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Time-sensitive value calculator for energy efficiency and other distributed energy resources

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1. Introduction

The Time-Sensitive Value Calculator (Calculator) is a publicly available, free tool by Berkeley Lab that estimates the value of energy efficiency and other distributed energy resource (DER) measures using hourly estimates of electricity system costs. The tool is available at <https://emp.lbl.gov/publications/time-sensitive-value-efficiency>.

The Calculator takes hourly profiles of up to six measures at a time and monetizes their value for six value streams, producing outputs in tabular and graphical formats. The Calculator was designed for public utility commissions, state energy offices, utilities and stakeholders to estimate the value of energy efficiency and DER measures under various future electricity system scenarios.

This user guide explains how to use the Calculator and provides optional sources for publicly available data for hourly measure shapes and electricity system cost inputs. Use cases for the Calculator include demand-side management planning, distribution system planning and integrated resource planning. For additional information on the time-sensitive value of efficiency, see Frick and Schwartz (2019); Mims, Eckman and Schwartz (2018); and Mims, Eckman and Goldman (2017). Refer to the Glossary for definitions of terms formatted in bold italics.

1.1 Overview

The Calculator can be used to analyze the time-sensitive value of many types of *measure shapes* including end-use (energy consumption),¹ energy savings, and DERs such as solar (energy generation) (Figure 1).

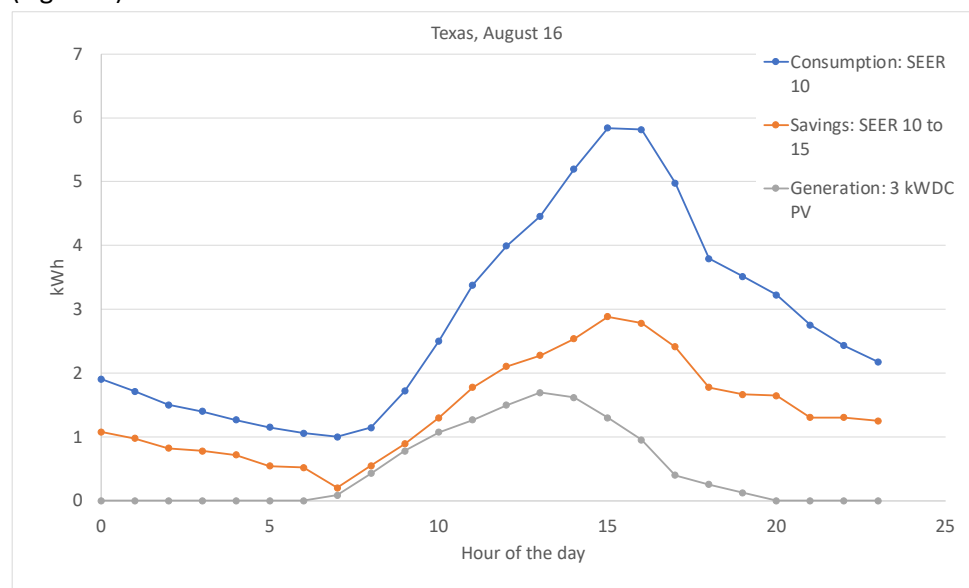


Figure 1. Example of a measure shape – residential cooling in uninsulated homes and PV generation

¹ If data are not available for energy savings shapes for an efficiency measure, end-use load profiles can be used as proxies. See Frick et al. 2019.

The Calculator monetizes one year of a measure shape by multiplying each hour's demand by the corresponding hour's cost for each value stream. Users can choose eight analysis years and estimate the **net present value** (NPV) of the value of each measure for these years. The Calculator can perform two types of analysis, referred to as "Shape+" and "Shape Only":

- **Shape+** includes the timing (hour of the day) of the measure savings or generation; quantity of savings or generation (e.g., kWh); and measure lifetime in the analysis.
- **Shape Only** includes just the timing of the measure savings or generation in the analysis.

1.1.1 Shape+

The Shape+ analysis answers the question, "what is the value of the total savings or generation of this measure?" For example, users may employ the Shape+ analysis to compare the value of 10 megawatt-hours (MWh) of savings from a heating, ventilation and air-conditioning (HVAC) program and 15 MWh of savings from a lighting program.

The Shape+ analysis takes into account the *number of program participants or measure installations* and the **program or measure lifetime**. Examples of use cases include:

- Comparing the value of estimated energy efficiency program or measure savings shapes (Figure 2)
- Comparing the value of estimated energy efficiency program or measure savings shapes and solar photovoltaic generation
- Estimating the value of measures in different future electricity scenarios
- Estimating the value of increased or decreased participation by program or measure

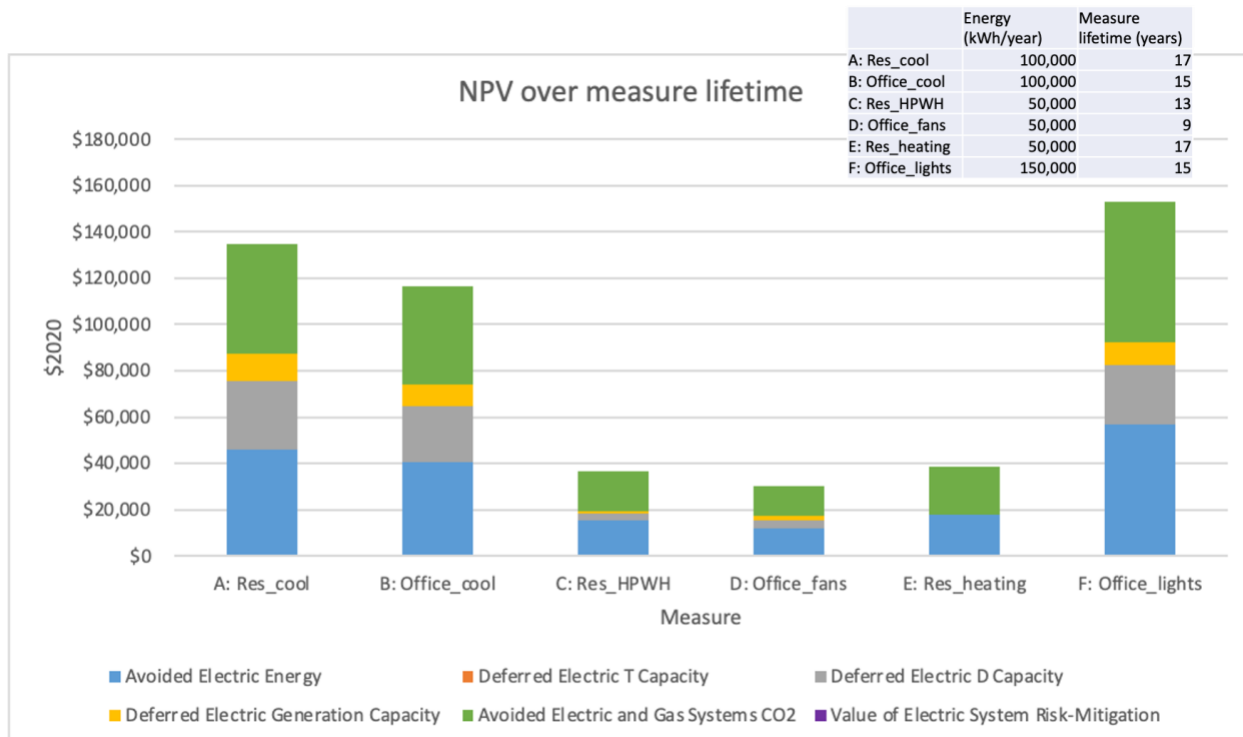


Figure 2. Shape+ analysis output for six example programs in Texas

Figure 2 is an example of the value of six savings shapes. The analysis considers example programs, using the energy savings and measure lifetimes shown in the table at the top of the chart. Figure 2 shows that office lighting has the highest overall savings, in part due to the larger quantity of savings it produces, and the highest value. However, the residential air-conditioning is worth more on a per unit basis (see Figure 3).

1.1.2 Shape Only

The Shape Only analysis uses the timing of the savings or generation to determine the value of a *single unit* of savings or generation. For example, users may employ the Shape Only analysis to identify high value end-uses or technologies to target in an energy efficiency program. Examples of use cases include:

- Comparing measure values during the user-defined base analysis year (e.g., a specific point in time) (Figure 3)
- Comparing measure values under different scenarios for future electricity system costs

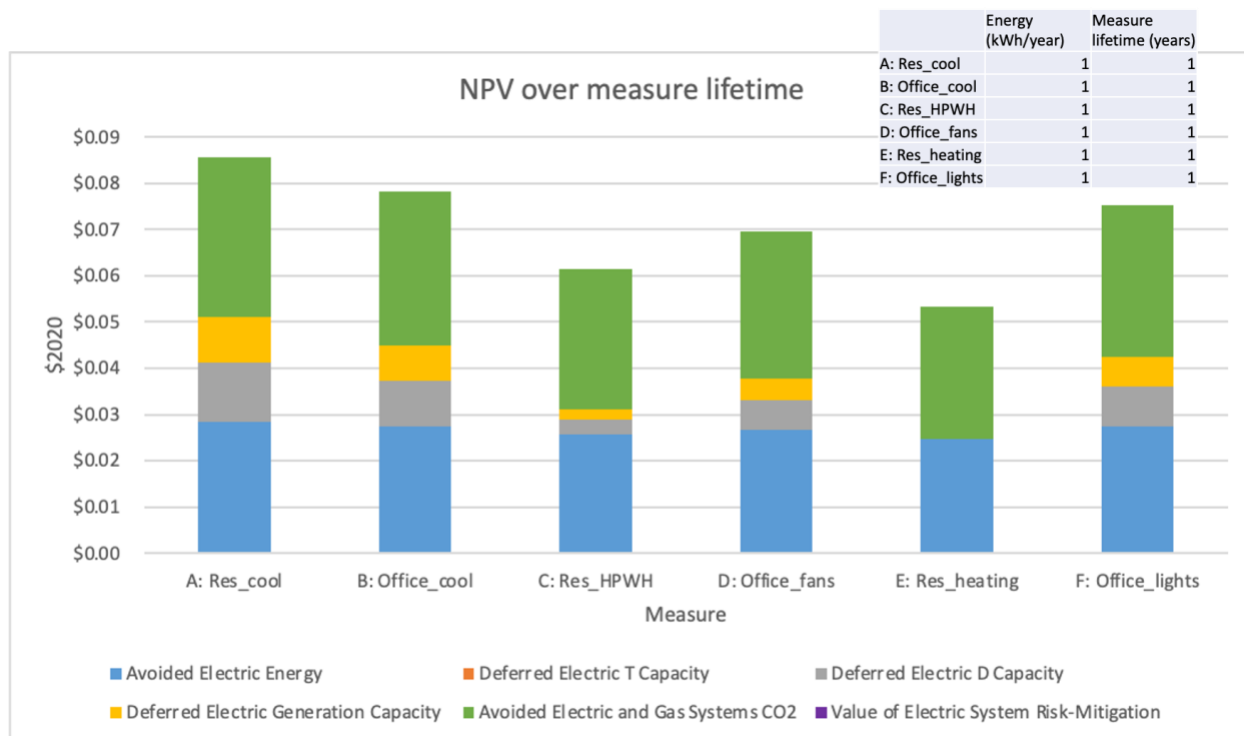


Figure 3. Shape Only analysis output for six Texas end-uses²

Figure 3 is an example of the Calculator's estimated value of six end-use (proxy savings) shapes, using the same measures as the previous figure, considering one year of measure savings. Here, residential and office cooling have a similar value on a *per unit basis* (1 kWh). Users can compare across different futures by changing the measure lifetime, as long as it is consistent for all measures.

1.2 User Guide Organization

This user guide is organized into six chapters plus a Glossary and Appendix:

- Chapter 2 provides the Calculator structure and describes the launcher and each sheet in the Calculator and the Auxiliary workbook, which may be used to assist with data conversions.
- Chapter 3 walks the user through identifying the scope of their analysis, data needs and publicly available data sources that they may need to complete their analysis.
- Chapter 4 is a step-by-step guide on using the Calculator and an Auxiliary workbook, if needed, with examples based on publicly available data. The chapter explains the five data input sheets: basic analysis parameters, costs, end-use load profiles (EULPs) or savings shapes, electricity system load, and general measure parameters. The final section describes how to perform the calculations.
- Chapter 5 describes the Calculator's outputs.

² The data for this chart comes from ResStock, ComStock, and Cambium. See Chapter 4 for step by step instructions for reproducing this example.

- Chapter 6 describes limitations of the Calculator related to interactive effects, distribution capacity costs and locational distribution costs.
- The Glossary provides definitions of the terms formatted in bold italics.
- The Appendix provides the formulas used by the Calculator.

Gray-shaded text boxes contain tips for running the Calculator. Green-shaded boxes are step-by-step examples of using the Calculator to produce a Shape+ analysis. Blue-shaded boxes highlight how to use the Calculator to produce a Shape Only analysis.

2. Calculator Structure

The Calculator is a package of three files:

1. The launcher opens the Calculator quickly using Excel’s calculation option set to “manual.”³
2. The Calculator contains input sheets and graphical and tabular results.
3. The Auxiliary workbook aids users in converting data into the Calculator’s format. Depending on the user’s data, the Auxiliary workbook may not be needed.

The Calculator has 13 user-accessible sheets grouped into four clusters using color-coding. The black sheet is the introduction and contains basic information and navigation, orange sheets (A1 - A3) contain the dashboard and data visualizations, blue sheets (B1 - B4) are output tables, and red sheets (C1 - C5) are Calculator inputs. The Auxiliary workbook has five sheets that can assist with data conversions. In both the Calculator and Auxiliary workbook files, the user should only edit the blue cells.

Table 1 describes the Calculator’s red input sheets and the Auxiliary workbook sheets. The first column, Data Reference, provides the User Guide chapter reference for the data inputs. The second column, Calculator Reference, provides the User Guide chapter reference for how to input the data into the Calculator. The third column, Sheet, identifies the worksheet in the Calculator or Auxiliary workbook where the data is entered. The last column describes the inputs.

³ Users who do not enable macros can open a blank Excel workbook and set the calculation option to “manual” before opening the Calculator itself instead of using the launcher.

Table 1. Description of Calculator input sheets and Auxiliary workbook

Data Reference	Calculator Reference	Sheet Name	Description
		Calculator	
3.3	4.1	C1 param input	Model-wide parameter inputs (analysis years, discount rates, line losses, deflation rate), selection of measures and value streams, annual risk mitigation adders
3.1	4.2	C2 cost data	Hourly cost data in \$/megawatt-hour (MWh) for each value stream in all analysis years
3.2	4.4	C3 shape data	Hourly measure shapes ⁴ for each measure
3.2	4.5	C4 load data	Hourly electricity system load at the transmission level for each analysis year
3.2	4.3	C5 measure data	Measure names, descriptions, and lifetimes
		Auxiliary workbook	
Not applicable	4.2.3	Annual to hourly costs	Used to create hourly costs from annual costs and the system load shape
	4.2.3	Annual to hourly costs - season	Used to create hourly costs from seasonal costs and the system load shape
	4.2.4	Emissions to dollars	Used to create hourly carbon dioxide costs from a dollar per ton cost and hourly emissions
	4.4	15 min to hourly	Used to aggregate data with a 15 minute timestamp to hourly (8,760). Optionally, calculate the portion of annual consumption during each hour, specify the size of a measure and shift dataset calendar days
	4.2.3 and 4.5	Normalization	Used to convert hourly system load to one (i.e., each hourly number is divided by the maximum number in the year)

⁴The measure shapes can be end-use, savings or generation profiles. For brevity, they are referred to as “measure shapes” everywhere in this guide where no distinction is required. If data are not available for energy savings shapes for an efficiency measure, end-use load profiles can be used as proxies.

3. Calculator Inputs and Data Sources

Prior to using the Calculator, users must identify their data needs and gather their data. To help users determine their data needs, Figure 4 and Figure 5 provide flow charts for preparing hourly inputs. These data inputs are used in:

- Sheet C2: cost data
- Sheet C3: shape data and
- Sheet C4: load data

The remainder of this chapter provides data inputs and optional data sources in three sections: avoided cost inputs, system and measure inputs, and risk and financial inputs. Refer to the Glossary for definitions of terms formatted in bold italics.

3.1 Avoided cost inputs and data sources

Figure 4 helps users determine what data they need to acquire for avoided cost inputs. Data sources are below the figure. Definitions of all bold, italicized terms are in the Glossary.

The deployment of measures and programs can, in the near term, reduce fuel costs, and over time defer the need to add generation, expand transmission and distribution infrastructure, and decrease the requirement for additional ancillary services. Therefore, its economic value depends on the cost, timing, and magnitude of required investments in these utility system assets.

Cambium Dataset

The National Renewable Energy Laboratory (NREL)'s Cambium dataset can be used if the user does not have data specific to their analysis (e.g., from a utility filing).⁵ Cambium contains simulated hourly cost and operational data for multiple future scenarios projected out to 2050 at the state or Balancing Authority level. The dataset covers the contiguous United States.

A determination must be made regarding the scope of the costs that are “avoided” due to installing a measure. The Calculator focuses on the utility system avoided cost resulting from energy and capacity savings. The cost includes avoided investments in energy generation (both fuel and capital cost), avoided capital investments in peak capacity, deferred investments in transmission and distribution capacity, and reduced requirements for additional ancillary services such as spinning and operating reserves. Depending on the location and the market structure, other avoided utility system costs might include avoided cost of compliance with carbon dioxide and other emissions regulations, avoided renewable portfolio compliance costs, and risk mitigation costs.

⁵ From cambium.nrel.gov, select “Cambium Scenarios (Hourly and annual data)” and then “Download Data.” For the Texas example in Chapter 4 of this guide, the scenario is “Low Wind Cost,” and the File is “data_hourly_state.zip.” The downloaded zip file will contain a set of spreadsheets for each state.

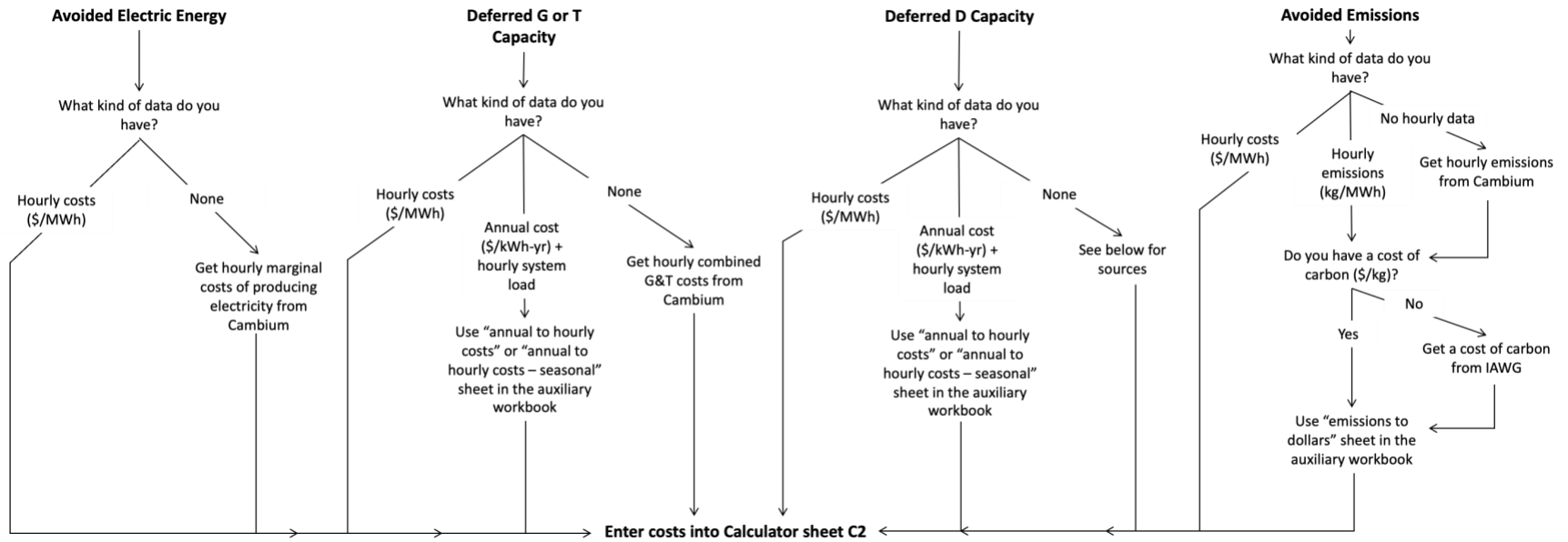


Figure 4. Flow chart for gathering and preparing hourly avoided cost inputs

Following are optional data sources for the five hourly avoided cost inputs. Both the avoided cost inputs and the discount rate should be real or nominal (e.g., if a real avoided energy cost is used, a real discount rate should be used). Refer to the Glossary for definitions of terms formatted in bold italics.

1. ***Avoided electric energy avoided costs*** - Chapter 4.2.2 discusses how to include this input in the Calculator. If the user does not have access to this data, the Cambium dataset is a publicly available source.
2. ***Generation capacity avoided costs*** - Chapter 4.2.3 discusses how to include this input in the calculator. If the user does not have access to capacity cost data, the Cambium dataset is a publicly available source.⁶
3. ***Transmission capacity avoided costs*** - Chapter 4.2.3 discusses how to include this input in the calculator. If the user does not have access to this data, the Cambium dataset can be used.⁷
4. ***Distribution capacity avoided costs*** - Chapter 4.2.3 discusses how to include this input in the calculator. Below are publicly available sources of avoided distribution system costs that users can explore using.
 - New England states: The Avoided Energy Supply Cost study provides distribution system costs for Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island and Vermont (Knight et al. 2021).
 - Northwestern states: The Northwest Power and Conservation Council provides an annual distribution system cost for Idaho, Montana, Oregon, and Washington in its draft 8th Power Plan.⁸ PacifiCorp provides an annual avoided cost for transmission and distribution for California, Oregon, Washington, Idaho, Utah, and Wyoming in its 2021 IRP.⁹
 - California: The California Avoided Cost Calculator includes distribution system costs for investor-owned utilities in the state.¹⁰
 - Other states: Utilities are required to file distribution system or grid modernization plans in many states¹¹ (Schwartz 2020). Users may consult websites for their utility, state public utility commission, state energy office, or regional energy efficiency organization to learn if the utility distribution system or grid modernization plans include costs that can be used in the Calculator, or identify if there is a more applicable distribution system cost.
 - FERC Form 1: The Federal Energy Regulatory Commission (FERC) requires major utilities to file an annual report which contains peak demand and distribution system costs. Form 1 filings can be accessed through FERC’s eLibrary.¹²
 - 2019 Distribution System Upgrade Unit Cost Database. The National Renewable Energy

⁶ The Cambium data combines avoided generation and transmission and assigns non-zero costs only to the top 40 hours of a year. See the Cambium data documentation for more information (Gagnon et al. 2020).

⁷ Ibid.

⁸ https://www.nwcouncil.org/2021powerplan_cost-and-benefits-energy-efficiency-resources

⁹ See table 7.10 in PacifiCorp’s 2021 IRP: <https://www.pacificorp.com/energy/integrated-resource-plan.html>

¹⁰ https://www.ethree.com/public_proceedings/energy-efficiency-calculator/

¹¹ For example, CA, CO, DC, HI, IN, MA, MD, ME, MI, MN, NV, NY, OH, PA, RI, VA, WA.

¹² <https://elibrary.ferc.gov/eLibrary/>. Form 1 filings can be found using both “Annual Report of Major Electric Utilities” and “Form 1” in the keyword search box. Include the quotation marks.

Laboratory’s database contains unit cost for components that may be used to integrate distributed photovoltaics on to a distribution system. Users must determine which components are required and circuit level analysis is recommended.¹³

5. **Emissions costs** - Chapter 4.2.4 discusses how to include this input in the calculator. If a user does not have access to this data, one data source is the Interagency Working Group on Social Cost of Greenhouse Gases, United States Government Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (Interagency Working Group 2021). The National Association of Regulatory Utility Commissioners (NARUC) also provides a summary of the approaches various commissions take for calculating the social cost of carbon (NARUC 2021). Users who have data for other greenhouse gases, both emissions levels and costs, may include them as an input.

3.2 System and measure inputs and data sources

Figure 5 helps users determine what data they need to acquire for **system load** and **measure shape** inputs. Refer to the Glossary for definitions of terms formatted in bold italics. Following are optional data sources for the four system load and measure shape inputs.

1. **System load** - Chapter 4.5 discusses how to include this input in the calculator. If the user does not have access to hourly system load data, the Cambium dataset is a publicly available source.¹⁴
2. **Line losses** -Section 4.3.2 describes how to input this factor in the Calculator. If a user does not have line loss inputs, the National Standard Practice Manual for Distributed Energy Resources includes a discussion on calculating transmission and distribution system line losses. Other data sources include:
 - Energy Information Administration provides state transmission and distribution line losses through its State Electricity Profiles.¹⁵
 - California: For investor-owned utilities in the state, the California Avoided Cost Calculator includes an adjustment to the value for deferring transmission and distribution investments that accounts for losses during the peak period.¹⁶
 - New England states: The Avoided Energy Supply Cost study explains the approach used to determine and apply marginal and average line losses. The study provides avoided transmission and distribution line loss values for Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island and Vermont (Knight et al. 2021).
 - Pacific Northwest: The Northwest Power and Conservation Council accounts for transmission and distribution system “no-load core losses” and resistive losses due to

¹³ <https://data.nrel.gov/submissions/101>

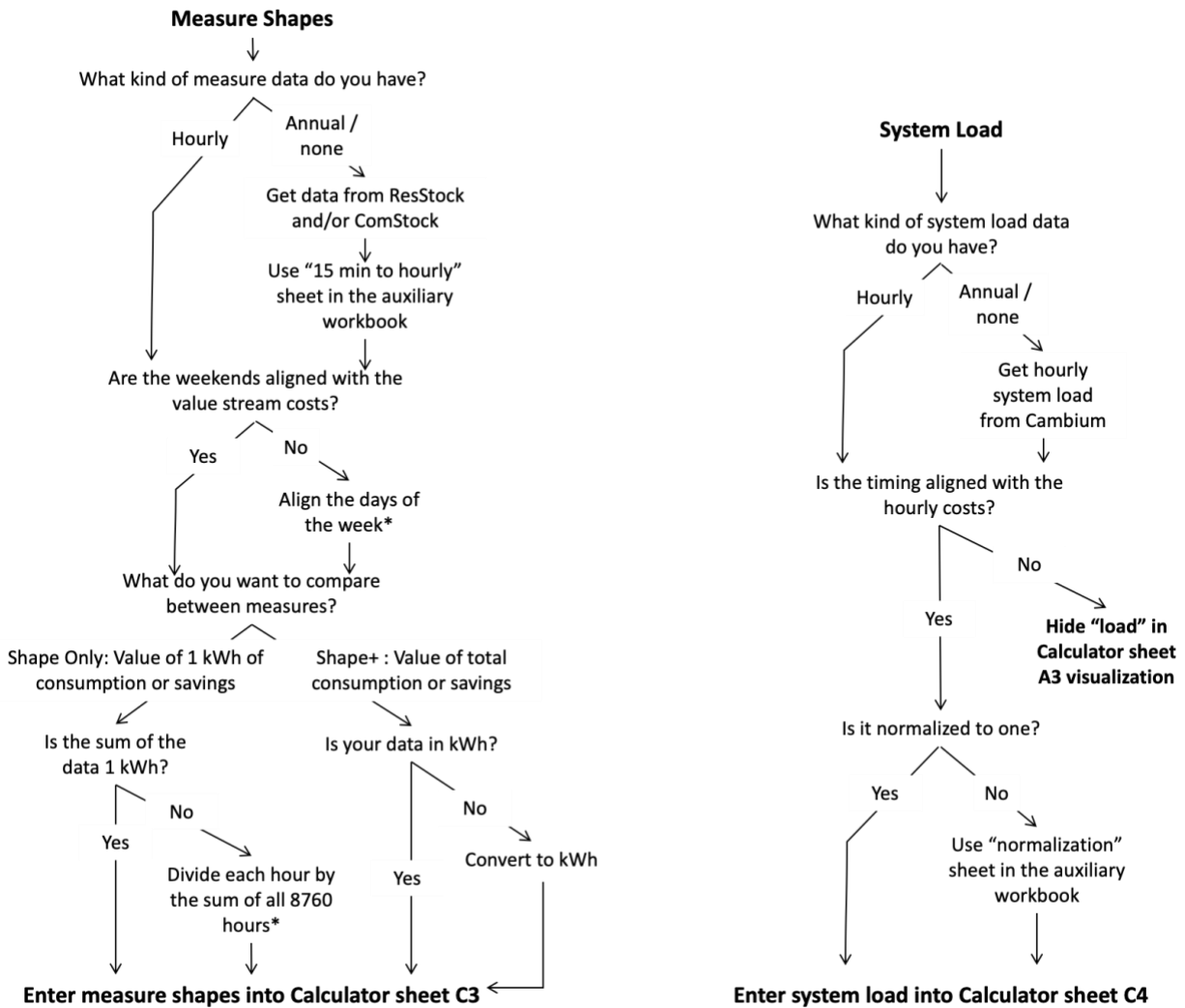
¹⁴ The Cambium data combines avoided generation and transmission and assigns non-zero costs only to the top 40 hours of a year. See the Cambium data documentation for more information (Gagnon et al. 2020).

¹⁵ <https://www.eia.gov/tools/faqs/faq.php?id=105&t=3#:~:text=The%20U.S.%20Energy%20Information%20Administration,in%20the%20State%20Electricity%20Profiles.>

¹⁶ https://www.ethree.com/public_proceedings/energy-efficiency-calculator/

crowded lines and transformers. Resistive losses increase during peak periods. The Council accounts for both types of losses.¹⁷

- Other states: The Database of State Efficiency Screening Practices¹⁸ identifies states that use avoided transmission and distribution line losses in their cost-benefit analysis. As of January 2022, 36 states included these losses. The Database includes citations to the policy and value source that can be used to identify appropriate costs for the jurisdiction.



* If using ResStock or ComStock EULPs and Cambium data, the “15 min to hourly” sheet in the Auxiliary workbook can shift the days of the week. The “15 min to hourly” sheet can also transform data for a Shape Only analysis.

Figure 5. Flow chart for gathering and preparing hourly measure shapes and system load inputs

3. **Measure shapes** - Chapter 4.4 discusses using this input in the Calculator. If a user does not have hourly measure shapes, hourly **end-use load profiles** are available from ResStock and ComStock

¹⁷ https://www.nwcouncil.org/2021powerplan_cost-and-benefits-energy-efficiency-resources

¹⁸ <https://www.nationalenergyscreeningproject.org/state-database-dsp/database-of-state-efficiency-screening-practices/>

(see text box). Users can also find measure shapes through Berkeley Lab’s end-use load profile library¹⁹ and the simulated consumption of 16 building types available on Open EI.²⁰ See Mims, Eckman and Goldman (2017) for a discussion on the availability and challenges with using end-use and savings profiles.

ResStock and ComStock End-Use Load Profiles

End-use load profiles (EULPs) are available from NREL’s ResStock and ComStock models. The EULPs provide residential and commercial building energy consumption by end-use at a 15 minute resolution for residential and commercial buildings.²¹

The ResStock and ComStock "data viewers" allow users to download the interval data for the desired subset of buildings at a variety of levels of geographic aggregation. Residential load profiles are available for the lower 48 states and the District of Columbia; commercial load profiles are available for all 50 states and the District of Columbia.

4. ***Measure lifetime*** - Chapter 4.3.1 discusses how to include this input in the Calculator. If a user does not have efficiency measure lifetimes, this information is commonly included in demand-side management filings by utilities or other program administrators, or in state or regional technical reference manuals. Berkeley Lab publications on measure lifetime (Murphy and Deason 2021) and technical reference manuals (Schiller et al. 2017) may also be a useful data source. Users may consult websites for their utility, state public utility commission, state energy office, or regional energy efficiency organization to learn if there is more specific information on measure lifetimes that may be used as a Calculator input.

3.3 Risk and financial inputs and data sources

Following are optional data sources for five risk and financial inputs. Refer to the Glossary for definitions of terms formatted in bold italics.

1. ***Electricity system risk mitigation*** - Chapter 4.1 discusses how to include this input in the Calculator. If users do not have data on electricity system risk mitigation, Appendix G of the National Standard Practice Manual for Distributed Energy Resources provides guidance on determining a discount rate that accounts for risk (Woolf et al. 2020). Regional and specific utility examples are below.
 - New England states: The Avoided Energy Supply Cost study provides risk reduction values for Connecticut, Massachusetts, Maine, New Hampshire, Rhode island and Vermont (Knight et al. 2021).

¹⁹ The inventory is published as a spreadsheet and lists publicly available sources of hourly end-use load profiles (Frick 2019).

²⁰ <https://data.openei.org/submissions/153>

²¹ From resstock.nrel.gov or comstock.nrel.gov, use the Data Viewer to select the desired dataset, geographical extent, and building characteristic filters, then use "Export CSV" and then "15 Minute Resolution" to download the data.

- Pacific Northwest states: The Northwest Power and Conservation Council provides a risk mitigation credit for energy efficiency.²²
 - PacifiCorp: In its 2021 IRP, the company used a stochastic risk reduction value of \$3.59/MWh.²³
 - The Database of State Efficiency Screening Practices²⁴ provides risk mitigation values for applicable jurisdictions. As of January 2022, that included Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont, Washington, Oregon, and the District of Columbia.
2. **Analysis years** - Chapter 4.1 discusses how to include this input in the Calculator. Users chooses up to eight analysis years. All data inputs are identified for each analysis year. Any desired year range may be used.
 3. **Basis year** – Chapter 4.1 discusses how to include this input in the Calculator. Users chooses the basis year. Any year may be selected.
 4. **Value stream inflater/deflator** - Chapter 4.1 discusses how to include this input in the Calculator. If a user does not have an inflater/deflator input,, Appendix E of the New England Avoided Energy Supply Cost provides guidance on conversion of nominal dollars to constant 2021 dollars, as well as calculating a real discount rate (Knight et al. 2021).
 5. **Discount rate** Chapter 4.3.2 discusses how to include this input in the Calculator. It is a component of the net present value calculation. Chapter 4.1 explains how to input it into the Calculator. Both the avoided cost inputs and the discount rate should be real or nominal (e.g., if a real avoided energy cost is used, a real discount rate should be used). Appendix G of the National Standard Practice Manual for Distributed Energy Resources provides “guidance on how to determine a cost-effectiveness test discount rate that is consistent with the objective(s) of the cost-effectiveness analysis and the jurisdiction’s applicable policy goals” (Woolf et al. 2020, p. G-1). The guidance provided in the National Standard practice Manual for DERs may be used to determine the discount rate used in the Calculator.
 - Pacific Northwest states: The Northwest Power and Conservation Council used a 3.75% discount rate in its draft 8th Power Plan (Starrett 2019).
 - New England states: Appendix E of the New England Avoided Energy Supply Cost provides guidance on calculating a real discount rate and real discount rate comparisons (Knight et al. 2021).

4. User Instructions

The user instructions are broken into six sections. The first five sections correspond to the five data input sheets:

- Basic analysis parameters,
- Avoided costs,
- Measure shape,
- Electricity system shape, and

²² https://www.nwcouncil.org/2021powerplan_cost-effective-methodology

²³ PacifiCorp’s 2021 IRP available here: <https://www.pacificorp.com/energy/integrated-resource-plan.html>

²⁴ <https://www.nationalenergyscreeningproject.org/state-database-dsp/>

- General measure parameters.

The final section describes how to perform calculations for results.

In each section, we walk through producing the Shape+ analysis shown in Figure 6. Specifically, the example uses data for Texas —the “Low Wind Cost” Cambium scenario²⁵ and the ResStock and ComStock six hourly load profiles for the residential building stock, medium offices and large offices.²⁶ We assume that the savings shapes are the same as the analogous end-use shapes and consider six hypothetical efficiency programs with annual savings shown in Figure 6. This main analysis is described in the green boxes. The blue boxes describe how to adjust the analysis to create Shape Only results.

Tip: Macros and Running the Calculator

To keep the Calculator as fast as possible, the launcher opens the Calculator with calculations and formulas set to update manually rather than automatically. To update simple formulas and cell references, click on “Calculate Sheet” in Excel’s “Formulas” toolbar.

There are three ways to run the Calculator and get new results. Users may click on “Calculate Now” in Excel’s “Formulas” toolbar. Users who have enabled macros can also go to the dashboard (sheet A1) and press “Calculate Values.” Saving the Calculator also triggers the calculation.

In general, blue cells are for user input, while grey and unfilled cells should not be edited.

4.1 Step 1: Define basic analysis parameters (sheet C1)

After identifying and sourcing data to use in the Calculator, the first step in using the Calculator is defining the basic analysis parameter (sheet C1). Refer to the Glossary for definitions of terms formatted in bold italics. Optional data sources for the inputs are provided in Chapter 3.

Analysis Years: In the blue cells, identify eight years to use in the analysis by inputting the years in cells B5-I5. These years propagate through the entire Calculator. . A suggested configuration is to use five consecutive years and then add every fifth year to cover a 20-year study horizon (e.g., 2023, 2024, 2025, 2026, 2027, 2030, 2035, and 2040). If the analysis period contains any non-consecutive years (e.g., 2030, 2035 and 2040 in the example above), the Calculator fills in the intermediate years with values from the previous year.

For measures with lifetimes longer than the analysis period, the Calculator estimates the benefit from the entire lifetime. The Calculator will use the value stream inputs for the last analysis year for any

²⁵ From cambium.nrel.gov, select “Cambium Scenarios (Hourly and annual data)” and then “Download Data.” For this example, the Scenario is “Low Wind Cost,” and the File is “data_hourly_state.zip.” The downloaded zip file will contain a set of spreadsheets for each state.

²⁶ From resstock.nrel.gov or comstock.nrel.gov, select “Data Viewer.” For this example, the dataset is “National Load Profiles by State 2018” and the state is Texas. For ComStock, add a filter such that the building type is large office or medium office. In both cases, the data can be downloaded by clicking on “Export CSV” and then “15 Minute Resolution.”

years after the specified analysis period. In the Shape+ analysis, measures with lifetimes less than the analysis period contribute value only for the years within their lifetimes; in other words the measures are not “reinstalled.”

Measure Parameters: Chapter 4.3 (Step 3) discusses how to populate these cells.

Avoided Cost Value Streams: In the blue cells, identify which of the six avoided cost value streams will be included in the analysis (“enable”). Chapter 4.2 (Step 2) discusses how to input the avoided cost value stream data.

Basis Year: In the blue cell, input the basis year. All results will be reported in dollars from this year. For example, if the basis year is 2016, the results will be reported in \$2016. The user can choose the basis year to use for reporting results.

Value stream inflater/deflator: In the blue box input the inflater or deflator to convert values into dollars from the chosen basis years.

Electricity System Risk Mitigation: In the blue cells, identify the value of risk mitigation associated with each measure in each year.

Texas Example

Enter the desired analysis years; in this case 2020, 2022, 2024, 2026, 2028, 2030, 2040, and 2050. Because Cambium reports combined generation and transmission avoided costs, disable the “Deferred Electric T Capacity” value stream. The “Value of Electric System Risk Mitigation” stream is not selected because Texas does not include it as an efficiency benefit.

Analysis years									
Input 8 years to be used in the analysis									
	1	2	3	4	5	6	7	8	
	2020	2022	2024	2026	2028	2030	2040	2050	
Measure parameters									
	Discount rate	Lifetime	Enable?	% line losses					
A: Res_cool	3%	17	Yes	5%					
B: Office_cool	3%	15	Yes	5%					
C: Res_HPWH	3%	13	Yes	5%					
D: Office_fans	3%	9	Yes	5%					
E: Res_heating	3%	17	Yes	5%					
F: Office_lights	3%	15	Yes	5%					
Value Stream									
Avoided Electric Energy			Yes						
Deferred Electric T Capacity			No						
Deferred Electric D Capacity			Yes						
Deferred Electric Generation Capacity			Yes						
Avoided Electric and Gas Systems CO2			Yes						
Value of Electric System Risk-Mitigation			No						
Base year									
	2020								
Value stream inflator/deflator									
	3%								
Value of Electric System Risk-Mitigation									
The value of electric system risk mitigation is not time-sensitive at the hourly level, hence it is not input as a cost.									
Use the following template to add risk mitigation and other side benefits of each measure									
The input should be a % of the monetary savings that accrue from the remaining time sensitive value streams									
	2020	2022	2024	2026	2028	2030	2040	2050	
A: Res_cool	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B: Office_cool	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C: Res_HPWH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
D: Office_fans	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E: Res_heating	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F: Office_lights	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Figure 6. Sheet C1 param input

4.2 Step 2: Input cost data (sheet C2)

In the second step, users populate the Calculator with costs. The inputs for sheet C2 “cost data” are hourly cost data for the selected (1) analysis years and (2) value streams (selected in Step 1). This sheet includes a filter on the row names. We recommend filtering for the corresponding avoided cost and then inputting data. This process is repeated for all five avoided cost streams.

Refer to the Glossary for definitions of terms formatted in bold italics. Optional data sources for the inputs are provided in Chapter 3.

4.2.1 Input year of cost data

Users input the data year for each of the cost value streams in the “value_dollar_year” column of the sheet C2. Using the *basis year* and *inflater/deflator* chosen on sheet C1 (Step 1), these costs will be converted to basis year dollars.

Texas Example

The Cambium 2020 Standard Scenario data is in 2019 dollars, so input 2019 into column C, “value_dollar_year” for Avoided Electric Energy and Deferred Electric G Capacity.

stream	value_dollar_year	hour_of_year	hour_of_day	value_dollar_mwh									
				2020	2022	2024	2026	2028	2030	2040	2050		
Avoided Electric Energy	2019	1	1	15.67	2.35	1.85	2.11	2.69	2.18	2.25	2.1		
Avoided Electric Energy	2019	2	2	15.47	2.27	1.75	2.02	2.59	2.08	2.05	2.1		
Avoided Electric Energy	2019	3	3	15.70	16.60	1.69	20.10	21.41	2.05	2.11	2.1		
Avoided Electric Energy	2019	4	4	17.13	16.78	16.94	20.16	21.57	19.55	2.09	2.1		
Avoided Electric Energy	2019	5	5	17.83	16.90	17.07	20.19	22.41	20.26	2.05	2.1		
Avoided Electric Energy	2019	6	6	17.92	16.84	17.22	21.43	22.50	20.40	1.95	1.1		
Avoided Electric Energy	2019	7	7	19.12	16.87	17.31	21.28	21.92	20.28	2.03	2.1		
Avoided Electric Energy	2019	8	8	20.50	17.06	17.51	21.65	22.91	20.62	1.97	2.1		
Avoided Electric Energy	2019	9	9	20.73	18.45	17.63	21.73	22.99	21.28	1.74	1.1		
Avoided Electric Energy	2019	10	10	17.46	17.84	3.55	3.78	2.47	1.84	0.43	0.1		
Avoided Electric Energy	2019	11	11	19.66	19.33	3.57	3.65	2.38	1.84	0.38	0.1		
Avoided Electric Energy	2019	12	12	22.12	19.73	20.25	22.76	2.40	1.82	0.40	0.1		
Avoided Electric Energy	2019	13	13	22.75	19.93	20.38	23.04	22.78	21.33	0.44	0.1		
Avoided Electric Energy	2019	14	14	22.77	19.89	20.39	23.14	22.83	22.54	0.45	0.1		
Avoided Electric Energy	2019	15	15	22.84	19.94	20.38	23.10	22.62	21.90	0.42	0.1		
Avoided Electric Energy	2019	16	16	22.99	20.11	20.47	23.13	22.79	23.60	0.42	0.1		
Avoided Electric Energy	2019	17	17	24.26	24.24	21.44	24.35	25.79	25.97	1.78	1.1		
Avoided Electric Energy	2019	18	18	31.41	27.51	26.22	28.62	31.46	32.13	26.69	21.1		

Figure 7. Sheet C2 dollar year

4.2.2 Input hourly avoided electric energy costs

Users input hourly *avoided electric energy costs* values for the years of the analysis in \$/MWh in sheet C2.

Texas Example

Avoided Electric Energy: Short-run marginal costs of providing electricity can be copied directly from the Cambium data column “energy_cost_busbar.”

stream	value_dollar_year	hour_of_year	hour_of_day	value_dollar_mwh									
				2020	2022	2024	2026	2028	2030	2040	2050		
Avoided Electric Energy	2019	1	1	15.67	2.35	1.85	2.11	2.69	2.18	2.25	2.1		
Avoided Electric Energy	2019	2	2	15.47	2.27	1.75	2.02	2.59	2.08	2.05	2.1		
Avoided Electric Energy	2019	3	3	15.70	16.60	1.69	20.10	21.41	2.05	2.11	2.1		
Avoided Electric Energy	2019	4	4	17.13	16.78	16.94	20.16	21.57	19.55	2.09	2.1		
Avoided Electric Energy	2019	5	5	17.83	16.90	17.07	20.19	22.41	20.26	2.05	2.1		
Avoided Electric Energy	2019	6	6	17.92	16.84	17.22	21.43	22.50	20.40	1.95	1.1		
Avoided Electric Energy	2019	7	7	19.12	16.87	17.31	21.28	21.92	20.28	2.03	2.1		
Avoided Electric Energy	2019	8	8	20.50	17.06	17.51	21.65	22.91	20.62	1.97	2.1		
Avoided Electric Energy	2019	9	9	20.73	18.45	17.63	21.73	22.99	21.28	1.74	1.1		
Avoided Electric Energy	2019	10	10	17.46	17.84	3.55	3.78	2.47	1.84	0.43	0.1		
Avoided Electric Energy	2019	11	11	19.66	19.33	3.57	3.65	2.38	1.84	0.38	0.1		
Avoided Electric Energy	2019	12	12	22.12	19.73	20.25	22.76	2.40	1.82	0.40	0.1		
Avoided Electric Energy	2019	13	13	22.75	19.93	20.38	23.04	22.78	21.33	0.44	0.1		
Avoided Electric Energy	2019	14	14	22.77	19.89	20.39	23.14	22.83	22.54	0.45	0.1		
Avoided Electric Energy	2019	15	15	22.84	19.94	20.38	23.10	22.62	21.90	0.42	0.1		
Avoided Electric Energy	2019	16	16	22.99	20.11	20.47	23.13	22.79	23.60	0.42	0.1		
Avoided Electric Energy	2019	17	17	24.26	24.24	21.44	24.35	25.79	25.97	1.78	1.1		
Avoided Electric Energy	2019	18	18	31.41	27.51	26.22	28.62	31.46	32.13	26.69	21.1		

Figure 8. Sheet C2 electric energy cost

4.2.3 Input deferred electric capacity costs – generation, transmission and distribution

Users input hourly **generation capacity avoided costs**, **transmission capacity avoided costs**, and **distribution capacity avoided costs** for the selected year of the analysis in \$/MWh in sheet C2.

Users who have annual **generation capacity avoided costs**, **transmission capacity avoided costs** and **distribution capacity avoided costs** can use the Auxiliary workbook sheets “annual to hourly costs” and “annual to hourly costs – season” to create hourly costs based on the annual cost and a **system load shape**. In both cases, the user determines the number of hours with the highest system load that receive a capacity value (Cambium uses 40 hours).

The weight of each top hour is calculated as its contribution to the total load during the specified number of top hours. Then the annual costs are multiplied by the hourly weights to generate the hourly cost profile. In the sheet “annual to hourly costs,” the top hours are chosen based solely on the system shape and may occur in any month(s) of the year. In the sheet “annual to hourly costs – season,” the user defines summer and winter seasons and determines how much of the annual cost to attribute to each one. This will force non-zero capacity value in specific months for systems with capacity constraints in those months.

Texas Example

Reminder: Cambium data combines avoided generation and transmission. If using Cambium data, in sheet C1, users enable all of the value streams except for “Deferred Electric T Capacity.”

Deferred Electric G Capacity: These costs can be copied directly from the Cambium data column “capacity_cost_busbar.” In the 2020 Standard Scenarios release, they will only be non-zero for 40 hours of the year.

Deferred Electric D Capacity: Cambium does not report distribution costs. In this example, we use data from Entergy Texas’s 2017-2019 FERC Form 1 filings. The average of these years was 37 \$/kW-yr.²⁷ In addition, we use an 8% rate of year over year increase, which is the 2000-2019 average for 5 Texas utilities.

We use the Auxiliary workbook “annual to hourly costs” and “normalization” sheets to convert from annual to hourly costs by spreading them across the 40 hours with the highest system load. To use the Auxiliary workbook for this purpose:

- Hourly costs:
 - Copy the analysis years from the Calculator parameters and paste them into the blue cells in “annual to hourly costs” row 9. Copy the normalized system load shape from the yellow cells in the “normalization” sheet into the remaining blue cells in columns C-J.
 - Input 40 into cell A6 to indicate that 40 hours of the year should have a non-zero distribution capacity cost.
 - In columns L-S, insert annual avoided capacity cost (\$/kW-yr) in row 8.
- Normalization
 - Copy the analysis years from the Calculator parameters and past them into the blue cells in “normalization” row 6.
 - For each analysis year, copy the 8760-hour data “net_load_busbar” of the appropriate Cambium spreadsheet and paste it into the blue cells.
 - Copy the data in the yellow cells and paste it in sheet C2 of the Calculator.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
1	This sheet will distribute annual avoided costs across the desired number of hours with the highest system load to create hourly costs for input into Calculator sheet C2.																			
2	Inputs: number of hours to distribute costs across, normalized system load shape, annual avoided capacity costs (\$/kW-yr)																			
3	Output: hourly avoided capacity costs (\$/MWh)																			
4																				
5	Number of hours to distribute the annual costs across. 40 is typical.																			
6	40 top hours																			
7																				
8	load_shape											Annual avoided capacity cost (\$/kW-yr) -->								
9		2020	2022	2024	2025	2028	2030	2040	2050			37	43.1568	50.33809152	58.71434995	68.48441778	79.8802249	172.4554143	372.3183049	
10	0.2193634	0.22806074	0.26175533	0.23810194	0.2040673	0.17714018	0.15900326	0.15050325												
11	0.22152855	0.22933661	0.26595975	0.23757411	0.21526142	0.18623391	0.17446115	0.16281349												
12	0.23893676	0.24547471	0.26531671	0.24712127	0.23324984	0.1888888	0.16060772	0.16161728												
13	0.24550916	0.25003578	0.26903236	0.25252083	0.23912292	0.18856004	0.16298437	0.17004232												
14	0.2409732	0.24735614	0.2726793	0.2557865	0.24261874	0.19602095	0.16244898	0.169670399												
15	0.2378479	0.23941714	0.27105873	0.25661205	0.24241751	0.20077793	0.16255807	0.15146809												
16	0.24094545	0.23526197	0.2675907	0.25222101	0.2375922	0.19125689	0.16038133	0.16466837												
17	0.24869631	0.24247307	0.27801294	0.26682603	0.25529889	0.20666685	0.16966083	0.16461682												
18	0.2727665	0.26328964	0.27717024	0.27743473	0.25694758	0.20762051	0.16463969	0.162708815												
19	0.27140004	0.26323166	0.25183007	0.22806323	0.20491552	0.15236059	0.15449227	0.16345833												
20	0.28645511	0.27589704	0.25288939	0.22371865	0.20575235	0.15236059	0.13511478	-0.0714847												
21	0.3058462	0.29742054	0.27413393	0.23919749	0.2009007	0.16509351	0.16010448	0.16148191												
22	0.31936126	0.31209688	0.28966293	0.25847278	0.22690074	0.19726184	0.16511083	-0.0219445												
23	0.32499114	0.31818283	0.29498361	0.26502438	0.23596989	0.20904392	0.16404872	-0.0267369												
24	0.32561191	0.31879324	0.29260979	0.26073278	0.22985156	0.20071284	0.16571264	0.160661567												
25	0.32760167	0.32028756	0.29159555	0.25853398	0.22713944	0.19941394	0.15907925	-0.081117												
26	0.3273407	0.32602516	0.30138698	0.26206329	0.23068448	0.19881742	0.12754732	-0.0430928												
27	0.43447222	0.43484936	0.45544649	0.46324838	0.46838134	0.47783873	0.26943391	0.18749944												
28	0.43886307	0.43791052	0.47144481	0.50166795	0.51269611	0.52310786	0.30911026	0.21756215												
29	0.42273931	0.42008572	0.45255668	0.48211715	0.49005055	0.49662328	0.28031411	0.21323603												
30	0.40261331	0.39893357	0.42786349	0.45847548	0.46514936	0.47125933	0.25895719	0.19828188												
31	0.3850809	0.37888314	0.40753451	0.43407157	0.43937966	0.44387486	0.22902248	0.15628628												
32	0.36842324	0.36509877	0.39203144	0.41846765	0.42073899	0.42724241	0.20870211	0.13149388												
33	0.34514994	0.34049892	0.36646524	0.39155491	0.39348159	0.39829728	0.17924433	0.12501959												

Figure 9. Auxiliary workbook “annual to hourly costs”

²⁷ This was calculated using the peak demand (p. 401b) and Additions to the Distribution Plant (p. 206). It does not include operations and maintenance costs.

Tip: Use Paste Special

When copying inputs to the Calculator from the Auxiliary workbook, use “Paste Special”, “Values” from Excel’s “Edit” menu. Otherwise, the formulas will be pasted, which will cause errors.

4.2.4 Input avoided electricity systems CO₂

Users input an hourly avoided electricity systems CO₂ value stream in \$/MWh in sheet C2. Users who have hourly emissions and costs of carbon can use the “emissions to dollars” sheet in the Auxiliary workbook to convert to hourly costs.

Texas Example

Avoided Electricity System CO₂: As described in Cambium documentation, the Cambium data provides hourly emissions data for four different metrics. In all cases they are given in units of kg CO₂/MWh and must be converted to cost (\$/MWh) for the Calculator.

The “emissions to dollars” sheet in the Auxiliary workbook can perform the conversion with a user-provided cost of carbon:

- Copy the analysis years from the Calculator parameters and paste them into the blue cells in row 6.
- Copy the desired emissions metric from the Cambium data files and paste it into the remaining blue cells in columns C-J. In this case we have used short-run marginal emission rates (“co2_srmer_enduse”).
- In columns L-S, input a carbon cost (\$/ton) in row 5. Note that the calculator will internally convert units from kg CO₂ to metric tons CO₂. In this case we have used the social cost of carbon developed for use by federal agencies. Data sources for the inputs are provided in Chapter 3.
- Copy the data in the yellow cells and paste it in sheet C2 of the Calculator.
- The social cost of carbon is in 2020 dollars, so input 2020 into column C, “value_dollar_year” for Avoided Electric Systems CO₂.

Hourly carbon emissions (kg CO ₂ /MWh)										Carbon cost (\$/ton)							
2020	2022	2024	2026	2028	2030	2040	2050	51	51	56	56	56	62	73	85		
390.50	121.10	35.80	79.30	53.70	32.00	30.50	51.00	19.9155	6.1761	2.0048	4.4408	3.0072	1.984	2.2265	4.335		
346.70	103.20	47.30	30.30	37.40	30.20	68.40	30.10	17.6817	5.2632	2.6488	1.6968	2.0944	1.8724	4.8692	2.5585		
353.10	383.80	60.60	362.00	826.30	29.90	77.60	788.50	18.0081	19.5738	3.3936	20.272	46.2728	1.8538	5.6648	64.8125		
369.90	391.80	315.10	813.80	844.10	774.90	78.60	29.10	18.8649	19.9818	17.6456	45.5728	47.2696	48.0438	5.7378	2.4735		
410.50	336.60	326.30	832.50	330.30	795.10	38.90	763.10	20.9355	17.1666	18.2728	46.62	18.4968	49.2962	2.8397	64.8635		
413.70	381.90	329.50	342.50	322.40	798.00	27.30	28.00	21.0987	19.4769	18.452	19.18	18.0544	49.476	1.9929	2.38		
491.10	396.80	333.60	341.30	832.70	800.30	26.60	28.10	25.0461	20.2368	18.6816	19.1128	46.6312	49.6186	1.9418	2.3885		
931.20	405.90	367.70	334.60	998.20	803.70	68.30	27.20	47.4912	20.7009	20.5912	18.7376	55.8992	49.8294	4.9859	2.312		
400.90	378.70	370.10	889.50	940.80	833.60	64.40	22.60	20.4459	19.3137	20.7256	49.812	52.6848	51.6832	4.7012	1.921		
487.00	483.40	62.80	59.40	35.80	28.70	4.80	43.60	24.837	24.6534	3.5168	3.3264	2.0048	1.7794	0.3504	3.706		
421.20	389.40	148.90	56.30	792.10	82.70	4.40	56.60	21.4812	19.8594	8.3384	3.1528	44.3576	5.1274	0.3212	4.811		
516.10	402.10	451.40	982.00	49.40	89.10	21.70	24.60	26.3211	20.5071	25.2784	54.992	2.7664	5.5242	1.5841	2.091		
458.20	512.30	459.20	437.00	908.60	916.20	4.50	52.60	23.3682	26.1273	25.7152	24.472	50.8816	56.8044	0.3285	4.471		
352.30	414.40	468.80	504.70	846.10	963.00	24.60	7.10	28.1673	21.1344	26.2528	28.2632	47.3816	59.706	1.7958	0.6035		
441.10	503.20	456.00	433.70	846.00	930.90	6.10	57.90	22.4961	25.6632	25.536	24.2872	47.376	57.7158	0.4453	4.9215		
546.70	418.50	479.30	385.40	859.50	1286.30	4.60	67.40	27.8817	21.3435	26.8408	21.5824	48.132	79.7506	0.3358	5.729		

Figure 10. Auxiliary workbook “emissions to dollars”

4.3 Step 3: Input measure characteristics (sheet C5)

4.3.1 Input the name, description and lifetime of the measures

Users input the name, description and lifetime of up to six measures in sheet C5. The measure label will propagate through the Calculator to identify the measures, including on all tables and graphs. It is important to only edit the measure names in this sheet and not alter measure names in other parts of the Calculator.

The “annual energy” column will populate based on the measure shapes in sheet C3.

Texas Example

In sheet C5 enter the measure name, description, and lifetime. In this case we use the measure lifetimes from Texas’s Technical Resource Manual (TRM) version 9.0. Enter a lifetime for all of the measures to avoid errors in sheet A1 after running the Calculator.

Measure	Label	Description	Lifetime	Annual energy (kWh)	notes			
Measure A	A: Res_cool	Residential cooling	17	100000	ResStock - TX 2018 AMY weather; TX TRM 9.0			
Measure B	B: Office_cool	Medium and large office cooling	15	99994	ComStock - TX 2018 AMY weather; TX TRM 9.0			
Measure C	C: Res_HPWH	Residential heat pump water heater	13	50010	ResStock - TX 2018 AMY weather; TX TRM 9.0			
Measure D	D: Office_fans	Medium and large office fans	9	50001	ComStock - TX 2018 AMY weather; TX TRM 9.0			
Measure E	E: Res_heating	Residential electric heating	17	50176	ResStock - TX 2018 AMY weather; TX TRM 9.0			
Measure F	F: Office_lights	Medium and large office interior lighting	15	149583	ComStock - TX 2018 AMY weather; TX TRM 9.0			

Figure 11. Measure label name, description and lifetime

Shape Only Analysis

For a Shape Only analysis, input the same lifetime (typically 1) for all measures.

4.3.2 Define measure parameters

After designating the measure name, description and lifetime, users return to sheet C1 to complete the parameter input sheets. The measure lifetimes defined in sheet C5 are displayed, but cannot be modified on sheet C1. For each measure, users input the:

- Discount rate
- Measures included in the analysis (“enable”)
- Line losses

Texas Example

For this example, we used a 3% real discount rate for all measures to represent a societal cost of capital (Woolf et al. 2020). If the avoided cost data is sources from Cambium data, which is provided in real dollars, real discount rates should also be used for consistency. After entering the discount rate, enable all measures and enter a line loss for each measure. For this example, we used a 5% line loss based on EIA’s Texas Electricity Profile.

Analysis years									
Input 8 years to be used in the analysis									
	1	2	3	4	5	6	7	8	
	2020	2022	2024	2026	2028	2030	2040	2050	
Measure parameters									
	Discount rate	Lifetime	Enable?	% line losses					
A: Res_cool	3%	17	Yes	5%					
B: Office_cool	3%	15	Yes	5%					
C: Res_HPWH	3%	13	Yes	5%					
D: Office_fans	3%	9	Yes	5%					
E: Res_heating	3%	17	Yes	5%					
F: Office_lights	3%	15	Yes	5%					
Value Stream									
	Enable?								
Avoided Electric Energy	Yes								
Deferred Electric T Capacity	No								
Deferred Electric D Capacity	Yes								
Deferred Electric Generation Capacity	Yes								
Avoided Electric and Gas Systems CO2	Yes								
Value of Electric System Risk-Mitigation	No								
Base year									
	2020								
Value stream inflator/deflator									
	3%								
Value of Electric System Risk-Mitigation									
The value of electric system risk mitigation is not time-sensitive at the hourly level, hence it is not input as a cost. Use the following template to add risk mitigation and other side benefits of each measure The input should be a % of the monetary savings that accrue from the remaining time sensitive value streams									
	2020	2022	2024	2026	2028	2030	2040	2050	
A: Res_cool	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B: Office_cool	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C: Res_HPWH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
D: Office_fans	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E: Res_heating	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F: Office_lights	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Figure 12. Measure parameters inputs

4.4 Step 4: Input measure shapes (sheet C3)

Users input annual hourly (8,760 hours) *measure shapes* in sheet C3. Refer to the Glossary for definitions of terms formatted in bold italics. Optional data sources for the inputs are provided in Chapter 3. The *measure shapes* should be from the same year as the *electricity system load shape* data or be modified to have the same weekday and weekend hours.

All hourly inputs in the Calculator must be aligned and begin on the same *time zone* and *day of the week*, for example Sunday January 1 at midnight Eastern Standard Time. This is because weekend and weekday load shapes often vary substantially.

4.4.1 ResStock and ComStock Data

Using the ResStock and ComStock data in the Calculator requires aligning the data to begin on the same day of the week, in the same time zone. The Auxiliary “15 min to hourly” sheet was designed to assist users with aligning Cambium, ResStock and ComStock data.

- The ResStock and ComStock EULPs are provided in 15 minute increments. The “15 min to hourly” tab of the Auxiliary workbook can aggregate the ResStock and ComStock EULPs into hourly inputs.
- Cambium data starts on Sunday, and the ResStock and ComStock EULPs start on Monday; if they are used in conjunction the weekends need to be shifted so that they both start on Sunday.²⁸ If the analyst is using Cambium data, they will use the “shifted hourly” outputs in the Auxiliary sheet.

If ResStock or ComStock EULPs are used to determine the value of efficiency, the analyst is using an end-use load profile as a proxy for savings. The user may wish to change the quantity of savings in the Calculator (e.g., to simulate program savings). To do so, users enter the EULPs from ResStock and ComStock in the “15 min to hourly” tab of the Auxiliary workbook. Columns H-P provide the user with three sets of results (Table 2).

- Shape +: Total end-use hourly consumption
- Shape + and user defined savings: Allows users to employ the EULP shape and estimate the impact of installing an efficiency measure.
- Shape Only – The EULP consumption is summed to 1 kWh/year to allow for comparisons of EULP shapes.

Table 2. Description of Auxiliary workbook tab “15 min to hourly” outputs

Analysis Type	Description	Auxiliary Spreadsheet Column	
		Hourly	Shifted Hourly
Shape+	ResStock and ComStock EULPs are aggregated from 15 minute to annual sum data (e.g. total end use consumption)	H	I
Shape+ and user defined savings quantity	User chooses annual sum (e.g. to set program savings). Annual sum is entered in cell K10.	K	L
Shape Only	Annual sum is 1 kWh/yr	O	P

²⁸ The data from the last Sunday of December is copied to the first day of January. Because the calendar year begins and ends on the same day of the week, the last 24 hours of the original ResStock and ComStock EULPs are discarded, and Sunday, December 31 and Sunday, January 1 have identical shapes.

Texas Example

Process the downloaded ResStock and ComStock EULPs using the “15 min to hourly” sheet in the Auxiliary workbook (see gray text box above). It is used to shift the ResStock and ComStock EULPs to begin on Sunday. One measure at a time, paste the 15 minute data into the blue cells in column D and input the annual savings for the measure in cell K10. For example, the example residential cooling program has an annual savings of 100,000 kWh/yr (Figure 15).

The user should convert one measure at a time, repeating this process for as many measures as needed.

month-day-hour	minute	15 min shape	month-day-hour	hourly	shifted hourly	Shape+ original magnitude	Shape+ specified magnitude	Shape Only magnitude of one
010100	0	10478.92739	010100	39673.40637	71555.25124	100,000 kWh/yr	100,000 kWh/yr	100,000 kWh/yr
010100	15	13544.73077	010101	9508.591666	53532.34973			
010100	30	8319.286863	010102	3233.373971	41980.0849			
010100	45	7330.461348	010103	2849.335342	33604.43122			
010101	0	6225.086829	010104	2558.386614	26902.36702			
010101	15	2148.328649	010105	1467.54314	18736.81632			
010101	30	656.4414417	010106	2209.278038	15654.65682			
010101	45	478.7347465	010107	3660.284718	17035.3336			
010102	0	537.4202807	010108	4099.194905	24183.95095			
010102	15	2030.765492	010109	3544.11536	30562.09613			
010102	30	356.4097118	010110	3245.079178	31696.59765			
010102	45	308.7784868	010111	3838.370557	27406.83773			
010103	0	353.316086	010112	4055.063968	25781.95068			
010103	15	1799.691965	010113	4685.968648	22838.84746			
010103	30	382.1308539	010114	5449.366858	18733.90861			
010103	45	314.1964372	010115	7223.113507	18738.1428			
010104	0	242.3944839	010116	8775.360243	18653.1734			
010104	15	1732.585671	010117	9652.3158	18731.21601			

Figure 13. Processing ResStock and ComStock EULPs with the Auxiliary Workbook sheet “15 min to hourly”

Texas Example

Paste these aggregated and shifted measure shapes that sum to the annual savings of each measure from column L of the Auxiliary Workbook into sheet C3, column E of the Calculator.

measure	hour_of_day	hour_of_year	measure_shape_kW	select_shape_kW
A: Res_cool	1	1	0.082042908	0.082042908
A: Res_cool	2	2	0.019663361	0.019663361
A: Res_cool	3	3	0.006686479	0.006686479
A: Res_cool	4	4	0.005892304	0.005892304
A: Res_cool	5	5	0.005290634	0.005290634
A: Res_cool	6	6	0.003034816	0.003034816
A: Res_cool	7	7	0.004568693	0.004568693
A: Res_cool	8	8	0.007569312	0.007569312
A: Res_cool	9	9	0.00847696	0.00847696
A: Res_cool	10	10	0.007329071	0.007329071
A: Res_cool	11	11	0.006710685	0.006710685
A: Res_cool	12	12	0.007937586	0.007937586
A: Res_cool	13	13	0.008385699	0.008385699
A: Res_cool	14	14	0.009690383	0.009690383
A: Res_cool	15	15	0.011269058	0.011269058
A: Res_cool	16	16	0.01493709	0.01493709

Figure 14. Sheet C3 measure shape data inputs

Shape Only Analysis Modification

For a Shape Only analysis, transform the measure shapes so that the annual consumption is 1 kWh and each hour is the fraction of the 1 kWh contributed by that hour. To do this, divide each hour by the annual sum of the measure shape.

4.5 Step 5: Input electricity system load shape (sheet C4)

The system load shape input does not impact the Calculator value outputs because the values are based on the system costs.²⁹ It provides a visual comparison of the system load and measure shapes. Users who would like to see the visual comparison (sheet A3) enter the system load shape into “C4 shape data.”

The system load shape must be normalized to one so that each hourly number is a percentage of the maximum. The “normalization” sheet of the Auxiliary workbook can perform this.

Texas Example

For each of the years chosen for analysis in Step 1, take the 8760-hour data “net_load_busbar” of the appropriate Cambium spreadsheet and paste it into the blue cells of the “normalization” sheet of the Auxiliary workbook. Copy the normalized data from the yellow cells and paste it into sheet C4 of the Calculator.

shape	hour_of_day	hour_of_year	2020	2022	2024	2026	2028	2030	2040	2050
Load	1	1	0.219363	0.220861	0.261755	0.228104	0.204097	0.17714	0.099035	0.055052
Load	2	2	0.221529	0.229037	0.26596	0.237574	0.215261	0.186234	0.074461	0.028138
Load	3	3	0.238937	0.245475	0.265317	0.247121	0.23325	0.188689	0.100691	0.081617
Load	4	4	0.245509	0.250036	0.269032	0.252521	0.239123	0.18856	0.102984	0.070042
Load	5	5	0.240973	0.247356	0.272679	0.255787	0.242619	0.196021	0.082449	0.096704
Load	6	6	0.237785	0.239417	0.271059	0.256012	0.242418	0.200778	0.062559	0.051468
Load	7	7	0.240945	0.235262	0.267591	0.252221	0.237592	0.191257	0.100383	0.094698
Load	8	8	0.248696	0.242473	0.278013	0.266826	0.255299	0.206667	0.090601	0.094617
Load	9	9	0.272767	0.26329	0.27717	0.277435	0.256948	0.207621	0.0464	0.027068
Load	10	10	0.2714	0.263232	0.25383	0.226063	0.204916	0.152361	0.054492	0.033458
Load	11	11	0.286455	0.275897	0.252869	0.223719	0.205752	0.152361	0.035115	-0.07148
Load	12	12	0.305885	0.297421	0.274134	0.239197	0.209007	0.165094	-0.00104	0.001482
Load	13	13	0.319361	0.312097	0.289663	0.258473	0.226901	0.197262	0.051108	-0.02194
Load	14	14	0.324991	0.318183	0.294984	0.265024	0.23597	0.209044	0.064049	-0.02674
Load	15	15	0.325612	0.318739	0.29261	0.260732	0.229352	0.200713	0.057124	0.006416
Load	16	16	0.327602	0.320288	0.292596	0.258833	0.227139	0.199414	0.039076	-0.08213
Load	17	17	0.372734	0.368025	0.352387	0.326206	0.306384	0.288817	0.027547	-0.04369
Load	18	18	0.434472	0.434846	0.455446	0.463248	0.468581	0.477839	0.26944	0.187499

Figure 15. Sheet C4 Load data inputs

4.6 Step 6: Run the Calculator (sheet A1)

After all data and parameters in the Calculator are input and set up, go to the dashboard (sheet A1) and

²⁹ The system load shape is also used by the Auxiliary workbook to convert annual costs to hourly costs (Figure 9).

press “Calculate Values” to view the results.

For the equations used in the calculations see Appendix A.

5. Calculator Outputs

The calculator has six outputs.

- NPV of the value of the selected measures over their lifetime by value stream. (Sheet A1)
- Annual value by selected measures and value streams for each year of the analysis. (Sheet B4)
- Hourly value for selected measures and value streams for:
 - A user-defined day (Sheets A2 and B1)
 - An average day in each selected year (Sheet B2)
 - An average day in each month and year (Sheet B3)
- Electricity system shape and selected measure shape for a user-defined day. This output is used to visualize and compare measure and system load shapes, but it is not the output of a calculation. (Sheet A3)

5.1 Dashboard and Graphical Visualizations (Orange)

The dashboard and visualizations are located on sheets A1 – A3.

- A1 Dashboard: NPV of the value of selected measures over their lifetime. This output is used to create a stacked bar chart that displays the NPV of each measure by value stream (Figure 16).

The Calculator estimates the net present value of the hourly savings produced during each measure’s lifetime. If the analysis period contains any non-consecutive years, the Calculator fills in the intermediate years with the benefits from the previous year. The length of the analysis period does not affect the net present value of the measure benefits. Measures with lifetimes less than the analysis period contribute value only for the years within their lifetimes; in other words the measures are not “reinstalled.” For measures with lifetimes longer than the analysis period, the benefit from the whole lifetime is calculated. Any years after the specified analysis period will use the value stream inputs for the last analysis year.

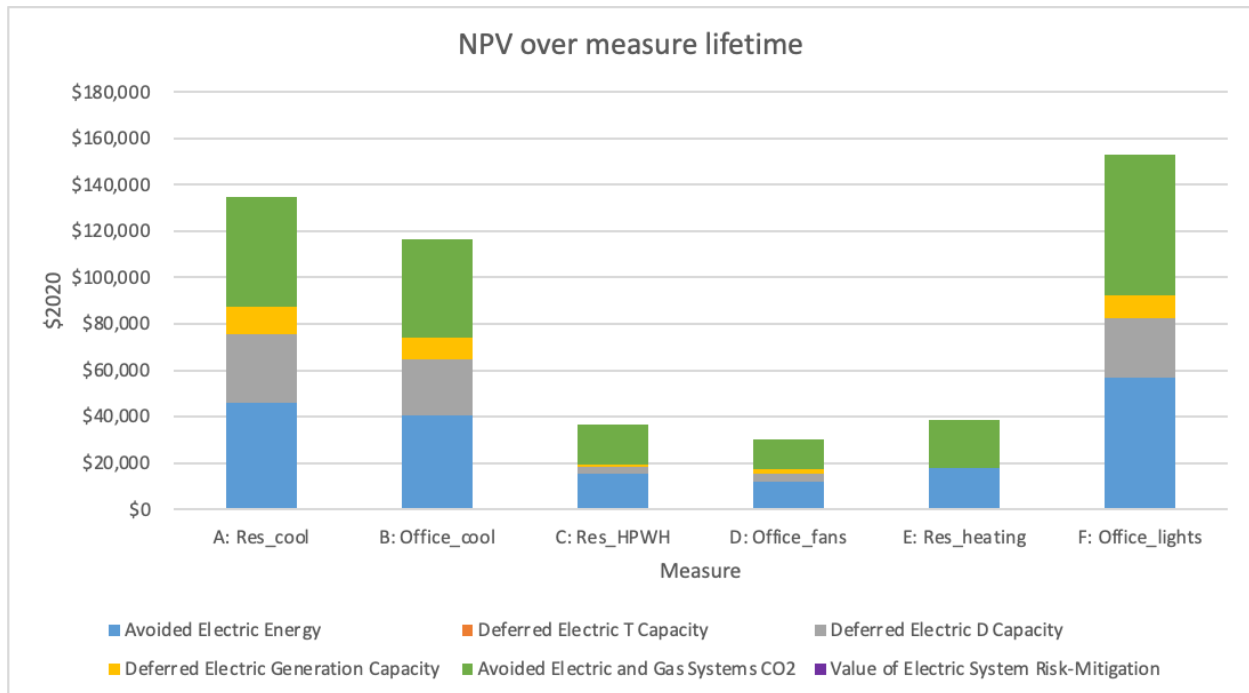


Figure 16. NPV of each measure over its lifetime by value stream (Shape+)

- A2 visuals 1 – meas svgs: Hourly value of a selected measure for a selected day by value stream (Figure 17). The value is for a single day rather than over the lifetime of the measure. It is presented in real dollars from the base year and no discount rate is applied (i.e. it is not a net present value). The user can calculate savings for different days of the year and paste the charts on a separate Word or PowerPoint document to compare them side by side. Use the dropdown menus in the blue cells to select the measure and day to display and click “Refresh this chart.”³⁰

³⁰ If macros are not enabled, go to sheet B1 and click “Calculate Sheet” in Excel’s toolbar; return to sheet A2 and click “Calculate Sheet” to see the updated chart.

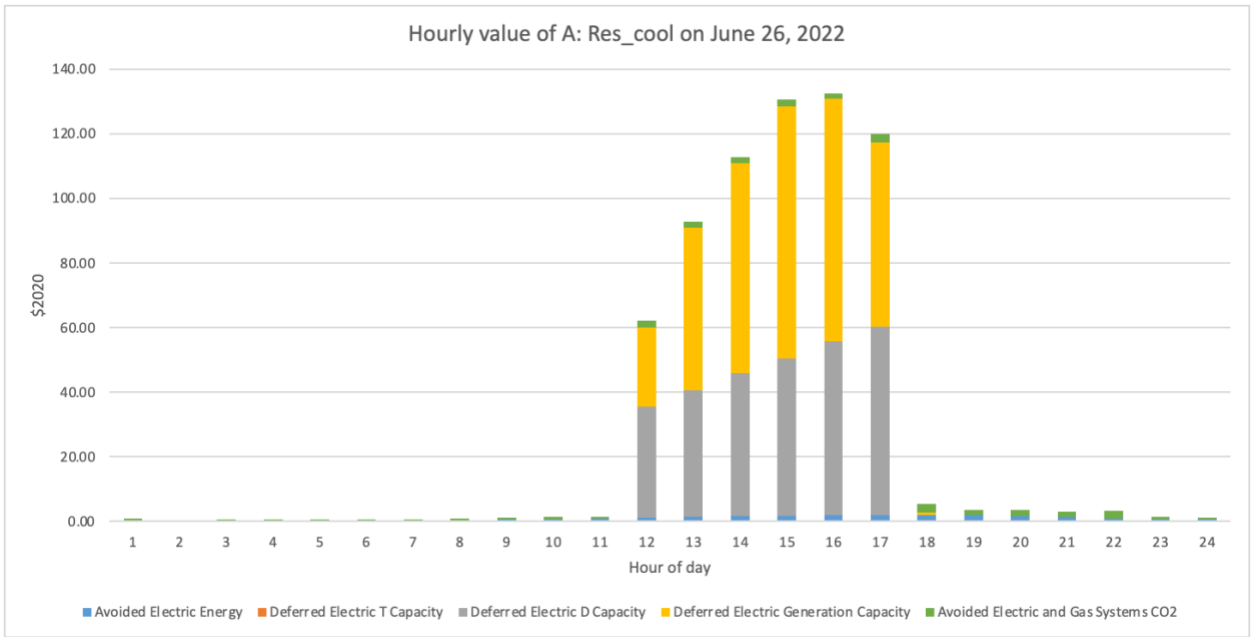


Figure 17. Hourly value by stream for selected day and measure (sheet A2 visuals 1 – meas svgs)

- A3 visual 2 – shapes: Hourly shapes on a selected day for the electricity system and up to six measures (Figure 18). Load and measure shapes are used jointly in graphs to provide the user a visual check of consistency between end-use load or savings shapes and the electricity system shapes. Users whose system load shape is not aligned with the costs should hide the load from the chart.

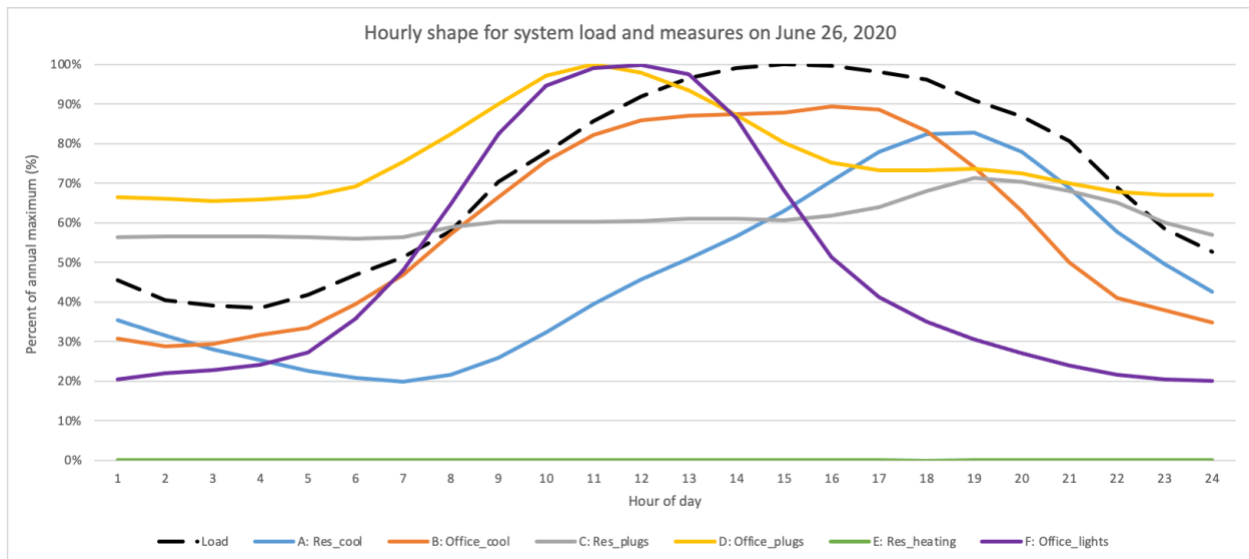


Figure 18. Hourly shape for system load and measures (sheet A3 visuals 2 – shapes)

5.2 Tabular Outputs (Blue)

The tabular Calculator outputs are located on sheets B1 – B4.

- B1 output-select day: Hourly value of a selected measure for a selected day by value stream. Because this sheet provides the underlying information for the graph in “A2 visuals 1 – meas svgs”, the date selection is in sheet A2 and should not be edited in this aggregate sheet.
- B2 output- average day: Average hourly value for all enabled measures and value streams for one day in each analysis year (e.g., 1 am is the average of hour ending 1 am for every day in the year). There is no data visualization associated with this output.
- B3 output-average day-month: Average hourly value for all enabled measures and value streams by hour in each month and analysis year. There is no data visualization associated with this output.
- B4 output- sum-hour: Total value of the enabled measures and value streams for each hour of the day in all years in the analysis.

6. Limitations

The Calculator has limitations that the users should be aware of prior to implementing it and when interpreting the results.

Interactive effects – The Calculator considers each measure separately and does not account for interaction between those measures, so users should be cautious about combining the values of multiple measures. For example, if one measure is heating and another is lighting, the sum of the values of the two measures will underestimate the value of the measures in combination since there is an increased heating load due to reduced heat gains from using a more efficient lighting technology. Similarly, if one measure is efficiency and another measure is another DER, such as demand response, the interactive effects between the measures are not considered.

Distribution capacity costs – There is not a publicly available national dataset of hourly distribution capacity avoided costs. The Auxiliary workbook implements a method for distributing annual avoided costs across the hours of the year based on the electricity system load (see Chapter 4.2.3 for more information). However, the distribution system is not necessarily constrained during the electricity system peak, so this method may over or under estimate the value of electricity on the distribution system peak.

Locational distribution costs – The Calculator accepts one distribution system avoided cost input. Some users may have access to locational distribution costs (i.e. avoided costs for different parts of the distribution system for a given jurisdiction). A user could potentially focus their TSV assessment using a locational distribution cost and input the locationally relevant measures to assess. However, users cannot input more than one distribution system cost nor they can link specific measures with specific costs.

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Glossary

Analysis years determine inputs cost and system load information for those years. Any desired year range may be used. A suggested configuration is to use five consecutive years and then add every fifth year to cover a 20-year study horizon (e.g., 2023, 2024, 2025, 2026, 2027, 2030, 2035, and 2040).

Average days: Two of the outputs refer to an average day (B2, B3). The hourly results are calculated as the average of the benefits at that particular time of day, i.e. hour ending 1 am, hour ending 2 am, etc. The overall average day (B2) uses the benefits of that hour for the 365 days in the year. The average day in the month (B3) uses the benefits of that hour for the 28-31 days in the particular month.

Avoided electric energy avoided costs correspond to hourly electricity consumption reductions due to installation of an energy savings or other DER measure. These avoided electric energy costs are determined based on the cost of generating electricity including power plant fuel and operating costs.

Basis year is the year whose dollars will be used for reporting results. For example, if the basis year is 2016, the results will be reported in \$2016. The user can choose the basis year to use for reporting results.

Discount rate is a component of the net present value calculation. It represents the rate of return that the user expects or the user's cost of borrowing money.

Distribution capacity avoided costs correspond to distribution system investments that are deferred or avoided due to installation of a measure. These costs are determined based on the cost of building new distribution system capacity.

Electricity system risk mitigation is derived from reduced dependence on factors such as fuel prices and changes in technology (Frick et al. 2018). The value is estimated on an annual basis as a percent adder to the monetary value of the five avoided costs for each of the analysis years. The results depend on which of the avoided costs are enabled for the analysis.

Emissions costs are determined based on the assumed cost of carbon dioxide or other greenhouse gases emitted by the electric system.

End-use load profiles are the hourly, annual energy consumption that inform *how* and *when* energy is used.

Generation capacity avoided costs correspond to generation capacity whose deployment is deferred by reducing energy consumption due to installation of a measure. It is determined based on fuel, capital, fixed operation and maintenance costs, and periodic capital replacement cost. Typically, avoided capacity costs are zero for many hours of the year but can be large during high load hours.

Line losses occur from a number of factors that increase resistance, and electricity loss, when transmitting or distributing electricity on the grid. The line loss factor is a multiplier that is applied when calculating the results.

Measure lifetime is the duration of time that a measure consumes electricity, produces savings, or generates electricity. The Calculator uses this metric to determine the number of years to assess a measure.³¹

Measure shapes are hourly (8,760) electricity consumption, savings, or generation profiles.

Net present value is a financial calculation that quantifies the current value of future energy savings or generation.

Shape+ analysis answers the question, “what is the value of the total consumption or savings of this measure?” For example, users may employ the Shape+ analysis to compare the value of 10 megawatt-hours (MWh) of savings from a heating, ventilation and air-conditioning (HVAC) program and 15 MWh of savings from a lighting program.

Shape Only analysis uses the timing of the end-use consumption, savings or generation to determine the value of a *single unit* of consumption, savings or generation. For example, users may employ the Shape Only analysis to identify high value end-uses or technologies to target in an energy efficiency program.

System load shape is the electricity need for a designated geographic area (e.g., utility service territory, state). In the Calculator, it is used as a point of visual comparison for the measure shapes (sheet A3). The system load shape may also be used in conjunction with annual capacity avoided cost to create hourly capacity avoided costs.

Transmission capacity avoided costs correspond to transmission infrastructure whose deployment is deferred or avoided due to installation of a measure. These costs are determined based on the cost of deferring transmission system expansion as estimated by the Cambium capacity expansion modeling.

Value stream inflator/deflator is an average real annual inflator or deflator (typically 2.5%–3%) for converting between dollar values using different basis years. If a user inputs hourly cost values with a different basis or dollar year, this inflator/deflator is used to adjust those costs to the basis year. If a user inputs hourly avoided cost values with a different basis year, the inflator/deflator is used to adjust those costs to the basis year.

³¹ Measures are not “reinstalled” after their lifetime and the Calculator does not consider measure degradation.

Appendix A. Equations

For the five hourly avoided costs, the annual value of the stream for a measure in year y is

$$V_y = \sum_{h=1}^{8760} \frac{M_h * V_h}{(1+i)^{(y-y_0)}} * (1+ll)$$

Where:

V_y is the value of the value stream in year y

M_h is the measure savings or generation in hour h

V_h is the value of the value stream in hour h

i is the inflator/deflator for converting to dollars of the base year

y_0 is the base dollar year

ll are the line losses

For the electric system risk mitigation, the annual value for a measure in year y is

$$R_y = \sum_{j=1}^5 V_{jy} * (1+r)$$

Where:

R_y is the value of electric system risk mitigation in year y

V_{jy} is the annual value of value stream j in year y

r is the risk system mitigation multiplier

Finally, the net present value of the measure over its lifetime is

$$NPV = \sum_{y=1}^{eul} \frac{T_y}{(1+d)^{(y-1)}}$$

Where:

NPV is the net present value of a measure over its lifetime

eul is the measure's lifetime

T_y is the total annual value from all value streams in year y of the analysis

d is the discount rate