total Resource Cost Test, Ratepayer Impact Measure Test, and Program Administrator Cost Test.

**DEFAULT VALUE:**

**MORE INFORMATION:**
California avoided cost factors can be found in the \Modeling\Data\AvoidedCosts directory.

## CA Climate Zone Region (California Metrics)

Region ◉ Peninsula ○ East Bay

This input will only show up when a California climate zone weather file (e.g. CZ01RV2.epw) is specified as the EPW Location.

**INPUT:**
Select the region within the California climate zone for the utility-sponsored energy efficiency program.

**EFFECT IN CALCULATION:**
When calculating California metrics, some climate zones have different avoided cost factors for different regions. The choice of region will dictate which avoided cost factors to use. Avoided costs are used in the calculation of the Total Resource Cost Test, Ratepayer Impact Measure Test, and Program Administrator Cost Test.

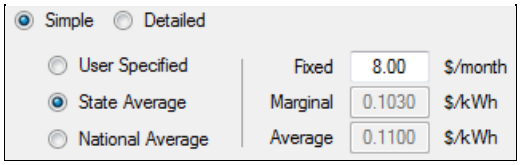
**DEFAULT VALUE:**

**MORE INFORMATION:**
California avoided cost factors can be found in the \Modeling\Data\AvoidedCosts directory.

## Utility Rates

- Electric Utility Rates
- Non-Electric Utility Rates
- Utility Rate Wizard
- Fuel Escalation (Real)
- Centrally Metered (Multifamily)
- Net Metering
- Feed-in Tariff
- PV Monthly Grid Connection Fee
- Source/Site Ratio
- Carbon Factor

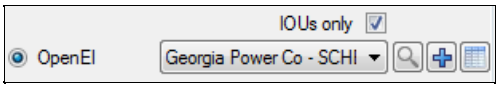
## Electric Utility Rates




**INPUT:**
BEopt can handle electric utility rates of varying complexity. Choose between Simple (flat) or Detailed (time-of-use, tiered, tiered time-of-use, or real-time pricing).

- Simple
  - *User Specified* - Enter the Marginal Cost not including monthly fixed costs, enter monthly Fixed Cost, and BEopt will calculate and display the Average Cost
  - *State Average* - Enter the monthly Fixed Cost, and BEopt will calculate and display the Marginal Cost and the Average Cost based on the most recently available EIA data.
  - *National Average* - Enter the monthly Fixed Cost, and BEopt will calculate and display the Marginal Cost and the Average Cost based on the most recently available EIA data.

- Detailed
  - *OpenEI* - Select the utility and tariff structure of interest from a list of thousands of rates provided by the OpenEI database; the tariff may be defined in terms of time-of-use and/or tiered rates. (Note: When a California climate zone weather file (e.g. CZ01RV2.epw) is specified as the EPW Location, only the applicable OpenEI IOU rates for the current CA Climate Zone Utility will be available.)

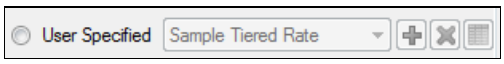
    Checking the "IOUs only" box will filter the list of utilities by only those utilities that are Investor Owned Utilities. (Note: This checkbox is not available for the California Metrics project type.)

    Clicking on the magnifying glass button provides a popup window where the user can search for utility tariffs by zipcode. (Note: This button is not available for the California Metrics project type.)

    Clicking on the plus button creates a copy of the selected OpenEI rate. The Utility Rate Wizard is automatically opened for this copy to allow modifications.

    Clicking on the table button opens the Utility Rate Wizard where the rate can be viewed.

  - *User Specified* - Select from your list of user-defined tariff structures; the tariffs may be defined in terms of time-of-use and/or tiered rates, as well as real-time pricing. The tariffs may also be copied from an OpenEI rate (see above) as a template for your custom rate.

    Clicking on the plus button creates a copy of the selected user specified rate.The Utility Rate Wizard is automatically opened for this copy to allow modifications.

    Clicking on the X button deletes the currently selected rate. Note that sample rates cannot be deleted.

    Clicking on the table button opens the Utility Rate Wizard where the rate can be edited/viewed.

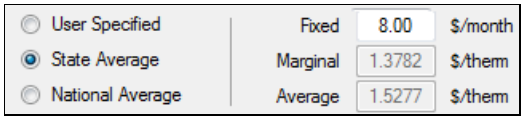
**DEFAULT VALUE:**
Simple; State Average

**MORE INFORMATION:**
Electricity prices can vary dramatically from region to region. Check with the utility in the building's area for more accurate values. Historical data for electricity and residential customers is available through the Energy Information Administration at www.eia.doe.gov.

Open Energy Information (OpenEI) contains utility tariff information for thousands of utilities around the country, which is made available through the BEopt interface. See http://en.openei.org/wiki/Gateway:Utilities for more information on the raw data. BEopt currently uses OpenEI v2 data.

**EFFECT IN CALCULATION:**
For simple utility rates, utility bill costs are calculated based on the marginal cost of electricity and any monthly fixed charges. For detailed utility rates, utility bill costs are calculated based on the tariff structure defined by OpenEI or the user.

## Non-Electric Utility Rates




**INPUT:**
Natural gas, oil, and propane utility rates can be entered in a few different ways:

- *User Specified* - Enter the Marginal Cost not including monthly fixed costs, enter monthly Fixed Cost, and BEopt will calculate and display the Average Cost
- *State Average* - Enter the monthly Fixed Cost, and BEopt will calculate and display the Marginal Cost and the Average Cost based on the most recently available EIA data.
- *National Average* - Enter the monthly Fixed Cost, and BEopt will calculate and display the Marginal Cost and the Average Cost based on the most recently available EIA data.

Note that there are no monthly fixed charges associated with oil and propane utility rates.

**EFFECT IN CALCULATION:**
Utility bill costs are calculated based on the marginal cost of fuel and any monthly fixed charges.

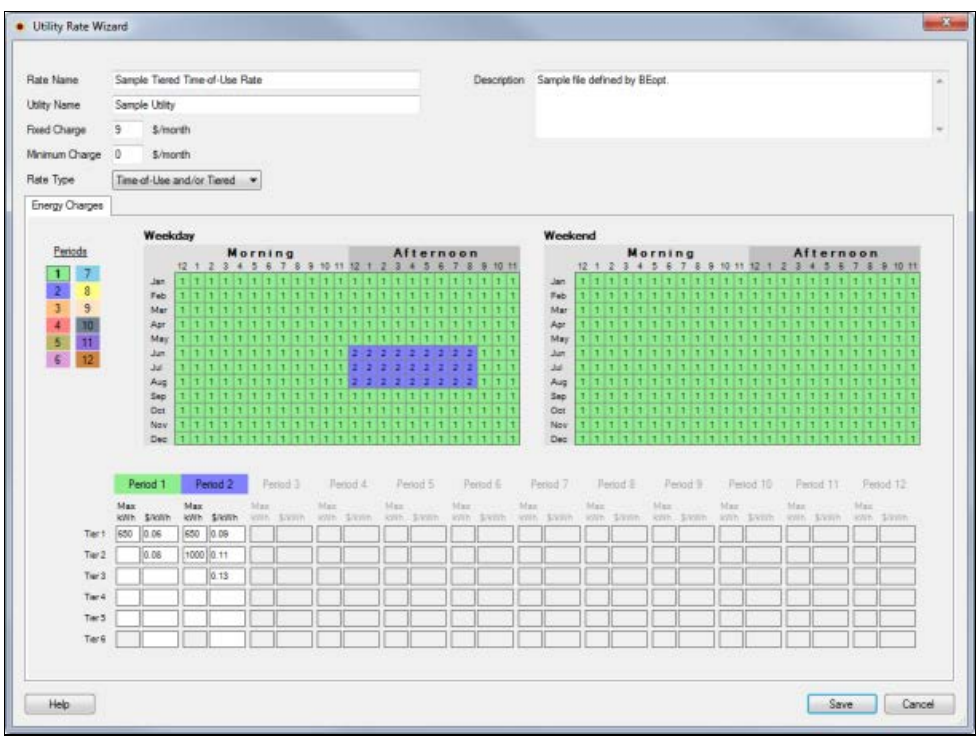
**DEFAULT VALUE:**
State Average

**MORE INFORMATION:**
Fuel prices can vary dramatically from region to region. Check with the utility in the building's area for more accurate values. Historical data for fuels and residential customers is available through the Energy Information Administration at www.eia.doe.gov.

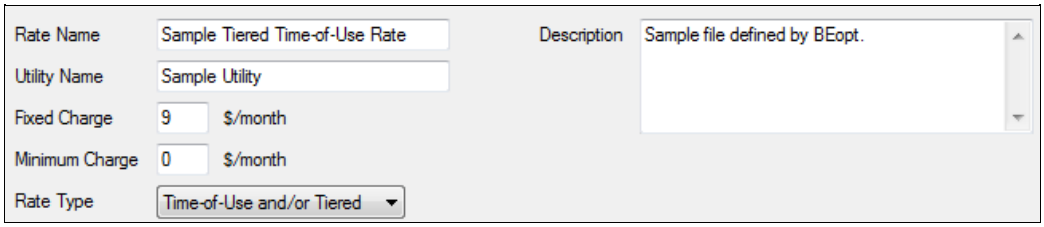
## Utility Rate Wizard

The utility rate wizard can be launched for detailed electric utility rates and allows viewing/editing of utility tariffs.

Note that OpenEI rates and sample custom rates can be viewed or copied, but not modified.



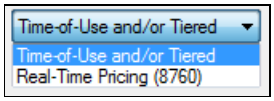
The top of the dialog allows general information to be provided, including the rate name, utility name (if applicable), fixed and/or minimum charge, description, and rate type.




Most utilities use fixed charges, but some utilities are moving to replace or supplement fixed charges with minimum charges. A monthly utility bill with fixed charges is calculated as the sum of the fixed and electricity charges. A monthly utility bill with minimum charges is calculated as the higher charge between the minimum and electricity charges. A monthly utility bill with both fixed and minimum charges is calculated as the higher charge between the minimum and the sum of fixed and electricity charges. That is:

- Utility bill with fixed charges = Fixed Charges + Electricity Charges
- Utility bill with minimum charges = MAX(Minimum Charges, Electricity Charges)
- Utility bill with fixed and minimum charges = MAX(Minimum Charges, Fixed Charges + Electricity Charges)

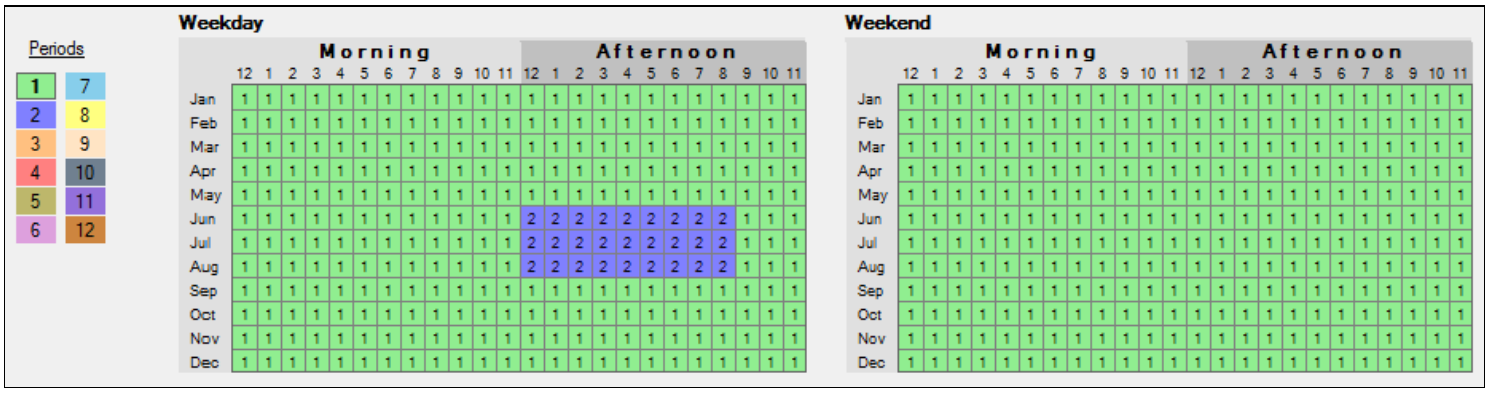
The rate type dropdown provides two choices:



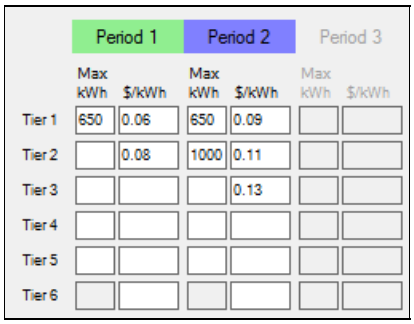

- **Time-of-Use and/or Tiered**
  The time-of-use/tiered rate type provides a simple interface for rapidly defining tariffs with time-of-use, tiered, or tiered time-of-use rates. The interface is split into two parts: the definition of periods (time-of-use) and the definition of tiers.

  Periods are portions of the year that have a single or tiered rate. To define a period, first click on a period number on the left side; if selected, it will be highlighted in bold. Then click and drag the mouse over the appropriate portion of the year (hours/months) for weekdays and/or weekends for which the period applies. Up to 12 periods can be defined (e.g., one for each month).

  In the example below, period 2 applies to the months of June-August at noon through 9pm for weekdays only; the remainder of the year is defined by period 1.

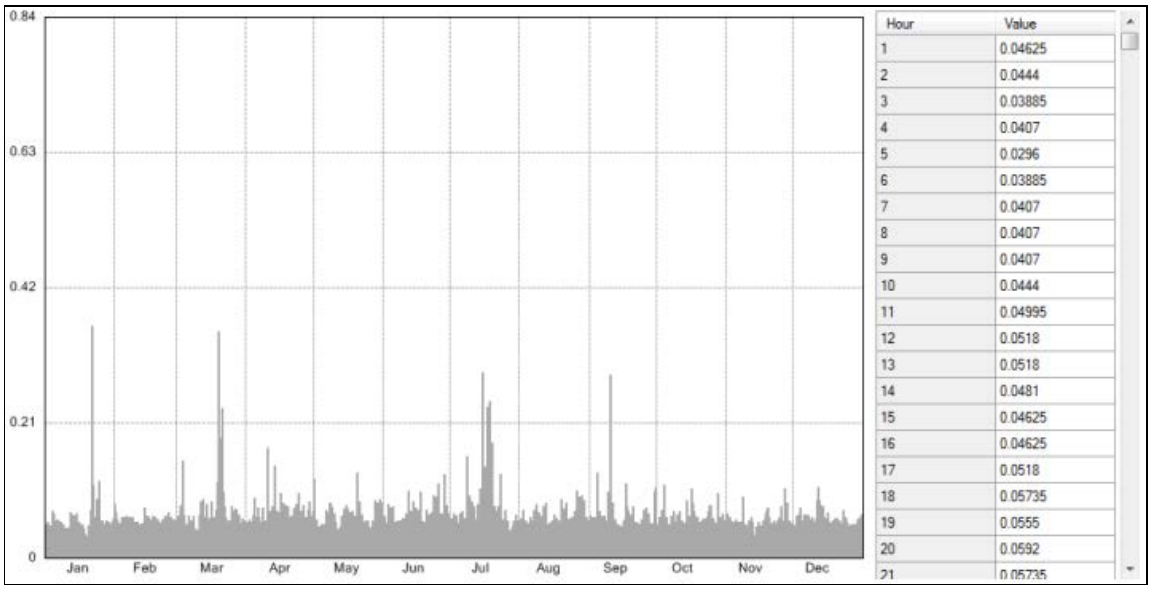



  When a period is defined for either weekdays or weekends, it becomes enabled below for entering rate values.One or more tier values can be entered for the period of interest. If a single rate is entered, no tier values need to be supplied; if multiple (tiered) rates are entered, one less maximum tier value must also be supplied. Up to 6 tiers can be defined.

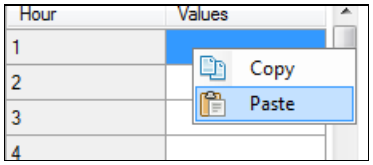



  Periods 1 and 2 above demonstrate inclining tiered block rates. In Period 1, the first 650 kWhs of monthly energy consumption is costed at $0.06/kWh and any additional monthly consumption is costed at $0.08/kWh. In Period 2, the first 650 kWhs of monthly energy consumption is costed at $0.09/kWh, the next 350 kWhs is costed at $0.11/kWh, and any additional monthly consumption is costed at $0.13/kWh.

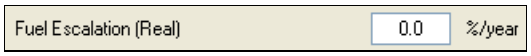
- **Real-Time Pricing (8760)**
  The real-time pricing rate type allows values for every hour of the year (8760) to be entered and visualized.




Hourly rate data from external files can be copied and pasted by right-clicking on the table.




## Fuel Escalation (Real)



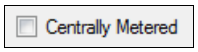

**INPUT:**
This value allows the user to determine how fuel rates rise year over year (excluding inflation).

**EFFECT IN CALCULATION:**
Utility rates (both fixed charges and energy charges) over the analysis period will increase each year by combining fuel escalation and inflation. If 0% is entered, utility bills will rise with inflation.

**DEFAULT VALUE:**
0%

**MORE INFORMATION:**

## Centrally Metered (Multifamily)




This input will only show up for multifamily buildings .

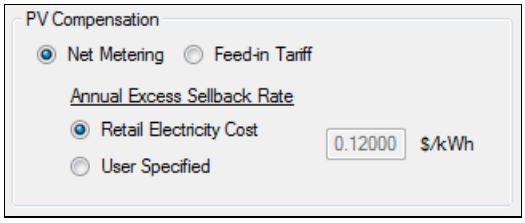
**INPUT:**
This value allows the user to determine whether the fuel is centrally metered, or individually metered at the multifamily unit.

**EFFECT IN CALCULATION:**
Utility rates for individually metered units, will include fixed charges for each unit in the building. Utility rates for central metering will include a single fixed charge.

**DEFAULT VALUE:**
False

**MORE INFORMATION:**

## Net Metering




**INPUT:**
Select either Retail Electricity Cost or User Specified for the annual excess sellback rate. When Retail Electricity Cost is selected, the annual excess PV production is credited using the Marginal Rate for Electricity or OpenEI Utility Rate, depending on the type of electricity rate specified.

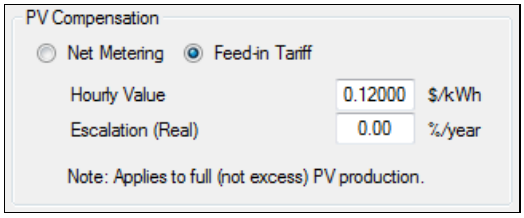
**EFFECT IN CALCULATION:**

Net-metering credits annual PV production less than or equal to the annual building electricity consumption at the retail rate of electricity (i.e., the meter runs backwards). When the annual PV production exceeds the annual building electricity consumption, BEopt uses this rate to determine the value of the excess electricity sold back to the utility. This may happen to offset gas consumption, for example. Since there are very few cases where modeled electricity consumption will increase from one year to the next, "indefinite rollover" of annual excess generation credit is best approximated by setting the user specified sell-back rate to zero. Note that some time of use rates may result in an annual credit even if annual PV production does not exceed annual electricity consumption.

**DEFAULT VALUE:**
Retail Electricity Cost

**MORE INFORMATION:**
The sellback rate is often significantly below the retail rate. Net metering rules for each state (along with other applicable renewable incentives) can be found through the Database of State Incentives for Renewable Energy or DSIRE; www.dsireusa.org. Check with the appropriate utility to verify current rates.

## Feed-in Tariff




**INPUT:**
Specify the hourly value of PV production as well as the escalation rate (excluding inflation). A negative value can also be specified for the escalation rate if the feed-in tariff rate is reduced over time.

**EFFECT IN CALCULATION:**

The hourly value is applied to full, not excess, annual PV production. The PV credit in future years is adjusted based on the escalation rate.

**DEFAULT VALUE:**
Hourly Value: 0.12 $/kWh
Escalation (Real): 0 %/year

**MORE INFORMATION:**
Note that some utilities/regions may have a feed-in tariff policy where compensation occurs for excess PV production (i.e., PV-generated electricity sent to the grid that is not immediately consumed by the building), rather than full PV production. BEopt, which uses simulation engines that perform calculations on a time-step basis, is currently unable to calculate utility bills for such a feed-in tariff policy.

## PV Monthly Grid Connection Fee

**INPUT:**
This value specifies the monthly fee for connecting a PV system to the grid. The value can be entered in $/kW/month or $/month.

**EFFECT IN CALCULATION:**
Utility rate fixed charges will include this connection fee if the building has a PV system.

**DEFAULT VALUE:**
$0/kW

**MORE INFORMATION:**
A fee of $0.70/kW per month has recently been introduced in Arizona (http://www.bloomberg.com/news/articles/2013-11-15/arizona-regulators-impose-power-grid-fees-for-solar-roofs).

## Source/Site Ratio

| Source/Site Ratio | 3.365 |
|---|---|

This input is read only when using a Building America project.

**INPUT:**
Enter the ratio of energy consumed at a central power plant to that delivered to the residential customer.

**EFFECT IN CALCULATION:**
This ratio is used to determine the percentage of source energy that is saved. The energy efficiency measures that are evaluated through BEopt save more energy than just the amount saved at the end use. This concept is sometimes referred to as "downstream efficiency". For example if the source/site ratio is set to "3", one unit of energy saved in the residence will actually save three units of source energy. Similarly, when adding PV to the home, one unit of electricity produced by PV would offset three units of source energy that do not have to be produced.

**DEFAULT VALUE:**
3.15 (Electricity)
1.09 (Natural Gas)
1.19 (Fuel Oil)
1.15 (Propane)

(national averages, ANSI/ASHRAE Standard 105-2014, Appendix J)

**MORE INFORMATION:**
If regional source/site ratios are desired, eGRID subregions are the recommended granularity because power is frequently wheeled within these subregions, and much less frequently wheeled across subregions. The eGRID subregion for a particular site can be found using the EPA Power Profiler. Source energy and carbon factors for eGRID subregions are published in ANSI/ASHRAE Standard 105-2014, Appendix J.

## Carbon Factor

| Carbon Factor | 1.670 | lb/kWh |
|---|---|---|

**INPUT:**
This value allows the user to modify the lbs of carbon emitted per unit of fuel consumed.

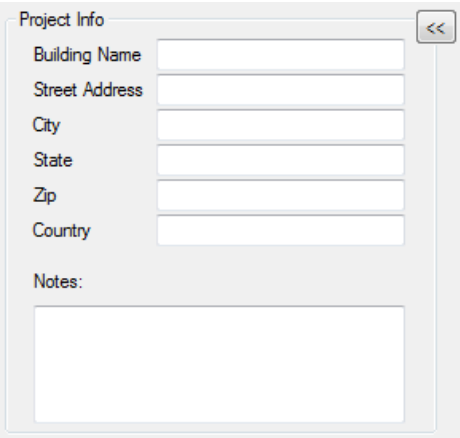
**EFFECT IN CALCULATION:**
The Carbon Factor is used to calculate equivalent CO2 emissions (shown on the CO2e emissions graph) for each fuel energy use. The default value is a national average of pounds of equivalent carbon dioxide released per unit of fuel, as published in ANSI/ASHRAE Standard 105-2014, Appendix J. Equivalent CO2 is calculated using 100-year time horizon global warming potential (GWP) values for CO2, NOx, and methane emissions.

**DEFAULT VALUE:**
1.53 lb/kWh (Electricity)
14.15 lb/therm (Natural Gas)
27.37 lb/gal (Fuel Oil)
15.70 lb/gal (Propane)

(national averages, ANSI/ASHRAE Standard 105-2014, Appendix J)

**MORE INFORMATION:**
If regional carbon factors are desired, eGRID subregions are the recommended granularity because power is frequently wheeled within these subregions, and much less frequently wheeled across subregions. The eGRID subregion for a particular site can be found using the EPA Power Profiler . Source energy and carbon factors for eGRID subregions are published in ANSI/ASHRAE Standard 105-2014, Appendix J.

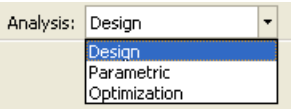
## Project Info




**INPUT:**
The project info panel is a series of textboxes where the energy analyst can store various information related to the building or project.

**MORE INFORMATION:**
The panel can be collapsed by clicking on the <<
button (and re-expanded by clicking on the >> button).

## Analysis Modes



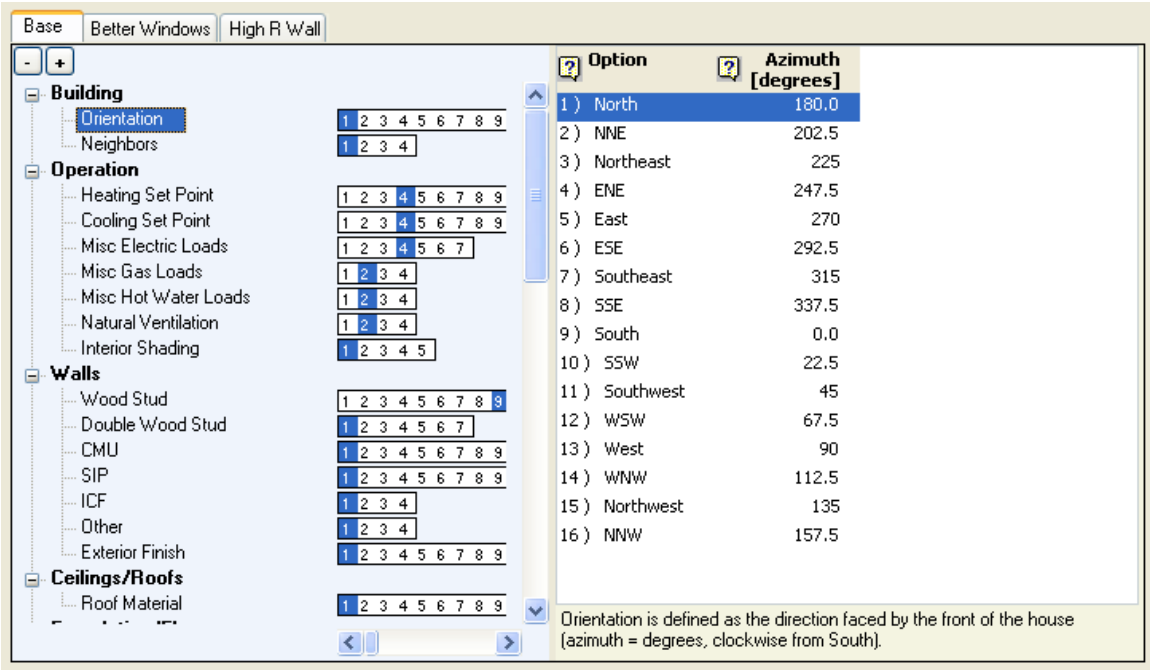

Select one of three analysis modes: [D] Design, [P] Parametric, or [O] Optimization. The choice of analysis mode will influence the design tabs that are displayed in the Options input screen.

- Design Mode
- Parametric Mode
- Optimization Mode

## Design Mode

In design mode, the user can create multiple individual building designs.

- To create a new design or rename an existing design, right click on the tabs with names in the upper left quadrant of the Options Input Screen.
- Right click on the design tab to delete the current design or to keep the current design and delete all of the other designs in the case.
- Only a single option can be selected in each category for each design.
- Designs all share an identical set of inputs as specified on the Geometry and Site input screens. Only the selected options here can differ between designs.
- If the reference is set to be the same as one of the user designs, the reference tab will not be displayed.

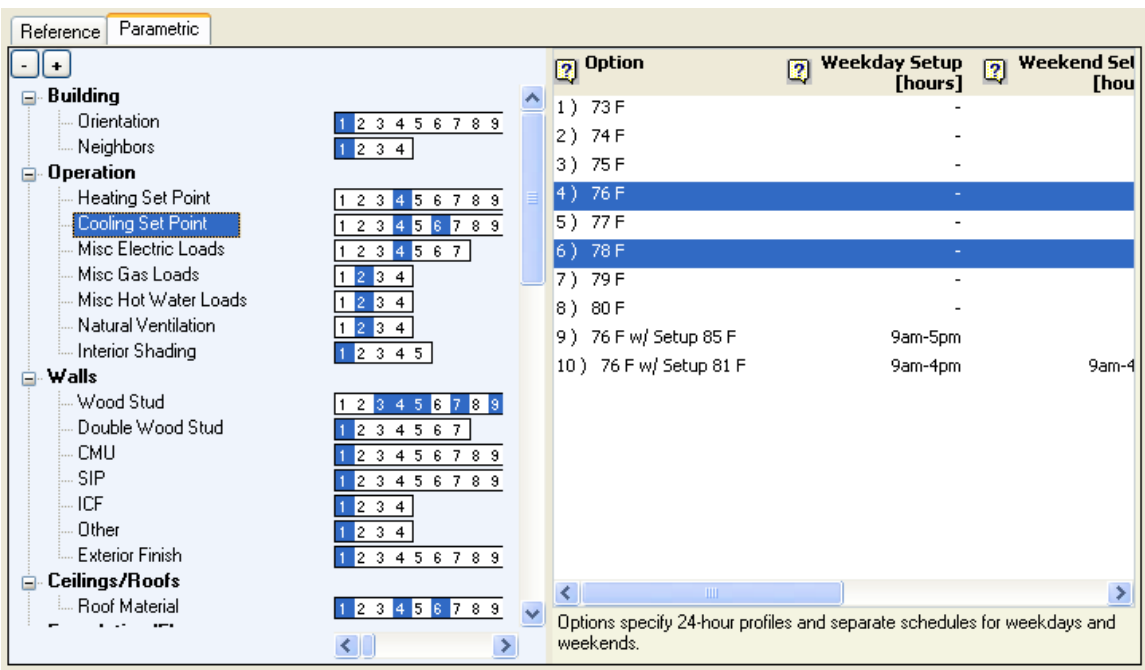



See Design Tabs for more information on the tabs that are displayed.

## Parametric Mode

Parametric mode allows the user to perform small or large parametric simulation analyses.

- The user may select multiple options in multiple categories.
- The number of combinations is calculated by multiplying the number of options in category A by the number of options in category B. For example, you could run a parametric with 4 wall options and 3 furnace options, giving 4 * 3 = 12 combinations.
- When selecting options, keep in mind that run time may increase dramatically as more options are selected.




See Design Tabs for more information on the tabs that are displayed.

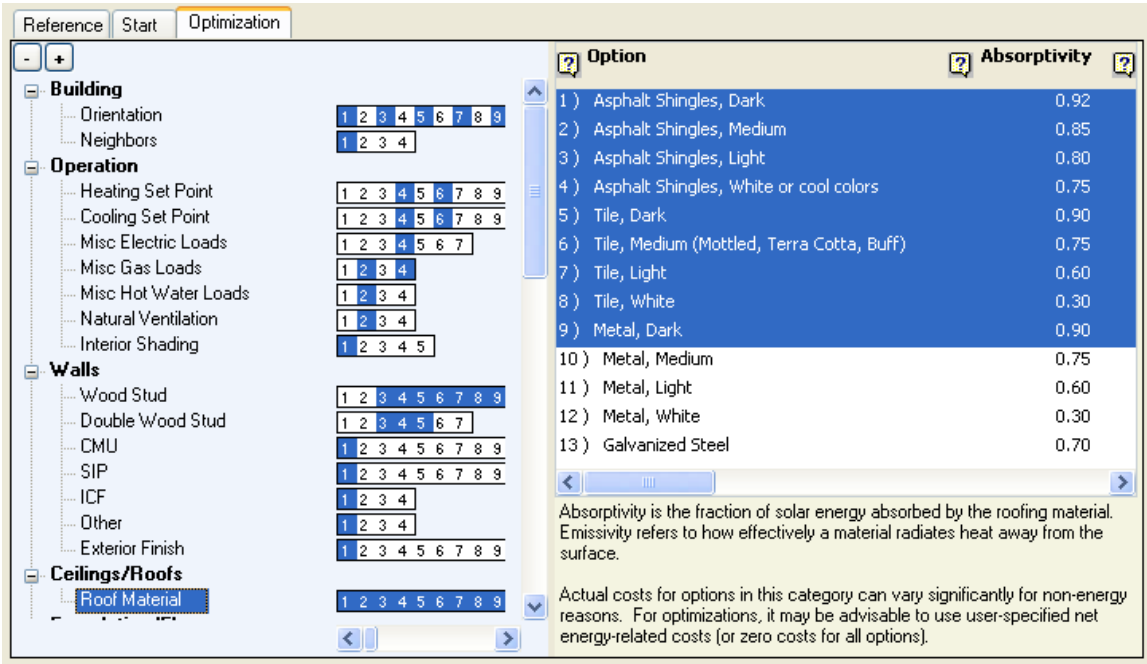
## Optimization Mode

Optimization Mode is used to search for "optimal" designs, defined as designs that offer the lowest cost at a given level of energy savings.

- In optimization mode, any number of options can be selected within each category. BEopt will consider all of these selected options when running simulations

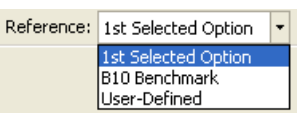
but not all combinations will be run.

- When selecting options, keep in mind that run time may increase dramatically as more options are selected.
- The Start tab displays the building design from which the optimization search technique will start. It is currently set to the first selected option in each category and cannot be changed.




See Design Tabs for more information on the tabs that are displayed.

## References




The user can choose from multiple references from the dropdown. The choice of reference will affect energy savings and incremental costs in the Cost/Energy Graph. Most references will result in a Reference design tab being displayed in the Options input screen. Within this tab, the user can view the selected options and can sometimes modify the selection.

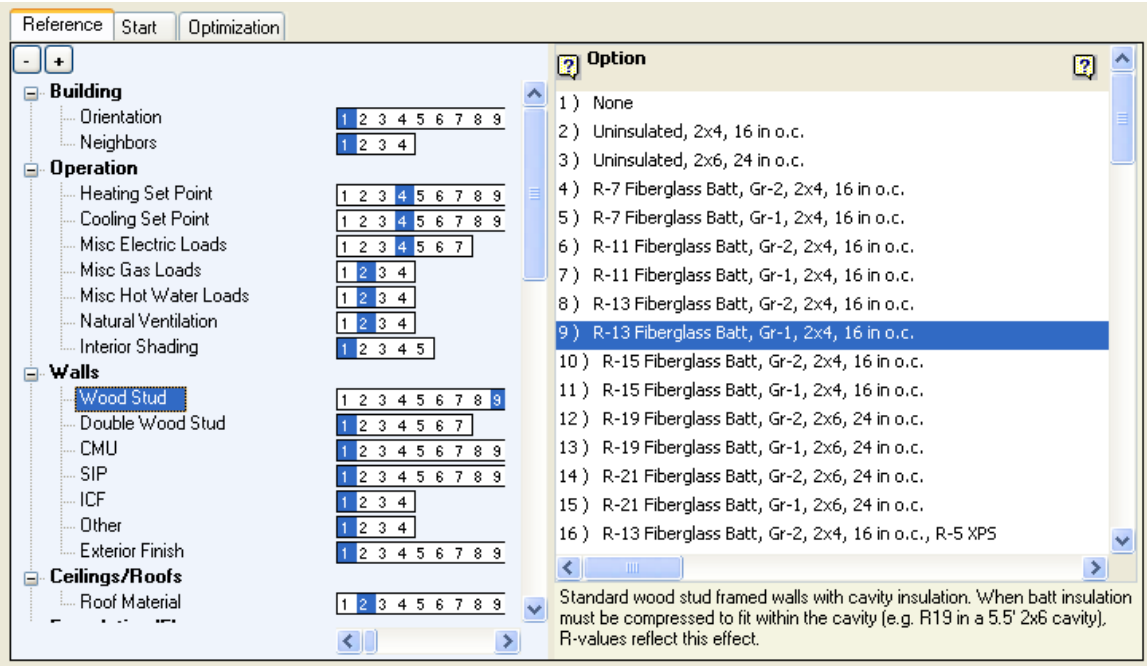
The possible references are:

- 1st Selected Option (Parametric/Optimization Modes)
- User Designs (Design Mode)
- User-Defined
- B10 Benchmark (New Construction)
- Existing (w/ Min Replace) (Retrofit)

## 1st Selected Option (Parametric/Optimization Modes)

The 1st Selected Option reference is only available when using Parametric or Optimization modes. Users can choose this by selecting 1st Selected Option from the Reference dropdown on the case input toolbar. When selected, the first option selected by the user in each category will be used in the reference.

The options that make up the 1st Selected Option building design can be viewed in the Reference tab. Option selection is disabled for this reference since the options are automatically selected by BEopt.

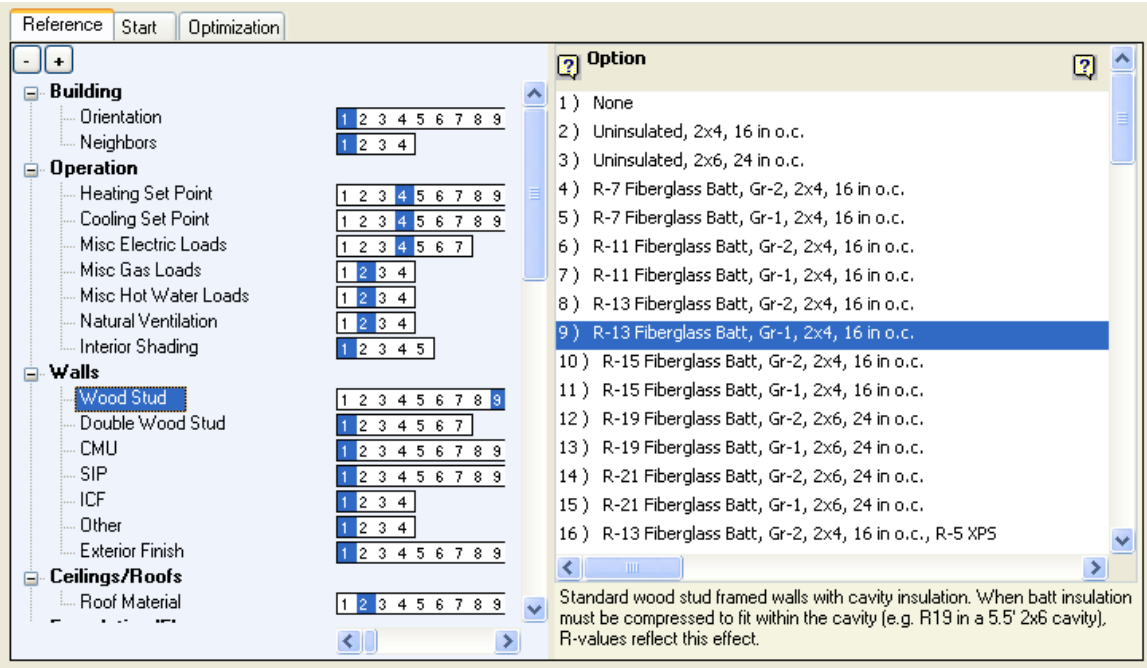



## User Designs (Design Mode)

User design references are only available when using Design mode. Users can choose this by selecting from one of their design names from the Reference dropdown on the case input toolbar. When a user design is selected, the reference tab is hidden and the options selected from the appropriate design are also used for the reference.

## User-Defined

Users can select their own reference on the options input screen by choosing User-Defined from the Reference dropdown on the case input toolbar. The reference will be defined by the options selected in the reference tab.

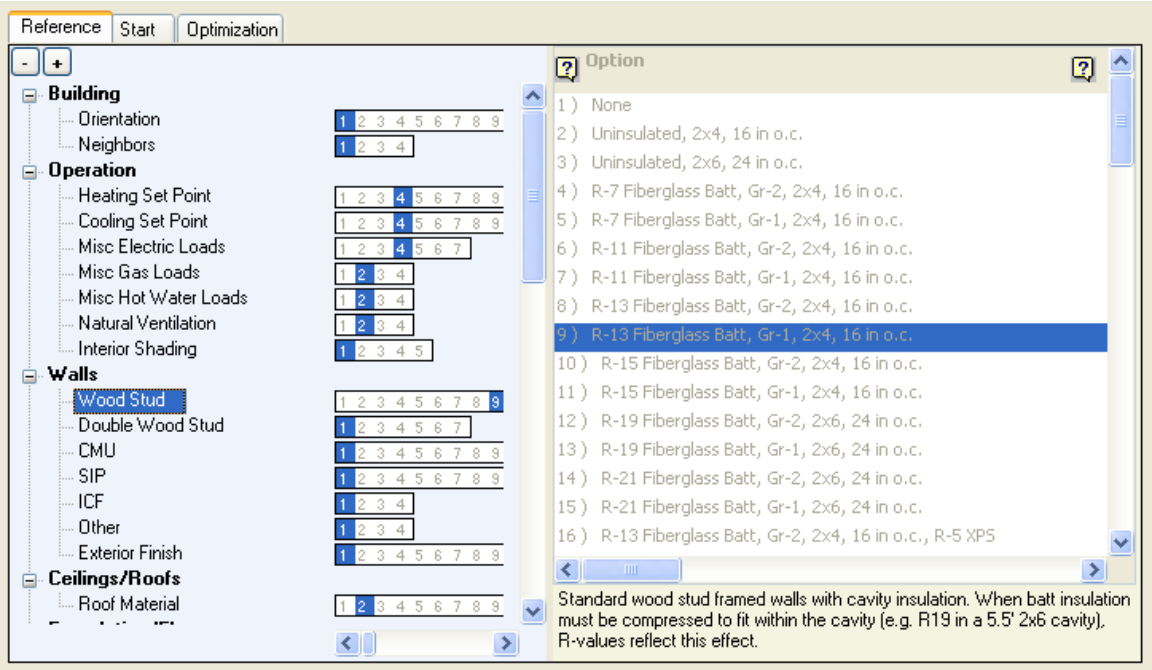


Note that the options selected by default when first choosing the User-Defined reference will be retained from the previous reference's option selection. This can be useful for making slight modifications or overrides to automated references like the B10 Benchmark or Existing (w/ Min Replace). For example, select the B10 Benchmark, then select the User-Defined reference and change only those option selections you want to differ from the B10 Benchmark.

## Building America B10 Benchmark (New Construction)

The B10 Benchmark reference is only available when performing new construction analysis. The Building America Benchmark defines a new construction (2010) building, based on the 2009 IECC code, with which to measure energy savings. This building varies as a function of location and building geometry. To run a Benchmark-referenced analysis, select B10 Benchmark from the Reference dropdown on the case input toolbar.

The options that make up the B10 Benchmark building design can be viewed in the Reference tab. Option selection is disabled for this reference since the options are automatically selected by BEopt.




There are certain occupancy-related options that, if selected, will generate a warning. The warning indicates that the option is not specifically allowed in the Prototype building unless there is a strong technical justification for it. These warnings, for categories like heating/cooling setpoint and natural ventilation, are informational only and do not prevent running simulations.

Note: The Benchmark definition includes a house size multiplier that is applied to a single-family detached Benchmark building (and thus, impacts energy savings relative to the Benchmark building). The adjusted Benchmark Source energy assumes that a typical house size is 2400 sqft with three bedrooms:

Adjusted Benchmark Source MBtu = (Msize) x Source MBtu

where:

$$M_{size} = \left(\frac{N_{br}}{3}\right)^{0.034} x \left(\frac{2400}{Floor\ Area}\right)^{0.167}$$

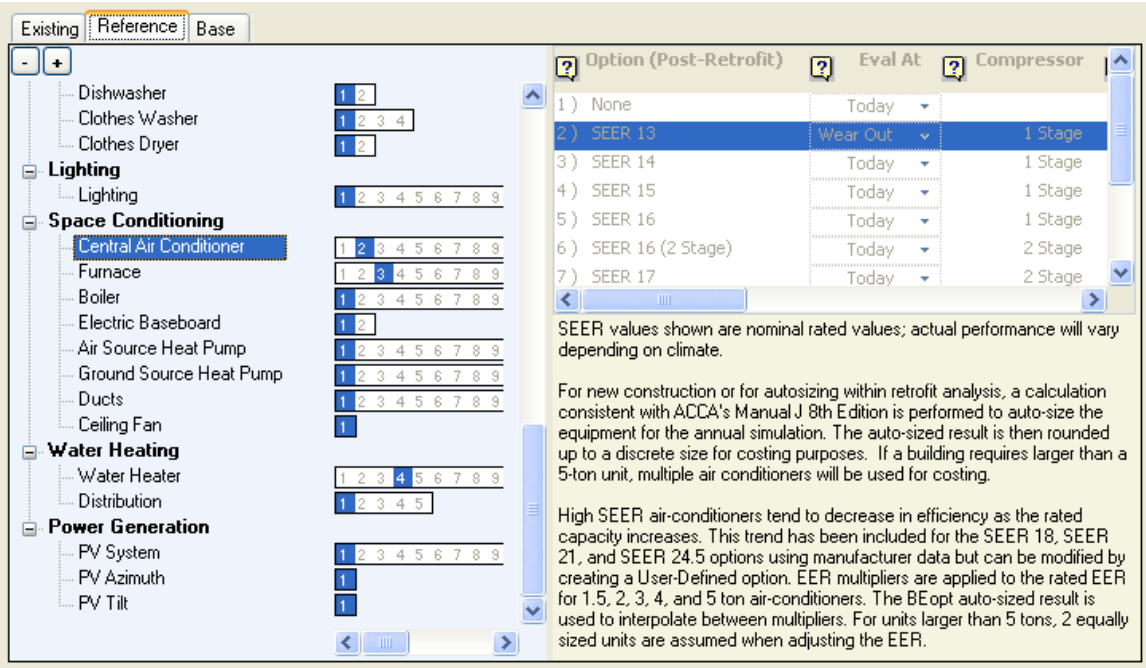
This house size multiplier is included in the calculation of the Source Energy Savings x-axis metric on the Cost/Energy graph. It is also included in the numerical data label when viewing Source Energy in the End Use graph. All other displays and outputs exclude the house size multiplier.

See the BA Housing Simulation Protocols under BEopt's Help menu for more details.

## Existing (w/ Min Replace) (Retrofit)

The Existing (w/ Min Replace) reference is only available when performing retrofit analysis.

The options that make up the Existing (w/ Min Replace) building design can be viewed in the Reference tab. Option selection is disabled for this reference since the options are automatically selected by BEopt.



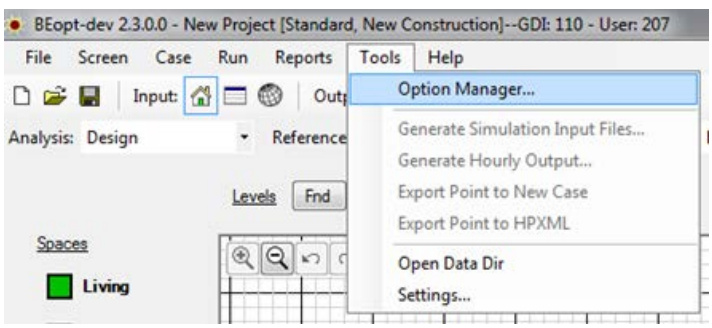

When this reference is selected, options selected as existing options are generally used for the reference. However, in situations where the existing option does not meet the applicable federal standards or cannot be purchased on the market (e.g. SEER 8 air conditioner), the reference will include the minimum replace option (SEER 13) at wear out. By defining such a reference, we ensure that energy savings for an upgraded air conditioner (e.g. SEER 15) is calculated fairly given the most typical baseline scenario for the analysis period (as opposed to using the SEER 8 air conditioner's energy use for the entire analysis period).

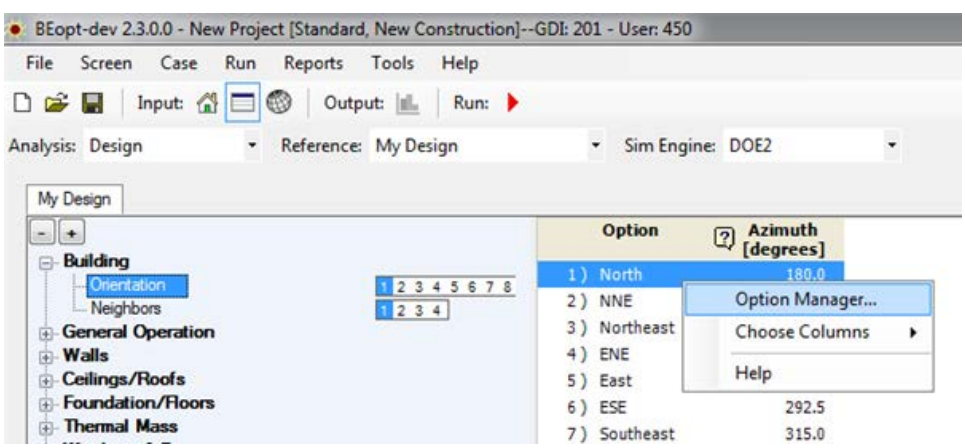
If instead you wanted to calculate energy savings against a different scenario, you can choose a User-Defined reference.

## Library Management

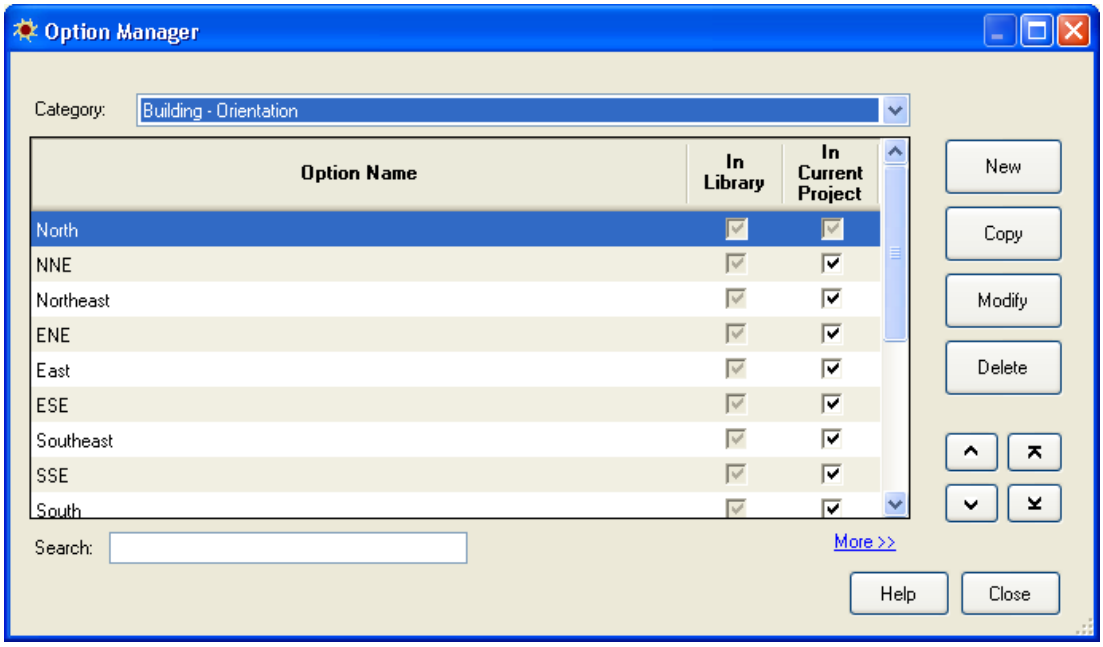
Library Management is performed via a screen called the Option Manager.

It is accessed via the Tools menu on the main application screen or from the Options input screen.




## Option Manager




Use the Option Manager to:

1. Create new options
2. View or modify options
3. Delete options
4. Import library options into the current project
5. Import project options into your library
6. Remove options from the current project
7. Remove options from your library
8. Reorder options
9. Choose options available for new projects
10. Choose selected options for new projects

Once the option manager is open select a category in the Category drop down list at the top of the screen to see all of that category's options displayed in the grid.

To quickly search for options, type one or more characters in the Search box at the lower left of the screen. A second or two after you quit typing the grid will filter itself so that only options containing the characters you typed are visible. To see all options remove all characters from the Search box.

To select an option in the grid, click on its name with the mouse. The row containing the option will be highlighted. If you click a part of the row other than the option name, such as a check box, the item you click will be updated, but the row itself will not be selected, so be sure to click on the option name to select it before trying to modify it, delete it, etc.

Some operations, such as reordering and deleting options, can apply to more than one option. To select multiple options, hold down the <Ctrl> key while you click on each option. Click an option a second time with the <Ctrl> key pressed to deselect that option without deselecting other selected options. To select a range of options hold down the <Shift> key while clicking on the first and last option in the range.

When you close the Option Manager, it will save your changes.

**Create New Options**
If you want to create your own option, click the New button. This will open the Option Editor screen. If you want to use an existing option as a template, select the option and click the Copy button. This will also open the Option Editor, but instead of having blank property values and costs, they will be populated with the property & cost values from the selected option.

**View or modify options**
If you want to view or modify an option, select that option and click the Modify button. This will open the Option Editor, where you can change the name, properties, costs, or just about any other characteristic of an option. Note, however, that you can't change most characteristics of built-in options, with the exception of costs. You can create, modify, and delete cost sources and set their corresponding costs and lifetimes for the option. However, you can only change costs for cost sources that are built into the system; you cannot delete them.

Both Material and Labor costs can be updated in this way. Details of how to modify costs and other properties of options are explained in the Option Editor description.

**Delete Options**
To delete an option, select it and click the Delete button. If you need to delete several options, you can multi-select them and click the Delete button to delete them all at once. Once you delete an option, it can't be recovered -- in this way, it is different than simply removing an option from the current project or removing an option from the library. Note that built-in options can't be deleted.

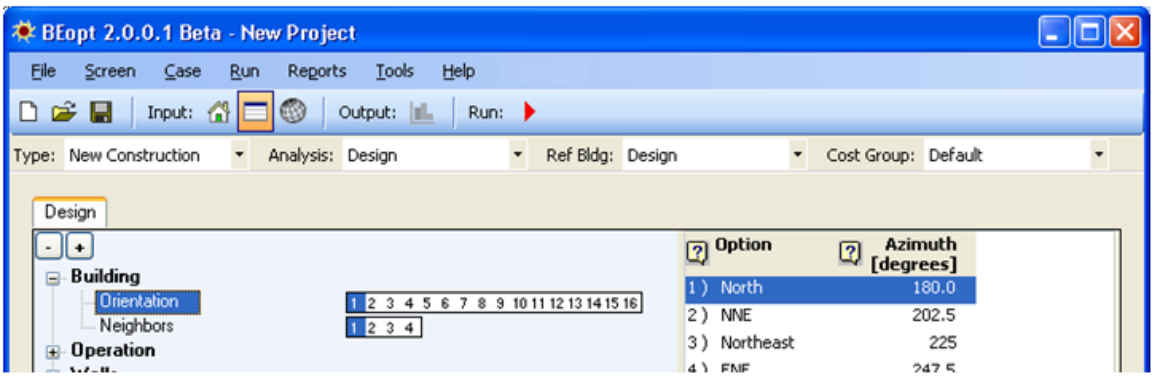
**Import library options into the current project**
The In Current Project column of the grid indicates whether the option is available in the current project. If the In Current Project box is unchecked, check the box to import the option into your current project.

**Import project options into your library**
The In Library column of the grid indicates whether the option is in your library. If the In Library box is unchecked, check the box to import the option into your library. This is especially useful if a colleague has sent you their project file and you want to import some of their options to use in your own projects.

**Remove options from the current project**
The In Current Project column of the grid indicates whether the option is available in the current project. If the In Current Project box is checked, uncheck the box to remove the option from your current project. If the In Library box is checked, the option can still be (re-)imported to any project. If both In Current Project and In Library are unchecked, the option will be permanently deleted.

**Remove options from your library**
The In Library column of the grid indicates whether the option is available in your library. If the In Library box is checked, uncheck the box to remove the option from your library. This essentially makes the option a temporary option, meaning that you will not be able to use this option in any other project unless you first import the option back into your library. If both In Current Project and In Library are unchecked, the option will be permanently deleted.

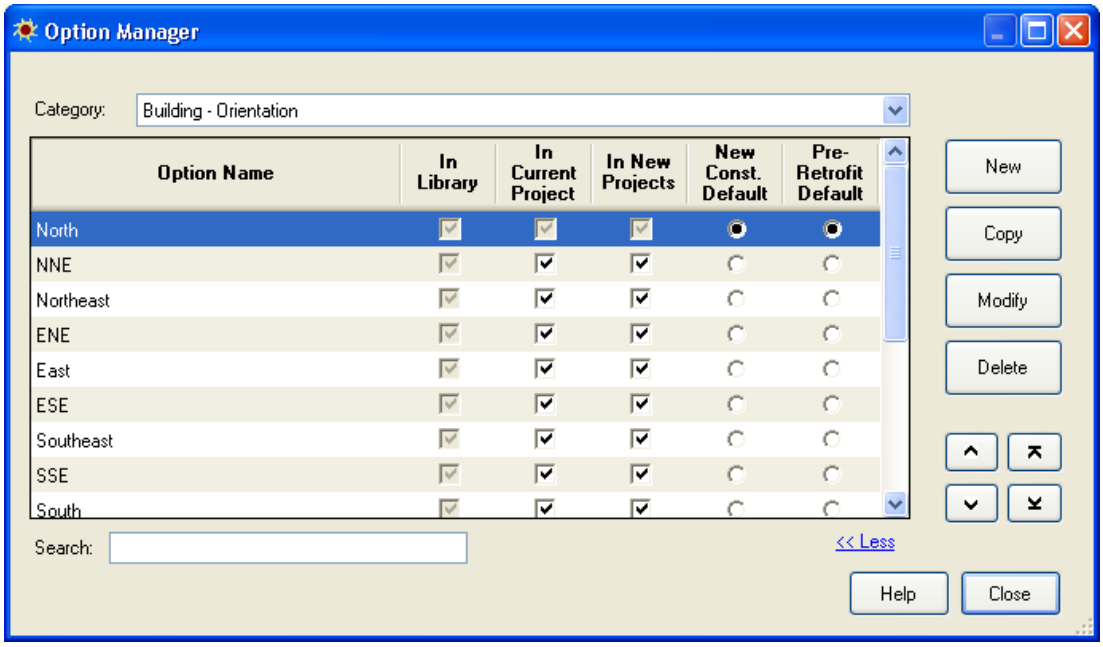
**Reorder options**
The sequence that options appear in the Option Manager grid is the same as the order they appear in the Options Input screen.




Changing the order of the options in the Option Manager grid also changes their sequence of appearance in the Options Input screen. For instance if we move the North option to the third row of the Option Manager grid it will also appear on the third row of the Options Input screen grid and be represented by the number 3 in the list of options to the right of the Orientation category in the category tree.

To change the order of options in a category use the arrow buttons. The left up button moves the selected option(s) up one row and the left down button moves them down one row. The right up button moves the selected option(s) to the top of the grid and the right down button moves them to the bottom of the grid. Note that these buttons are disabled when the list of options is filtered by a search. Clear the contents of the Search text box at the lower left of the screen to re-enable them.

**Choose options available for new projects**
To change other option settings click the More>> link at the bottom right of the grid. It will change into a Less<< link and three additional columns will be displayed in the grid.



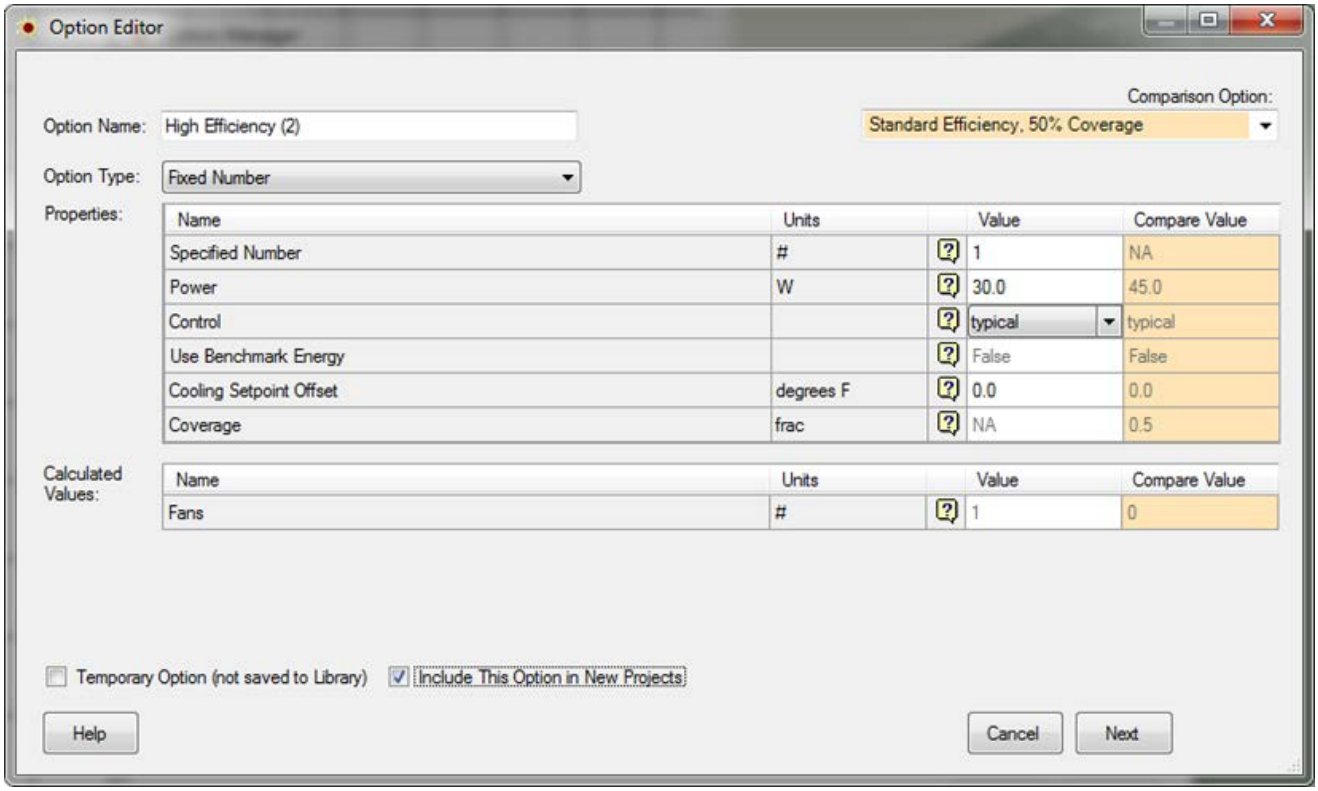

Check the box in the In New Projects column next to an option to have it automatically available for any new projects that you create. Clear this box if you don't want the option to automatically be available -- this helps to prevent clutter of the interface with infrequently used options. If an option is not automatically made available for a new project, you will still be able to import the option manually to your project at any time. Note that for a few built-in options that are required in all projects, this box can't be unchecked.

**Choose selected options for new projects**
You can also control which option in each category is selected by default in new projects. You can choose one default option for new construction cases and one for the existing building of retrofit cases. Just click the radio button in the New Const. Default or Pre-Retrofit Default columns next to an option to select it as the corresponding default. All other options in the category will automatically be deselected since only one option in the category can be the default. Note that these radio buttons are not available for an option whose In New Projects check box is unchecked. They may also be absent for certain built-in options that are not appropriate to use as a default.

## Option Editor

When you click the New, Copy, or Modify button on the Option Manager screen, the Option Editor will open. This is a wizard consisting of two screens. The first screen allows you to edit the properties of the option and the second screen allows you to update cost information. You can click the Cancel button from either screen to close the Option Editor and return to the Option Manager screen without saving your changes.

**Screen 1: Properties**
The first screen allows you to edit the properties of the option.



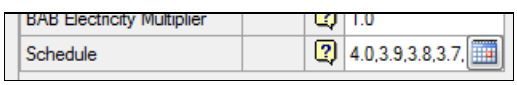

Each option must have a unique name within its category. You enter this name in the Option Name box at the upper left of the screen.

Each option must also be assigned an option type. The option type determines which properties are available for the option in the properties grid. If there is only one option type available for the option's category then it will not be displayed on the screen. However, if multiple option types are available then they will be displayed in a drop down list.

If you would like to compare another option's property values to the current option, you can select an option from the Comparison Option drop down list at the upper right of the screen. Its values will be displayed in orange. If the comparison option has a different option type than the current option then all properties that apply to either option type will be displayed. However any properties that don't apply to the current option will display "NA" as their value.

The properties grid displays the list of properties for the option where you can enter an appropriate value for each property in the Value column of the grid. For each property, you can hover over the question mark icon for more details. In some cases you select one of a limited number of choices from a drop down list. In others you type your own value. If you enter a value that is inappropriate for the property, a message describing the acceptable values will be displayed so you can update the value appropriately.

Any properties that are related to schedules will show a button to modify/view the schedule. Clicking on this button will launch the Schedule Wizard. Schedules must be edited through the Schedule Wizard.



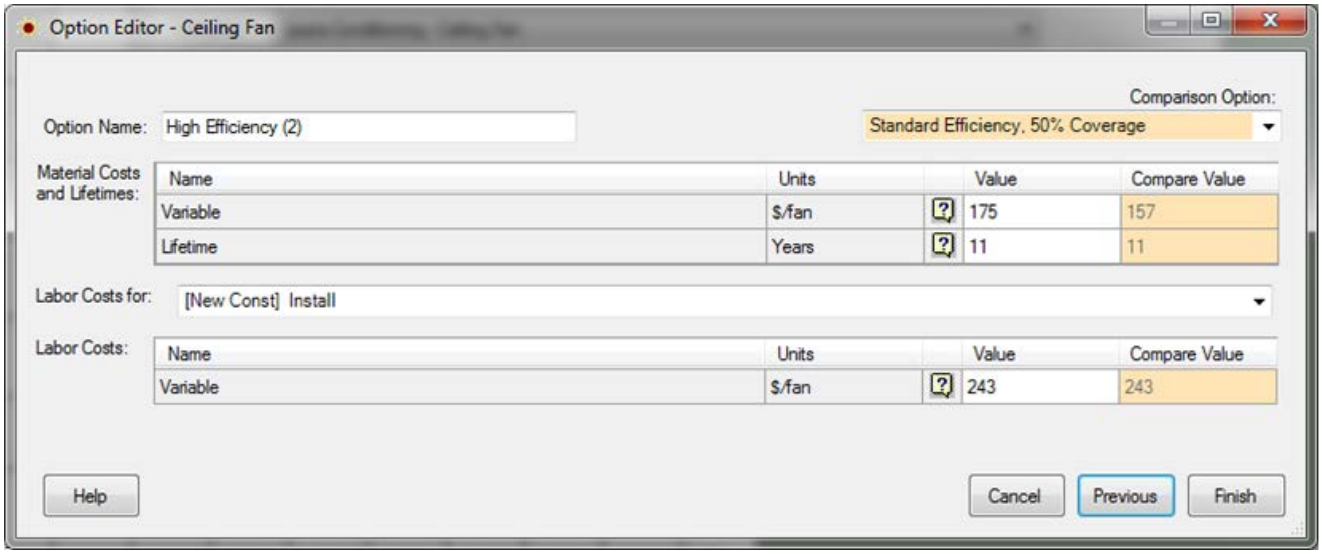

Some options have additional properties that are automatically calculated and are displayed in a second grid. Since the values are calculated automatically they can't be edited. These same calculated values will also appear in the Options input screen and, in some instances, may be the result of using geometry or site information from your current project's case (e.g. calculating areas for the Window Areas category).

At the lower left of the screen are two additional check boxes (this information can also be specified in the Option Manager). If you check the Temporary Option box, the option will only be available in the current project and will not be added to your library to prevent clutter. Uncheck this box if you may want to use the option in other/future projects. For built-in options this check box is disabled.

Checking the Include This Option in New Projects box will automatically add this option to any new projects you create. Uncheck the box to prevent the option from being automatically added to new projects. You will still be able to manually import the option to a project at any time via the Option Manager.

When you are done entering values in this screen, click the Next button to go to the second screen.

**Screen 2: Costs**
The second screen allows you to modify/view cost information.




This screen consists of two similar grids: one for editing material cost/lifetimes and the other for editing labor costs. Both are similar in layout to the properties grid on the previous screen. The Material Costs grid contains cost information for the material cost of the current option. The Labor Costs grid, on the other hand, contains labor cost information specific to the situation in which the option is being used (e.g. being installed in new construction, being installed in an existing building, replacing a technology in an existing building, being removed from an existing building, etc.). C osts needs to be entered for both material and labor costs and lifetimes need to be entered for materials. However, BEopt will always default the labor costs for all the various situations as well as the material cost and lifetimes for built-in options, so you only need to add costs for options you create, or update values you want to change for built-in options. You enter costs simply by typing a value in the Value column next to the cost/lifetime you want to update.

Orange cells may be displayed in the Comparison value column for comparison if you have selected a comparison option, but these are not editable. If you want to edit the comparison option's costs you must return to the option manager, select it, and then click the Modify button.

Note that the Labor Cost drop down list will only show replacement options that can replace the option you are working on. If you want to replace a different option with the option you are working on, you will need to finish editing the option you are working on, return to the Option Manager screen, select the other option, and edit it. You will then see a Labor Cost entry in the drop down list for replacing that option with the option you just finished editing.

When you are done editing costs click the Finish button to save your changes and return to the Option Manager screen. If you want to return to the Properties screen click the Previous button.

## Schedule Wizard

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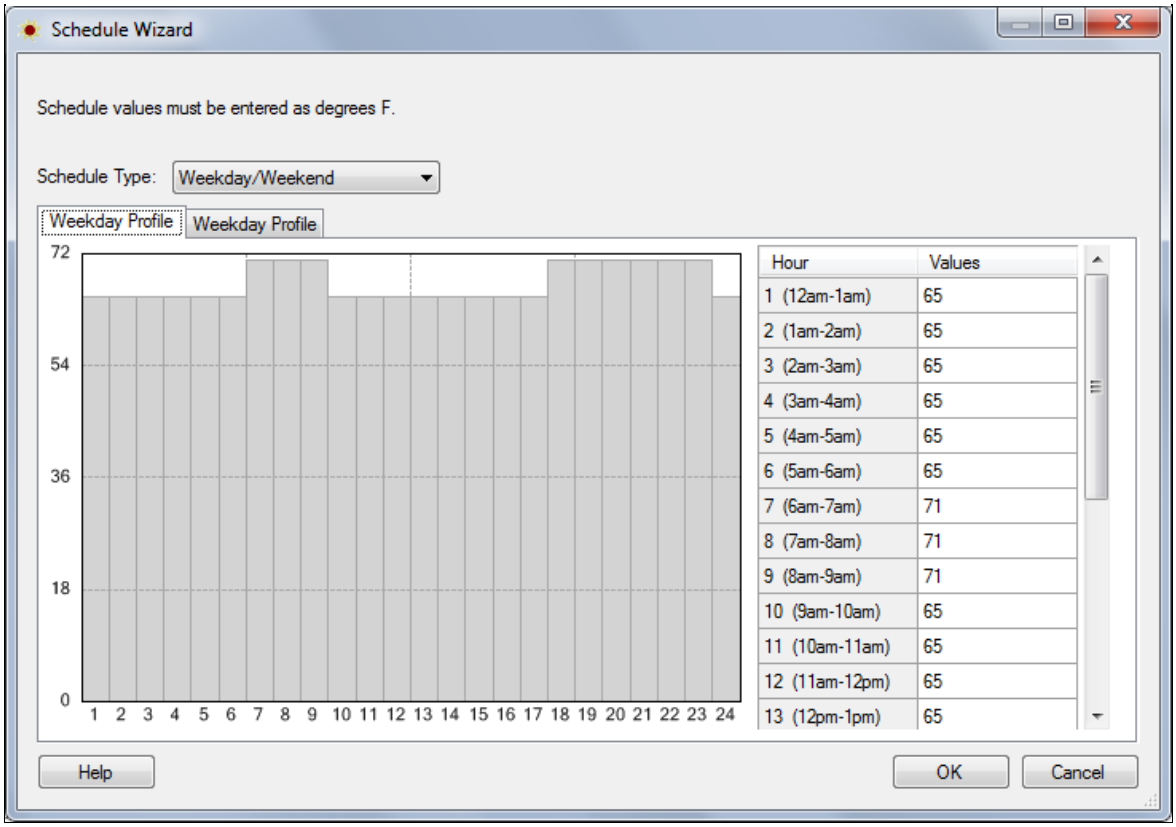
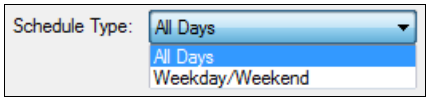
The schedule wizard facilitates viewing and editing schedules and can be launched from either the Option Editor or the Options Input Screen.




**Classes of Schedules**
There are three classes of schedules that can be defined: Daily, Monthly, and Annual.

- **Daily Schedules**
  Daily schedules, such as heating and cooling set point schedules, allow the user to either specify the schedule for all days (24 values) or for weekdays vs weekends (48 values).

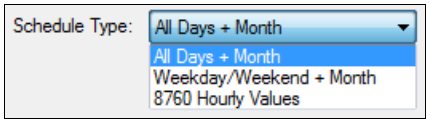
  
  

  If the schedule type is All Days, a single Daily Profile tab is available. If the schedule type is Weekday/Weekend, Weekday Profile and Weekend Profile tabs are available.

- **Monthly Schedules**
  Monthly schedules, such as Interior Shading's cooling shade schedule, allow the user to specify the a value for each month of the year (12 values).

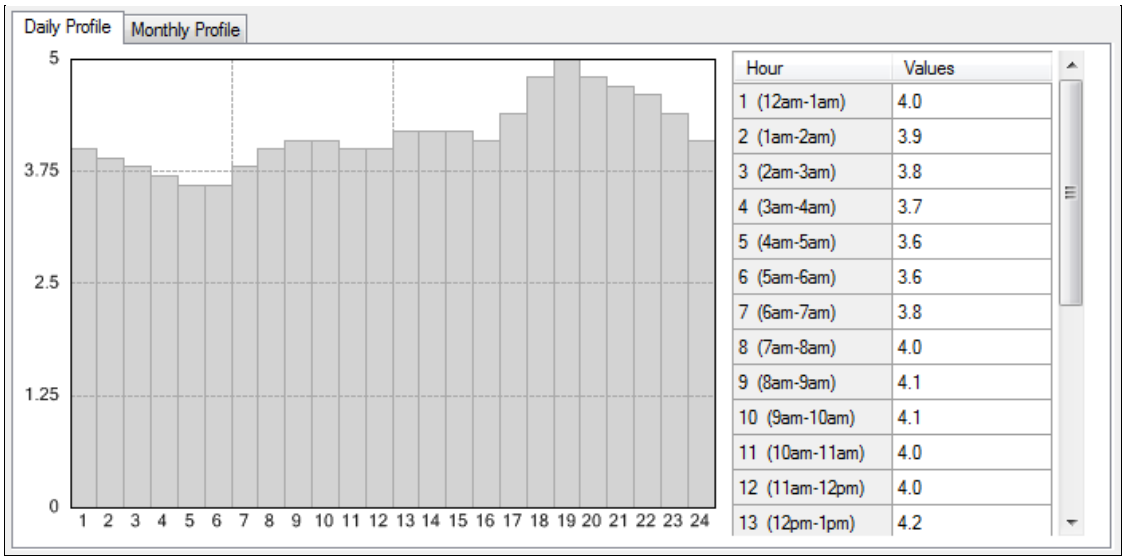
  A single Monthly Profile tab is available.

- **Annual Schedules**
  Annual schedules, such as major appliance schedules and misc load schedules, allow the user to specify the schedule for all days + months (24 + 12 values), weekdays vs weekends + months (48 + 12 values), or all hours of the year (8760 values).

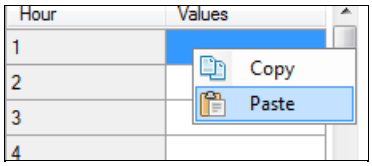
  
  

  If the schedule type is All Days + Month, Daily Profile and Monthly Profile tabs are available. If the schedule type is Weekday/Weekend + Month, Weekday Profile, Weekend Profile, and Monthly Profile tabs are available. If the schedule type is 8760 Hourly Values, a single Annual tab is available.

**Schedule Inputs**
In any given schedule tab, there is a table where schedule inputs can be entered and a graphical display of the schedule.

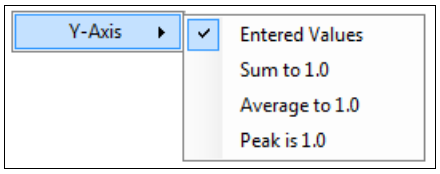



Values can be entered manually or hourly data from external files can be copied and pasted by right-clicking on the table.



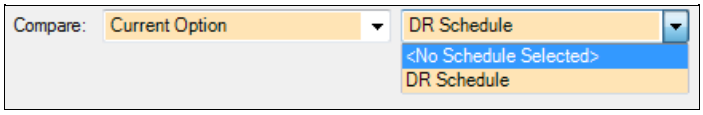

Note that schedules can have different units:

- **Temperature schedule**: Values should be entered as degrees F.
- **On/off schedule**: Values should be entered as 0 or 1.
- **Numerical schedule**: Values can be entered in any units (e.g. fractions, percentages, multipliers, absolute values). BEopt will apply the schedule profile to the energy use. For these types of schedules, you can right-click on the graph to view the schedule profile normalized in a few different ways:

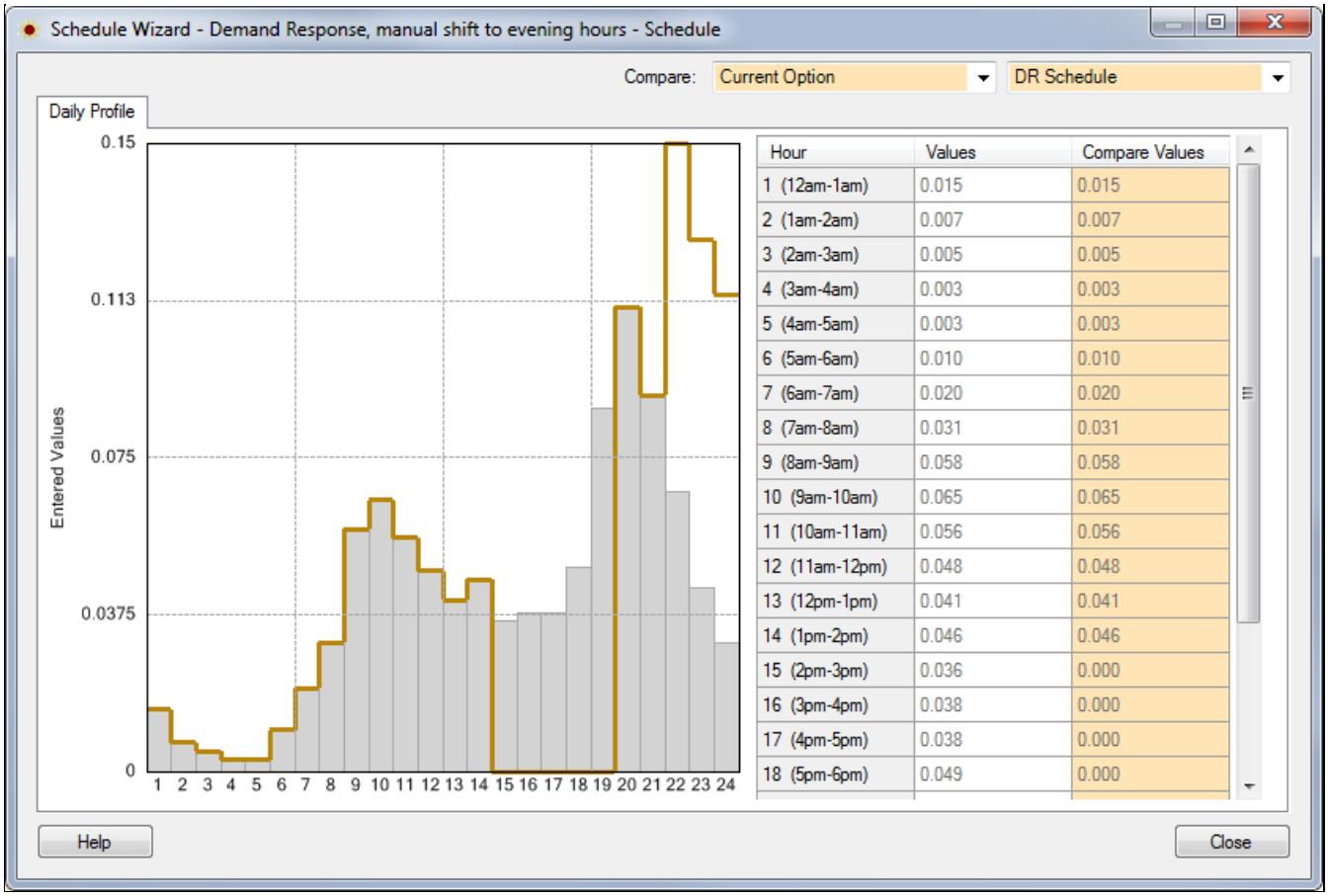



As values are entered, the graph will automatically update to show the schedule profile as vertical bars.

**Schedule Comparison**
Other schedules from the same option or even another option from another category can be easily compared to the current schedule.




When a comparison schedule is selected, its values will appear in the table and its schedule profile will be overlayed on the graph as a line.




## Version Migration

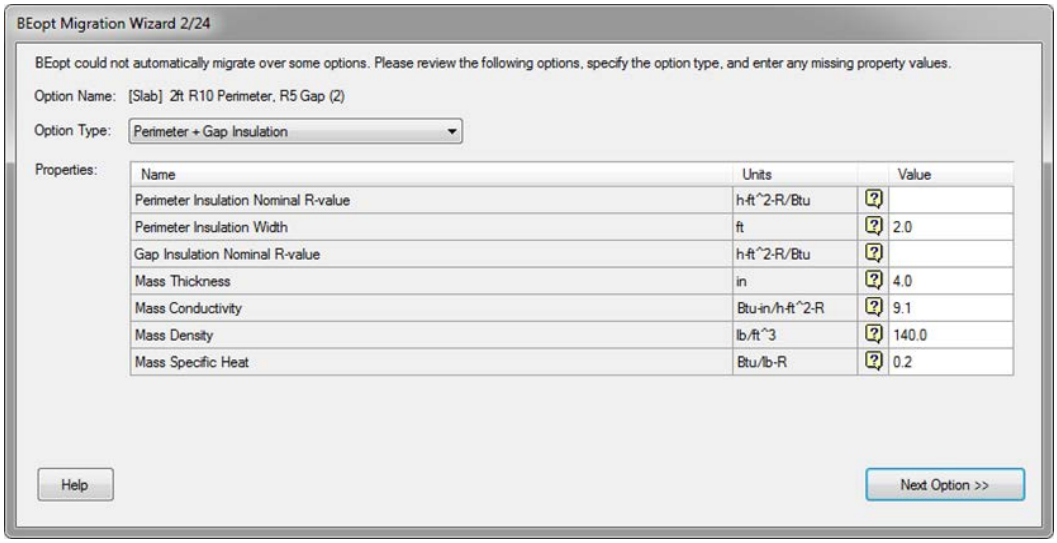
When you load the new version of BEopt for the first time or open a project file from an older version of BEopt, you may be prompted to migrate the data over to the new version. If you are migrating an older project file, BEopt will retain a backup of the existing project file before updating it to the latest version.

While BEopt will automatically migrate your data as much as possible, you may be asked to review or provide some additional information. If this occurs, you will see one or both of the following screens:

- Option migration screen

## Option Migration Screen

When you migrate a library or older project file to a new version of BEopt, as many of your options as possible will be automatically updated. However, there will often be cases where the system needs additional information from the user -- for example, a new property may exist in the new version of BEopt that didn't exist when the option was created. If this happens, BEopt will display a screen during migration that will allow you to review and/or set the appropriate values.




First, simply select the most appropriate option type for your option. The option type determines which properties are available for the option in the properties grid. If there is only one option type available for the option's category then the Option Type drop down list will not be displayed on the screen. However, if multiple option types are available then they will be displayed in a drop down list.

Once an option type is selected, the corresponding properties will be displayed in the Properties grid so that you can enter an appropriate value for each missing property. In some cases, you select one of a limited number of choices from a drop down list. In others you type your own value. If you enter a value that is inappropriate for the property, a message describing the acceptable values will be displayed so you can update the value appropriately. For each property, you can hover over the question mark icon for more details.

It is possible to see an option in this screen with no missing property values and the correct option type already selected. In these circumstances, the system is not positive that the option is being migrated correctly, so the information is made available to the user for review (and modification if necessary).

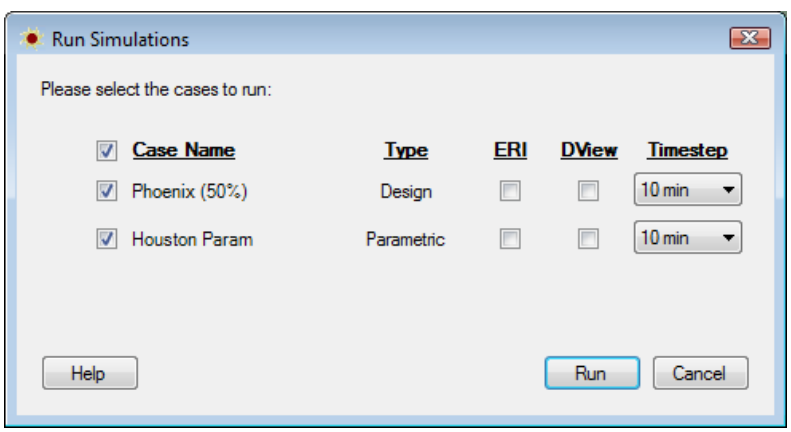
When you are done with the option click the Next Option button and continue this process until all options have been updated. When the last option is finished, click the Close button to continue the migration. A progress bar will be displayed as your options are processed.

## Running BEopt

It is only possible to run BEopt simulations for cases without output. If no cases have output, the user will not be able to run BEopt until a new case is created or output is cleared from an existing case.

- Run Dialog
- BEopt Error Log

## Run Dialog




The run dialog displays the cases that currently do not have output and are ready to be run. The user can then select the cases that they want to run. If multiple cases are checked, they will be run through sequentially without interruption.

Options available include:

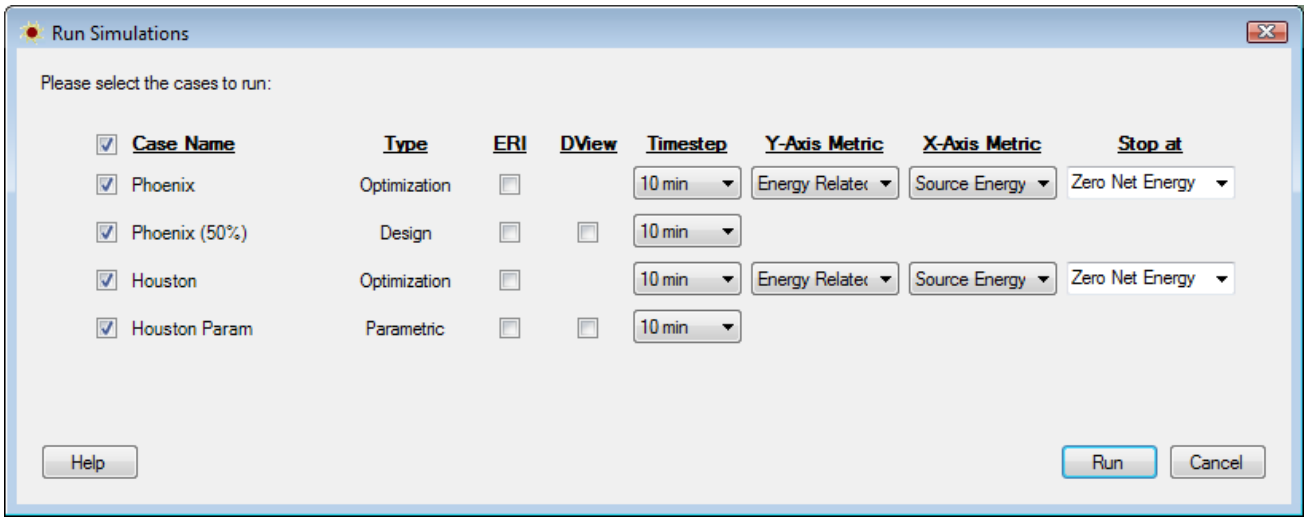
- **ERI**: If checked, BEopt will calculate an Energy Rating Index (ERI) for each output point, which requires two additional simulations per output point. The ERI is calculated per the ANSI/RESNET 301-2014 "Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the HERS Index" as well as the ANSI/RESNET 301-2014 Addendum A-2015 "Addendum on Domestic Hot Water (DHW) Systems".

- **DView:** For design cases or small parametric cases (<12 combinations), you can specify that you want to automatically visualize all of the designs'

hourly results in DView. When the simulations are complete, a DView window will pop-up for each design. While hourly results can always be requested from the Case Output Toolbar, it requires additional simulations to be performed when done that way. By requesting the DView hourly results upfront, less simulations are required and the user obtains the hourly results faster. The user can also specify hourly results from across multiple design mode cases here.

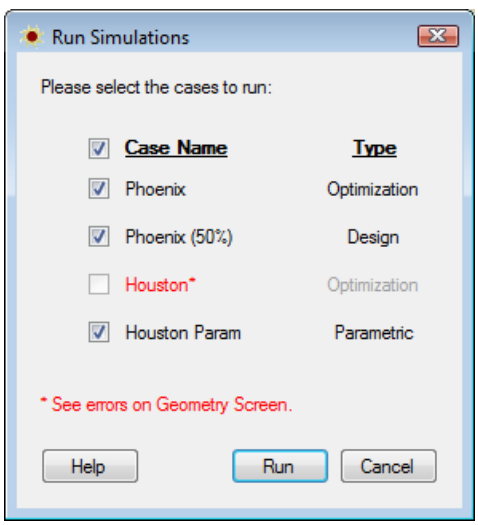
- **Timestep**: For all cases, you can specify the timestep used by the simulation engine. In general, shorter timesteps give better accuracy but increase runtime. EnergyPlus can be run at timesteps between 1 and 60 minutes and will default to the value specified in the Simulation Engines Settings. Recommendations for timesteps are 10 mins or less in general; 3 mins or less for cases with Phase Phase Change Materials (PCMs).

For optimization cases, additional options are available:




Options include the choice of Y-axis metrics and X-axis metrics to optimize over, as well as the stopping constraint. The stopping constraints available to the user will be specific to the x-axis metric specified. For the Source Energy Savings x-axis metric, the default stopping constraint is Zero Net Energy, in which the optimization proceeds until it reaches 100% source energy savings. The defaults for all three options can be changed in the Settings dialog.

If a case does not have its building geometry completely defined, the run dialog will indicate it has geometry errors. BEopt will prevent running simulations for such cases until the geometry errors are fixed.

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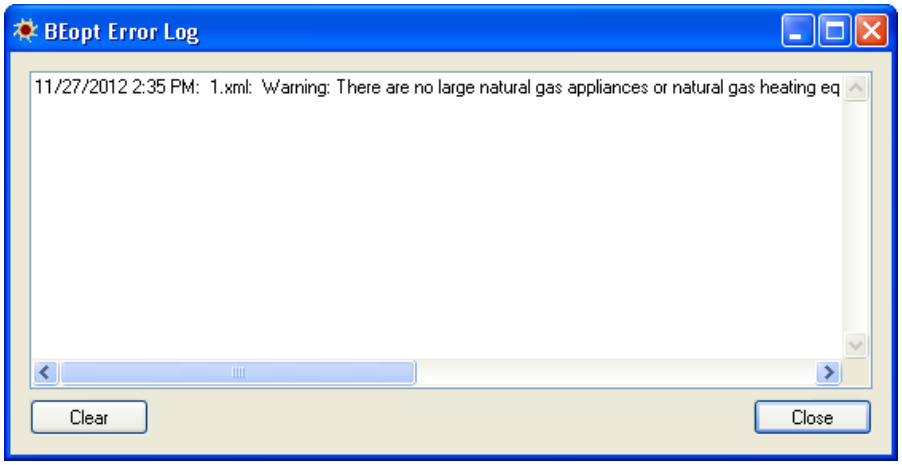
**BEopt Error Log**




Once a case has began to run, BEopt will report any errors/warnings that it runs into for a given simulation. As BEopt encounters errors/warnings, they will be listed in a pop-up window titled "BEopt Error Log". In general, the format for messages in the error log is as follows:

| e | File which caused the error | Error Type | Error Message |
|---|---|---|---|
| 2 2:35 PM | 1.xml | Warning | There are no large gas appliances or natural gas heating eq... |

There are two types of messages that show up in the log:

**Simulation Warnings**
These warnings are used to alert the user that the simulation in question may not reflect the input as it was intended by the user OR that there are combinations of inputs that do not necessarily make sense from a construction or operation point of view. Although simulation warnings show up in the error log, they will not prevent the simulation from running.

> Example: If the user specifies not major gas appliances or equipment and does not set miscellaneous gas loads to zero, a warning will appear to alert the user that the home will need gas connection solely for the miscellaneous gas load.

**Simulation Errors**
These errors indicate that BEopt has aborted the simulation from running to prevent problems occuring in the simulation engines, or that an error in the simulation itself has occurred. Please report such errors to the BEopt development team.

## Output

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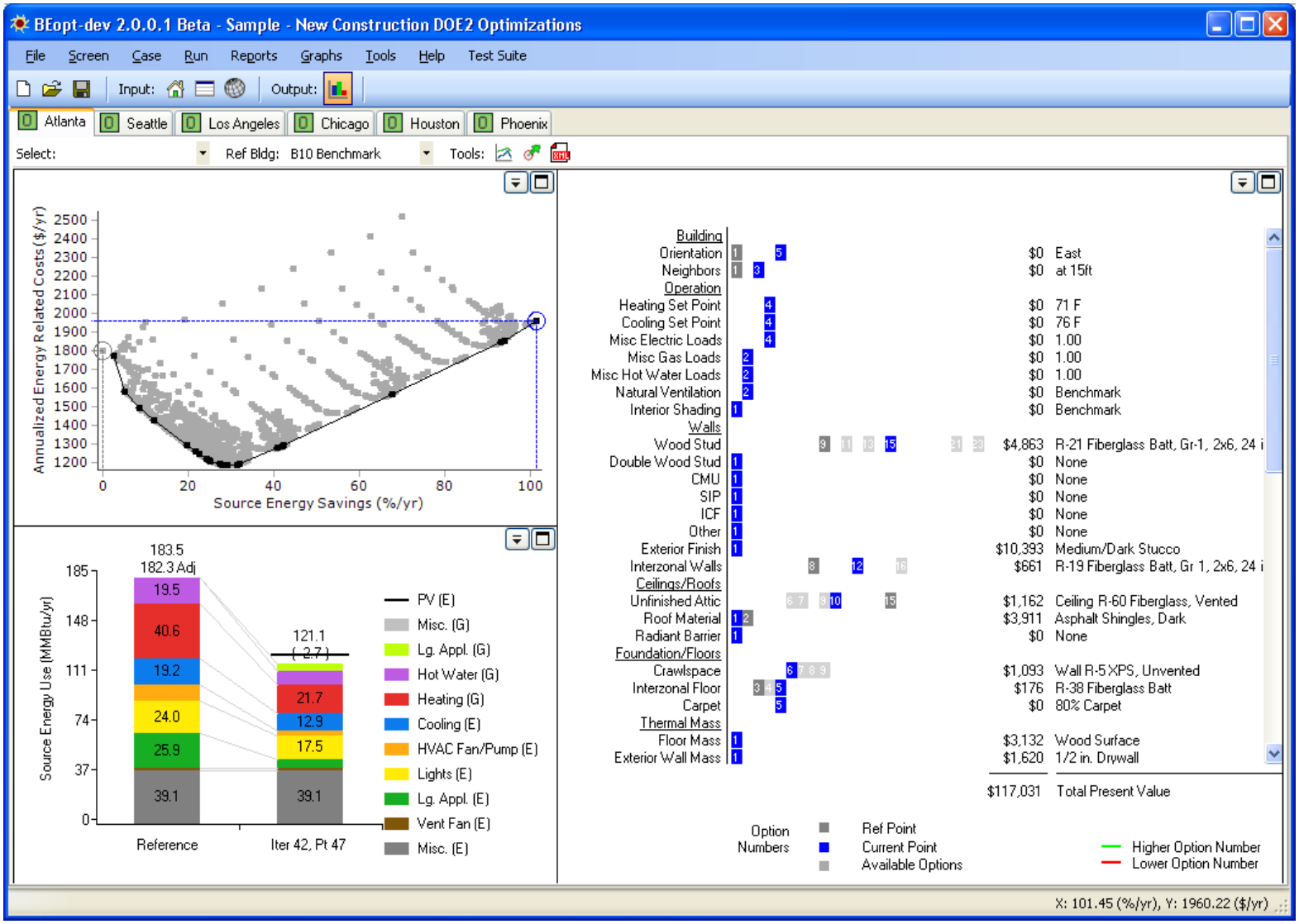
Output screens are available for each case that has results.




Results are displayed in three different areas of the screen:

- Cost/Energy Graph (upper left) -- shows the cost and energy savings for each simulation.
- End Use Graph (lower left) -- shows the magnitude of different energy end uses.
- Options Graph (right side) -- shows information about the options for a selected point or points.

The user can zoom, pan, and select points in the Cost/Energy Graph. The output screen will change in appearance based on the number of points the user selects on the Cost/Energy Graph. There are different display modes for Single Point Selection, Two Point Selection, and Multiple Point Selection .

- To Maximize the graphs you may press the maximize button located in the upper right hand corner of each graph.
- To select more options for each graph you may either:

  A. Click the menu button in the upper right corner of each graph.
  **OR**
  B. Right click on each graph to see an options menu specific to that graph.

## Cost/Energy Graph

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The Cost/Energy Graph can be found in the upper left of the Output Screen. This graph displays points that were simulated for the case. See the sections on X-axis metrics and Y-axis metrics for more details.

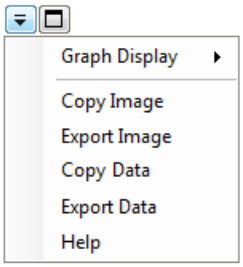
For multifamily buildings, this graph shows whole-building totals.

Graph points can be selected either by clicking directly on a point, dragging a box around several points, or choosing an item in the Select dropdown on the Case Output toolbar. Selecting different points will influence the information that is displayed in the End Use Graph and Options Graph.

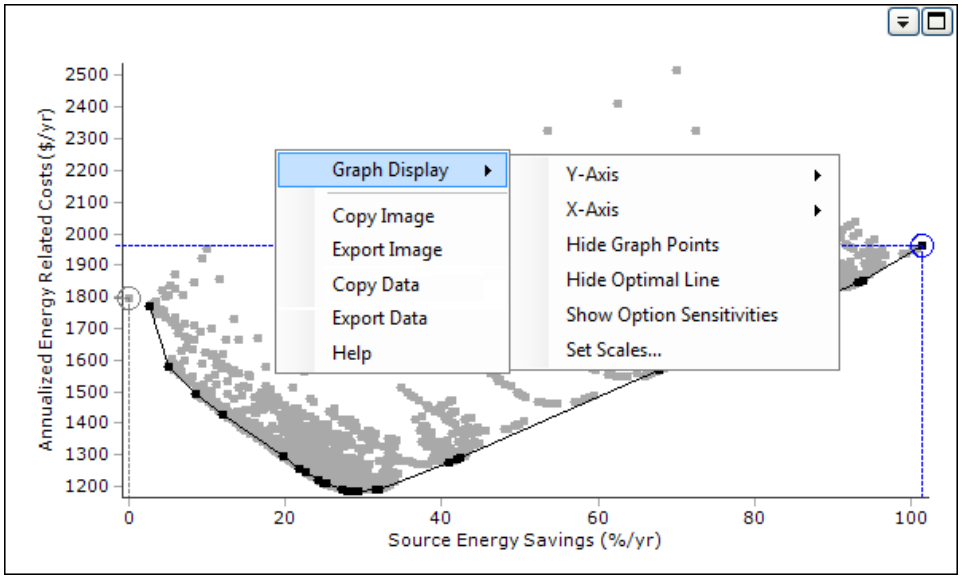
The graph defaults to zoom-to-fit, such that all of the points are visible; it can be manually zoomed by using your mouse-wheel while the mouse is over the graph (note that you cannot zoom out beyond the default zoom-to-fit).

The graph can be panned by holding down the mouse button and moving the mouse over the graph.

By right-clicking on the graph, a menu of options will appear. The options also appear by clicking on the menu button in the top right corner of the graph.




**Graph Display**




- Y-Axis: Choose the y-axis metric to display.
- X-Axis: Choose the x-axis metric to display.
- Hide Graph Points: Hide all gray points (those not found along the optimization's optimal line). (Optimization Mode only)
- Hide Optimal Line: Hide the optimization's optimal line. (Optimization Mode only)
- Show Option Sensitivities: For categories with multiple options selected, shows the lower boundary of each option for the category selected in the dropdown. The lower boundaries are displayed by scanning the output points that were simulated. This display can be used to understand where along the x-axis various options were most cost-effective or how far from cost-effective the options are relative to the optimal solutions. (Optimization and Large Parametrics only)
- Set Scales: Allows the user to specify if they want the graph to autoscale (default) or use fixed min/max values.

**Copy Image**
This option will copy the currently displayed image to the clipboard.

**Export Image**
This option will create an image file that displays the graph.

**Copy Data**
This option will copy the graph data to the clipboard (which can be pasted into Excel). All of the points shown on the graph will be listed in a tabular format.

**Export Data**
This option will create a .csv file that can be opened in Excel. All of the points shown on the graph will be listed in a tabular format in the file.

## Y-Axis Metrics

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- Energy Related Costs, Annualized
- Energy Related Costs, Net Present Value
- Energy Related Costs, Life Cycle Cost
- Payback, Simple
- Payback, Modified
- Modified Internal Rate of Return
- Levelized Cost of Energy, Source
- Participant Cost Test (PCT) (California Metrics)
- Ratepayer Impact Measure (RIM) Test (California Metrics)
- Total Resource Cost (TRC) Test (Calfornia Metrics)
- Program Administrator Cost (PAC) Test (California Metrics)

## Energy Related Costs, Annualized

Annualized energy related costs, the default y-axis metric on the Cost/Energy Graph, are calculated by annualizing the energy related cash flows over the analysis period. The annualized cost is then subtracted from the reference for every cash flow but utility bills (i.e. the values displayed in the Cost/Energy graph are full annualized utility bills plus incremental annualized values for every other cash flow).

Cash flows consist of mortgage/loan payments, replacement costs, utility bill payments, mortgage tax deductions (for new construction), and residual values. Costs, excluding mortgage/loan payments, are inflated based on the time they occur in the analysis period using the equation

$$COST_{year=k} = COST_{initial}(1+i)^k$$

where *i* is the inflation rate, $COST_{initial}$ is the cost at the beginning of the analysis period, and $COST_{year=k}$ is the cost at the end of year *k*.

This annualized energy related cost is calculated by annualizing the cash flows. The most straightforward way to annualize complex cash flows is to determine the present worth (PW) of the cash flow by converting the total cost (TC) for each year to the value at the beginning of the analysis period according to the equation

$$PW = \sum_{k=0}^{k=N} -TC_{year=k}(1+d_n)^{-k}$$

where $TC_{year=k}$ is the total cost in year *k* and $d_n$ is the nominal discount rate. The annualized energy related cost (AERC) is then determined by annualizing the PW using the real discount rate, $d_r$, according to

$$AERC = \frac{-PW(d_r)}{\left(1 - \frac{1}{(1+d_r)^N}\right)}$$

which gives the annual equivalent cost for the complex, time-series cash flow.

Note that if the real discount rate is zero (which results in a divide by zero error above), BEopt instead uses:

$$AERC = \frac{-PW}{N}$$

which approximates the previous equation for very small values of the real discount rate.

The AERC is finally subtracted by the AERC of the reference (excluding utility bills).

See Cash Flows for more details.

## Energy Related Costs, Net Present Value

Net present value (NPV), or net present worth (NPW), is the sum of the present values of the individual cash flows of the same entity. NPV provides an indicator of the value of investing in a given technology.

Net present value energy related costs are calculated identically to annualized energy related costs, except that:

1. Cash flows are converted to the present value, rather than annualized, and
2. All cash flows are incremental (relative to the reference)

When comparing the net present values of two technologies, the higher NPV indicates a more worthwhile investment -- however, there may be capital cost constraints that limit the selection of technologies. Any NPV that is greater than zero indicates a net positive cash flow over the analysis period.

See Cash Flows for more details.

## Energy Related Costs, Life Cycle Cost

Life Cycle Cost (LCC) refers to the total cost of ownership over the life of a technology.

Life cycle energy related costs are calculated identically to annualized energy related costs, except that:

1. Cash flows are converted to the present value, rather than annualized, and
2. All cash flows are absolute (not relative to the reference)

When comparing the life cycle costs of two technologies, the lower LCC indicates a more worthwhile investment -- however, there may be capital cost constraints that limit the selection of technologies.

See Cash Flows for more details.

## Payback, Simple

Simple payback refers to the period of time, in years, required for a return on an investment to repay the sum of the original investment. Simple payback is often used because it is easy to calculate and understand. However, it has a number of serious limitations:

- It excludes payments in the future (e.g. replacement costs or technology upgrades at wear-out)
- It excludes changes to cost savings in the future (e.g. utility bill changes due to fuel escalation or technology replacements/upgrades at wear-out)
- It does not take into account time value of money or loan financing

The modified payback is therefore considered a better indicator of cost/energy performance as it incorporates the above complexity and is based on actual cash flows during the analysis period.

Simple payback is calculated as:

$$Payback\ (yrs) = (I - TC - R)/UB$$

where:

I is the first-year incremental capital cost investment (excluding financing)

TC is the first-year incremental tax credits (as applicable)

R is the first-year incremental rebates (as applicable)

UB is the first-year utility bill savings

If a value cannot be calculated for a given output point (i.e., there is no payback), the point will not appear in the Cost/Energy graph.

See Cash Flows for more details.

## Payback, Modified

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Modified payback refers to the period of time, in years, required for a return on an investment to repay the sum of the original investment. Unlike simple payback, which has a number of serious limitations, modified payback incorporates a number of improvements:

- It includes payments in the future (e.g. replacement costs or technology upgrades at wear-out)
- It includes changes to cost savings in the future (e.g. utility bill changes due to fuel escalation or technology replacements/upgrades at wear-out)
- It takes into account time value of money or loan financing

The modified payback is therefore considered a better indicator of cost/energy performance as it incorporates the above complexity and is based on actual cash flows during the analysis period.

Modified payback is calculated by first summing all of the cash outflows. Then the cumulative positive cash flows are determined for each year. The modified payback is the moment in time where the cumulative positive cash flow exceeds the total cash outflow. (Note: The *total* cash outflow, rather than the *cumulative* positive cash flow, is used in the calculation. The latter can result in multiple answers -- that is, multiple moments in time that cumulative net cash flows become positive.)

If a value cannot be calculated for a given output point (i.e., there is no payback), the point will not appear in the Cost/Energy graph.

See Cash Flows for more details.

## Modified Internal Rate of Return

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The modified internal rate of return (MIRR) is a measure of investment cost effectiveness. Per Wikipedia, it is a modification of the internal rate of return (IRR) that aims to resolve some problems:

- IRR assumes that interim positive cash flows are reinvested at the same rate of return as that of the project that generated them.This is usually an unrealistic scenario and a more likely situation is that the funds will be reinvested at a rate closer to the firm's cost of capital. The IRR therefore often gives an unduly optimistic picture of the projects under study. Generally for comparing projects more fairly, the weighted average cost of capital should be used for reinvesting the interim cash flows.
- More than one IRR can be found for projects with alternating positive and negative cash flows, which leads to confusion and ambiguity. MIRR finds only one value.

MIRR is calculated as follows:

$$\mathrm{MIRR} = \sqrt[n]{\frac{FV(\text{positive cash flows, reinvestment rate})}{-PV(\text{negative cash flows, finance rate})}} - 1$$

where:

n is the number of years

PV is present value

FV is future value

If a value cannot be calculated for a given output point (i.e., there is no return on the investment), the point will not appear in the Cost/Energy graph.

See Cash Flows for more details.

## Levelized Cost of Energy, Source

The Levelized Cost of Energy (LCOE) is the price at which the energy must be saved/produced to break even over the lifetime of the project. Because multiple fuel types can be involved, BEopt performs a Levelized Cost of *Source* Energy calculation (see Source/Site Ratio).

LCOE is calculated by dividing the Net Present Value (NPV) of all cash flows, excluding utility bills, by discounted life-cycle source energy savings.

$$LCOE = \frac{NPV}{\sum_{t=1}^{t=N} \frac{\Delta SES}{(1+d_n)^{t-1}}}$$

where:

NPV = Energy Related Costs, Net Present Value, excluding utility bills

SES = Source energy savings in year t

dn = Nominal discount rate

N = Analysis period

If the discounted life-cycle source energy savings is less than or equal to zero, then the LCOE is not a meaningful value and so the point will not appear in the Cost/Energy graph.

See Cash Flows for more details.

## Participant Cost Test (PCT) (California Metrics)

The Participant Cost Test is a measure of the quantifiable direct monetary benefits and costs to the customer due to participation in a utility conservation program. The test provides a measure of the cost-effectiveness of a utility-sponsored energy efficiency program, per the California Standard Practice Manual.

The Net Present Value metric is available for optimizing over, while both the Net Present Value and Benefit-Cost Ratio metrics are available for display in the Cost/Energy Graph.

**Net Present Value**

NPVp is the difference between the NPV of participant benefits (Bp) and the NPV of participant costs (Cp):

$$NPVp = Bp - Cp$$

NPV of participant benefits, Bp, is calculated using the following formula:

$$Bp = TC + INC + BR$$

Where:

TC = Tax credits. Net present value of yearly differences in tax credits between the retrofit and reference case represented in nominal dollars. Applicable tax credits include the PV investment tax credit and tax credits available for energy efficiency. Both state and federal tax credits should be included.

INC = Incentives. NPV of the yearly differences in incentives between the retrofit and reference case.

BR = Bill Reduction. Net present value of difference in utility bill between retrofit and reference case, in nominal dollars, for all years in which the retrofit case utility bill is less than that in the reference case. The difference in utility bill is determined separately for all years, then the total net present value of all utility bill reductions is calculated.

NPV of participant costs, Cp, is calculated as follows:

$$Cp = LP + CP + RC + O\&M + RV + BI$$

Where:

LP = Total loan payments. NPV of yearly differences in loan payments between the retrofit case and reference case, where yearly loan payments are assumed to be in nominal dollars. Total loan payments include both interest and principal payments. If a homeowner uses a home equity line of credit to finance a retrofit, interest payments are tax deductible. The tax deduction should be subtracted from the annual loan payment value.

CP = Total cash payments. NPV of yearly differences in cash payments between the retrofit case and reference case, where yearly cash payments are assumed to be in nominal dollars.

RC = Replacement costs. NPV of difference in replacement costs between retrofit case and reference case in nominal dollars.

O&M = Operation & maintenance costs. NPV of difference in O&M costs between retrofit and reference cases in nominal dollars.

RV = Residual value. NPV of difference in residual value between retrofit and reference cases in nominal dollars.

BI = Bill Increase. This is analogous to Bill Reduction above, except that difference in utility bill between the retrofit and reference cases is included only for those years when the retrofit case has the higher utility bill. The total net present value of all utility bill increases is used.

**Benefit-Cost Ratio**

BCRp is the ratio of NPV of participant benefits to NPV of participant costs.

$$BCRp = \frac{Bp}{Cp}$$

Where Bp and Cp are calculated as described above in NPVp.

See Cash Flows for more details.

## Ratepayer Impact Measure (RIM) Test (California Metrics)

The Ratepayer Impact Measure (RIM) test measures what happens to customer bills or rates due to changes in utility revenues and operating costs caused by a conservation program. If a program causes a larger increase in utility revenues than utility costs, customer rates will decrease. If a program results in a larger increase in utility costs than revenues, customer rates will increase. The test provides a measure of the cost-effectiveness of a utility-sponsored energy efficiency program, per the California Standard Practice Manual.

The Net Present Value metric is available for optimizing over, while both the Net Present Value and Benefit-Cost Ratio metrics are available for display in the Cost/Energy Graph.

**Net Present Value**

$NPV_{RIM}$ is calculated as follows:

$$NPV_{RIM} = B_{RIM} - C_{RIM}$$

Where $B_{RIM}$ and $C_{RIM}$ are calculated as follows:

$$B_{RIM} = NTG \times [UAC + BI]$$

Where:

BI = Bill Increase. This is analogous to Bill Reduction above, except that difference in utility bill between the retrofit and reference cases is included only for those years when the retrofit case has the higher utility bill. The total net present value of all utility bill increases is used.

UAC = Net present value of utility avoided supply costs, for all hours in which the retrofit electricity/gas consumption is lower than the reference.

NTG = Net-to-gross ratio.

$$C_{RIM} = INC + NTG \times [UIC + BR] + PR$$

Where:

INC = Incentives. NPV of the yearly differences in incentives between the retrofit and reference case.

UIC = Net present value of utility increased costs, for all hours in which the retrofit electricity/gas consumption is higher than the reference.

BR = Bill Reduction. Net present value of difference in utility bill between retrofit and reference case, in nominal dollars, for all years in which the retrofit case utility bill is less than that in the reference case. The difference in utility bill is determined separately for all years, then the total net present value of all utility bill reductions is calculated.

PRC = NPV of per-home program administration program costs

NTG = Net-to-gross ratio.

**Benefit-Cost Ratio**

$BCR_{RIM}$ is calculated using the following method:

$$BCR_{RIM} = \frac{B_{RIM}}{C_{RIM}}$$

Where $B_{RIM}$ and $C_{RIM}$ are again calculated as above.

See Cash Flows for more details.

## Total Resource Cost (TRC) Test (California Metrics)

The Total Resource Cost (TRC) Test measures the net cost of an energy conservation program, viewing the program as a utility resource option. Both utility and participant costs are included. The TRC Test reflects the impacts of a program on both participating and non-participating customers. In a sense, it is the summation

of the benefit and cost terms in the Participant and RIM tests, where revenue/bill costs and incentives intuitively cancel out. The test provides a measure of the cost-effectiveness of a utility-sponsored energy efficiency program, per the California Standard Practice Manual.

The Net Present Value metric is available for optimizing over, while both the Net Present Value and Benefit-Cost Ratio metrics are available for display in the Cost/Energy Graph.

**Net Present Value**

$NPV_{TRC}$ is calculated as follows:

$$NPV_{TRC} = B_{TRC} - C_{TRC}$$

Where:

$B_{TRC}$ = Program benefits

$$B_{TRC} = TC_f + UAC * NTG$$

Where:

UAC = Net present value of utility avoided supply costs, for all hours in which the retrofit electricity/gas consumption is lower than the reference.

NTG = Net-to-gross ratio.

$TC_f$ = NPV of federal tax credits. Net present value of yearly differences in tax credits between the retrofit and reference case represented in nominal dollars. Applicable tax credits include the PV investment tax credit and tax credits available for energy efficiency. Only federal tax credits are included in the TRC costs because state tax credits are viewed as a transfer payment.

$$C_{TRC} = NTG \cdot (LP + CP + RC + O\&M + RV + UIC) + (1 - NTG) \cdot INC + PRC$$

Where:

NTG = Net-to-gross ratio.

LP = Total loan payments. NPV of yearly differences in loan payments between the retrofit case and reference case, where yearly loan payments are assumed to be in nominal dollars. Total loan payments include both interest and principal payments. If a homeowner uses a home equity line of credit to finance a retrofit, interest payments are tax deductible. The tax deduction should be subtracted from the annual loan payment value.

CP = Total cash payments. NPV of yearly differences in cash payments between the retrofit case and reference case, where yearly cash payments are assumed to be in nominal dollars.

RC = Replacement costs. NPV of difference in replacement costs between retrofit case and reference case in nominal dollars.

O&M = Operation & maintenance costs. NPV of difference in O&M costs between retrofit and reference cases in nominal dollars.

RV = Residual value. NPV of difference in residual value between retrofit and reference cases in nominal dollars.

INC = Incentives. NPV of the yearly differences in incentives between the retrofit and reference case.

UIC = Net present value of utility increased costs, for all hours in which the retrofit electricity/gas consumption is higher than the reference.

PRC = NPV of per-home program administration program costs.

**Benefit-Cost Ratio**

$BCR_{TRC}$ is the ratio of NPV of participant benefits to NPV of participant costs.

$$BCR_{TRC} = \frac{B_{TRC}}{C_{TRC}}$$

Where $B_{TRC}$ and $C_{TRC}$ are calculated as above in the NPV calculation.

See Cash Flows for more details.

## Program Administrator Cost (PAC) Test (California Metrics)

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The Program Administrator Cost Test measures the net costs of a demand-side management program as a resource option based on the costs incurred by the program administrator, including incentive costs and excluding any net costs incurred by the participant. The test provides a measure of the cost-effectiveness of a utility-sponsored energy efficiency program, per the California Standard Practice Manual.

The Net Present Value metric is available for optimizing over, while both the Net Present Value and Benefit-Cost Ratio metrics are available for display in the Cost/Energy Graph.

**Net Present Value**

NPVpa is the difference between the program benefits and program costs:

$$NPVpa = Bpa - Cpa$$

Where:

Bpa = Program benefits

$$Bpa = NTG \times UAC$$

Where:

UAC = Net present value of utility avoided supply costs, for all hours in which the retrofit electricity/gas consumption is lower than the reference.

NTG = Net-to-gross ratio.

Cpa = Program costs

$$Cpa = INC + NTG \times UIC + PR$$

Where:

PRC= NPV of per-home program administration program costs.

INC = Incentives. NPV of the yearly differences in incentives between the retrofit and reference case.

UIC = Net present value of utility increased costs, for all hours in which the retrofit electricity/gas consumption is higher than the reference.

NTG = Net-to-gross ratio.

**Benefit-Cost Ratio**

BRCpa is calculated as follows:

$$BCRpa = \frac{Bpa}{Cpa}$$

Where Bpa and Cpa are calculated as above, in the NPVpa calculation.

See Cash Flows for more details.

## X-Axis Metrics

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- (Adjusted) Source Energy Savings
- Source Energy Consumption
- Site Energy Savings
- Site Energy Consumption
- CO2e Savings
- CO2e Emissions
- TDV Energy Savings (California Metrics)
- TDV Energy Consumption (California Metrics)
- Energy Rating Index

## (Adjusted) Source Energy Savings

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Average source energy savings (ASES), the default x-axis metric on the Cost/Energy Graph, is the difference in average source energy use between a prototype building and the reference, either given as MMBtu/yr or, when divided by the reference, as %/yr:

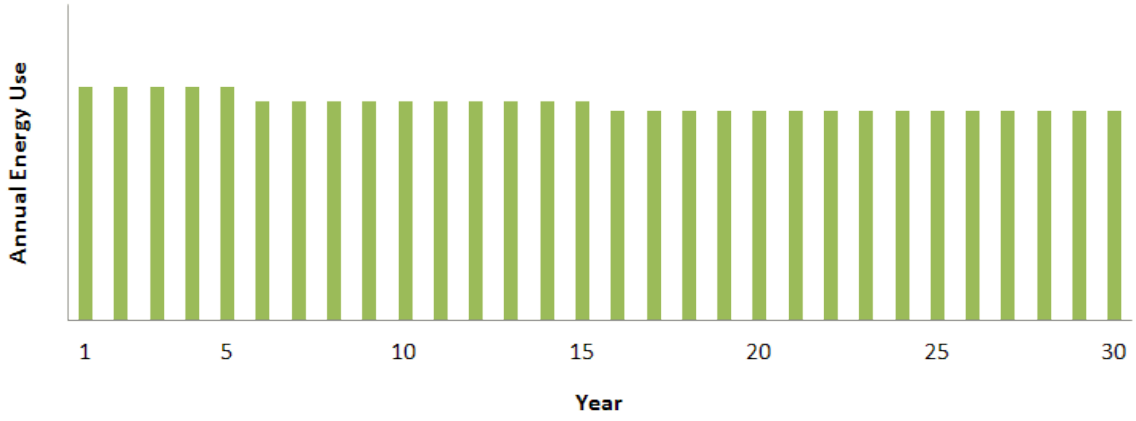
$$ASES = \frac{AEU_{ref} - AEU_{proto}}{AEU_{ref}}$$

Average energy use (AEU) is the average of annual energy uses over the analysis period,

$$AEU = \frac{\sum_{k=1}^{k=N} EU_k}{N}$$

where $EU_k$ is the energy use in year $k$ and $N$ is the number of years in the analysis period.

Here is an example annual energy use diagram for retrofit analysis that includes energy efficiency upgrades at wear-out:




**Example annual energy use diagram.**

For new construction or for retrofits where all measures are evaluated today, the annual energy use will be constant over the entire analysis period.

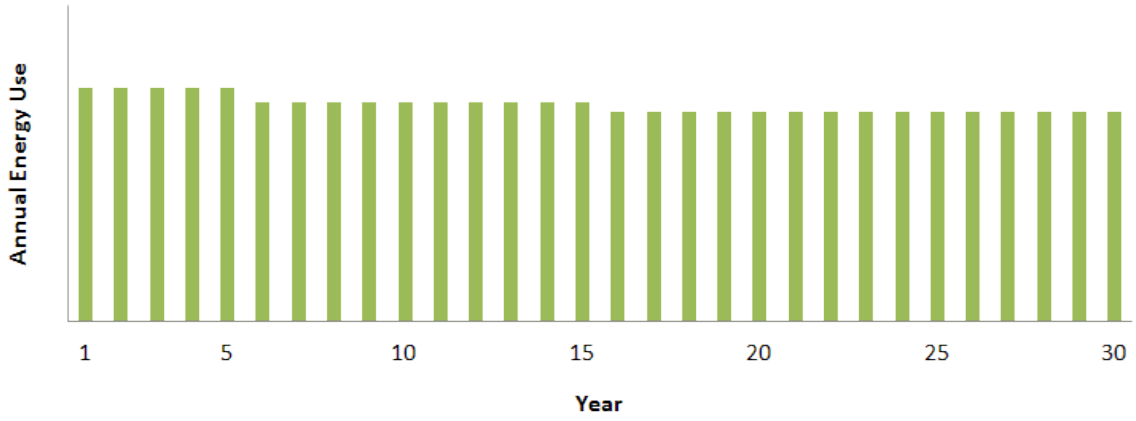
**Adjusted Source Energy Savings**

When the Building America Benchmark is set as the reference and it's a single-family detached building , the x-axis metric will become *Adjusted* Source Energy Savings. The adjustment accounts for the house size multiplier in the Benchmark specification and is applied to the Benchmark building source energy (and thus, impacts energy savings relative to the Benchmark building). See the Building America Benchmark topic for more details.

## Source Energy Consumption

Source Energy Consumption is the average source energy use for a building, expressed in MMBtu/yr.

Here is an example annual energy use diagram for retrofit analysis that includes energy efficiency upgrades at wear-out:




**Example annual energy use diagram.**

For retrofits where all measures are evaluated today, or for new construction, the annual energy use will be constant over the entire analysis period.

## Site Energy Savings

Average site energy savings (ASES) is the difference in average site energy use between a prototype building and the reference, either given as MMBtu/yr or, when divided by the reference, %/yr.

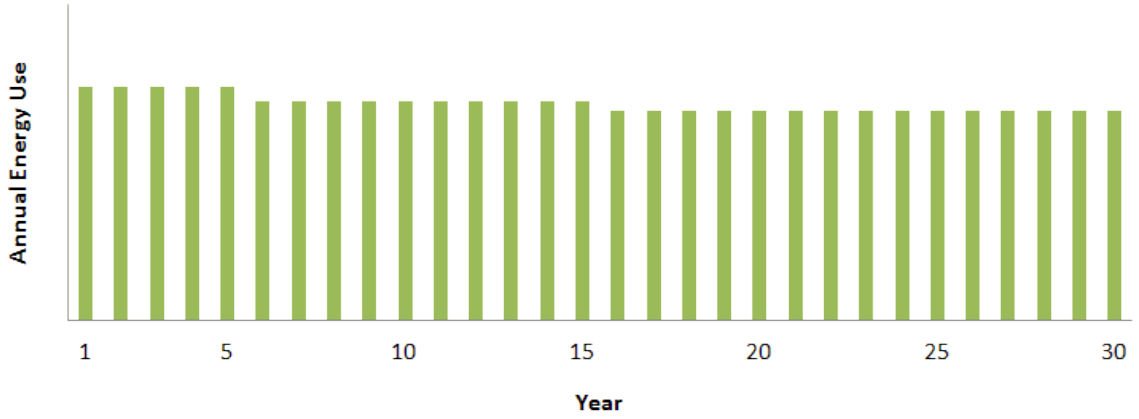
$$ASES = \frac{AEU_{ref} - AEU_{proto}}{AEU_{ref}}$$

Average energy use (AEU) is the average of annual energy uses over the analysis period,

$$AEU = \frac{\sum_{k=1}^{k=N} EU_k}{N}$$

where $EU_k$ is the energy use in year $k$ and $N$ is the number of years in the analysis period.

Here is an example annual energy use diagram for retrofit analysis that includes energy efficiency upgrades at wear-out:




**Example annual energy use diagram.**

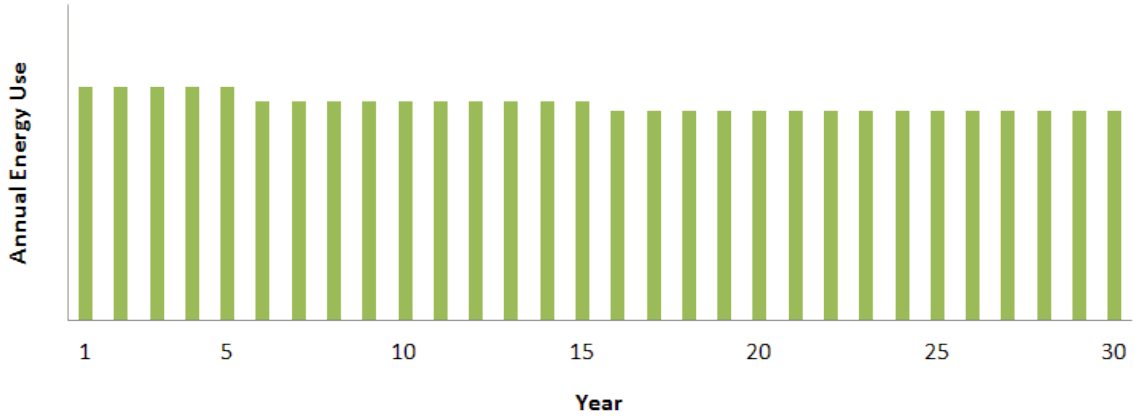
For retrofits where all measures are evaluated today, or for new construction, the annual energy use will be constant over the entire analysis period.

## Site Energy Consumption

---

Site Energy Consumption is the average site energy use for a building, expressed in MMBtu/yr.

Here is an example annual energy use diagram for retrofit analysis that includes energy efficiency upgrades at wear-out:




**Example annual energy use diagram.**

For retrofits where all measures are evaluated today, or for new construction, the annual energy use will be constant over the entire analysis period.

## CO2e Savings

---

CO2e Savings is the difference in average equivalent CO2 emissions between a prototype building and the reference, either given as metric tons/yr or, when divided by the reference, %/yr.

It is the same calculation as Site Energy Savings, except that site energy is converted to CO2e emissions using the appropriate carbon factor for each fuel.

## CO2e Emissions

---

CO2e Emissions is the average equivalent CO2 emissions for a building, expressed in metric tons/yr.

It is the same calculation as Site Energy Consumption, except that site energy is converted to CO2e emissions using the appropriate carbon factor for each fuel.

## TDV Energy Savings (California Metrics)

---

TDV Energy Savings is the difference in average TDV Energy between a prototype building and the reference, either given as MMBtu/yr or, when divided by the reference, %/yr.

It is the same calculation as Site Energy Savings, except that site energy is converted to TDV energy using hourly TDV factors.

## TDV Energy Consumption (California Metrics)

TDV Energy Consumption is the average TDV energy consumption for a building, expressed in MMBtu/yr.

It is the same calculation as Site Energy Consumption, except that site energy is converted to TDV energy using hourly TDV factors.

## Energy Rating Index

The Energy Rating Index (ERI) is calculated per the ANSI/RESNET 301-2014 "Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the HERS Index" as well as the ANSI/RESNET 301-2014 Addendum A-2015 "Addendum on Domestic Hot Water (DHW) Systems". This metric is a performance compliance path in the 2015 IECC.

This output metric is only available if ERI has been checked on the Run Dialog.

## Cash Flows

BEopt calculates the following cash flows for purposes of calculating various y-axis metrics.

- **Loan Principal:** The principal portion of loan payments that are made for the length of the loan period. The principal and interest portions of the loan sum to the total loan payment.
- **Loan Interest:** The interest portion of loan payments that are made for the length of the loan period. The principal and interest portions of the loan sum to the total loan payment.
- **Replacement Costs:** For components that wear-out before the end of the analysis period, replacement costs are incurred. The cost is adjusted based on inflation between the beginning of the analysis period and the time of replacement. For retrofit analysis where efficiency upgrades are paid in cash today, these costs will also show up as replacement costs.
- **Utility Bills:** Utility bill costs are calculated from the annual energy uses, including energy rates that inflate with time (or via the fuel escalation rate). Energy use is multiplied by the marginal fuel costs and added to any fixed monthly charges.
- **Loan Tax Deductions:** For new construction or tax-deductible retrofit loans, a tax deduction on the interest portion of loan payments can be made. Since the interest portion of a loan decreases over time, the tax deduction cash flow will also decrease over time.
- **Residual Values**: All components that wear out during the analysis period are assumed to have no residual value (salvage value, resell value, scrap value etc.). However, the fact that multiple technologies are modeled with different useful lives inevitably leads to components with remaining life at the end of the analysis period. As recommended in *NIST Handbook 135: Life-Cycle Cost Manual for the Federal Energy Management Program [ref NIST],* the "value in place" of a component with remaining life at the end of the analysis period is calculated by linearly prorating its initial cost according to the equation:

  $$\alpha = COST_{End}\frac{R}{L},$$

  where $COST_{End}$ is the inflated cost at the end of the analysis period, *R* is the component remaining life (years), and *L* is the component lifetime (years). The residual value for each component with remaining life at the end of the analysis period is included as a receipt in the cash flow at the end of the analysis period. These receipts represent the value added to the building when components are expected to function beyond the end of the analysis period. The main purpose of this term in our analysis is to avoid the situation of a technology looking artificially much more cost-effective, or much less cost-effective, simply because of the coincidence of how the length of its service life lines up with the end of the analysis period.
- **Rebates**: Rebates are calculated based on the specification of PV rebates or whole-building efficiency rebates.
- **Federal Tax Credits**: Federal tax credits are calculated based on the specification of PV tax credits or whole-house efficiency tax credits from the federal government. Federal and non-federal tax credits are disaggregated in order to calculate the Total Resource Cost Test.
- **Non-Federal Tax Credits**: Non-federal tax credits are calculated based on the specification of PV tax credits or whole-house efficiency tax credits from entities other than the federal government. Federal and non-federal tax credits are disaggregated in order to calculate the Total Resource Cost Test.
- **Cash Payment:** The upfront cash payment (e.g. 20% mortgage down payment).

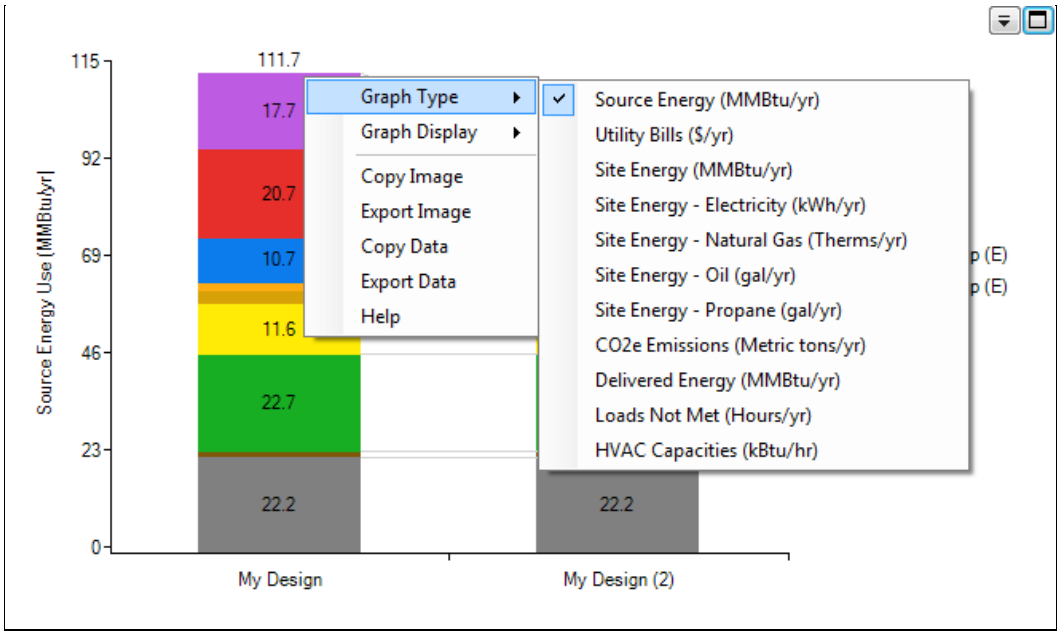
## End Use Graph

The End Use Graph is found in the lower left corner of the Output Screen.

The y-axis of this graph shows information about the building in a number of different ways. Natural gas uses are labeled with "G", electricity uses are labeled with "E", fuel oil uses are labeled with "O", and propane uses are labeled with "P". A separate gray line indicates the level of PV production.

By right-clicking on the graph, a menu of options will appear. The options also appear by clicking on the menu button in the top right corner of the graph.

**Graph Type**




- **Source Energy** : This shows energy consumption in terms of source energy (see Source/Site Ratio). Note that when the B10 Benchmark is the reference and the building is single-family detached , two values will appear for that point: the total source energy consumption as well as an adjusted source energy consumption (see B10 Benchmark).

- **TDV Energy** : This shows the TDV energy consumption as a function of fuel type. This option is only available when using the California Metrics project type.

- **Utility Bills** : This shows the energy consumption as an annual energy cost.

- **Site Energy** : This shows the annual site energy consumption (sum of site energy for each fuel type) in MMBtu/yr.

- **Site Energy - Electricity** : This shows the annual site electricity consumption in kWh/yr.

- **Site Energy - Natural Gas** : This shows the annual site gas consumption in Therms/yr.

- **Site Energy - Oil** : This shows the annual site fuel oil consumption in gal/yr.

- **Site Energy - Propane** : This shows the annual site propane consumption in gal/yr.

- **CO2e Emissions** : This shows the annual equivalent carbon emissions (see Carbon Factor) in Metric tons/yr.

- **Delivered Energy** : This shows the annual heating and cooling energy delivered to the conditioned space by the HVAC system, as well as the water heating energy delivered to the water heater. Heating and cooling energy lost due to distribution ducts is also shown. Cooling energy is split into sensible and latent components. For simulations with a dehumidifier, latent cooling provided by the dehumidifer is also shown. The delivered energy numbers include the thermal effects of heat pump water heaters, heat recovery ventilators, and HVAC fan heat as appropriate.

- **Loads Not Met** : This shows the number of hours per year that the heating and cooling loads are not met in the living space (and finished basement, as appropriate). For multifamily buildings, these values are the sum of the hours for each individual unit.

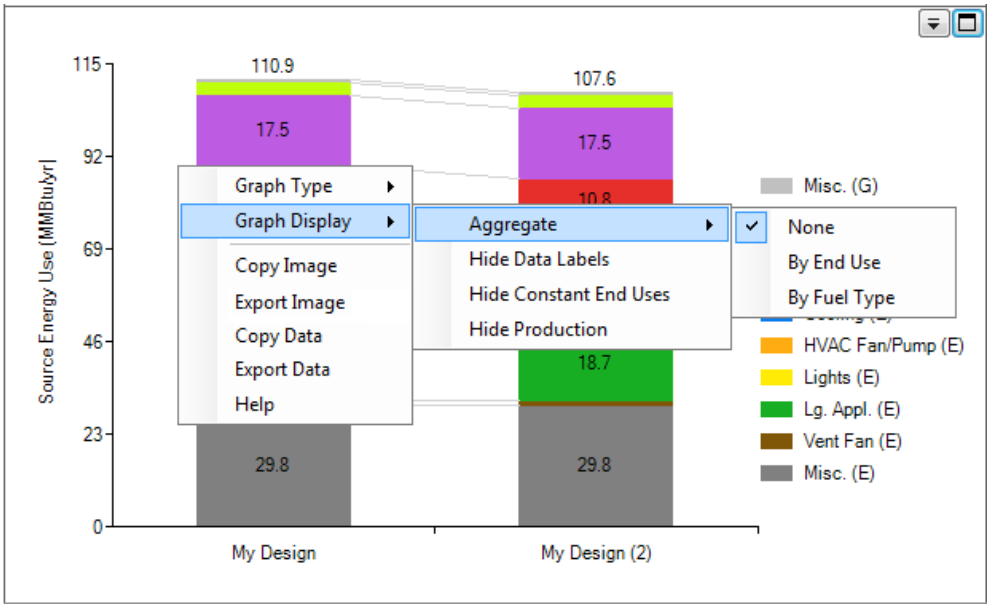
  Note: For homes with finished basements and central forced-air systems, this is a valuable enhancement because the number of heating loads not met for the finished basement will often be larger than expected. This is because the fractions of supply air being delivered to the living space and finished basement are based on peak design conditions. Then when outdoor air temperatures warm up later in the Spring, but ground temperature remain cool, finished basements tend to be under-heated. The reverse happens in the Fall. The hours not met may occur at only a few degrees above or below the heating or cooling set point.

- **Energy Rating Index**: This shows the Energy Rating Index, per the ANSI/RESNET 301-2014 "Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the HERS Index" as well as the ANSI/RESNET 301-2014 Addendum A-2015 "Addendum on Domestic Hot Water (DHW) Systems".

- **HVAC Capacities** : This shows the capacity of the heating and cooling system in kBtu/hr. All values displayed here are output capacities for the equipment.

  Note: For all heat pumps (i.e., air-source, ground-source, or mini-split), the cooling capacity reported is both the heating and cooling capacity of the heat pump itself. Any backup heat (e.g., supplemental heating for an air-source heat pump; electric resistance backup for a mini-split heat pump) will be the reported heating capacity.

**Graph Display**




- Aggregate end uses by fuel type (e.g., combine all electric uses) or end use (e.g., combine gas misc. and electric misc.) or neither
- Toggle numerical data labels on and off for the end uses.
- Toggle constant end uses on and off. These are end uses that are constant across all displayed points. Only available if multiple sets of bars are displayed.
- Toggle PV bars on and off.

**Copy Image**
This option will copy the currently displayed image to the clipboard.

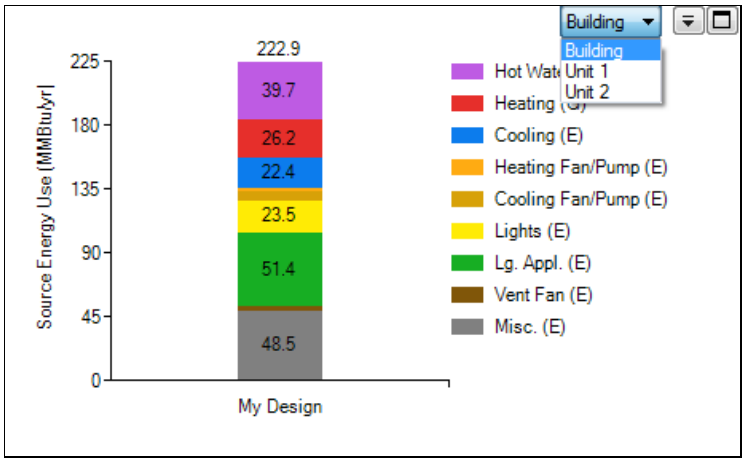
**Export Image**
This option will create an image file that displays the graph.

**Copy Data**
This option will copy the graph data to the clipboard (which can be pasted into Excel). All of the points shown on the graph will be listed in a tabular format.

**Export Data**
This option will create a .csv file that can be opened in Excel. All of the points shown on the graph will be listed in a tabular format in the file.

**Multifamily Buildings**

For multifamily buildings , this graph can show either whole-building totals or values specific to each multifamily unit. To switch between the two, use the dropdown box at the top of the graph:

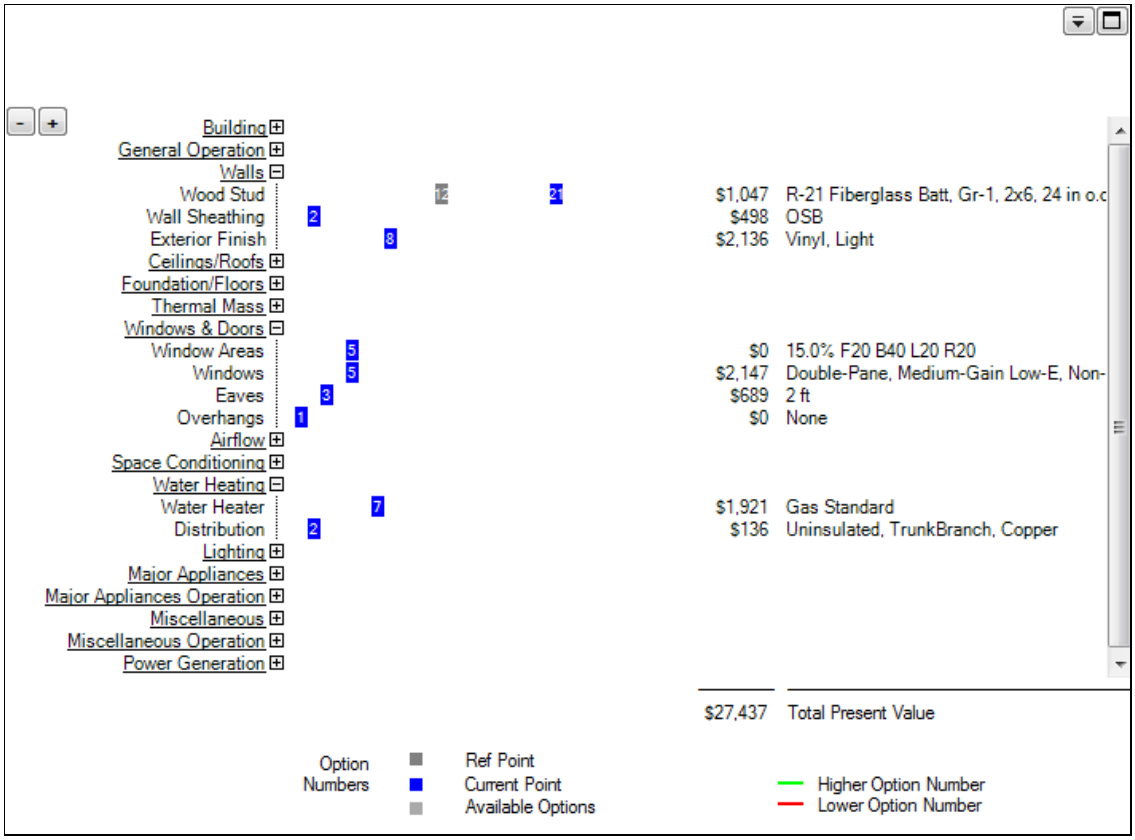



## Options Graph

The Options Graph occupies the right side of the Output Screen. The display features will vary based on the number of points selected: Single Point Selection, Two Point Selection, Multiple Point Selection.

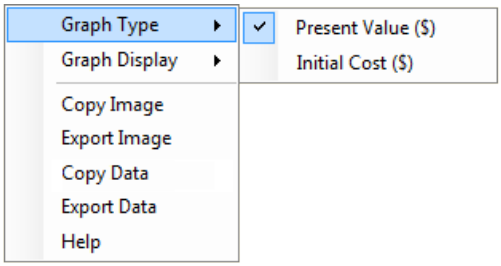
For multifamily buildings, this graph shows whole-building cost totals.

Like on the options input screen, groups can be expanded/collapsed by clicking on the +/- icon next to the group name. You can also click on the buttons at the top-left to collapse/expand all the groups at once.




By right-clicking on the graph, a menu of options will appear. The options also appear by clicking on the menu button in the top right corner of the graph.

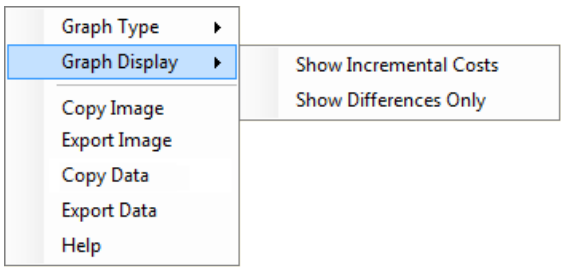
**Graph Type**




- Present Value ($) - The upfront cost of the technology plus any future replacement costs (discounted to the present) plus any residual value (discounted to the present), regardless of whether the technology is actually being paid for immediately or with cash. This cost is not directly used in the cash flow calculations for the various y-axis metrics, the value here is only for informational display purposes. No financing, rebates, or incentives are applied to these values.

- Initial Cost ($) - The upfront material and labor costs of the technology, regardless of whether the technology is actually being paid for immediately or with cash. This cost is not directly used in the cash flow calculations for the various y-axis metrics, the value here is only for informational display purposes. No financing, rebates, or incentives are applied to these values.

**Graph Display**




- Show Incremental Costs: Displayed costs will subtract out the reference costs, thus showing only the net costs related to energy efficiency improvements beyond the reference.

- Show Differences Only: If checked, only categories with differences in the options of the selected points will be displayed. If unchecked, all options will be displayed.

**Copy Image**
This option will copy the currently displayed image to the clipboard.

**Export Image**
This option will create an image file that displays the graph.

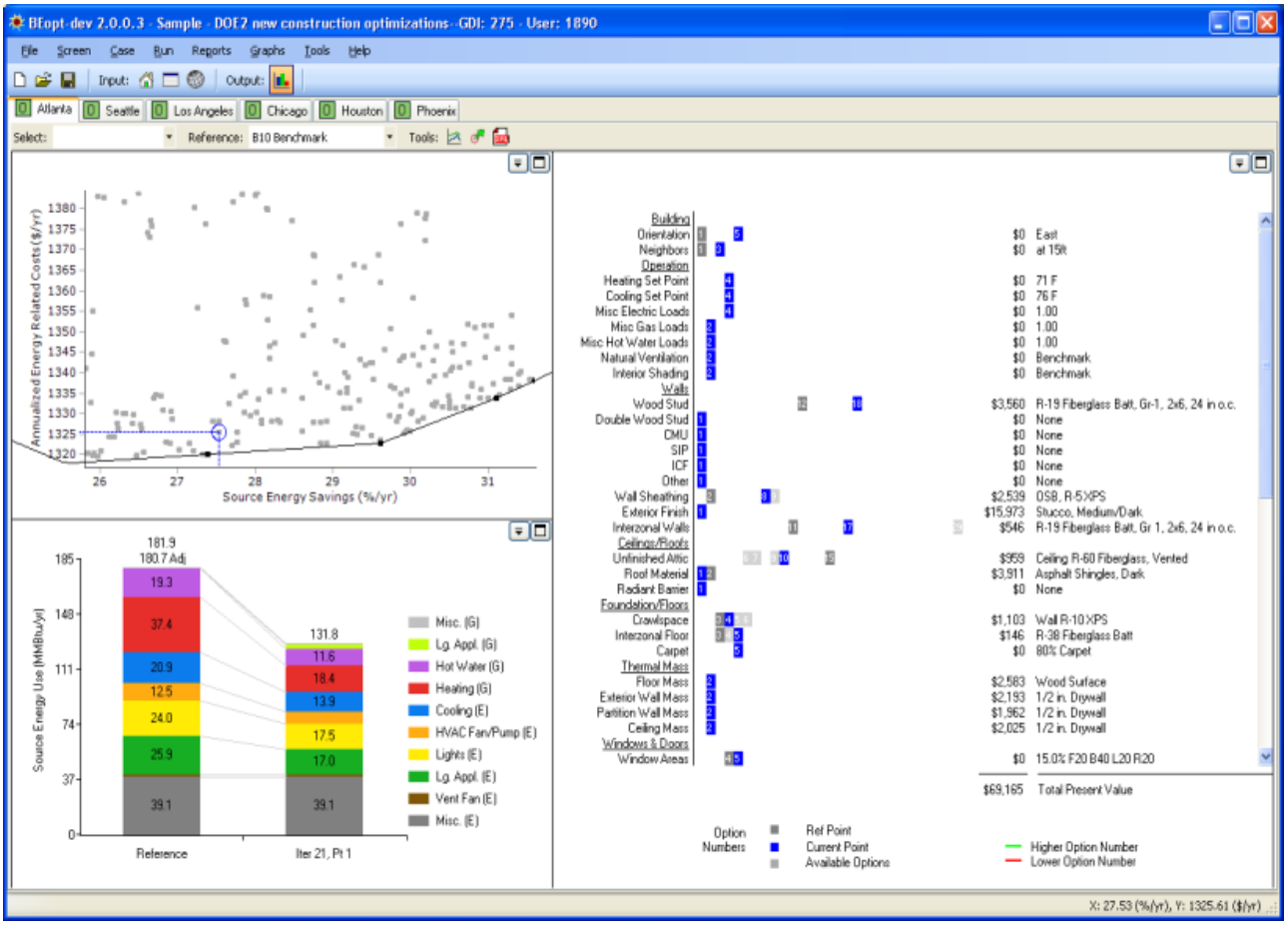
**Copy Data**
This option will copy the graph data to the clipboard (which can be pasted into Excel). All of the points shown on the graph will be listed in a tabular format.

**Export Data**
This option will create a .csv file that can be opened in Excel. All of the points shown on the graph will be listed in a tabular format in the file.

## Point Selection

- Single Point
- Two Point
- Multiple Point

## Single Point

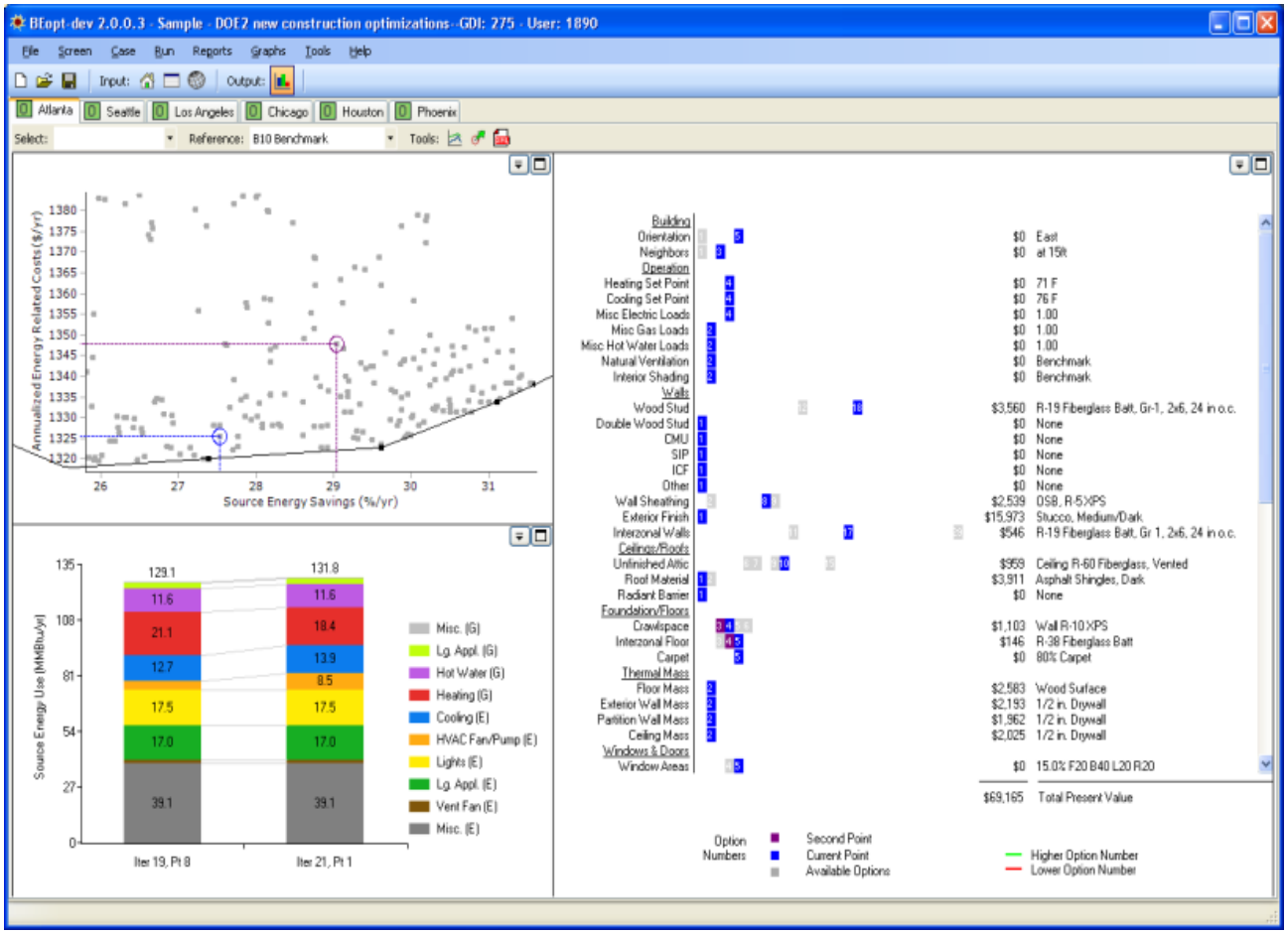



When a single point is selected in the Cost/Energy Graph, the selected point is compared to the Reference.

In the End Use Graph, the left stacked bar displays the end uses for the reference, while the right stacked bar displays the end uses for the selected point.

In the Options Graph, the options in the selected point is highlighted in blue, while the reference is shown in dark gray. Other options included in the analysis are shown in light gray.

## Two Point




When two points are selected in the Cost/Energy Graph (either by clicking and dragging or by Ctrl+clicking), the two points are compared to each other. The first point is indicated in magenta, while the second point is indicated in blue.

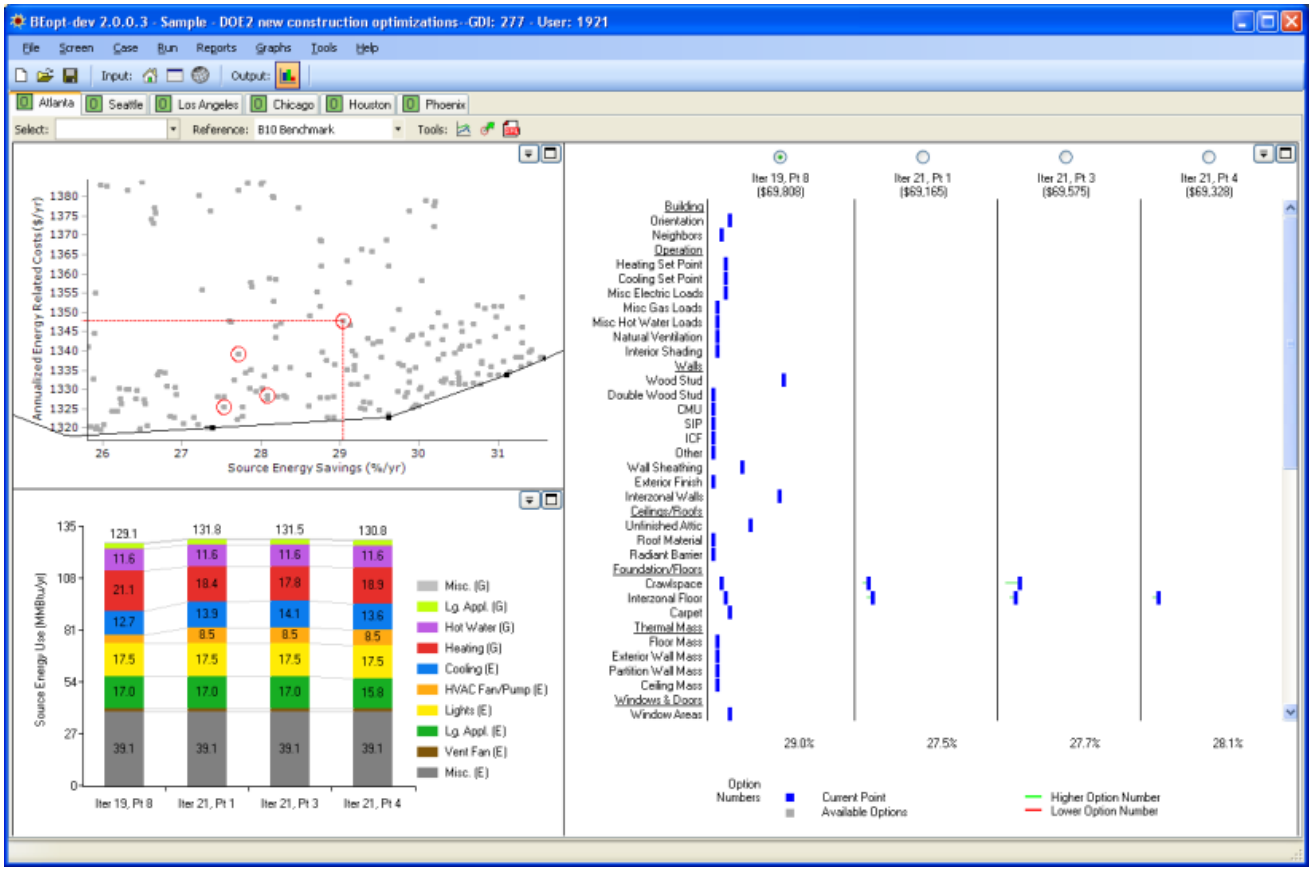
In the End Use Graph, the left stacked bar displays the end uses for the first point, while the right stacked bar displays the end uses for the second point.

In the Options Graph, the options in the first selected point are highlighted in magenta, while the options in the second selected point are highlighted in blue. Other options included in the analysis are shown in light gray.

## Multiple Point

---

To select multiple points on a graph (with a maximum of 12 at a time), it may be helpful to zoom-in on the Cost/Energy Graph using the mousewheel.




When three or more points are selected in the Cost/Energy Graph (either by clicking and dragging or by Ctrl+clicking), the points are compared to each other.

In the End Use Graph, the end uses for each point are displayed.

In the Options Graph, the options included in one of the points (the base point) are shown highlighted in blue. For each other point, the change in options relative to the base point is highlighted. Changes towards higher numbered options (nominally more efficient) are highlighted with a green tail. Changes towards lower numbered options (nominally less efficient) are highlighted with a red tail. Clicking the radio button above one of the other columns makes that point the base column instead.

## Reports

- Detailed Report

## Detailed Report

The detailed report can be generated from the Reports menu. The detailed report is a comma-separated value (csv) file that contains sections on both input data and, if available for a case, output data, for each case selected by the user. If there are multiple cases, they are listed sequentially in the file.

**INPUT DATA**

There are multiple input data sections available:

- **General:** This section lists input values specified in the Case Input toolbar.

| | | |
|---|---|---|
| Input - General | | |
| | | |
| | Input | Value |
| | Application Type | retrofit |
| | Analysis Mode | Optimization |

- **Geometry:** This section lists inputs from the Geometry input screen, including the total finished floor area and the number of bedrooms and bathrooms.

| Input - Geometry Screen | | |
|---|---|---|
| Input | Value | Units |
| Total Finished Floor Area | 1338 | sqft |
| Bedrooms | 3 | |
| Baths | 2 | |

- **Options:** This section displays the selected options for a given analysis, as specified in the Options input screen.

| Input - Options Screen | | | | | | |
|---|---|---|---|---|---|---|
| Group Name | Category Name | Option Na | Existing | Reference | Start | Optimization |
| | | | Selected | Selected | Selected | Selected |
| Building | | | | | | |
| | Orientation | | | | | |
| | | North | x | x | x | x |
| | | NNE | | | | |
| | | Northeast | | | | |

- **Site:** This section lists all of the inputs from the Site input screen, including location, fuel rates, and economic inputs.

| Input - Site Screen | | |
|---|---|---|
| Input | Value | Units |
| EPW Location | CZ03RV2.epw | |
| Terrain | Suburban | |
| Project Analysis Period | 30 | years |

**OUTPUT DATA**

There are multiple output data sections available, shown below. For optimization cases, each section will be repeated twice - once for optimal points only followed by once for all output points.

- **Option Names:** This section lists all of the option names, category by category, that make up each building design.

| Output - Option Names | | | | |
|---|---|---|---|---|
| Point | Orientation | Neighbors | Heating Se | Coo |
| Reference | North | None | 71 F | 76 |
| Iter 1, Pt 1 | North | None | 71 F | 76 |
| Iter 1, Pt 2 | North | None | 71 F | 76 |

- **Cost/Energy Graph Metrics:** This section lists all of the graph values across all x-axis metrics and y-axis metrics for the Cost/Energy Graph.

| Output - Cost/Energy Graph Metrics | | | | |
|---|---|---|---|---|
| Point | Source Ene | Source En | Site Energ | Site Ene |
| | [%/yr] | [MMBtu/y | [MMBtu/y | [%/yr] |
| Reference | 0 | 0 | 0 | |
| Iter 1, Pt 1 | 12.31 | 19.82 | 16.82 | 16. |
| Iter 1, Pt 2 | 2.96 | 4.76 | 3.92 | 3 |

- **End Use Graph Metrics**: This section lists all of the graph values for the End Use Graph. Fuel types are (E) for electric, (G) for natural gas, (O) for fuel oil, and (P) for propane.

| Output - End Use Graph Metrics | | | | |
|---|---|---|---|---|
| Point | Source Ene | Source En | Source En | Source |
| | Misc. (E) | Vent Fan ( | Lg. Appl. ( | Lights ( |
| | [MMBtu/yr | [MMBtu/y | [MMBtu/y | [MMBtu |
| Reference | 33.41 | 0.24 | 19.5 | 14. |
| Iter 1, Pt 1 | 33.41 | 0.24 | 19.5 | 14. |
| Iter 1, Pt 2 | 33.41 | 0.24 | 19.5 | 14. |

- **Options Graph Metrics**: This section lists all of the graph values for the Options Graph.

| Output - Options Graph Metrics | | | | |
|---|---|---|---|---|
| Point | Present Va | Present V | Present V | Prese |
| | Orientatior | Neighbors | Heating Se | Cooli |
| | [$] | [$] | [$] | [$] |
| Reference | 0 | 0 | 0 | |
| Iter 1, Pt 1 | 0 | 0 | 0 | |
| Iter 1, Pt 2 | 0 | 0 | 0 | |

- **Simulation End Uses**: This section lists the simulation end use results for each year of the analysis period. Energy use can change from year to year for retrofit measures replaced at wear out. Fuel types are (E) for electric, (G) for natural gas, (O) for fuel oil, and (P) for propane.

| Output - Simulation End Uses | | | | |
|---|---|---|---|---|
| Point | Year 1 | Year 2 | Year 3 | Year 4 |
| | Heating (E) | Heating (E | Heating (E | Heatir |
| | [MMBtu] | [MMBtu] | [MMBtu] | [MMB |
| Reference | 0 | 0 | 0 | |
| Iter 1, Pt 1 | 0 | 0 | 0 | |
| Iter 1, Pt 2 | 0 | 0 | 0 | |

- **Simulation Utility Bills**: This section lists the simulation utility bill values for each year of the analysis period. Utility bills can change from year to year for retrofit measures replaced at wear out.

| Output - Simulation Utility Bills | | | | |
|---|---|---|---|---|
| Point | Year 1 | Year 2 | Year 3 | Year 4 |
| | Fixed Charg | Fixed Cha | Fixed Cha | Fixed |
| | [$/yr] | [$/yr] | [$/yr] | [$/yr] |
| Reference | 96 | 96 | 96 | |
| Iter 1, Pt 1 | 96 | 96 | 96 | |
| Iter 1, Pt 2 | 96 | 96 | 96 | |

- **Simulation Cost Multipliers**: This section lists the simulation cost multipliers for each year of the analysis period. Cost multipliers, which are multiplied by unit costs to calculate total costs, can change from year to year for retrofit measures replaced at wear out. Note that some categories have multiple cost multipliers with different units (e.g. $/roof area and $/ceiling area).

| Output - Simulation Cost Multipliers | | | | |
|---|---|---|---|---|
| Point | Year 1 | Year 2 | Year 3 | Year |
| | Orientatior | Orientatic | Orientatic | Orie |
| Reference | 1 | 1 | 1 | |
| Iter 1, Pt 1 | 1 | 1 | 1 | |
| Iter 1, Pt 2 | 1 | 1 | 1 | |

- **Simulation Avoided Costs**: Avoided costs are only available for California Metrics project types. This section lists the simulation end use results for each year of the analysis period. Avoided costs can change from year to year for retrofit measures replaced at wear out. Note that avoided costs are sourced from the 2013-2014 E3 Calculator.

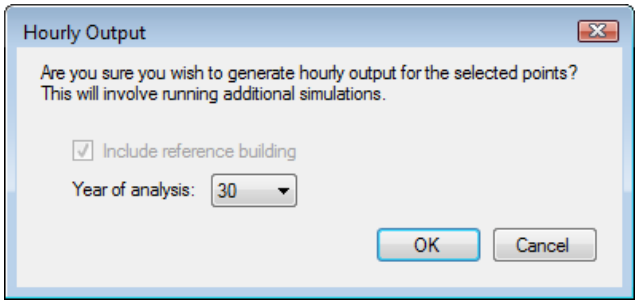
| Output - Simulation Avoided Costs | | | | |
|---|---|---|---|---|
| Point | Year 1 | Year 2 | Year 3 | Year 4 |
| | Electricity | Electricity | Electricity | Electri |
| | [$] | [$] | [$] | [$] |
| Reference | 0 | 0 | 0 | |
| Iter 1, Pt 1 | 44.83997 | 47.76001 | 50.38 | 53.64 |
| Iter 1, Pt 2 | 15.12 | 16.14001 | 17.04999 | 18.17 |

- **Cash Flows**: This section lists all of the disaggregated annual cash flows for each year of the analysis period.

| Output - Cash Flows | | | | | |
|---|---|---|---|---|---|
| | Point | Year 0 | Year 1 | Year 2 | Year 3 |
| | | LoanPrincip | LoanPrinc | LoanPrinc | LoanP |
| | | [$] | [$] | [$] | [$] |
| | Reference | 0 | 0 | 0 | |
| | Iter 1, Pt 1 | 0 | 286.45 | 307.16 | 32 |
| | Iter 1, Pt 2 | 0 | 76.12 | 81.62 | 8 |

## Hourly Results - DView

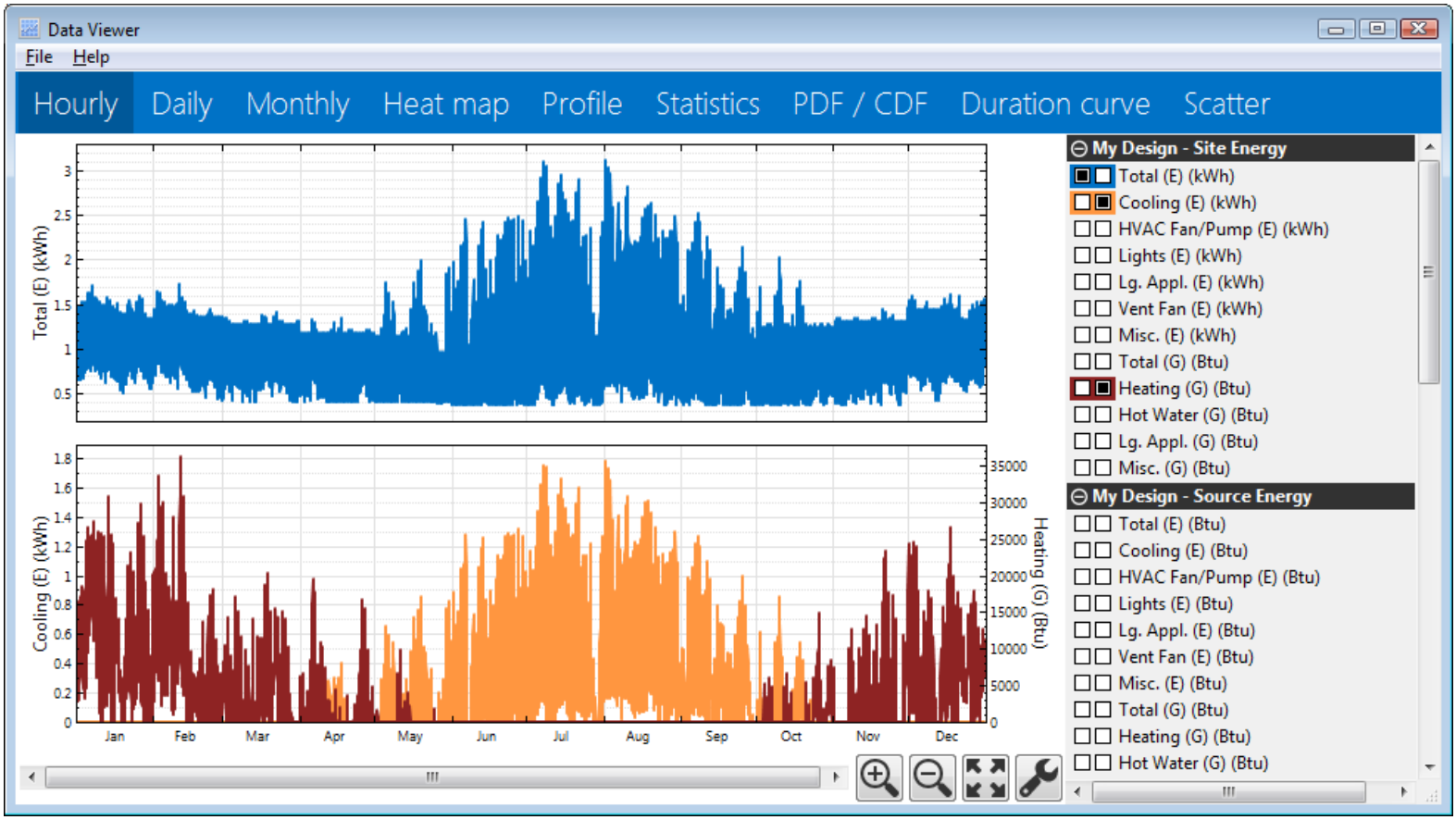
Clicking on the Hourly Output button in the Case Output toolbar allows the user to capture hourly data for the selected point(s) on the output screen.




The year of analysis dropdown will appear when the user has performed retrofit analysis. Since the building components can change over the analysis period, the user can choose results for any given year.

**DView:**

The hourly data opens in a separate window, which allows the user to look at hourly output organized into different graphical formats for ease of viewing. The data includes building site energy use, source energy use, PV energy use (if applicable), and weather data.




- To zoom out to the full year, click the Zoom Out or Zoom Fit buttons.

- To quickly zoom in, click and drag on the graph.
- Switch data views by clicking on the tabs at the top of the screen.
- Load data from outside BEopt for comparison by using the File > Open menu.

Right click on the graph to see various graph options.

## Batch Simulations


- Overview
- BEopt XML Files
- Generating 3D Geometry
- Simulation Input Files
- Running Simulations
- BEopt Output Files

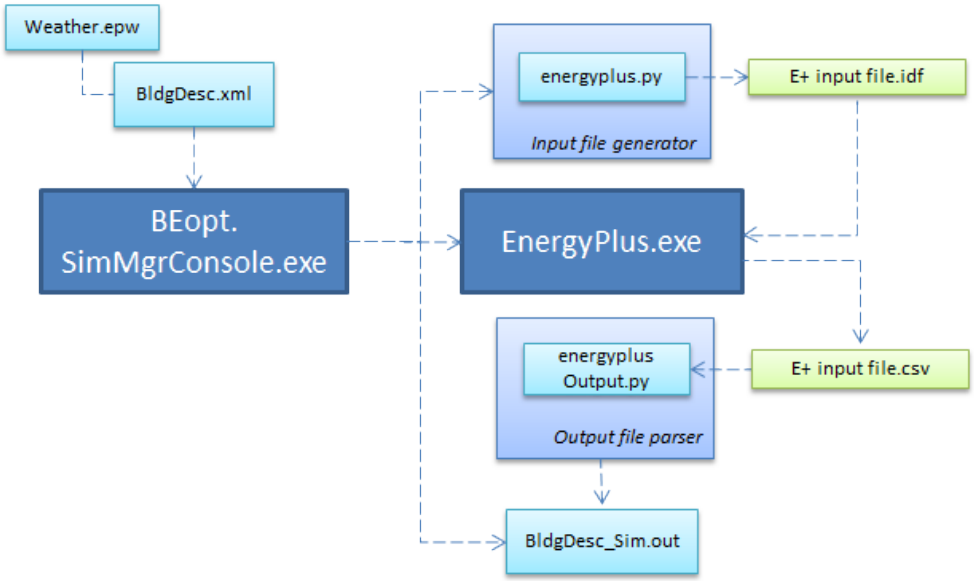

## Overview

BEopt provides an open architecture batch simulation modeling framework for the creation of simulation engine specific input files, running of simulations, and parsing of output files via the Python scripting language. The framework lives completely outside of the BEopt executable and uses a simple xml-based mechanism for exchanging information with the BEopt interface. The modeling framework can be used to quickly run batch simulations or automate various analysis workflows.

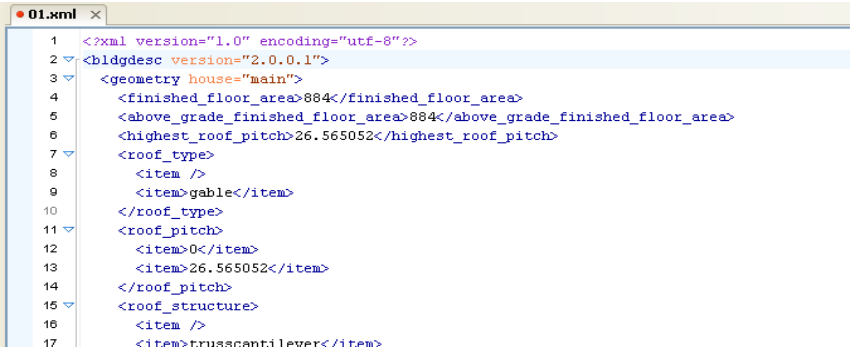
The documentation here describes how to:

1. Create BEopt xml files
2. Generate simulation input files (Generate 3D geometry)
3. Run simulations using multiple processors
4. Parse BEopt output files

The process of going from BEopt xml input file to BEopt output file, via running simulations, is illustrated below:




## BEopt XML Files



```
01.xml
<?xml version="1.0" encoding="utf-8"?>
<bldgdesc version="2.0.0.1">
  <geometry house="main">
    <finished_floor_area>884</finished_floor_area>
    <above_grade_finished_floor_area>884</above_grade_finished_floor_area>
    <highest_roof_pitch>26.565052</highest_roof_pitch>
    <roof_type>
      <item />
      <item>gable</item>
    </roof_type>
    <roof_pitch>
      <item>0</item>
      <item>26.565052</item>
    </roof_pitch>
    <roof_structure>
      <item />
      <item>trusscantilever</item>
```

BEopt XML files are used to exchange information between the BEopt interface and the modeling framework. The XML file provides a complete description of a single building, with an element for every input found in the BEopt interface. It contains sections on geometry, site information, weather data, and option properties. Each XML file produces a single simulation result and is simulation engine agnostic (aside from certain technologies that may only be simulated in a specific simulation engine).

The BEopt XML file's schema can be found at \Modeling\bldgdesc.xsd. There is also automated documentation that can be found at \Modeling\Documentation\bldgdesc.xsd\bldgdesc.html.

BEopt XML files can be generated in two primary ways.

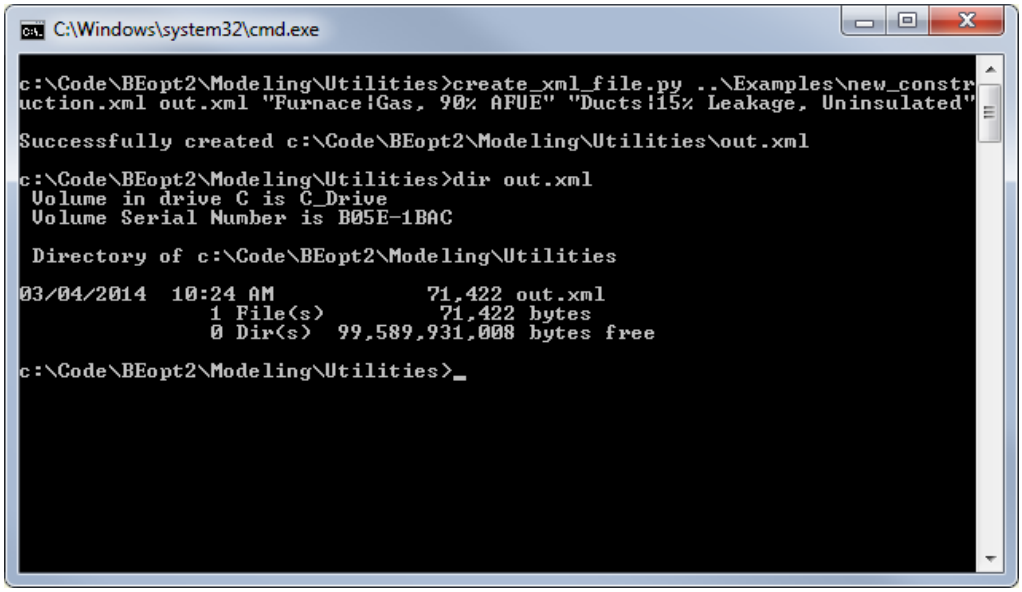
- **Approach 1: Using the interface (and create_xml_file.py)**

  This approach is the easiest way to create full BEopt XML files and is most suitable for situations where you want to define buildings using the BEopt library (using either shipped options or user options defined through the interface).

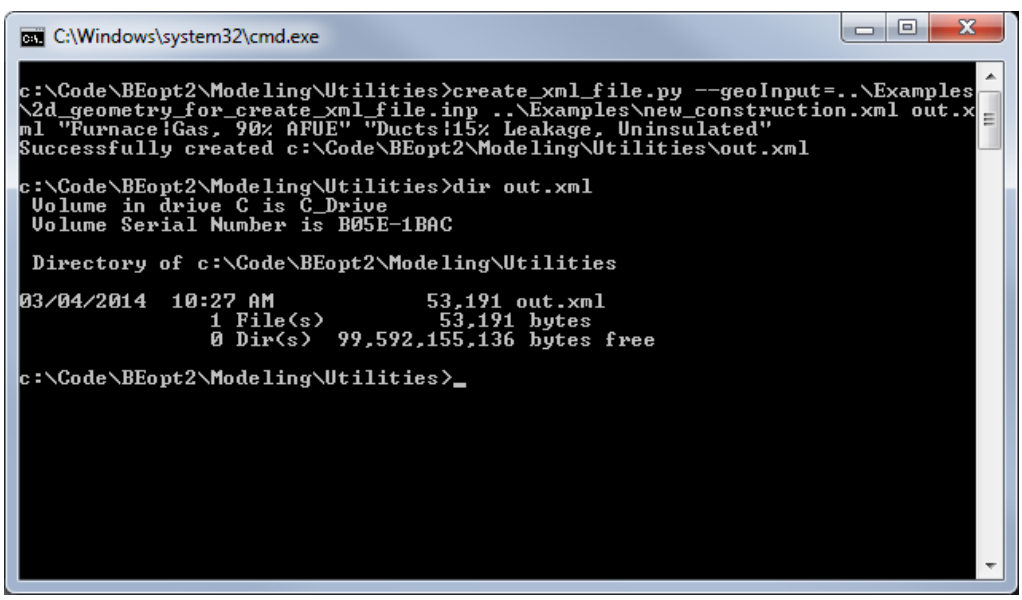
  The easiest way to create a full BEopt XML file is to use the BEopt interface, as it will include full 3D geometry data in the XML file, which is otherwise difficult to generate. When BEopt runs a simulation, it produces a BEopt XML file that can be found at \My Documents\BEopt_VERSION\TEMPX\ (or via Tools > Open Data Dir). Therefore, one can specify all the various inputs in the interface and produce a full BEopt XML file for a building.

  Modifications to options in the XML files can be made by using a simple python script -- \Modeling\Utilities\create_xml_file.py. You call this script with a source xml file and options to be included, and a new xml file will be generated identical to the original but with the specified options. You can even create new options through the BEopt interface's Option Editor and reference these options

  For example, the following call to the python script will create a copy of the example new_construction.xml file, but with the furnace and duct options replaced by a 90% AFUE furnace and 15% leakage, uninsulated ducts. The geometry and all other aspects of the source xml file remains untouched.

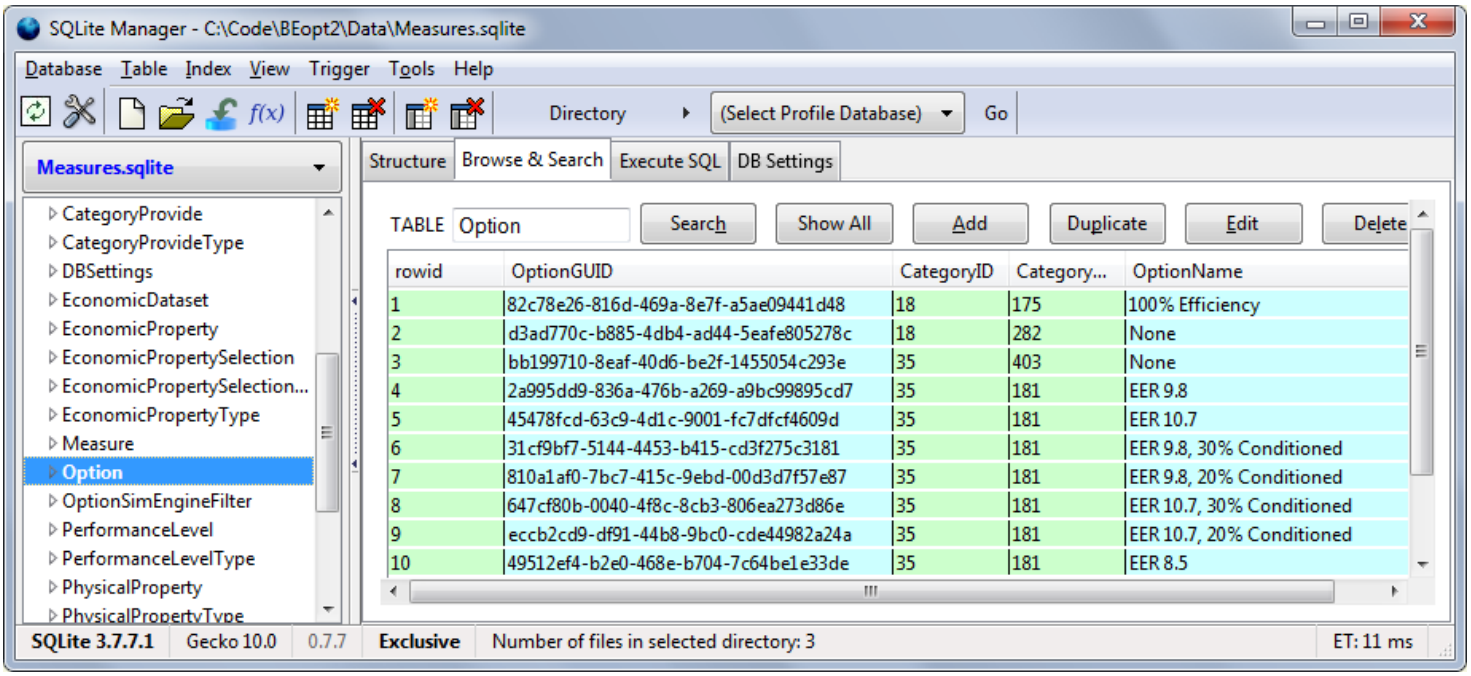



  Note that if you modify options that affect geometry, you'll need to provide a 2D geometry input file (without Category Inputs) via the --geoInput argument as well. For example:



When a --geoInput file is provided, a new 3D geometry will be automatically produced and inserted into the resulting xml's geometry section.

Also note that while you can specify category and option names as arguments for the script, these names may change from version to version. The script can alternatively take option GUIDs as arguments instead, which are unique identifiers that do not change from version to version. You can lookup option GUIDs by viewing the Option table in the Data\Measures.sqlite file. A useful application for viewing sqlite databases is the Firefox extension called SQLite Manager.




- **Approach 2: Using python classes**

  This approach is more flexible and is most suitable for situations where you want to dynamically create options on the fly using code/logic -- for example, if you are generating BEopt simulations for existing buildings that are described in various file formats.

  With this approach, BEopt XML files can be created using python classes that are automatically generated (using the third-party generateDS project) from the bldgdesc.xsd schema. The python classes are found at \Modeling\bldgdescDS.py**.** The full capabilities of python, including performing calculations and using its large set of built-in and third-party modules/libraries, are available. This is the approach internally used by BEopt to create simulation input files from inputs described in the BEopt interface.

There is also an automated approach for generating 3D geometry data needed for the XML file from a 2D geometry specification. It involves calling the BEopt executable with a file that describes the 2D geometry, and produces a BEopt XML file with only the geometry element defined.

Once you have one or multiple BEopt XML files defined, you can generate simulation input files or run simulations directly.

## Generating 3D Geometry

A complete BEopt XML file must contain full 3D geometry information for the building. The easiest way to generate the 3D geometry is to draw the building in BEopt (making sure to specify the appropriate options in categories that affect geometry), run a simulation, and extract the resulting xml file.

Alternatively, there is a way to automate the process of creating 3D geometry by using the BEopt executable to create a rendering based on 2D building information.

To do this, a text input file must be supplied to the BEopt executable. The input file has various geometry inputs including category inputs, general inputs, and level-by-level floor plans. Example input files can be found at \Modeling\Examples\2d_geometry_window_percents.inp and \Modeling\Examples\2d_geometry_window_sqfts.inp.

Once the geometry input file has been created, you can generate the 3D geometry via the BEopt executable.

**Category Inputs**

Category inputs are inputs that correspond to categories in BEopt that affect the geometry of the building. The categories are: Orientation, Neighbors, Window Areas, Eaves, and Overhangs. When constructing a BEopt XML file, be sure that the geometry section is consistent with the inputs specified in these categories. For example, if you generate a 3D geometry via the BEopt executable using an input file with NeighborOffset=10, this value should also be set in the categories section of the XML file.

| Variable | Description |
|---|---|
| Azimuth | The building's azimuth is measured clockwise from due south (when viewed from above). [degrees] |
| NeighborOffsetLeft | The minimum distance between the simulated building and the neighbor to the left (not including eaves). [ft] |
| | |

| | |
|---|---|
| NeighborOffsetRight | The minimum distance between the simulated building and the neighbor building to the right (not including eaves). [ft] |
| NeighborOffsetBack | The minimum distance between the simulated building and the neighbor to the back (not including eaves). [ft] |
| NeighborOffsetFront | The minimum distance between the simulated building and the neighbor to the front (not including eaves). [ft] |
| WindowAreaFractionOfWallArea | Ratio of total window area to exterior wall area of living space. [frac] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaFractionOfTotalFront | The ratio of window area facing front to total window area. [frac] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaFractionOfTotalBack | The ratio of window area facing back to total window area. [frac] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaFractionOfTotalLeft | The ratio of window area facing left to total window area. [frac] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaFractionOfTotalRight | The ratio of window area facing right to total window area. [frac] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaSqftFront | The total window area facing front. [ft^2] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaSqftBack | The total window area facing back. [ft^2] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaSqftLeft | The total window area facing left. [ft^2] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| WindowAreaSqftRight | The total window area facing right. [ft^2] Note: Either WindowAreaFraction* inputs or WindowAreaSqft* inputs should be specified. |
| DoorAreaSqft | The total door area. [ft^2] For multifamiily buildings, this is the door area for each unit. |
| EavesDepth | Depth of eaves' horizontal extension. [ft] |
| OverhangDepth | Depth of the overhang. The distance from the wall surface in the direction normal to the wall surface. [ft] |
| OverhangOffset | Height of the overhangs above windows, relative to the top of the window framing. [ft] |
| OverhangWidthExtension | Length that the overhang extends beyond the window width, relative to the outside of the window framing. Refers to the extended width on each side of the window (i.e. the total overhang width will be the window width plus two times the overhang width extension). [ft] |
| OverhangFirstStoryFront | Specifies the presence of overhangs on front windows on the first story. [True/False] |
| OverhangFirstStoryBack | Specifies the presence of overhangs on back windows on the first story. [True/False] |
| OverhangFirstStoryLeft | Specifies the presence of overhangs on left windows on the first story. [True/False] |
| OverhangFirstStoryRight | Specifies the presence of overhangs on right windows on the first story. [True/False] |
| OverhangSecondStoryFront | Specifies the presence of overhangs on front windows on the second story. [True/False] |
| OverhangSecondStoryBack | Specifies the presence of overhangs on back windows on the second story. [True/False] |
| OverhangSecondStoryLeft | Specifies the presence of overhangs on left windows on the second story. [True/False] |
| OverhangSecondStoryRight | Specifies the presence of overhangs on right windows on the second story. [True/False] |
| OverhangThirdStoryFront | Specifies the presence of overhangs on front windows on the third story. [True/False] |
| OverhangThirdStoryBack | Specifies the presence of overhangs on back windows on the third story. [True/False] |
| OverhangThirdStoryLeft | Specifies the presence of overhangs on left windows on the third story. [True/False] |
| OverhangThirdStoryRight | Specifies the presence of overhangs on right windows on the third story. [True/False] |
| OverhangFourthStoryFront | Specifies the presence of overhangs on front windows on the fourth story. [True/False] |
| OverhangFourthStoryBack | Specifies the presence of overhangs on back windows on the fourth story. [True/False] |
| OverhangFourthStoryLeft | Specifies the presence of overhangs on left windows on the fourth story. [True/False] |
| OverhangFourthStoryRight | Specifies the presence of overhangs on right windows on the fourth story. [True/False] |

**General Inputs**

General inputs describe the roof, number of bedrooms/bathrooms, and various building component heights.

| Variable | Description |
|---|---|
| RoofType2 | The type of roof on the second story. Use 0 for gable, 1 for hip. [enum] |
| RoofType3 | The type of roof on the third story. Use 0 for gable, 1 for hip. [enum] |
| RoofType4 | The type of roof on the fourth story. Use 0 for gable, 1 for hip. [enum] |
| RoofPitch2 | The pitch of the roof on the second story. Use 1 for a 12:12 pitch, 0.5 for a 6:12 pitch, etc. [frac] |

| | |
|---|---|
| RoofPitch3 | The pitch of the roof on the third story. Use 1 for a 12:12 pitch, 0.5 for a 6:12 pitch, etc. [frac] |
| RoofPitch4 | The pitch of the roof on the fourth story. Use 1 for a 12:12 pitch, 0.5 for a 6:12 pitch, etc. [frac] |
| NumBedrooms | The number of bedrooms in the home, between 1 and 5. [integer] For multifamily buildings, enter values for each unit separated by a pipe like so: "3\|3\|4\|2". |
| NumBathrooms | The number of bathrooms in the home. [float] For multifamily buildings, enter values for each unit separated by a pipe like so: "2\|2\|2.5\|1.5" |
| CrawlspaceHeight | The height of the crawlspace, between 1.5 and 5. [ft] |
| PierbeamHeight | The height of the pier & beam foundation, between 0.5 and 8. [ft] |
| BasementHeight | The height of the basement. The value currently must be set to 8. [ft] |
| StoryHeight1 | The floor-to-ceiling height of the first story, between 8 and 20. [ft] |
| StoryHeight2 | The floor-to-ceiling height of the second story, between 2 and 20. [ft] |
| StoryHeight3 | The floor-to-ceiling height of the third story, between 2s and 20. [ft] |

**Level-by-Level Floor Plans**

Data describing level-by-level floor plans is similar to the information entered in the drawing area of the user interface. For each level of the building, a maximum of 400x400 grid with two-character strings (so, maximum of 800 characters x 800 characters) describes the geometry and type of building spaces. Each cell of the grid represents a 1ft x 1ft area.

The two-character space strings are:

| Space Name | Space String | Stories Available On |
|---|---|---|
| Empty Space | 00 | All |
| Slab | 01 | Foundation |
| Crawlspace | 18 | Foundation |
| Pier & Beam | 20 | Foundation |
| Unfinished Basement | 04 | Foundation |
| Finished Basement | 05 | Foundation |
| Living | 06 | First, Second, Third, Fourth, Fifth |
| Garage | 07 | First |
| Open to Below | 08 | Second, Third, Fourth, Fifth |
| Unfinished Attic | 19 | Second, Third, Fourth, Fifth, Sixth |
| Finished Attic | 10 | Second, Third, Fourth, Fifth, Sixth |
| Vaulted Ceiling | 11 | Second, Third, Fourth, Fifth, Sixth |
| Garage Roof | 15 | Second |
| Porch Roof (Pitched) | 12 | Second, Third, Fourth, Fifth, Sixth |
| Flat Roof/Deck | 13 | Second, Third, Fourth, Fifth, Sixth |
| Corridor | 21 | Foundation, First, Second, Third, Fourth, Fifth (Multifamily only) |

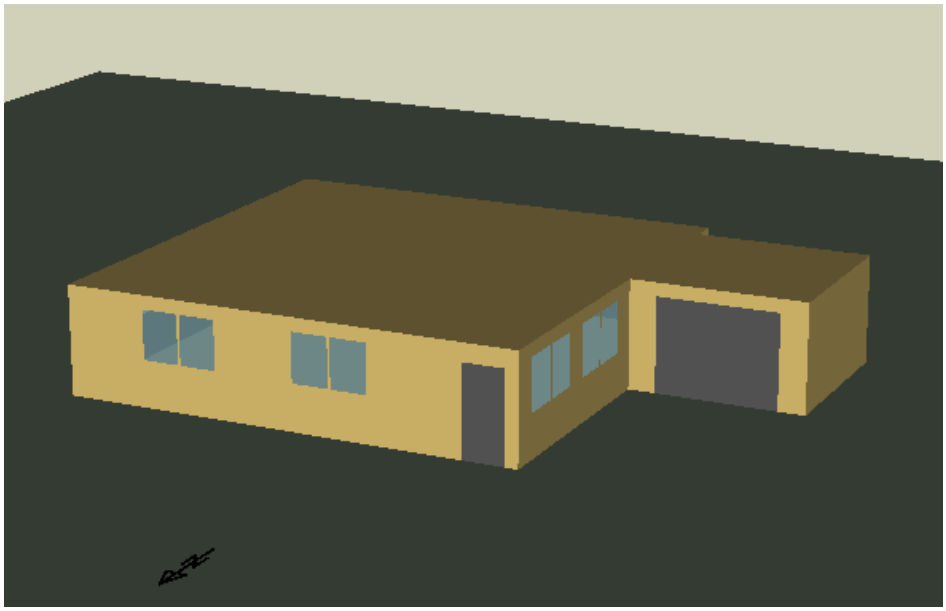
Note that spaces must only be included on the stories for which they are available, as denoted in the above table.s

For example, suppose you entered the following floor plan snippet for the first story of the building:

```
DrawingForLevel1=Begin
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606070707070707070707070707070707000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000
```

```
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000060606060606060606060606060606060606060606060606060606060606060606060606000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
  DrawingForLevel1=End
```

The two spaces "06" and "07" are highlighted in blue and red, respectively, so they are easier to see. The floor plan corresponds with living space (34ft x 33ft) and an attached garage area (13ft x 13) towards the back-right of the building. The rendering of this floor plan looks like this:



For multifamily buildings, several spaces require a specification of the unit number to which it applies. A maximum of 104 units may be referenced as dictated in the table below. All other spaces are not specified as unit-specific and therefore use the two-character strings from the table above (e.g., 06 for Living).

| Space Name | Possible Multifamily Space Strings |
|---|---|
| Living | LA-LZ, La-Lz, lA-lZ, la-lz |
| Finished Attic | AA-Az, Aa-Az, aA-aZ, aa-az |
| Finished Basement | BA-BZ, Ba-Bz, bA-bZ, ba-bz |

For example, LA denotes Living space for multifamily unit 1, LB for unit 2, LZ for unit 26, La for unit 27, Lz for unit 52, lA for unit 53, lZ for unit 78, la for unit 79 and lz for unit 104.

Look at the \Modeling\Examples\2d_geometry.inp example input file for a full example of level-by-level floor plan specifications. The floor plan for each level should be enclosed by a "Below" and "End" statement:

| Variable | Description |
|---|---|
| DrawingForLevel0=Begin | The start of the floor plan specification for the foundation level. |
| DrawingForLevel0=End | The end of the floor plan specification for the foundation level. |
| DrawingForLevel1=Begin | The start of the floor plan specification for the first level. |
| DrawingForLevel1=End | The end of the floor plan specification for the first level. |
| DrawingForLevel2=Begin | The start of the floor plan specification for the second level. |
| DrawingForLevel2=End | The end of the floor plan specification for the second level. |
| DrawingForLevel3=Begin | The start of the floor plan specification for the third level. |
| DrawingForLevel3=End | The end of the floor plan specification for the third level. |
| DrawingForLevel4=Begin | The start of the floor plan specification for the fourth level. |
| DrawingForLevel4=End | The end of the floor plan specification for the fourth level. |

**Generating the 3D Geometry**

When you have a fully-specified geometry input file, you can call the BEopt executable with the --geoInput=<file.inp> argument and the optional --geoOutput=<file.xml>. If you specify the --geoOutput argument, the BEopt interface will never appear and the BEopt XML file (with only the geometry element defined) will be produced. If you don't specify this argument, the BEopt interface will appear with a 3D rendering of the geometry that you provided.

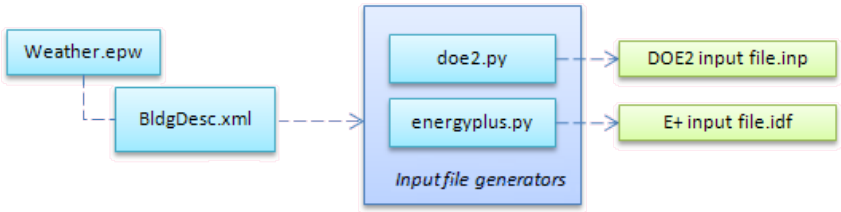
```
C:\WINDOWS\system32\cmd.exe

C:\Code\BEopt2\Build\debug>BEopt.exe --geoInput="C:\Code\BEopt2\Tests\Geometry\0
0001 - 1st floor outline.inp" --geoOutput="C:\Code\BEopt2\Tests\Geometry\00001 -
 1st floor outline.xml"

C:\Code\BEopt2\Build\debug>dir "C:\Code\BEopt2\Tests\Geometry\00001 - 1st floor
outline.xml"
 Volume in drive C is C_Drive
 Volume Serial Number is D077-17DE

 Directory of C:\Code\BEopt2\Tests\Geometry

02/14/2013  08:46 AM            40,799 00001 - 1st floor outline.xml
               1 File(s)         40,799 bytes
               0 Dir(s)  126,225,272,832 bytes free

C:\Code\BEopt2\Build\debug>_
```

You can also process multiple geometry input files at once by passing directory names to both --geoInput and --geoOutput, as shown below. This is much faster than calling the BEopt executable on each individual geometry input file.

```
C:\WINDOWS\system32\cmd.exe

C:\Code\BEopt2\Build\debug>BEopt.exe --geoInput=C:\Code\BEopt2\Tests\In --geoOut
put=C:\Code\BEopt2\Tests\Out

C:\Code\BEopt2\Build\debug>dir C:\Code\BEopt2\Tests\Out
 Volume in drive C is C_Drive
 Volume Serial Number is D077-17DE

 Directory of C:\Code\BEopt2\Tests\Out

02/14/2013  08:49 AM    <DIR>          .
02/14/2013  08:49 AM    <DIR>          ..
02/14/2013  08:49 AM            40,799 00001 - 1st floor outline.xml
02/14/2013  08:49 AM            62,525 00002 - 209 Benjamin.xml
02/14/2013  08:49 AM            18,388 00003 - attic wall 2.xml
               3 File(s)        121,712 bytes
               2 Dir(s)  126,223,790,080 bytes free

C:\Code\BEopt2\Build\debug>
```

## Simulation Input Files

Simulation input files can easily be generated from a BEopt XML file. Note that if you are interested in using BEopt's framework to run simulations (which includes creating input files, running simulations across multiple processors, and producing summary xml output files), you do not need to perform this step. This step is solely targeted at users that want to create their own workflow around the generation of simulation input files.




In order to generate a simulation input file, simply call the simulation engine's python script (e.g. energyplus.py) and provide the bldgdesc.xml file as an argument. Calling the script without any arguments will display all the possible arguments. Note that the appropriate version of python is included with the BEopt installation and can be found at \Include\python\.

```
C:\Windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserv

C:\Users\shorowit>cd c:\Code\BEopt2\

c:\Code\BEopt2>Include\python\python.exe Modeling\energyplus
.py Modeling\Examples\new_construction.xml EPinputFile.idf

c:\Code\BEopt2>dir EPinputFile.idf
 Volume in drive C is C_Drive
 Volume Serial Number is B05E-1BAC

 Directory of c:\Code\BEopt2

06/30/2015  05:43 AM           722,161 EPinputFile.idf
               1 File(s)        722,161 bytes
               0 Dir(s)  68,438,716,416 bytes free

c:\Code\BEopt2>_
```

## Running Simulations

One or multiple BEopt XML files can be directly simulated (across multiple local processors) to produce summary BEopt output files. This is done by calling the BEopt.SimMgrConsole.exe program, which uses the same code as the BEopt interface itself.

Calling the BEopt.SimMgrConsole.exe program without any arguments will display all the possible arguments.

```
C:\WINDOWS\system32\cmd.exe
C:\Code\BEopt2\Build\BEopt>BEopt.SimMgrConsole.exe
BEopt.SimMgrConsole 2.0.0.1
Copyright (C) 2011 NREL
Usage: BEopt --inputData=<xml input file or dir>
             --simEngineDirectory=<simulation engine dir>

  inputData                 Required. Path to building description xml input
                            file(s); can be a file or directory.

  simEngineDirectory        Required. Directory of simulation engine
                            installation.

  processors                Number of processors to use. Default: 1.

  simProjsDirectory         Directory under which all simulation processing
                            takes place.*

  outputDataDirectory       Directory of output files. Default: inputData
                            directory.

  ePlusPreProcessScript     Name of EnergyPlus pre-simulation script to run,
                            which generates simulation input files. Default:
                            energyplus.py.

  ePlusPostProcessScript    Name of EnergyPlus post-simulation script to run
```

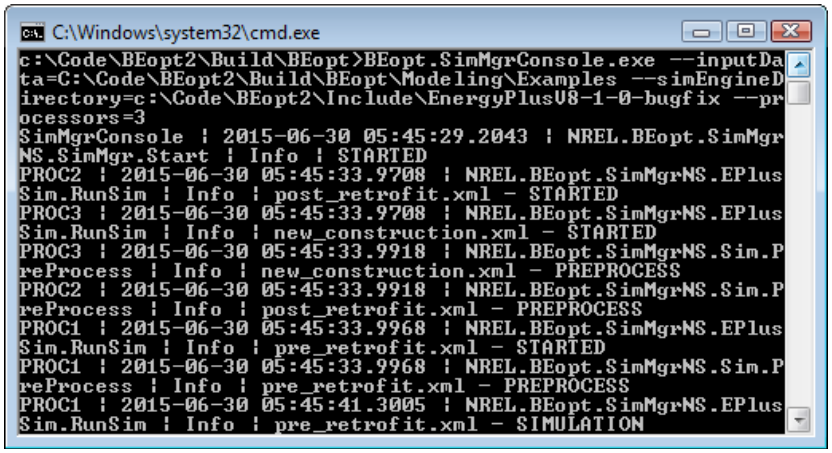
Two arguments are required and, in general, a third argument is frequently used. The other arguments are rarely used.

The **inputData** argument can point to the location of either a single bldgdesc.xml file or a directory of such files. Subdirectories will not be evaluated.

The **simEngineDirectory** argument points to the location of a simulation engine installation. BEopt will automatically figure out which simulation engine the directory is for.

The **processors** argument allows the use of multiple processors/cores on the local machine. It's generally recommended to use n-1 processors, where n is the number of processors on the local machine. For example, specify 3 processors on a 4-core machine. You can determine the number of processors/cores on your machine by counting the number of CPU usage graphs that show up under the Task Manager's Performance tab.

For example:




Information will be displayed as simulations runs showing which processor is being used, which XML file is being run, the timestamp, and the status of the run. Each run has a PreProcess, Simulation, PostProcess, and Finished status message. Upon simulations being complete, a number of output files from the simulation engine will be available as well as the summary BEopt Output Files.

## BEopt Output Files

The BEopt output file is a summary XML output file produced by parsing the simulation engine output file(s). Because this file is simulation engine agnostic, it is easy to read simulation output regardless of the simulation engine that was run.

The BEopt output file's schema can be found at \Modeling\output.xsd. There is also automated documentation that can be found at \Modeling\Documentation\output.xsd\output.html.

The output file includes energy information broken out by end use and fuel use, utility bills, and avoided costs (for California Metrics calculations), as well as HVAC capacities and loads not met.

## Frequently Asked Questions

**How do I set up a different case?**
A new case can be set up using the "Case" pull down menu at the top of the screen and selecting "New". This same menu can also be accessed by right clicking the selected case tab at the top of the screen. Use the Case Tab Bar along the top of the screen to organize and view multiple cases in BEopt.

**How do I select different options?**
Construction and equipment options for any case can be selected by switching to the Options input screen. Click on the desired category and then click each desired option that you want BEopt to consider for that particular case. Options can also be selected by clicking the corresponding option number in the summary matrix.

**How do I modify the building configuration and construction?**
Building geometry and characteristics can be described on the Geometry input screen.

**How do I specify the discount rate and other economic factors?**
Economic parameters can be set on the Site input screen.

**How do I compare my cases to a Building America Benchmark?**
Select B10 Benchmark from the Reference Dropdown on the input toolbar. It is advisable that you do this before selecting options and running the case.

**When should I use a new design vs a new case?**
It is always best to specify multiple designs within a single case where possible. However, multiple designs can only be specified within a case if the differences between designs are encompassed by the Options input screen (i.e. information on the Geometry and Site input screens will apply across all designs in a case, whereas energy efficiency measures can differ). If you are instead interested to compare designs with different geometry, locations, energy prices, etc., you must use multiple cases.

## Glossary

**Adjusted Source Energy Savings:** The default x-axis metric on the Cost/Energy Graph when using the B10 Benchmark as the reference and the building is single-family detached ; defined as the source energy savings divided by the reference energy use, and adjusted for house size. See B10 Benchmark for more information.

**Building America B10 Benchmark:** A building simulation model based on 2009 IECC code. Used for comparison with improved building prototypes.

**Case:** A single set of BEopt input parameters. Multiple cases may vary such characteristics as the building location or available construction options.

**Category:** A collection of BEopt options each describing the same characteristic of the dwelling unit(s) (such as Heating Set Point, Wall Mass, Infiltration, Clothes Dryer, etc.). Related categories are placed within the same group (see Category Group).

**Category Group:** A collection of related BEopt categories (such as Operation, Walls, Major Appliances, Space Conditioning, etc.).

**Cost Neutral Point:** The level of energy savings along the path to zero net energy at which the total annualized cost of the building (utilities + mortgage) is the same as the reference.

**Design:** A set of selected options within a design tab.

**Energy Efficiency Measure (EEM):** A change in a specific building characteristic (such as envelope, equipment, orientation, etc.) that improves overall building energy performance.

**Energy Related Costs, Annualized:** The default y-axis metric on the Cost/Energy Graph; calculated by annualizing the energy related cash flows over the analysis period.

**Energy Rating Index (ERI)** : The ERI is calculated per the ANSI/RESNET 301-2014 "Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the HERS Index" as well as the ANSI/RESNET 301-2014 Addendum A-2015 "Addendum on Domestic Hot Water (DHW) Systems". This metric is a performance compliance path in the 2015 IECC. The ERI calculation can be enabled from the Run Dialog .

**EnergyPlus:** Energy simulation program supported by the Department of Energy. See the EnergyPlus website (http://www.energyplus.net).

**EnergyPlus Weather File (EPW):** File of average hourly weather data measured at different locations throughout the United States.

**International Energy Conservation Code (IECC):** Commonly adopted code for energy efficiency standard and the basis of the IECC 2006 reference.

**Iteration:** A complete series of annual simulations where each available option has been included in the building configuration.

**Minimum Cost Point:** The level of energy savings along the path to zero net energy with the minimum total annualized cost of the building (utilities + mortgage).

**Multifamily**: In BEopt, multifamily mode is used to model all buildings with more than one unit (e.g., includes single-family attached dwellings such as duplexes).

**Net Metering:** An arrangement between a homeowner and local electric utility where the homeowner both consumes and produces energy. The electric meter records both consumption and production and the homeowner is charged for the net electric use. In many cases, the cost of electricity consumed is different than the price for electricity produced. See the Net Metered Sellback Rate in the Site input screen.

**Optimal Point:** A building design where a given percentage of energy savings is achieved with a least cost configuration of all available construction options.

**Optimization:** The use of a sequential search technique to identify cost optimal configurations of various construction options.

**Option:** For any given category, several options are available to describe a single characteristic of the building. Each option has a different impact on energy use and a different associated cost/lifetime.

**Path to Zero Net Energy:** A series of building designs that give the least cost combinations of energy efficiency measures for increasing amounts of overall energy savings. The path falls on a graph of the % energy savings along the x-axis, and the annualized energy costs on the y-axis. This annual cost is made up of both the energy costs each year plus the cost of energy efficiency measures that have been incorporated into the mortgage payments.

**Present Value:** The current value of a cash payment which will be made in the future, reduced by some discount rate.

**Project File:** A set of BEopt inputs and outputs saved into a single file. A single project file may contain multiple cases of varying analysis modes.

**Property:** The energy impact of each BEopt option is determined through specification of its properties. Properties represent the inputs for each characteristic of the building described by the category (such as the insulation R-value for the Ceiling Insulation category).

**Site Energy:** Energy that is produced at the building location such as photovoltaic energy. The value for the Source/Site Energy Ratio is located on the Site input screen.

**Source Energy:** Typically refers to the energy required by a central power plant to produce electricity. The value for the Source/Site Energy Ratio is located on the Site input screen.

**Source Energy Savings:** The default x-axis metric on the Cost/Energy Graph; defined as the source energy savings divided by the reference energy use.

**Special Case:** Condition during the optimization process where an option initially included in an optimal configuration on the path to zero net energy is later rejected. The occurrence of special cases leads to "orphaned" points that fall above the path.

**Summary Matrix:** A chart on the options input screen that illustrates the selected construction options that BEopt will consider for a particular case. Select options by clicking directly on the summary matrix chart.

**TDV:** Time-Dependent Valuation - method for valuing energy in the performance approach in California's Title 24. Under TDV, the value of electricity differs depending on time-of-use (hourly, daily, seasonal), and the value of natural gas differs depending on season. TDV is based on the cost for utilities to provide the energy at different times.

**Zero Net Energy (ZNE) Point:** A building design which produces as much energy on site as it consumes annually.