

An Introduction to the Time-Sensitive Value Calculator

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ABSTRACT

The Time-Sensitive Value Calculator (Calculator) is a publicly available, free spreadsheet 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. Use cases include demand-side management planning, distribution system planning and integrated resource planning. The Calculator and user manual are 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 paper introduces the Calculator and its use cases. 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) and Murphy, Deason and Satchwell (2021).

Overview

Most investment decisions for energy efficiency and solar consider only electricity and dollar savings over the course of a year. But the value of these measures—and other distributed energy resources (DERs)—varies hourly. That's because the cost of generating, transmitting and distributing electricity during peak hours is significantly higher than during lower load hours for most U.S. regions.

Yet electricity planning and programs across the United States often miss this temporal element (Frick et al. 2020). The Calculator is designed to assist state public utility commissions, state energy offices, utilities, and stakeholders estimate the hourly value of efficiency, solar and other DERs. Knowing when DERs are saving energy or generating power, and the hourly value of the energy and demand savings to the electricity system, provide key information needed to procure the optimal amount and type of these resources.

The value of DERs changes over the years. The Calculator allows users to consider value under various future scenarios. For example, users can input multiple measure shapes — from their own data sources or the recently released ResStock and ComStock end use load profiles¹ — that represent advances in building controls and shift electricity consumption to lower-cost time periods. Changes to the utility's or region's power plant mix may result in higher or lower values for DERs, and users can assume different hourly costs for eight unique years to better understand the changes in values.

¹ <https://www.nrel.gov/buildings/end-use-load-profiles.html>

Tools such as California’s Avoided Cost Calculator (E3 2021) and the Avoided Energy Supply Cost User Interface (Synapse 2021) allow for analysis of time-sensitive value in particular places, but this Calculator is the first that is not location specific and therefore broadly applicable.

The Calculator can be used to analyze the time-sensitive value of many types of measure shapes² including end-use (energy consumption), energy savings, and DERs such as solar (energy generation) (Figure 1). It 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 estimates the NPV 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. 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.

The Calculator can perform two types of analysis on measures, 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.

² The measure shapes can be end-use, savings or generation profiles. For brevity, they are referred to as “measure shapes” everywhere 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. See Mims, Eckman, and Goldman (2017).

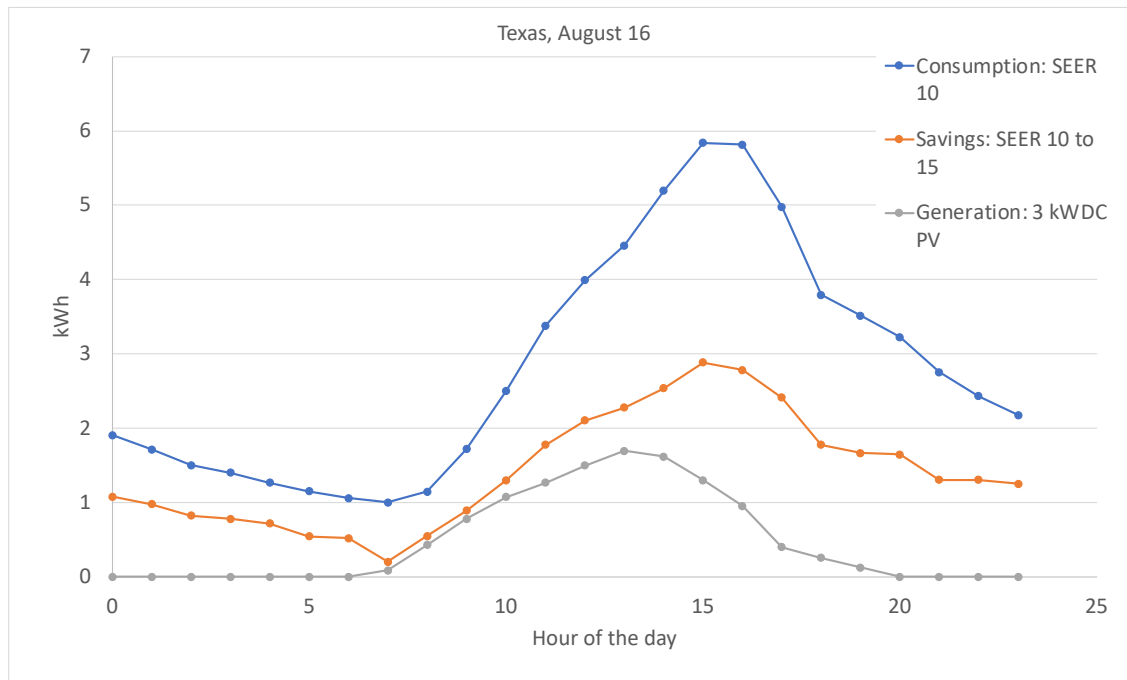


Figure 1. Example of a measure shape – residential cooling in uninsulated homes and PV generation

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 magnitude of savings, the number of program participants or measure installations and the program or measure lifetime in addition to timing.³ 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 planning scenarios
- Estimating the value of increased or decreased participation by program or measure

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 figure. 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.

³ If users wish to compare the value of one unit of savings (e.g., without considering the magnitude of savings, impacts of participation or measure lifetime), they can use the Shape Only analysis.

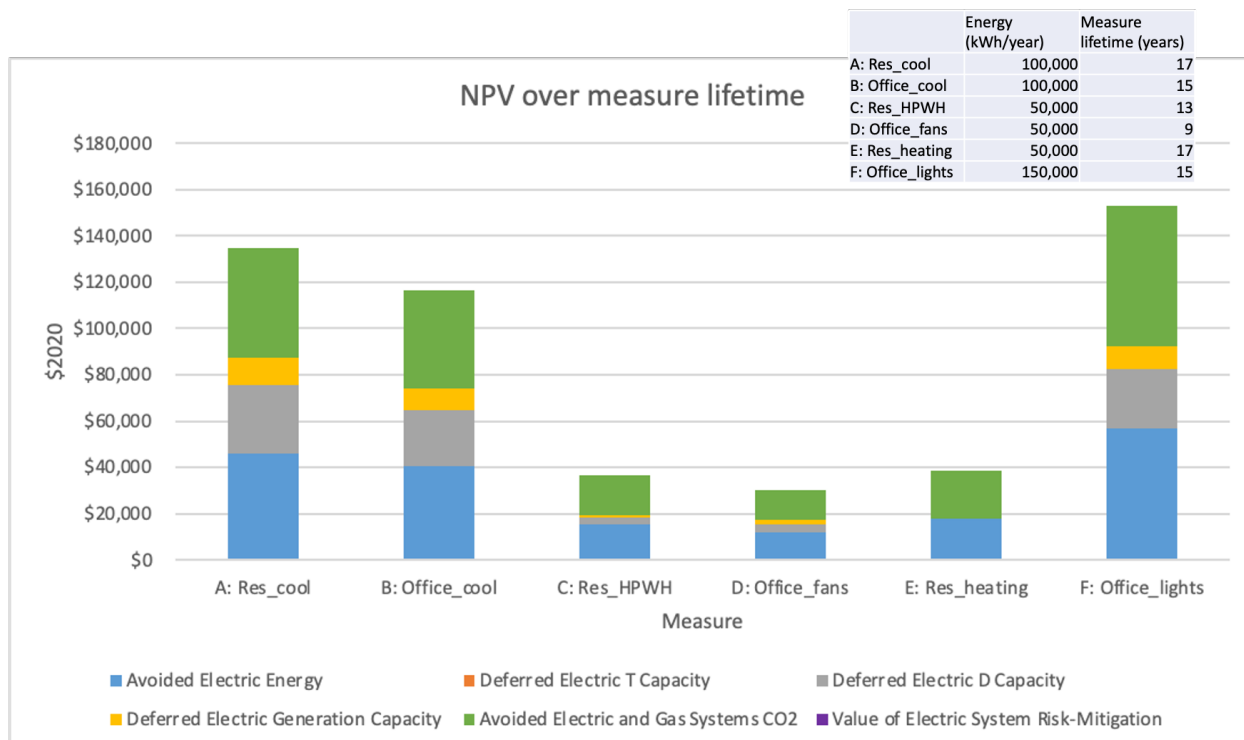


Figure 2. Shape+ analysis output for six example programs in Texas

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 is an example of the Calculator's estimated value of six end-use shapes (used as a proxy for savings shapes), using the same measures as the previous figure, considering one year of measure savings, as shown in the table at the top of the figure. 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.

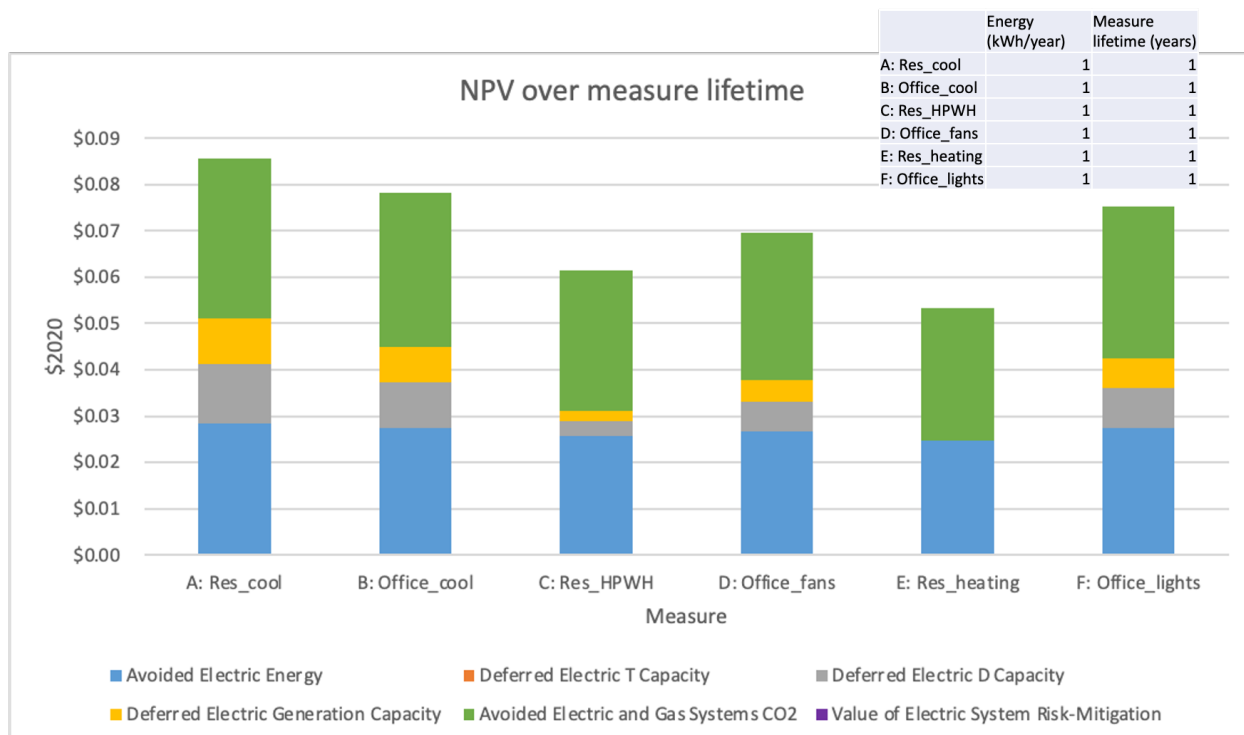


Figure 3. Shape Only analysis output for six Texas end-uses

Calculator Inputs

The Calculator has five main input groups (Table 1). This paper, which is an introduction to the Calculator, is abbreviated and does not describe all of the inputs or provide all of the steps to using the calculator. Berkeley Lab published a *Time-sensitive value calculator for energy efficiency and other distributed energy resources: User manual* that provides a comprehensive, step-by-step description of how to use the Calculator and potential sources for input data (Frick, Carvalho, and Pigman 2022). Here, we discuss the two primary inputs – value streams and measure shapes.

One of the primary Calculator inputs is value streams. The deployment of measures 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, the measure's economic value depends on the cost, timing, and magnitude of required investments in these utility system assets. Typically, for efficiency measures, the hourly avoided cost inputs represent this economic value.

The Calculator focuses on the utility system value streams that accrue to the measures considered in the analysis (e.g., 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. 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.

The Calculator can consider up to five hourly and one annual value streams:

- **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.
- **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.
- **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.
- **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.
- **Emissions costs** are determined based on the assumed cost of carbon dioxide or other greenhouse gases emitted by the electric system.
- **Electricity system risk mitigation** is derived from reduced dependence on factors such as fuel prices and changes in technology (Frick, Schwartz, and Taylor-Anyikire 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.

Because the values for all of these inputs are supplied by the user, they can determine what the exact definitions are for their particular analysis.

Table 1. Calculator input names and descriptions

Input Name	Input Description
Model-wide parameter inputs	• analysis years • discount rates • line losses, • inflation rate
Value stream	Hourly data in \$/megawatt-hour (MWh) for each value stream in all analysis years
Measure shape	Hourly measure shapes ⁴ for each measure for a representative year
Electricity system shape	Hourly electricity system load at the bulk power system level for each analysis year
Measure lifetime	Measure names, descriptions, and lifetimes

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.

Another primary input is measure shapes, which indicate when and how much energy is being consumed, saved, or generated (Figure 5). Measure shapes could include energy savings shapes, end-use load shapes (as a substitute for energy savings shapes) or distributed photovoltaic annual hourly production.

If a user does not have hourly measure shapes for their specific use case, NREL’s ResStock and ComStock end-use load profiles (EULPs) provide residential and commercial building energy consumption by end-use at a 15 minute resolution for residential and commercial buildings (Wilson et al. 2022). The ResStock and ComStock website “data viewers” allow users to download building interval data at a variety of levels of geographic aggregation.⁶ 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. Users can also find measure shapes through Berkeley Lab’s end-use load profile library⁷ and the simulated consumption of 16 building types available on Open EI.⁸ See Mims, Eckman, and Goldman

⁴ The measure shapes can be end-use, savings or generation profiles. For brevity, they are referred to as “measure shapes” everywhere 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. See Mims, Eckman, and Goldman (2018).

⁵ The Cambium dataset can be accessed at <https://www.nrel.gov/analysis/cambium.html>. For this analysis, Cambium data was used for all inputs except the measure shape.

⁶ NREL’s end use load profiles can be accessed at <https://www.nrel.gov/buildings/end-use-load-profiles.html>

⁷ The inventory is published as a spreadsheet and lists publicly available sources of hourly end-use load profiles (Frick 2019).

⁸ <https://data.openei.org/submissions/153>

(2017) for a discussion on the availability and challenges with using end-use and savings profiles.

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 5. Inputting measure shapes

Calculator Outputs

The calculator has seven preset outputs.⁹ The first output is the NPV of the value of the selected measures over their lifetime by value stream. It is reported as a stacked bar chart that displays the NPV of each measure by value stream. Figure 6 is an example of this output.¹⁰ The measures included in the analysis are listed on the horizontal axis, and the NPV of the measures by value stream are listed on the vertical axis. In this example, office lighting has the highest NPV. Avoided carbon dioxide emissions generates the majority of the value, followed by avoided energy costs.

⁹ The example analysis in this paper relies on Cambium data for all inputs except for the end-use load profiles. The user has access to several detailed intermediate and final results tables that can be used to produce other summary and visualization results.

¹⁰ This example is calculated using data from Cambium, ResStock and ComStock end use load profiles, and the Interagency Working Group on Social Cost of Greenhouse Gases. See Frick, Carvallo, and Pigman (2022) for more details.

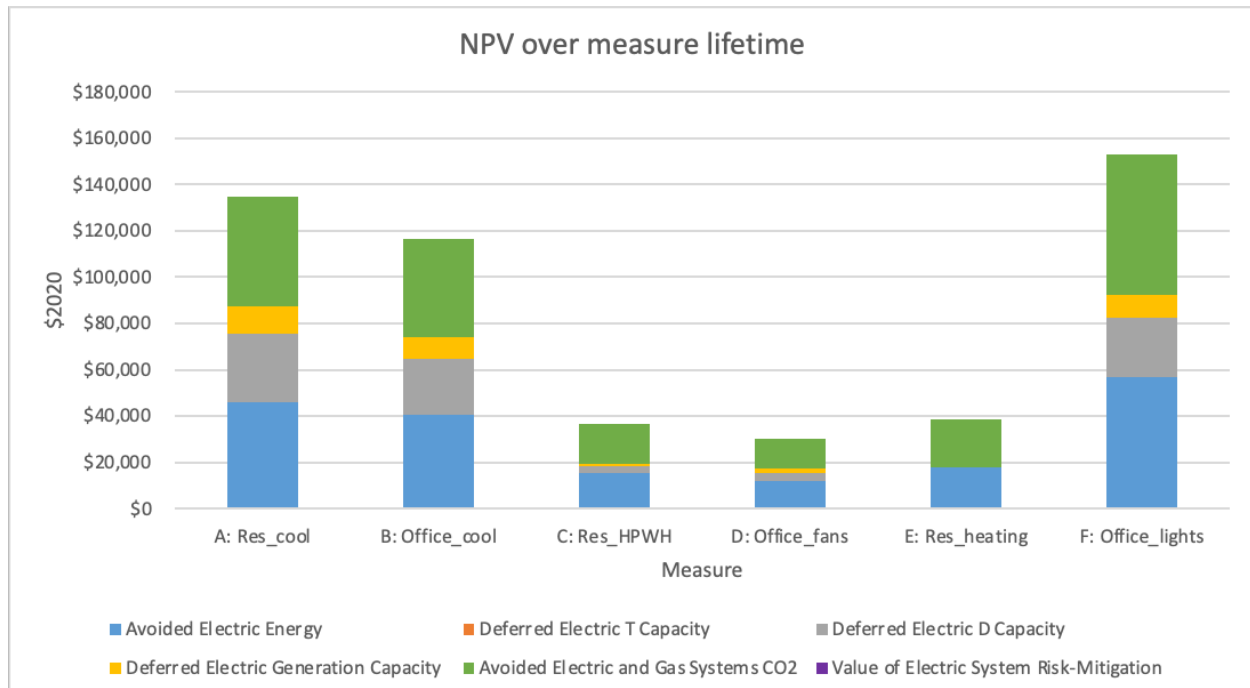


Figure 6. NPV of each measure over its lifetime by value stream (Shape+)

The second output is the hourly value of a select measure for a selected day by value stream. It is reported as a stacked bar chart of each measure by value stream, but is only representative of a single day of measure impact, rather than over the impact over the lifetime of the measure. Figure 7 is an example of this input. The measures and day selected for the analysis is shown in the title at the top of the chart. In this example it is the value of residential cooling savings on June 26, 2022. The horizontal axis is the hour of the day and the vertical axis is dollars. The results are presented in real dollars from the base year and no discount rate is applied (i.e. it is not a net present value). The stacked bars indicate the value of residential cooling by value stream. In Figure 7, hours 12-17 produce the most value from deferred generation and distribution capacity.

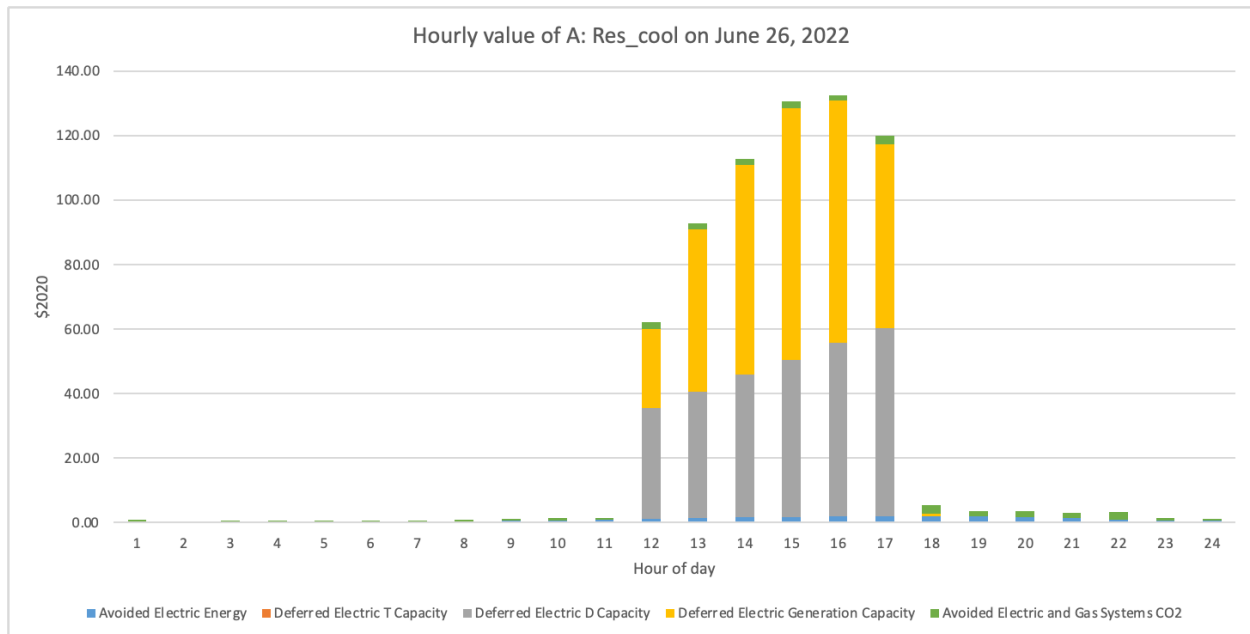


Figure 7. Hourly value by stream for selected day and measure

The third output is a visualization of the electricity system shape and the measure shapes selected for the analysis for a user-defined day (Figure 8). The day selected for the analysis is shown in the title at the top of the chart. In this example it is June 26, 2022. The measures included in the analysis are shown in the legend. The horizontal axis represents hours of the day and the vertical axis shows the percent the measure shape and electricity system shape are relative the annual maximum value. In Figure 8, office lights and office plug loads reach 100 percent of their annual maximum in hour ending 11. The electricity system reaches its annual maximum in hour ending 16. This indicates that savings that occur during hour ending 16 will be aligned with the system peak, and therefore more valuable.

The remaining outputs are tables that users can use for analysis. The first tabular output identifies the average hourly value for selected measures by value stream by hour in each month and analysis year (Figure 9). Users can filter and sort the results by measure, value stream, month, hour of the day or year of the analysis. For example, a user could identify the average value of one, or multiple measure shape for hour ending 16 in July, for all years of the analysis.

The second and third tabular outputs are similar, but identify the average hour value for selected measures by value for a specific day (e.g., June 26, 2022) or by each year of the analysis (e.g., 1 am is the average of hour ending 1 am for every day in the year).

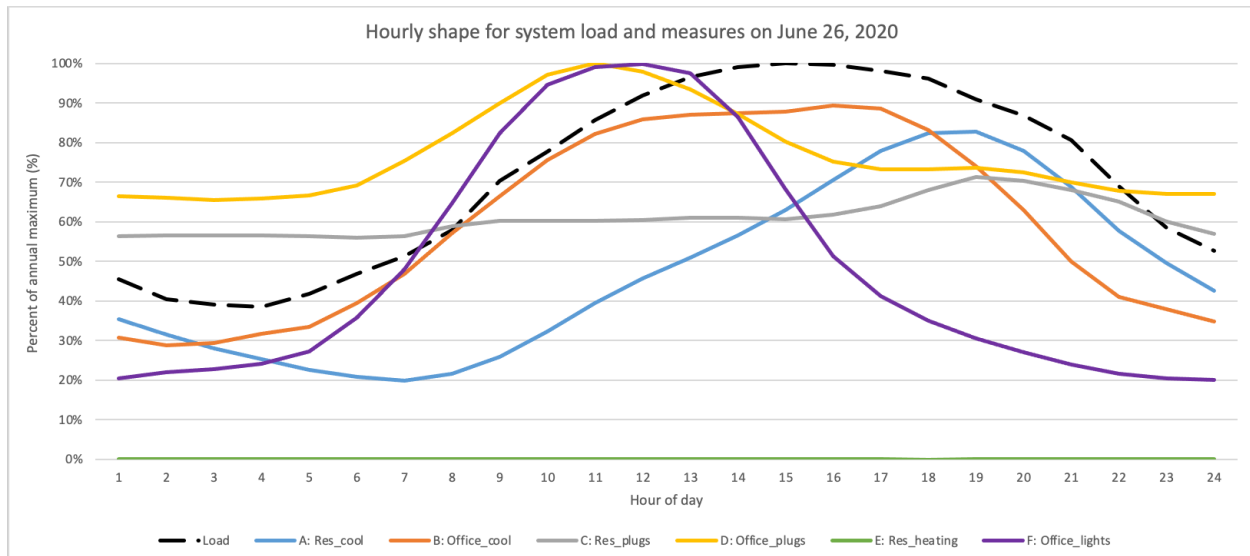


Figure 8. Hourly shape for system load and measures

measure	stream	month	Hour	20	20	20	20	20	20	20	20	20
A: Res_cool	Avoided Electric Energy	1	1	0.00307	0.00325	0.00277	0.00348	0.00336	0.00313	0.00252	0.00263	
A: Res_cool	Avoided Electric Energy	1	2	0.00201	0.00211	0.00203	0.00244	0.00255	0.00150	0.00142	0.00155	
A: Res_cool	Avoided Electric Energy	1	3	0.00152	0.00162	0.00147	0.00183	0.00190	0.00136	0.00110	0.00112	
A: Res_cool	Avoided Electric Energy	1	4	0.00134	0.00142	0.00131	0.00158	0.00166	0.00129	0.00094	0.00093	
A: Res_cool	Avoided Electric Energy	1	5	0.00124	0.00128	0.00131	0.00147	0.00153	0.00123	0.00107	0.00084	
A: Res_cool	Avoided Electric Energy	1	6	0.00110	0.00113	0.00112	0.00129	0.00134	0.00131	0.00092	0.00066	
A: Res_cool	Avoided Electric Energy	1	7	0.00130	0.00142	0.00125	0.00146	0.00148	0.00148	0.00110	0.00088	

Figure 9. Annual value by selected measure and value stream by month, hour and year

The final tabular output identifies the total value for each hour of the day in all years of the analysis, by selected measure shapes and value streams (Figure 10). Users can compare the annual values of each measure or value stream selected in the analysis.

measure	stream	2020	2022	2024	2026	2028	2030	2040	2050
A: Res_cool	Avoided Electric Energy	3022.268	3120.633	3186.061	4429.249	3776.844	3526.971	3116.636	2956.576
A: Res_cool	Deferred Electric T Capacity	0	0	0	0	0	0	0	0
A: Res_cool	Deferred Electric D Capacity	1360.79	1580.405	1803.406	2123.413	2486.693	3047.906	6214.963	11064.54
A: Res_cool	Deferred Electric Generation Capacity	1042.604	1070.646	1068.906	821.3245	761.4229	677.2078	2720.637	2150.532
A: Res_cool	Avoided Electric and Gas Systems CO2	3671.326	3656.476	3581.79	3485.981	3423.578	3686.78	4011.47	4424.145

Figure 10. Annual value by selected measure and value stream

Next Steps

Berkeley Lab completed building the Calculator in February 2022. Hundreds of users from public utility commissions, state energy offices, consumer advocates, cities, academia, independent system operations (ISOs); investor owned, municipal and cooperative utilities, and consultants have downloaded the calculator. We will continue to seek feedback from users on features that are useful and suggestions for improvement. As additional measure shapes, and in particular savings shapes, are developed, we will include those resources in updates to our user manual.

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