Tool Documentation

INDUSTRIAL DECARBONIZATION TOOLKIT

https://industrialdecarb.lbl.gov/

USER GUIDE FOR ELECTRIC LOAD PLANNING TOOL

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Table of Contents

Introduction

Load planning involves "strategic, long-term actions that affect the" electrical consumption profile of a facility's normal operation (Miller, 2020, p.5). A facility can shape its electrical demand through load shifting, load shedding, or electrification (load addition). Load shifting refers to "the ability to move or time" when loads occur, essentially a temporal manipulation of electrical demand (Nandy et al., 2022, p.17). On the other hand, load shedding solely involves reducing electricity consumption during a specific period (Nandy et al., 2022). Collectively, load shifting and load shedding can be grouped under the umbrella term demand management, load management, or demand response (Summerbell et al., 2017).

Changing a facility's electricity consumption patterns through load management can affect its electricity costs and scope 2 CO_2e emissions. Both electricity costs and scope 2 emissions associated with electricity consumption vary spatiotemporally because both electricity rates that determine costs and grid electricity emissions factors that determine scope 2 emissions differ based on location and the time of day. This is because grid regions with a greater penetration of renewables in the mix, particularly solar and wind are characterized by periods of excess renewable output in the grid mix which typically lowers both the grid carbon intensity and wholesale electricity prices. The alignment of cheaper and cleaner electricity in the middle of the day is often reflected in lower retail prices and lower scope 2 emissions for consumers with a greater portion of their demand occurring during periods of surplus renewables output. On the cost side, Time-of-Use retail electricity rates make it cheaper for facilities to consume electricity during periods of surplus renewable generation. On the scope 2 side, the lower emissions associated with consuming electricity during surplus renewable generation periods can be captured in hourly emissions factors.

Therefore, load planning has the potential to yield both cost and carbon savings when a facility aligns the timing of its electricity consumption with periods of excess renewable generation. Nonetheless, the complexities of Time-of-Use (TOU) retail electricity tariffs and more granular scope 2 emissions accounting need to be analyzed for a facility's load profile to better understand and estimate the electricity cost and scope 2 emissions reductions that load planning can facilitate. The Electric Load Planning Tool (ELPT) is an R-Shiny-based online web application to help a facility grasp the electricity bill and scope 2 emissions impacts of its electricity consumption, and the potential of load planning to help generate both cost and emissions savings. The tool requires inputs on a facility's load profile, its location and year of analysis, and its electricity billing tariff. The web application produces as its primary outputs visuals illustrating the cost and carbon impacts linked to a facility's electricity consumption.

How to Use the Tool

This section explains how to use the Electric Load Planning Tool. Please follow the steps outlined below in the correct order to avoid errors. The tool's web app provides further guidance in the form of "**?**" symbol pop-ups attached to the key steps and inputs in the tool's user interface. You can hover your cursor on these pop-ups to receive hints and suggestions on how to proceed with each step.

Step 1a: Select Your Load Profile Data Type & Date Range:

First, select the source for your load profile data (Figure 1). The tool lets you derive and submit your load profile data through the following sources.

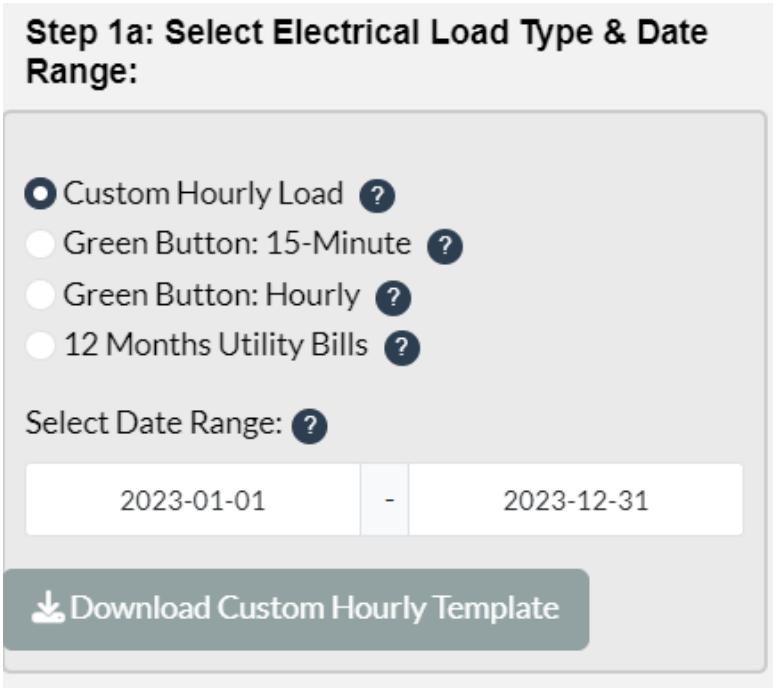

Figure 1: Selecting Load Profile Data Type & Date Range

Custom Hourly Load Profile

- An Excel input sheet to copy and paste your hourly load profile values.
- After selecting the Custom Hourly Load Profile Option, provide the date range corresponding to your hourly load profile values in the "Select Date Range" input boxes. *Do not select a date range that spans more than one calendar year*, as the tool's current version cannot analyze data exceeding more than one calendar year. Please make sure that your entered start date (first box in the "Select Date Range" section) does not exceed your entered end date (second box in the "Select Date Range" section).
- Click the Download Custom Hourly Template button and open the downloaded Excel file (Figure 2). Copy and paste your load values in the Load (in kW) column highlighted in yellow. These values should correspond to the date and time stamps in the

Date_Time column. The dates in the Date_Time column correspond to the date range selected in the previous step.

- Representative default load values have been provided for your convenience. You can overwrite these with your hourly load input values by pasting them in the Load (in kW) column.
- After pasting your load values, save and close the Excel file.
- Your load profile data is now ready to be uploaded to the tool.

Date_Time	Load (in kW)	hours	month	Day
2022-01-01 00:00:00	276.5069	1	January	1
2022-01-01 01:00:00	273.6742	2	January	1
2022-01-01 02:00:00	276.5669	3	January	1
2022-01-01 03:00:00	277.9939	4	January	1
2022-01-01 04:00:00	277.0734	5	January	1
2022-01-01 05:00:00	276.7004	6	January	1
2022-01-01 06:00:00	281.5253	7	January	1
2022-01-01 07:00:00	277.78435	8	January	1
2022-01-01 08:00:00	275.61605	9	January	1
2022-01-01 09:00:00	266.7784	10	January	1
2022-01-01 10:00:00	264.7216	11	January	1
2022-01-01 11:00:00	263.8083	12	January	1
2022-01-01 12:00:00	261.7266	13	January	1
2022-01-01 13:00:00	260.5731	14	January	1
2022-01-01 14:00:00	265.83075	15	January	1
2022-01-01 15:00:00	274.6743	16	January	1

Figure 2: Custom Hourly Load Profile Excel Template

12 Months' Utility Bills

(see Worked Example: 12 Months Utility Bills for further details)

- An hourly load profile for all 8,760 hours of the year is computed based on data from your utility bill for the past 12 months.
- After selecting the 12-Month Utility Bill Option, click the Download 12-month bills template button to download an Excel sheet.
- Open the Excel sheet and fill in the values for Energy Usage (kWh) and Billed Demand (kW) in each month of the year of your analysis. Illustrative default values have been provided for your convenience —fill in your input values by overwriting these defaults.
- Scroll to the right and answer three simple questions about your facility's operation, such as operation start and end time, estimated peak hour, and operation during weekends.
- Save and close the file. Your load profile data is now ready to be uploaded to the tool.
- The operation of the utility bills is based on its monthly energy usage (kWh), billed demand (kW), and hours of operation. Then, average daily energy usage is calculated by dividing monthly energy usage by the number of days. For each day, an hour that the user selected in the Excel input sheet will be designated as the peak hour for the year. That one-hour time window is assigned the monthly peak demand values. For the non-operational hours during weekdays and weekends, 30% of the peak demand is assigned as the baseload for the facility. The remaining hours are considered mid-

demand and are based on the remaining load after accounting for peak- and base-load hours.

Green Button: 15-minute or Hourly[1]

- This source of hourly sub-hourly load profile data (at the 15-minute interval) should be available for download from your utility's website as a .XML format file. Please visit your utility's website to download your green button file.
- After selecting the Green Button: 15-Minute or Hourly option and downloading your green button file from your utility's website, provide the date range corresponding to the load profile data you downloaded in the previous step.
- Your downloaded green button load profile data is ready to be uploaded to the tool.

Step 1b: Upload Load Profile

Click the browse button to locate and upload the load profile data file you derived in step 1a.

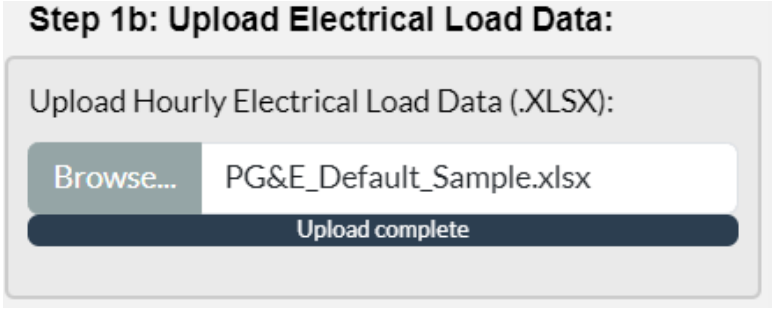

Figure 3: Uploading Load Profile Data

Step 2: Choose GHG Emission Parameters

Select GHG Emissions Forecast:

- Select one of the following emissions factors (Figure 4):
  - Select the year for which you want to analyze your scope 2 emissions impacts using hourly average emissions factors (kg/MWh) sourced from the standard mid-case scenario of NREL's Cambium database (Gagnon et al., 2023). Note that NREL Cambium only includes forecasted hourly data for even years. In our tool, however, for odd years, we employ the emissions factors of the preceding even years.
  - Or select the US EPA's 2022 static average annual emissions factor (kg/MWh) **[Not recommended for this tool][2]**

[1] https://www.greenbuttondata.org/

[2] A static annual average emissions factor cannot analyze the impacts of changing load shapes at the hourly resolution.

- Also, select the estimated percentage of clean electricity utilized by the facility through the purchase of Renewable Energy Certifications (RECs), Power Purchase Agreements (PPAs), and/or onsite electricity generation

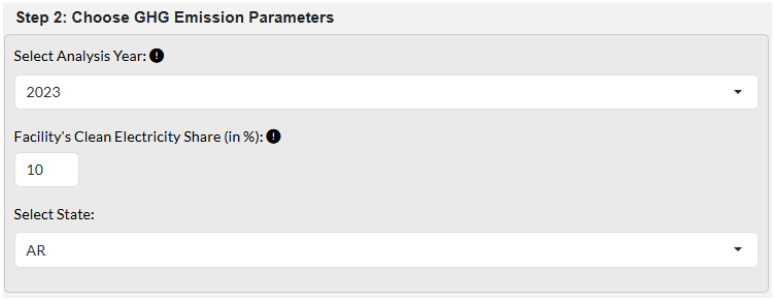

Figure 4: Choose GHG Emissions Parameters for the analysis

Step 3a: Your Rate Structure

This step asks you a few simple questions to understand the outline of your rate structure (Figure 5). Please consult your electricity bill or visit your utility's website to learn more about your rate structure.

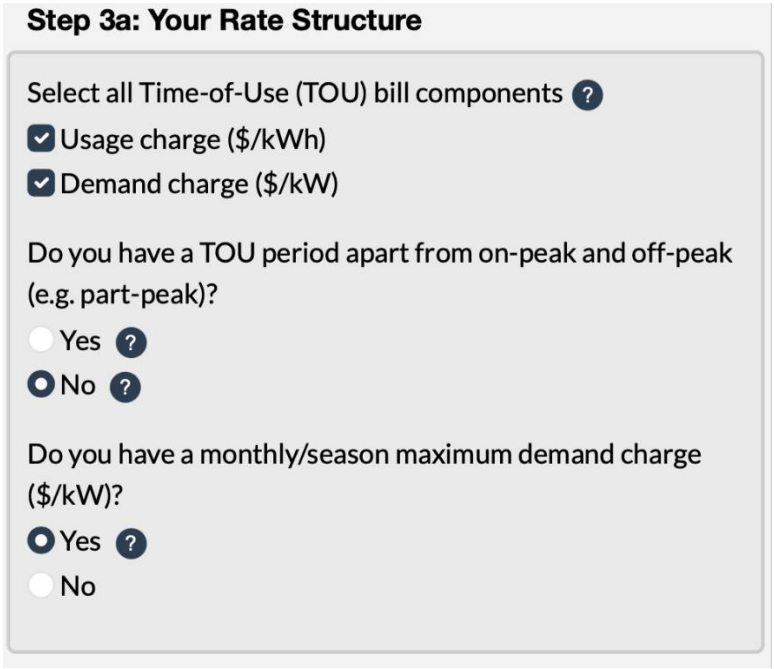

Figure 5: Questions to Understand Your Rate Structure

Select all Time-of-Use (TOU) bill components:

- Check all charges applied to your bill that have a TOU dimension, i.e. a varying/unique charge for each TOU period.
- If you have a varying usage charge ($/kWh) for each TOU period but a fixed demand charge ($/kW) that does not change based on the time of day, check the usage charge and uncheck the demand charge.

- If you have a varying demand charge ($/kW) for each TOU period but a fixed usage charge ($/kWh) that does not change based on the time of day, check the demand charge and uncheck the usage charge.
- If neither the usage nor demand charges applied to your bill have a TOU dimension, uncheck both options.

Do you have a TOU period apart from on-peak and off-peak (e.g. part-peak)?

- This question is applicable and will only be visible as an input if at least one charge applied to your bill varies with TOU periods. Please see the previous question.
- Select Yes if you have a third TOU period apart from on-peak and off-peak; otherwise, select No.

Do you have a monthly/seasonal maximum demand charge?

A fixed monthly/seasonal demand charge levies a $/kW cost on the highest demand (kW) in the summer and winter months, regardless of the TOU period in which this demand occurred. This demand charge applies independently of TOU and may or may not be paired with a separate TOU demand charge.

- Select Yes if your rate structure has a fixed monthly/seasonal demand charge. Otherwise, select No.

Step 3b: Enter Electricity Rate Schedule Info

Based on the rate structure specified in step 3a, in step 3b, you can provide inputs on the billing seasons, TOU hours, and the charges levied as part of your electricity bill (Figure 6). The information required in this section can be found in your electricity bill. Please check your utility's website if the information in your bill is insufficient to fill the inputs required in this section.

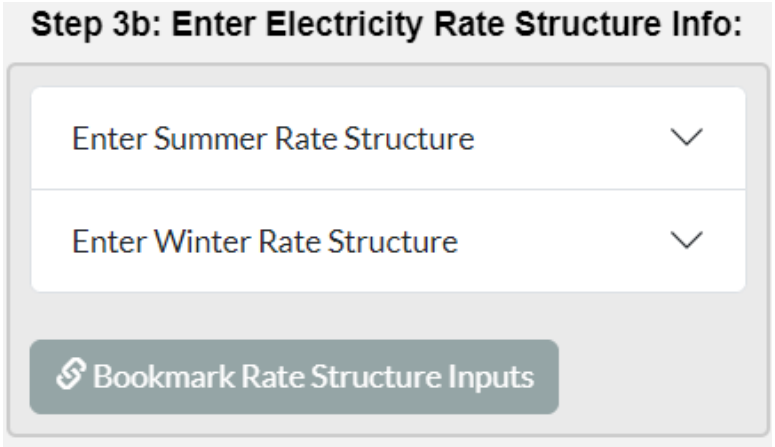

Figure 6: Entering Your Rate Schedule Info

Enter Summer and Winter Rate Structure

- Provide inputs on the billing months that fall in the summer and winter season bracket (Figure 7).
- If you have a rate structure with only a fixed usage charge and fixed monthly maximum demand charge (see step 3a), you do not have to provide any TOU-related inputs.
- For rates with a TOU dimension to either usage or demand charges but no third TOU period apart from on-peak and off-peak (see step 3a), select the chunk of hours in a day that falls within the on-peak bracket using the on-peak start and end hour dropdown box. All hours that are outside the on-peak bracket are considered off-peak.
- For rates with a TOU dimension to either usage or demand charges and a third TOU period apart from on-peak and off-peak, such as part-peak (see step 3a), select the chunk of hours in the day that falls within the on-peak, off-peak, and part-peak bracket using the start and end hour dropdown boxes for each TOU period.
- If applicable, provide your on-peak, off-peak, and part-peak usage and demand charge rates.

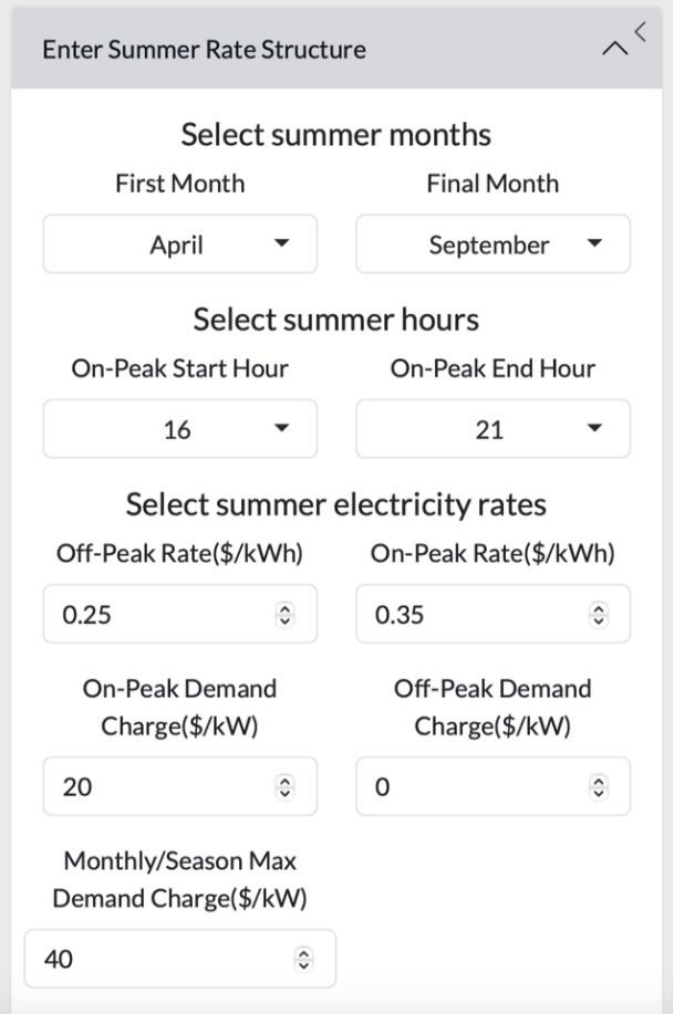

Figure 7: Entering Summer Season Rate Inputs

Bookmark Rate Structure Inputs

Click the "Bookmark Rate Structure Inputs" button (Figure 6) at the end if you wish to save and restore the electricity rate parameters you specified in steps 3a and 3b. Copy the URL in the dialogue box that appears on the screen and paste it into your browser to restore your rate inputs.

Step 4: Enter Load Management Inputs

Type of load management

Select the type of load management you want to use to shape your load profile (Figure 8). You can shift load from one period to another or add or shed load over a given period.

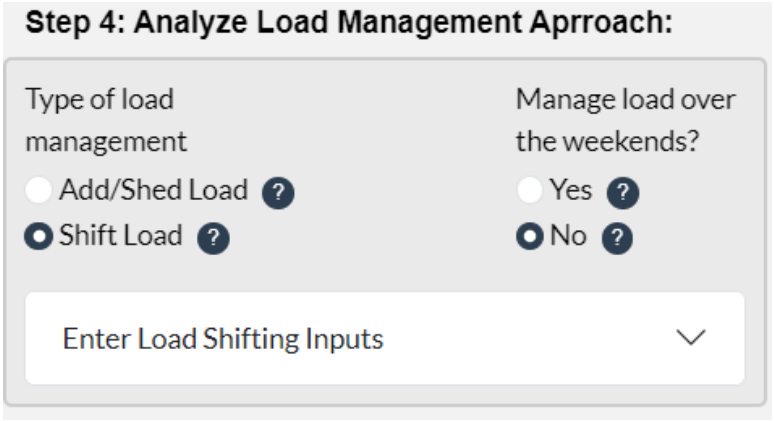

Figure 8: Enter Load Management Inputs

Manage load over the weekends?

Select “Yes” if you want to execute your load-shaping decisions over the weekdays and weekends and “No” if you want only to shape your load during weekdays (Figure 8).

Enter Load Shifting Inputs or Enter Load Addition/Shedding Inputs

Select Input Method:

You can provide your load management inputs by either entering them manually or uploading an existing spreadsheet (Figure 6b, 6c, and 6d).

- *Manually Enter Shaped Load(s) or Manually Enter Added Load(s)*: For load shifting, provide a positive numeric value for the flexible load (in kW) you want to shift and use the sliders to specify the hours of the day you want shift load from and to (Figure 9). For adding or shedding loads, specify a positive (for adding) or negative (for shedding) load value (in kW), and use the slider to specify the range of hours when you want to add or shed load (Figure 9).

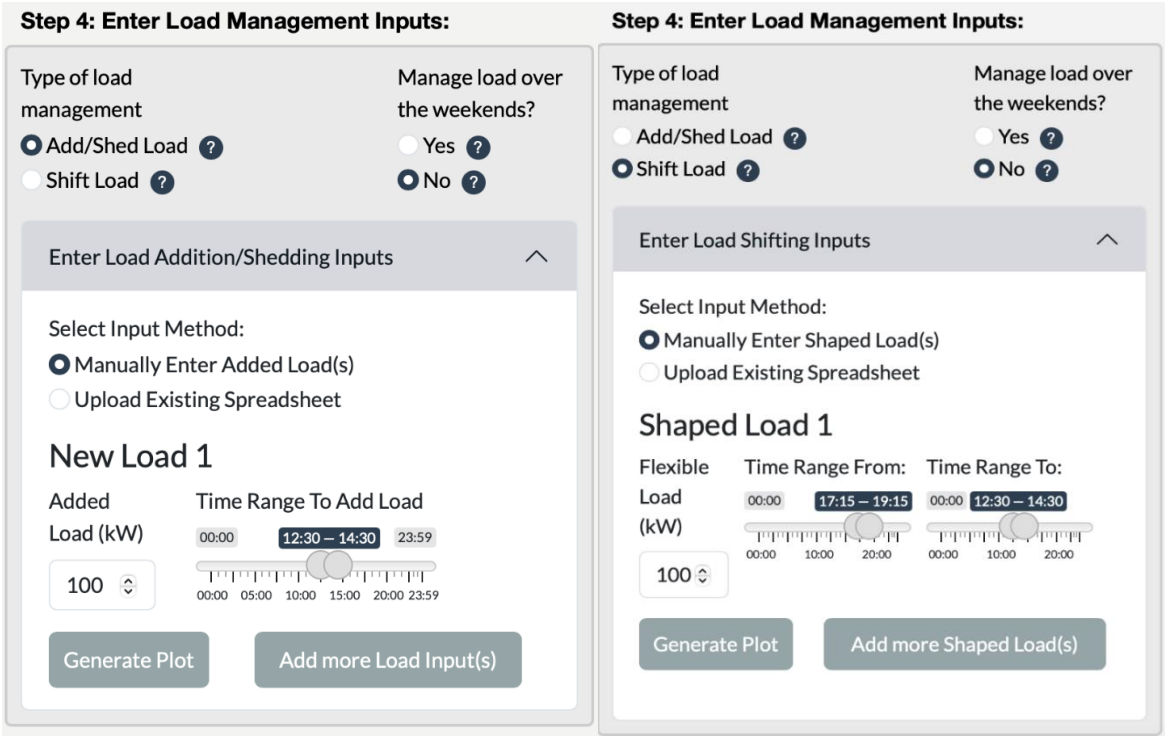

Figure 9: Entering Load Addition/Shedding Inputs

- *Upload Existing Spreadsheet*: You can also enter the loads you want to shape from a spreadsheet (Figure 10). Scroll down to the end of the sidebar and click the Download Input Data button to download the “input_data" Excel sheet. Open the Excel sheet and overwrite the default entries with values of the load you want to shape and the range of hours you want to shift load from and add load to. Follow the entry format as set in the default values. Save and close the Excel sheet once you have entered your load management inputs. Select the "Upload Existing Spreadsheet" option if you have not done so already, and then click browse to find and upload the “input_data" Excel sheet you filled out before.

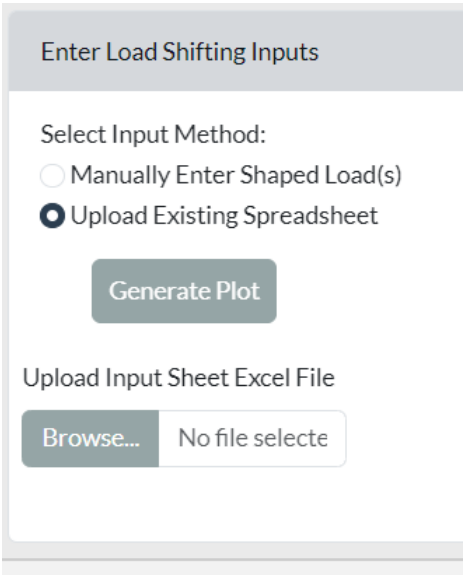

Figure 10: Upload Inputs from Spreadsheet

Generate Plot Button:

- After you have provided your load management inputs, press the generate plot button to generate plots. These plots help visualize the impact of your load management decisions on your load profile, electricity costs, and scope 2 CO_2e emissions.

Outputs

Load Profile Plot

The first plot shows your load profile (Figure 11), starting with your baseline load shape when you upload your load profile file and followed by a modified load after you enter all the steps' inputs and press generate plot.

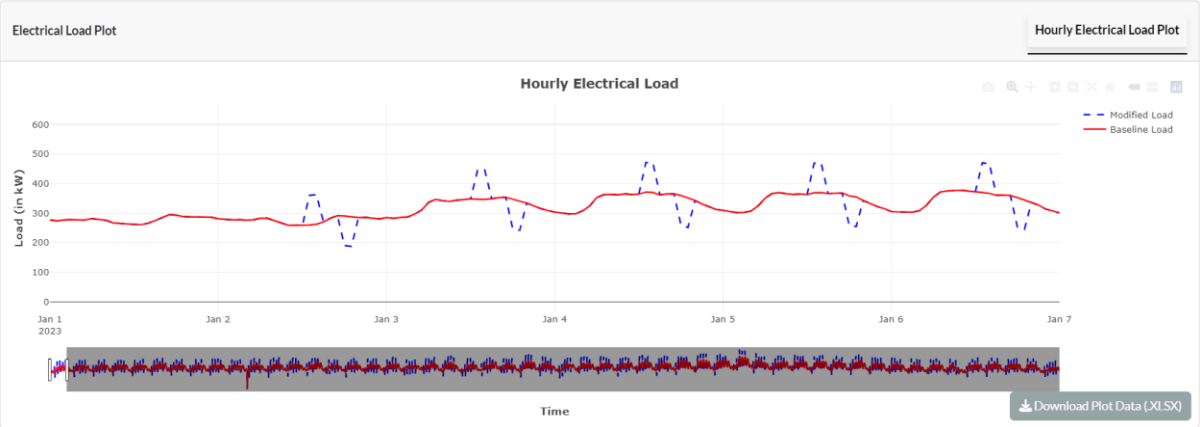

Figure 11: Load Profile Plot Output

CO_2e Plots

Electric Grid CO_2e Emissions Factor

In this panel, after you have selected your GHG emissions parameters in step 2, you can view a time series showing the hourly variation in the grid CO_2e emissions factor for your selected state and year (Figure 12).

Facility Hourly CO_2e Emissions

If you have completed steps 1 and 2 of uploading your load profile and selecting your emissions parameters, respectively, you will be able to view this plot (Figure 13) showing the hourly or sub-hourly variation in your facility's scope 2 CO_2e emissions (i.e., your hourly or sub-hourly electric load multiplied by the grid emissions factor). After you have completed all the steps and executed your load management decisions, this plot will also show you the facility's modified emissions profile associated with its shaped load.

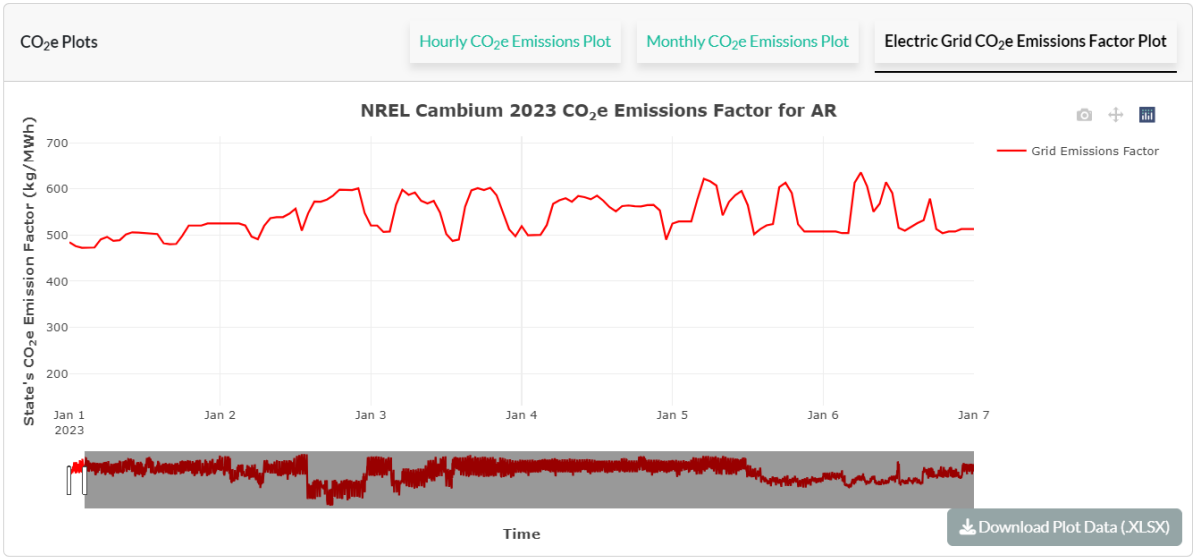

Figure 12: Electric Grid Emission Factors

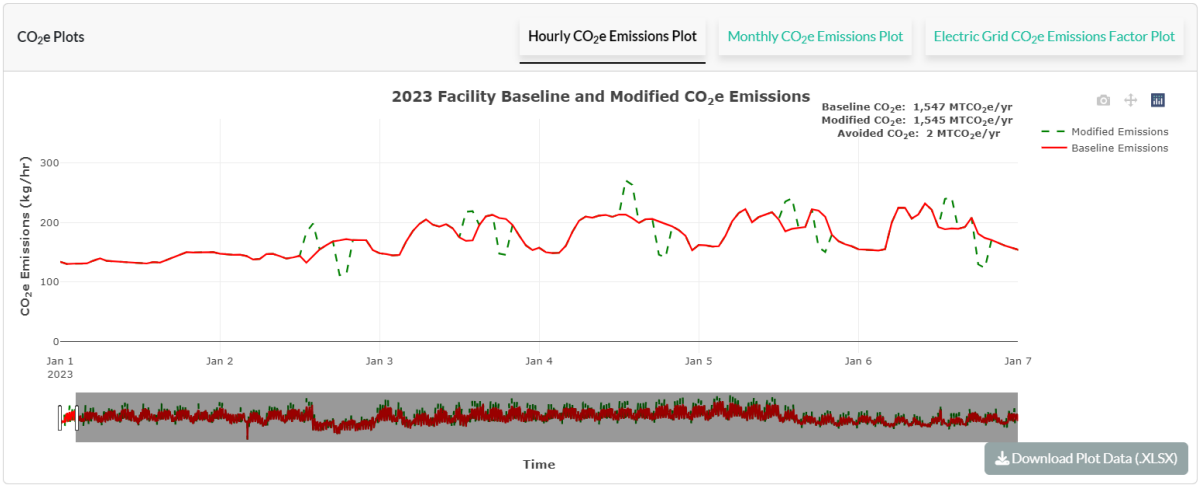

Figure 13: Facility Baseline and Modified Hourly Scope 2 Emissions Profile

Facility Monthly CO_2e Emissions

If you have completed steps 1 and 2, this plot will show your facility's baseline monthly total scope 2 CO_2e emissions (Figure 14) and also modified emissions following the load shaping.

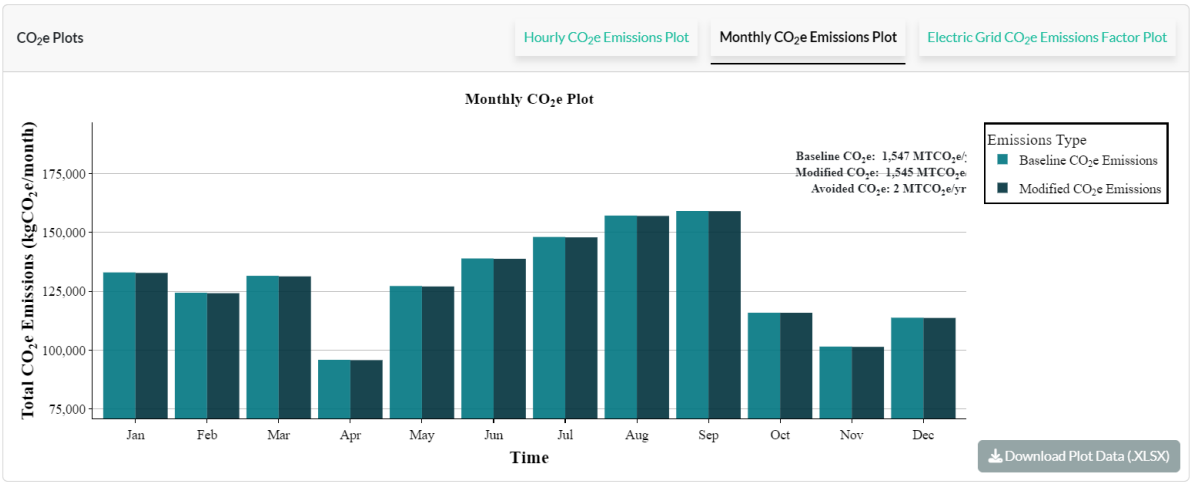

Figure 14: Monthly Baseline and Modified Emissions

Cost Plots

Cost Plot Selected Dates

This plot (Figure 15) initially shows you your baseline load shape's monthly electricity costs (for the date range you selected in Step 1). You can modify the date range in Step 1 to update the time horizon for which this plot shows you your baseline monthly electricity costs. After you click the generate plot button to execute your load management decisions, this cost plot will update to reflect the electricity costs of both your original and your modified load profile (obtained after executing load management action).

Figure 15: Monthly Cost Plot for Selected Dates

Cost Plot Annual

This plot shows an annual summary figure for the total electricity costs, split by usage and demand, for the baseline versus the modified load profile (Figure 16).

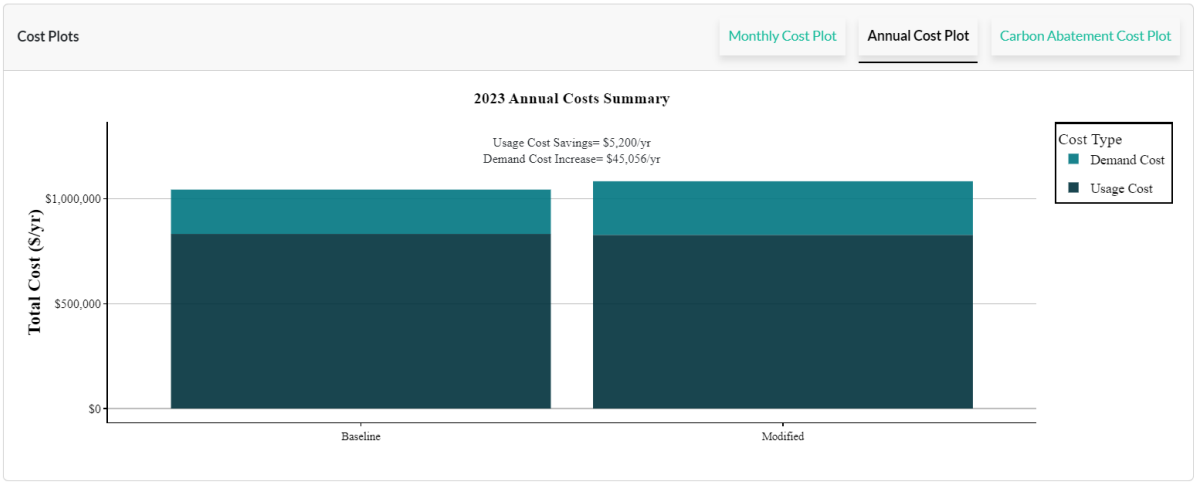

Figure 16: Annual Costs Summar Chart

Abatement Cost Plot

This panel displays a bar chart to show the electricity cost increase or savings delivered with each metric ton of scope 2 CO_2e emissions abated from your load management decisions (Figure 17). The metric shown on the Y axis is $\$/mtCO_2e$, indicating the $ value of the costs or savings per metric ton of scope 2 emissions abated. Each bar, highlighted with a different color, corresponds to a $\$/mtCO_2e$ for each month in the date range that your load profile data contains. A bar in the negative quadrant below the X-axis intercept indicates electricity cost savings associated with the scope 2 emissions abatement caused by your load-shaping decisions. Conversely, a bar in the positive quadrant above the X-axis intercept indicates the electricity cost increase associated with each metric ton of scope 2 emissions abated. The width of each bar on the X-axis corresponds to the quantity of scope 2 emissions abated.

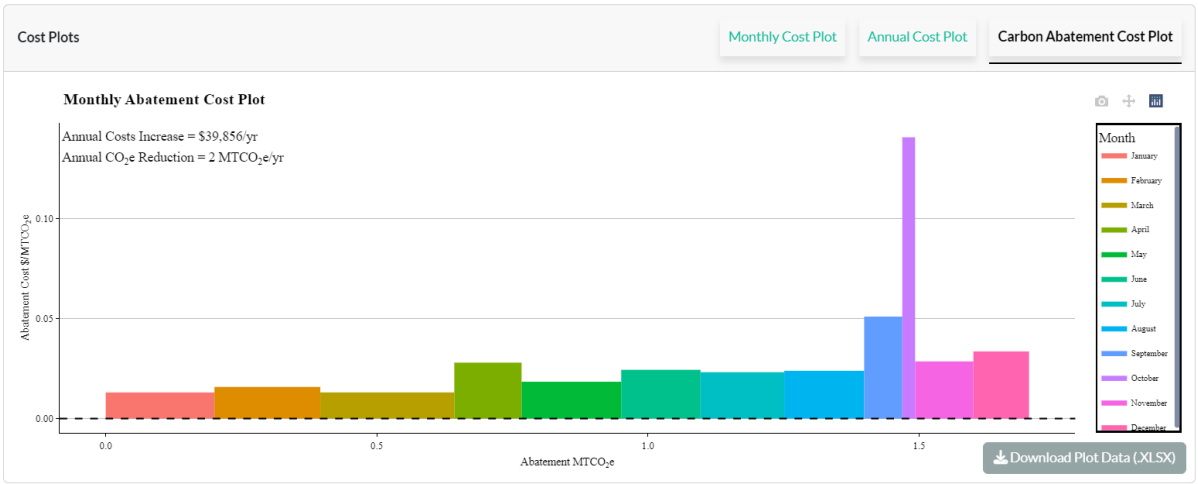

Figure 17: Abatement Cost Plot

Worked Example: For Green Button and Custom Hourly Load Profile Data Types

This section outlines how to use the Electric Load Planning Tool to execute load management decisions and analyze their impacts. The procedure can be split into three steps:

1. Uploading Load Profile Data
2. Selecting Emissions Parameters
3. Specifying Cost Structure
4. Executing Load Management Decisions

Step 1a: Select Your Load Profile Data Type & Date Range

Choose either the Custom Hourly Load Profile or one of the Green Button options based on your available load profile data. Then, choose the date range (2023-01-01 to 2023-12-31 for this example) corresponding to the dates you have available load profile data. If you choose the Custom Hourly option, click the "Download Custom Hourly Template" button to download an Excel template to input your load values (Figure 18). This template comes pre-filled with the date range you previously selected; you only have to open the template file to enter or copy and paste your load values in the 'Load (in kW)' column (highlighted in yellow), corresponding to the date time stamp in the Date_Time column. All other columns, deriving from the date range input provided before, are highlighted in grey and cannot be edited. For this example, we will only use the default pre-populated load values.

	A	B	C	D	E
1	Date_Time	Load (in kW)	hours	month	Day
2	2023-01-01 00:00:00	276.5069	1	January	1
3	2023-01-01 01:00:00	273.6742	2	January	1
4	2023-01-01 02:00:00	276.5669	3	January	1
5	2023-01-01 03:00:00	277.9939	4	January	1
6	2023-01-01 04:00:00	277.0734	5	January	1
7	2023-01-01 05:00:00	276.7004	6	January	1
8	2023-01-01 06:00:00	281.5253	7	January	1
9	2023-01-01 07:00:00	277.78435	8	January	1
10	2023-01-01 08:00:00	275.61605	9	January	1
11	2023-01-01 09:00:00	266.7784	10	January	1
12	2023-01-01 10:00:00	264.7216	11	January	1
13	2023-01-01 11:00:00	263.8083	12	January	1
14	2023-01-01 12:00:00	261.7266	13	January	1
15	2023-01-01 13:00:00	260.5731	14	January	1

Figure 18: Pre-filled Default Values in Custom Hourly Load Profile Template

Choosing one of the Green Button data type options requires you to upload a .XML Green Button file containing your load profile data. You can typically download this file from your utility's website. Please make sure that the dates chosen in the date range input correspond to the dates for which you downloaded your Green Button .XML data.

Step 1b: Upload Load Profile Data

After you upload the load profile data prepared in Step 1a, the Load Profile panel will show you an initial view of your baseline load profile for the time range you selected in Step 1a (Figure 21). Hover your cursor over the red time series line indicating your baseline load to see the load values and their corresponding date and time stamps.

If you move your cursor to the Time axis, you will notice that the plot shows you a week-long subset of your load data by default. You can adjust the temporal resolution of the plot's data using the dynamic scale on the Time axis to zoom in or out over specific periods. Simply hover your cursor on the top of the small white window in the greyed-out space of the time axis, and a ↔ icon will appear. Using your trackpad, drag the ↔ icon across the Time axis to view load profile data throughout your data range. You can also move across the entire period of your load data by clicking the ←↕→ pan icon in the top right corner of the Load Profile panel. To zoom in or out on a particular month, week, day, or hour, drag the left and right sides of the white window in the greyed-out space to expand or collapse the time horizon visible on the plot. To download the Load Profile plot as an image, click the camera icon (📷) on the top right corner of the Load Profile panel.

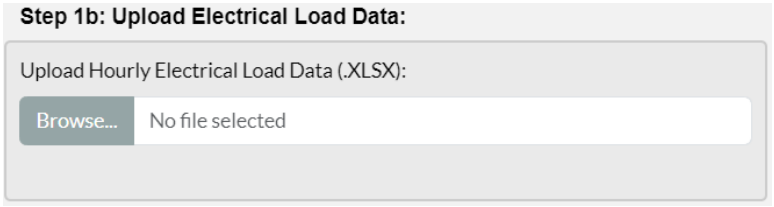

Figure 19: Step 1b Input for Green Button Data

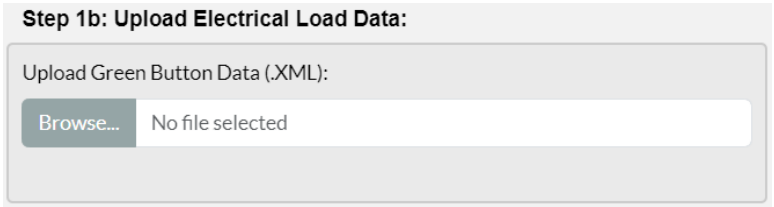

Figure 20: Step 1b Input for Custom Hourly Load Profile Data

After Steps 1a and 1b, the rest of the steps are the same for the Custom Hourly Load Profile data type and the Green Button data type. The remainder of this worked example will focus on the Custom Hourly Load Profile data type to illustrate the functioning of the tool.

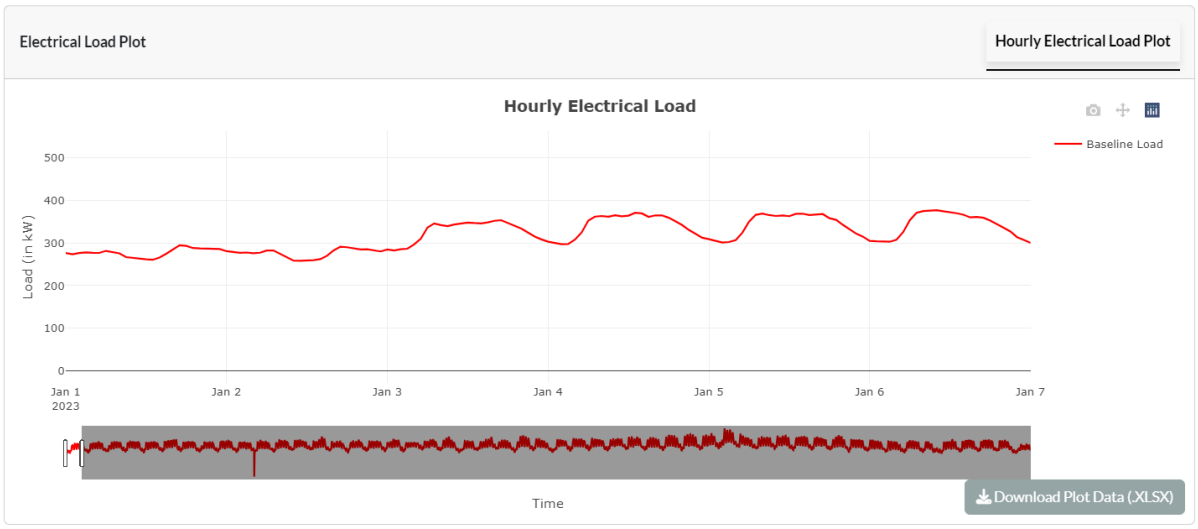

Figure 21: Baseline Load Profile Plot

Step 2: Choose GHG Emission Parameters

In this example, we will choose the default 2023 emissions scenario as it corresponds to the year of our load profile data (Figure 22). In the next dropdown box, select the state in which your facility is located. We will choose California for this work example. Once you have uploaded your load profile data and selected your GHG emissions parameters, the following plots will appear.

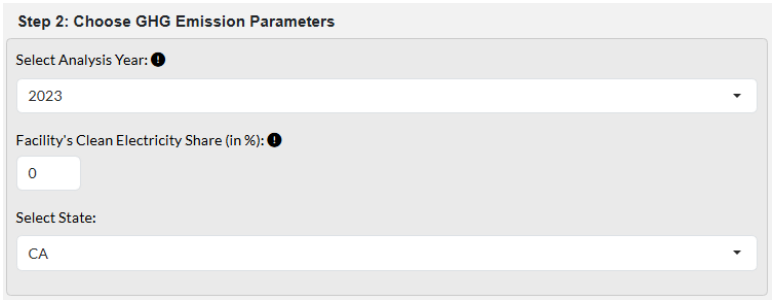

Figure 22: Choosing GHG Emissions Parameters

Facility Hourly CO_2e Emissions

This plot shows you your facility's baseline hourly scope 2 CO_2e emissions (Figure 23). The navigation of this interactive plot is similar to the Load Profile plot (see Step 1b). If you selected and uploaded the Green Button:15 Minute data in step 1, you can also zoom in and view your facility's scope 2 CO_2e emissions at the sub-hourly 15-minute interval (Figure 19).

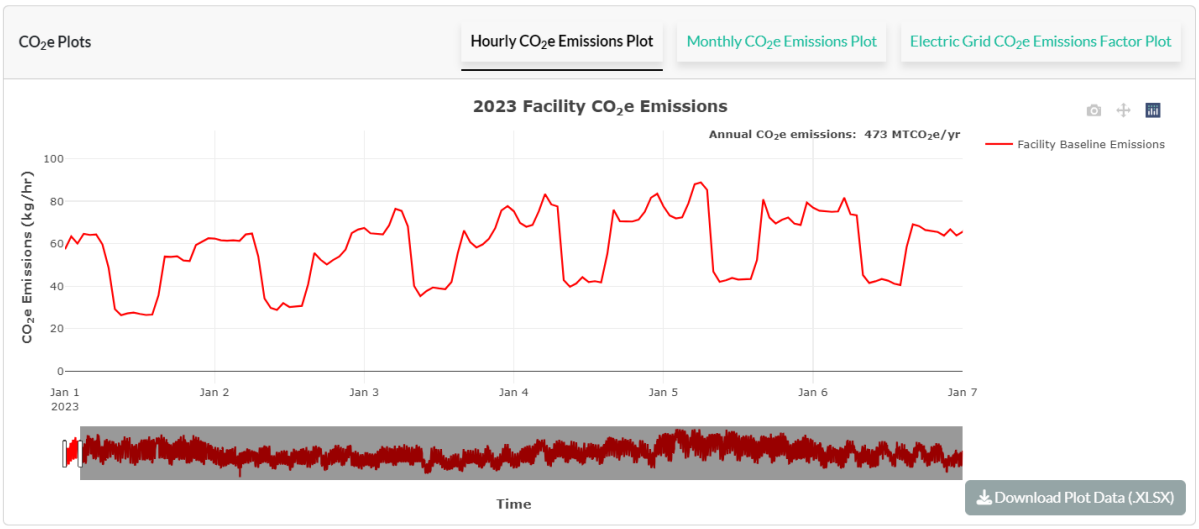

Figure 23: Facility's Baseline Hourly CO2e Emissions Profile

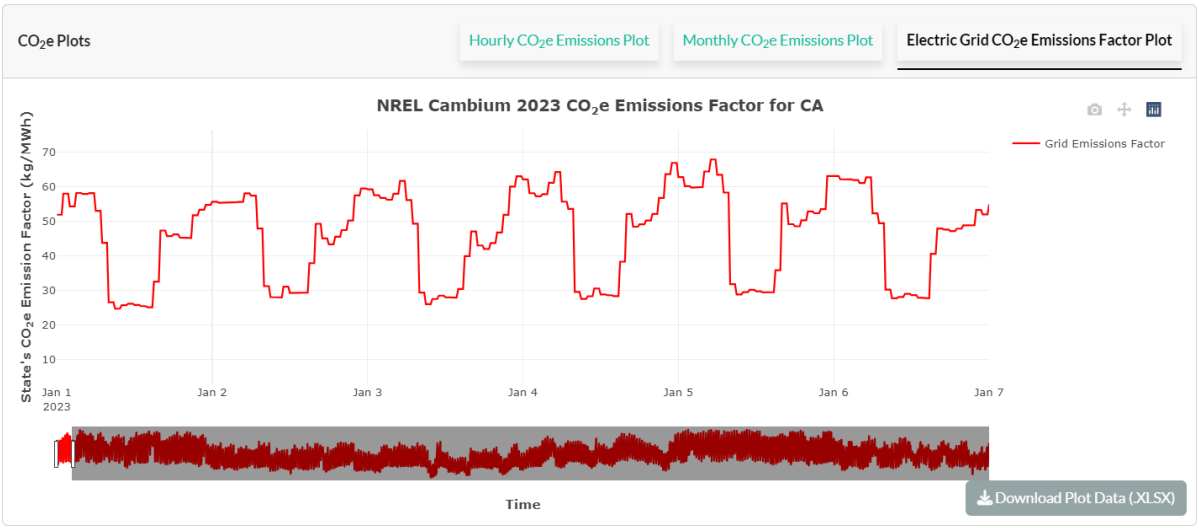

Figure 24: Sub-Hourly (15-Minute) Grid Emissions Factor

Electric Grid CO_2e Emissions Factor

The plot (Figure 25) displayed in this panel shows you the grid emissions factor for the state (California) and year (2023) selected in step 2. Depending on your choice of hourly or 15-minute data in step 1, you can view the grid emissions factor at an hourly or sub-hourly resolution[3]. This interactive plot's navigation is similar to that of the Load Profile plot and the Facility Hourly CO_2e Emission plot.

[3] Please note that in the absence of sub-hourly emissions factor data, the 15-minute emissions rate values are linearly extrapolated by dividing the hourly emission rate by 4.

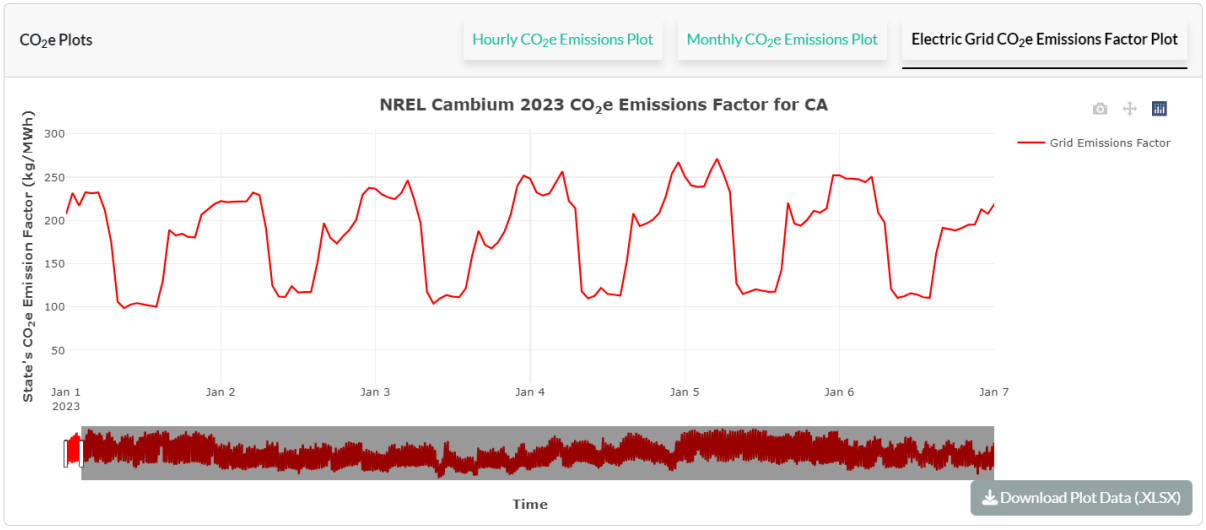

Figure 25: Hourly Grid Emissions Factor

Steps 3a and 3b: Your Rate Structure & Electricity Rate Schedule Info

This section requires you to outline your rate structure that determines your monthly electricity costs. The first set of questions in step 3a is intended to gather information on the fixed or TOU (Time-of-Use) varying nature of your usage ($/kWh) and demand charges ($/kW), the presence of a third TOU period apart from on-peak and off-peak, and if a monthly/season maximum demand charge applies to your bill apart from the TOU demand charges (Figure 26). For this example, we will continue with the pre-populated default rate structure selections made in step 3a. The default selections outline a rate structure with TOU usage and demand charges, no third TOU period apart from off-peak and on-peak, and a fixed monthly/season maximum demand charge on top of the TOU demand charges.

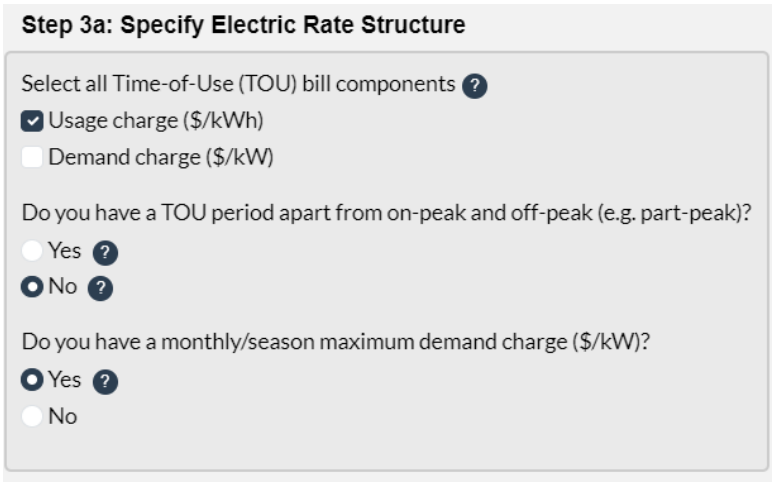

Figure 26: Rate Structure Selection

Step 3b requires you to specify the billing parameters of your rate schedule for the summer and winter seasons. Based on your choices in step 3a, inputs in this section could include the range of billing months in the summer category, the start and end hours of TOU period(s), and

any fixed usage and monthly maximum demand charges (if applicable). In step 3b, we will use the default rate schedule inputs for both summer and winter, as shown in Figure 27.

The tool can also remember all the rate structure inputs through the "Bookmark Rate Structure Inputs" button. When clicked, the button creates a URL that can be entered in any browser to restore the billing inputs entered in the tool.

As we have left the default rate structure inputs unchanged from the default values, we can instantly view the monthly and annual electricity costs associated with the uploaded load profile in the Cost Plots panel.

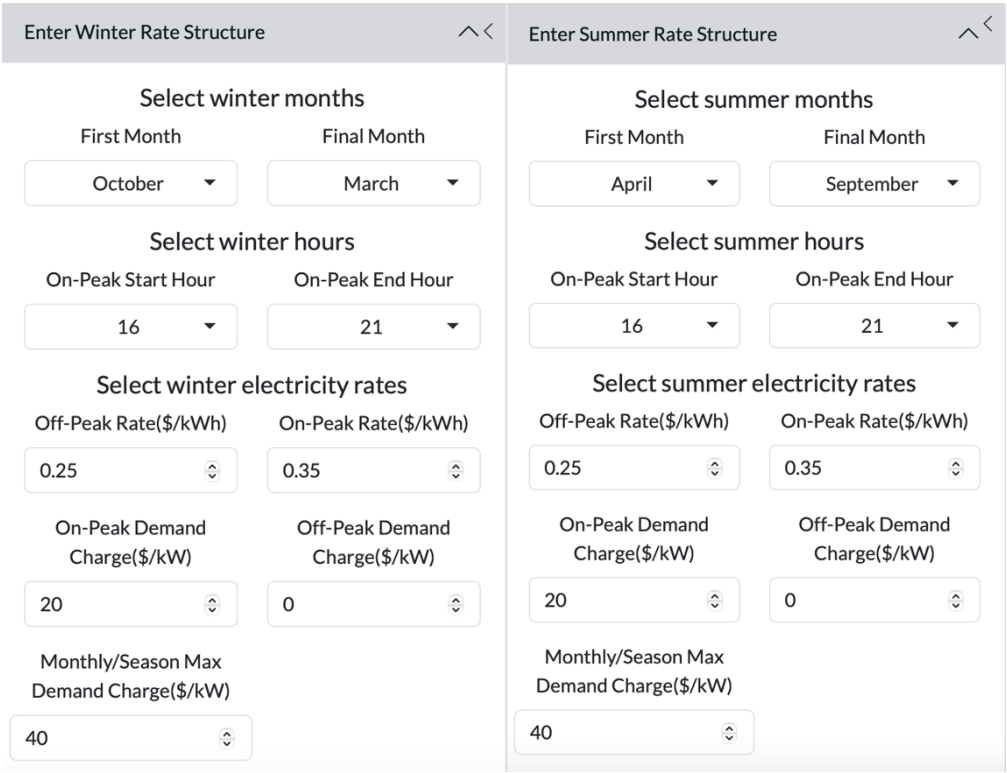

Figure 27: Rate Schedule Info

Cost Plot Selected Dates

The bar chart in Figure 28 shows the monthly electricity costs, split into usage and demand costs, associated with the facility's electricity consumption indicated in its baseline load profile. You can hover your cursor over each bar in the chart to see the value for monthly usage and demand costs underlying the electricity bill. Click the camera icon (📷) on the top right corner to download the plot as an image.

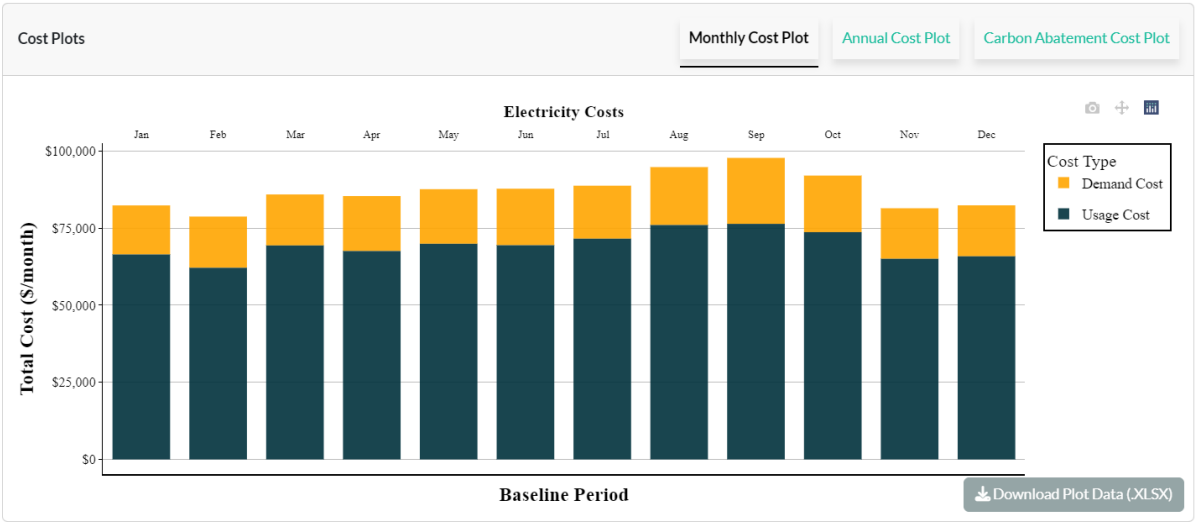

Figure 28: Monthly Cost Plot for Selected Dates

Cost Plot Annual

This plot (Figure 29) shows a single bar chart illustrating the total annual electricity costs, split into usage and demand, that are associated with the facility's baseline load. Navigating this bar chart to view bar values, download underlying data, and download the plot as an image is similar to the previous cost plot for selected dates.

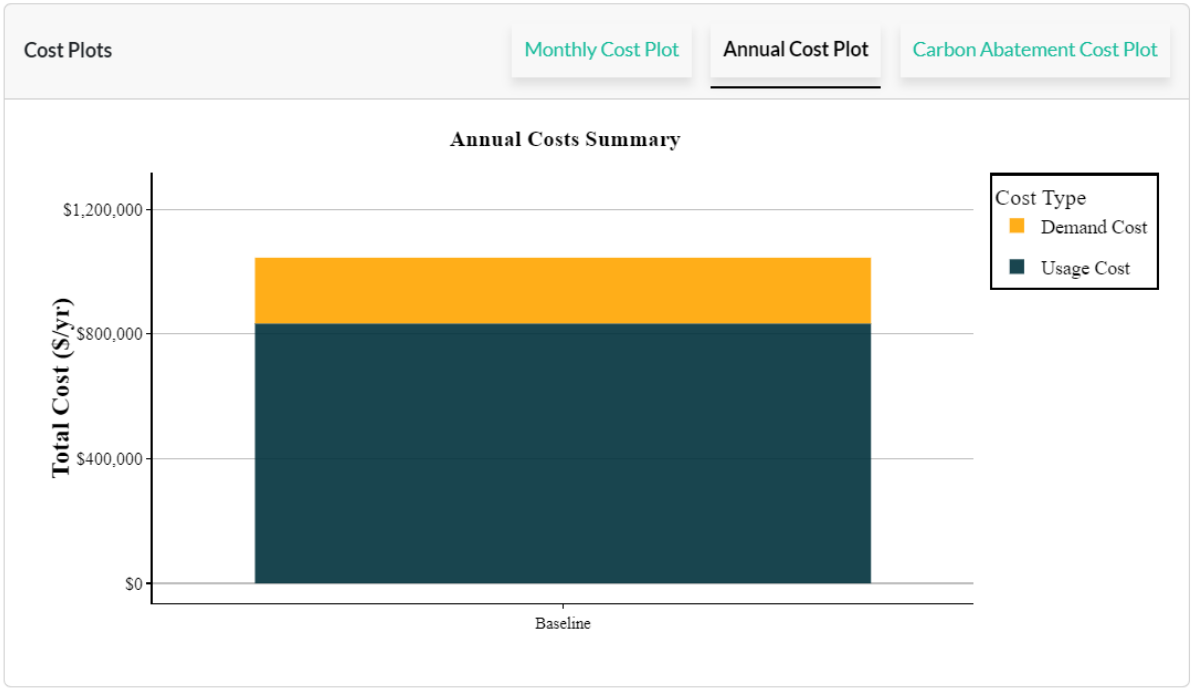

Figure 29: Annual Cost Plot

Abatement Cost Plot

The abatement cost plot uses a bar chart to show the electricity cost increase or savings associated with the scope 2 CO_2e emissions abated because of your load management

decisions. This plot does not appear when you initially upload your load profile and set your cost emissions parameters. Since load additions increase grid electricity consumption and the scope 2 emissions associated with it, there is no abatement cost plot displayed when the load is added. This abatement cost plot will only activate when your load-shifting or load-shedding actions yield a reduction in emissions. See Figure 17 for a visual of what the abatement cost plot might look like after load-shifting decisions have been executed.

Step 4: Enter Load Management Inputs

In this example, we will start by adding load.

Type of load management:

Select the Add/Shed Load option (Figure 24).

Manage load over the weekends:

Select "No" for this example. We assume that no load management decisions will take place over the weekends.

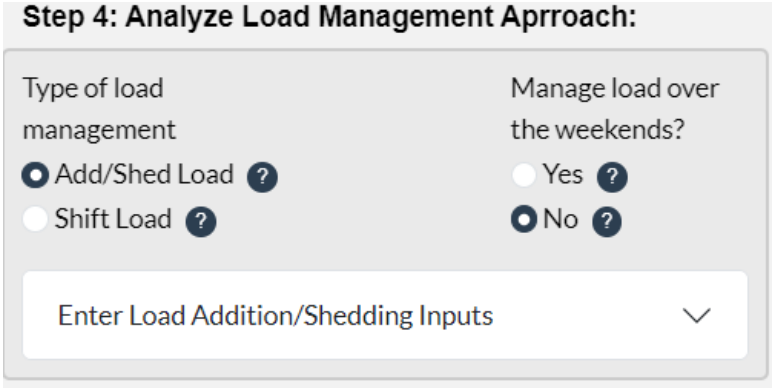

Figure 30: Entering Load Management Inputs

Enter Load Addition/Shedding Inputs

We will first add load using the *Manually Enter Added Load(s)* option as our input method. After selecting this option (also the default choice), we will click the "Add more Load Input(s)" button to add a total of two load addition decisions (Figure 31). In the Added Load (kW), you can provide the load you want to add (positive value) and use the endpoints of the adjacent slider to define the time range to which the load will be added. See Figure 31 to see the total load values added and the time ranges they were added to as part of this load management decision. Click the generate plot button after you have specified your load management decisions and completed all the preceding steps. The load profile, CO_2e emissions, and cost plot outputs will all update to reflect the changes made to your load profile by your load management decisions. You can now compare what your load shape, scope 2 emissions, and electricity costs look like for your baseline load profile versus your modified load profile.

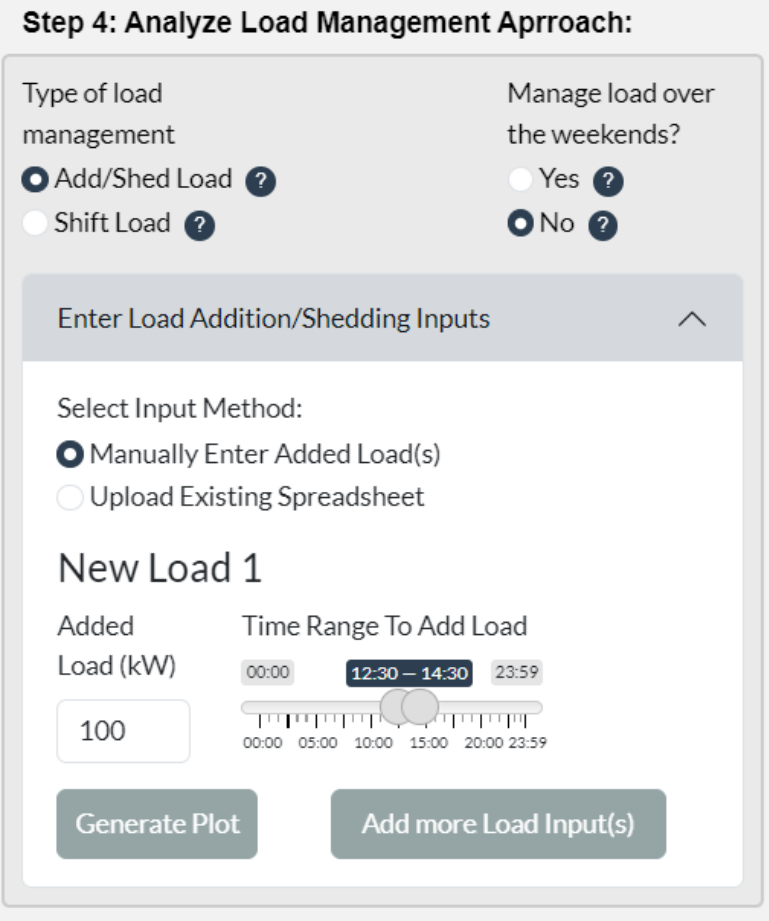

Figure 31: Load Addition Inputs

Shift Load

We will shift load using the *Manually Enter Added Load(s*) method and the *Upload Existing Spreadsheet* option. We enter 100 kW as the flexible load when specifying the load, we want to shift manually (Figure 32). Using the sliders, we can specify that this load is shifted from 5 PM-7 PM to 12 PM-2 PM. Click the generate plot button to update the load profile, CO_2e emissions, and cost plot outputs to reflect the changes made to the load profile by the load shifting decisions in this example. You can now compare the load shape, scope 2 emissions, and electricity costs for the baseline load profile versus the modified load profile.

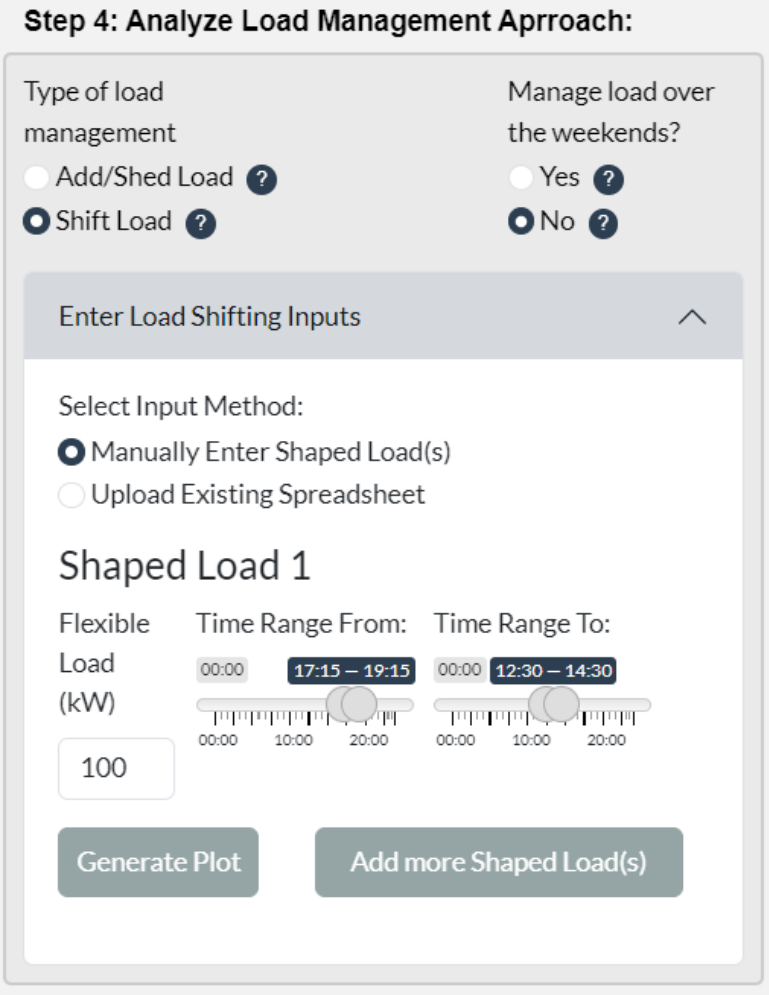

Figure 32: Load Shifting Inputs

To use the *Upload Existing Spreadsheet*, we must first click the Download Input Data button to download the load management decision input sheet. Open this spreadsheet and fill in your load-shifting inputs by overriding the defaults provided. In this case, where we have already executed load shifting using the *Manually Enter Added Load(s*) method, the defaults in the downloaded spreadsheet are the load management inputs we provided using the previous method. We will continue to use the same inputs to illustrate the *Upload Existing Spreadsheet* option. Figure 33 shows that the Excel sheet allows you to specify the flexible load you want to shift, the start and end hours of the time range you want to shift the load from, and the time range you want to shift the load to. Save and close the spreadsheet.

If you have not already, select the *Upload Existing Spreadsheet* input method and click browse to find and upload the load management input spreadsheet you prepared in the previous step. Once the sheet has been uploaded, go ahead and click the Generate Plot button again to execute your load-shifting decisions and update the load profile, emissions, and cost-related outputs.

A	B	C	D	E
Flexible Load (in kW)	Time Range From Start	Time Range From End	Time Range To Start	Time Range To End
100	17:00:00	19:00:00	12:00:00	14:00:00

Figure 33: Load Management Inputs Spreadsheet for Load Shifting

Step 5: Interpret Results

Upon shifting load, we see an increase in the facility's electricity costs and a reduction in its scope 2 CO_2e emissions. The reduction in the scope 2 CO_2e emissions can be attributed to shifting electricity consumption to morning and daytime hours of surplus renewable electricity production on the grid. This is evident from the modified load shape highlighted in blue in the Load Profile plot (Figure 34) and a net reduction in emission visible in the modified emissions profile (Figure 35). The electricity costs rise because the usage cost savings linked to the shifting of consumption during hours of cheaper TOU electricity rates are offset by the increase in demand charge-related payments (Figure 36). The increased costs but lowered emissions translate to positive abatement cost values on the Abatement cost plot (Figure 37).

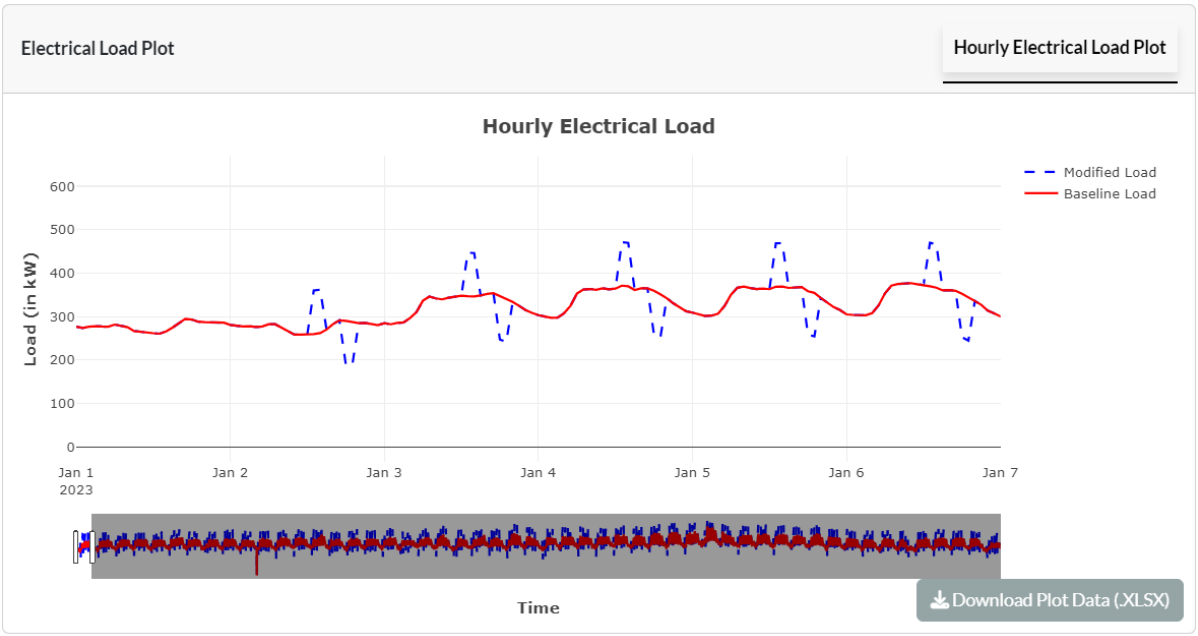

Figure 34: Load Shifting Output for Facility Electrical Load

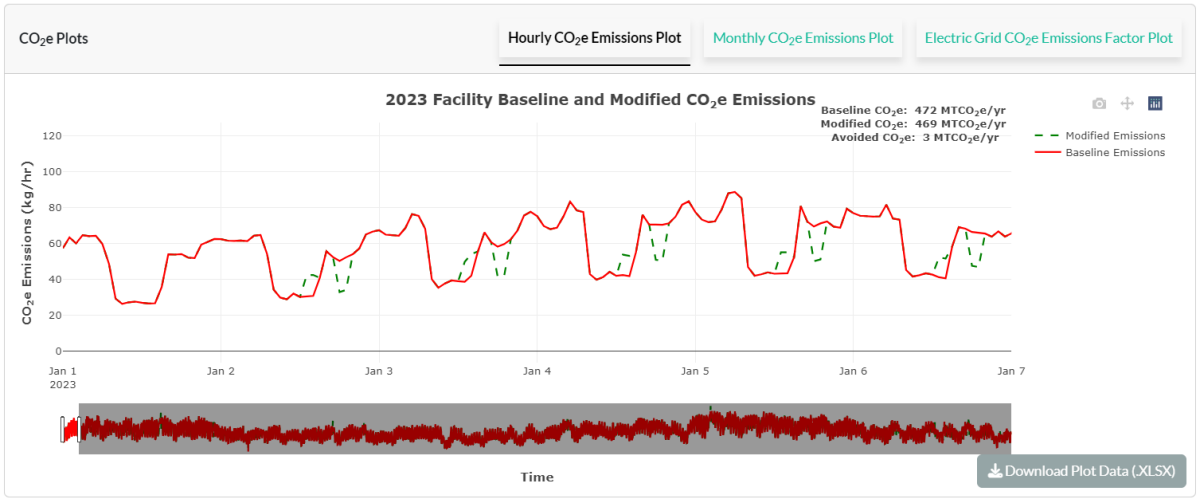

Figure 35: Facility's CO_2e Emissions after Load Shifting

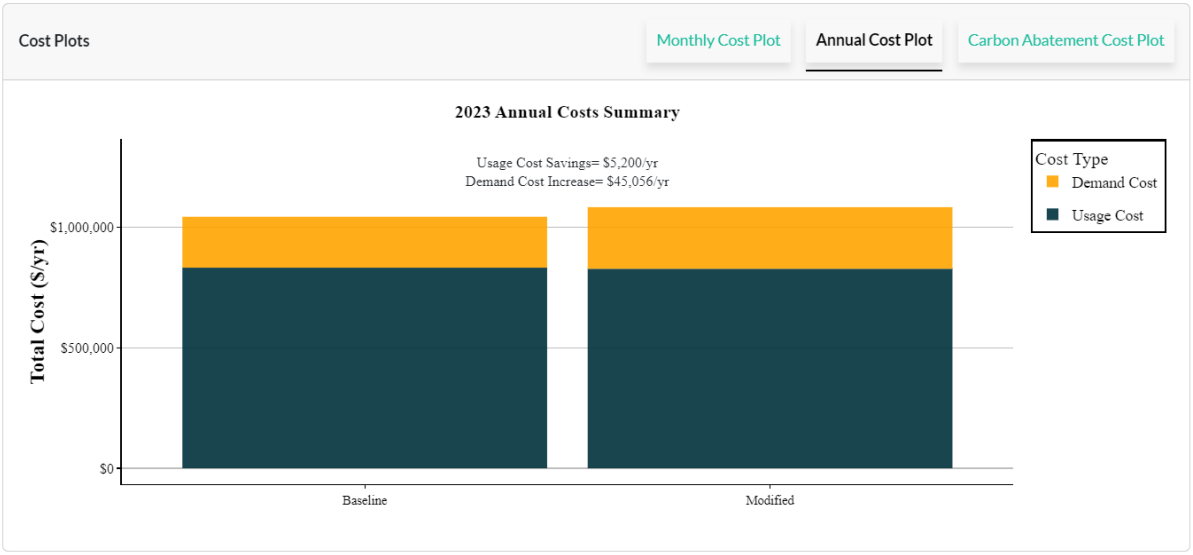

Figure 36: Costs Summary

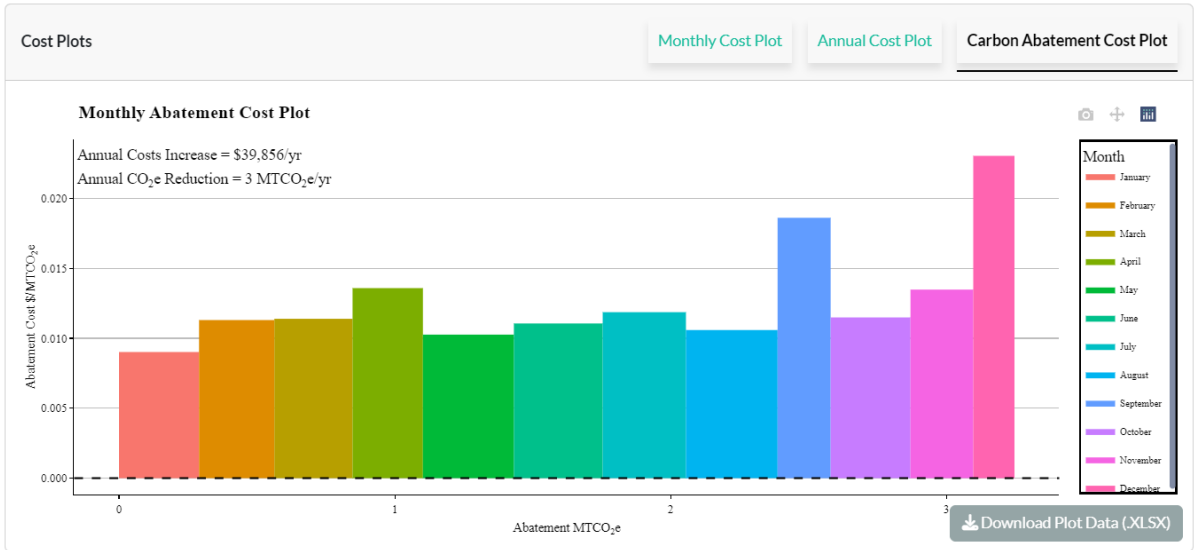

Figure 37: LCAC Plot

Worked Example: For 12 Months Utility Bills Data Types

This section outlines how to use the Electric Load Planning Tool to execute load management decisions and analyze their impacts using 12 months' utility bills. The procedure can be split into the five steps shown below:

1. Select Your Load Profile Data Type & Date Range
2. Upload Load Profile
3. Your Rate Structure and Schedule Info
4. Enter your Load Management Inputs
5. Interpret Results

Step 1a: Select Your Load Profile Data Type & Date Range

To input the data for the "12 Months Utility Bills" analysis, the user will need first to select the action button "12 months utility bills" and click on the button "Download 12 months Bills Template" (Figure 38). The required data to conduct load planning analysis with the choice as "12 months utility bills" Excel sheet includes entering your periods in the form of Year and Months, followed by energy parameters such as Energy Usage (kWh) and Billed Demand (kW). Users will also need to select whether they operate on weekends or not, and their working hours per day (), and when their peak hour often occurs (see Figure 39).

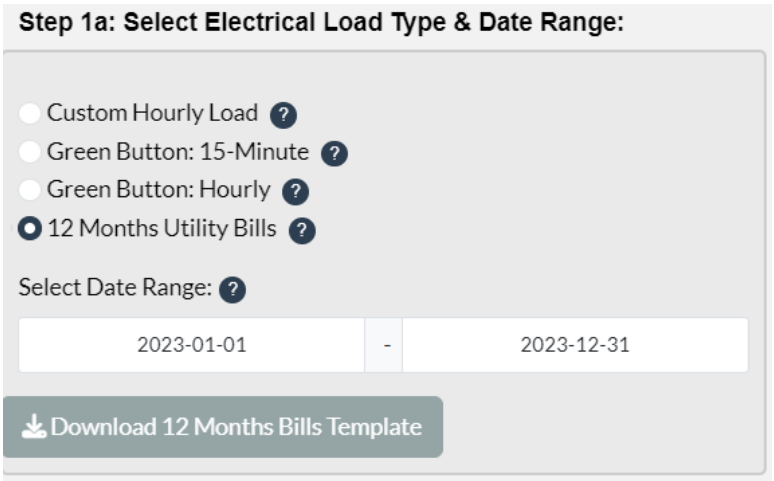

Figure 38: Step 1a: Prepare your 12 Months Utility Bills Data

Year	Month	Energy Usage, (kWh)	Billed Demand, (kW)
2023	January	467,556	1243
2023	February	491,493	1271
2023	March	517,635	1200
2023	April	513,095	1254
2023	May	545,780	1200
2023	June	490,251	1294
2023	July	562,127	1407
2023	August	594,446	1398
2023	September	495,666	1337
2023	October	467,462	1277
2023	November	492,539	1233
2023	December	591,213	1232

Please input values in these cells

Work on weekends?	N	*From Dropdown, choose "Y" or "N"*
Shift Start Time	5:00	*From Dropdown, Choose your shift start hour*
Shift End Time	23:00	*From Dropdown, Choose your shift end hour*
Choose Estimated Peak Hour	14:00	*From Dropdown, Choose an hour that best represents your facility's peak demand hour*

Figure 39: Input your utility bills data into the Excel template (the figure illustrates default data, which can be removed or overwritten for inputting user-specific data)

Step 1b: Upload Load Profile

Once the Excel template is filled out, it can be quickly loaded into the web tool by uploading through the interface shown in Figure 40.

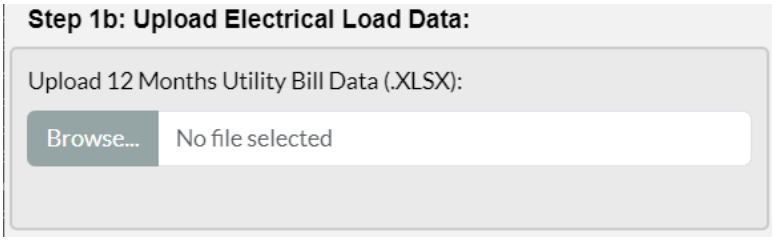

Figure 40: Upload Load Profile Panel

Once the file has been loaded, an 8,760-hour load profile will be displayed in the right section of the tool (Load Profile tab). The image defaults to a limited number of days in the main panel to prevent the 8,760-hour load profile from getting squished in the image panel. If the user would like to view the load profile for the entire year in one panel, they could extend the panel under the main graph.

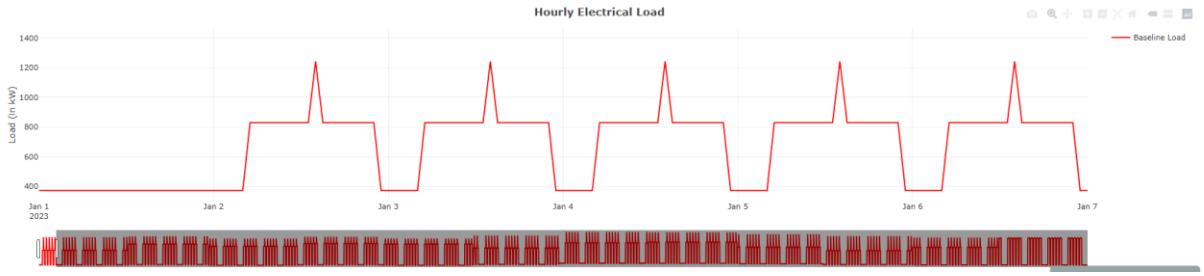

Figure 41: Load Profile Data for the Utility Bills Template

Step 2: Choose GHG Emission Parameters

Once the load profile has been loaded and displayed in the display panel, the user should select the year and the states for which they are performing their analysis. Users could either select the NREL Cambium Mid-Case Average Emission Factors Estimates or the U.S. EPA's eGRID 2022 estimates. For this exercise, we select NREL Cambium's 2022 data for the state of California.

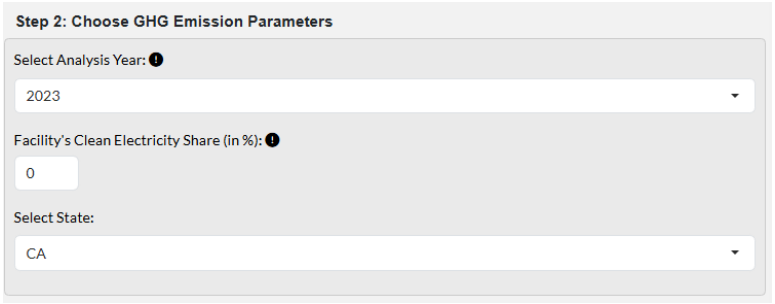

Figure 42: Choose GHG Emissions Parameters Panel

After both selections, the tool displays the hourly emissions for the facility based on their utility bills, location (state), and that particular year's emissions factors. The figure can be seen in the "CO_2e Plots" panel's "Facility Hourly CO_2e Emissions" tab. Under the chart, the window can be navigated to observe the emissions in various parts of the year. The window could also be expanded to display all hours in the corresponding year. Finally, the data can be downloaded using the "Download Plot Data (.xlsx)" button.

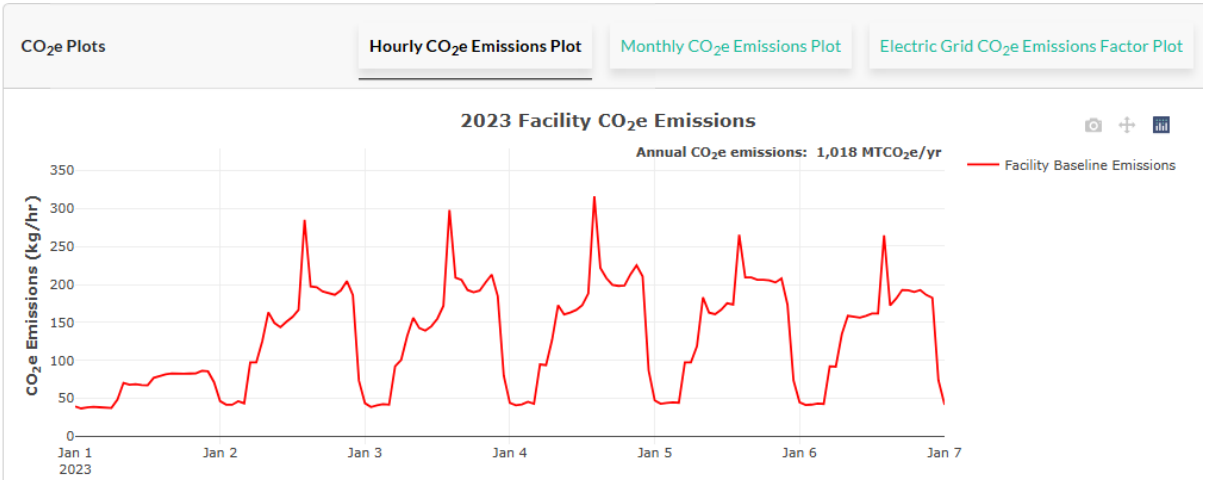

Figure 43: Facility Hourly CO_2e Emissions Plot

Annual emissions based on individual months can also be seen in the second tab named "Facility Monthly CO_2e Emissions" within the CO_2e emissions plots. The plot in Figure 44 the facility's scope 2 emissions each month.

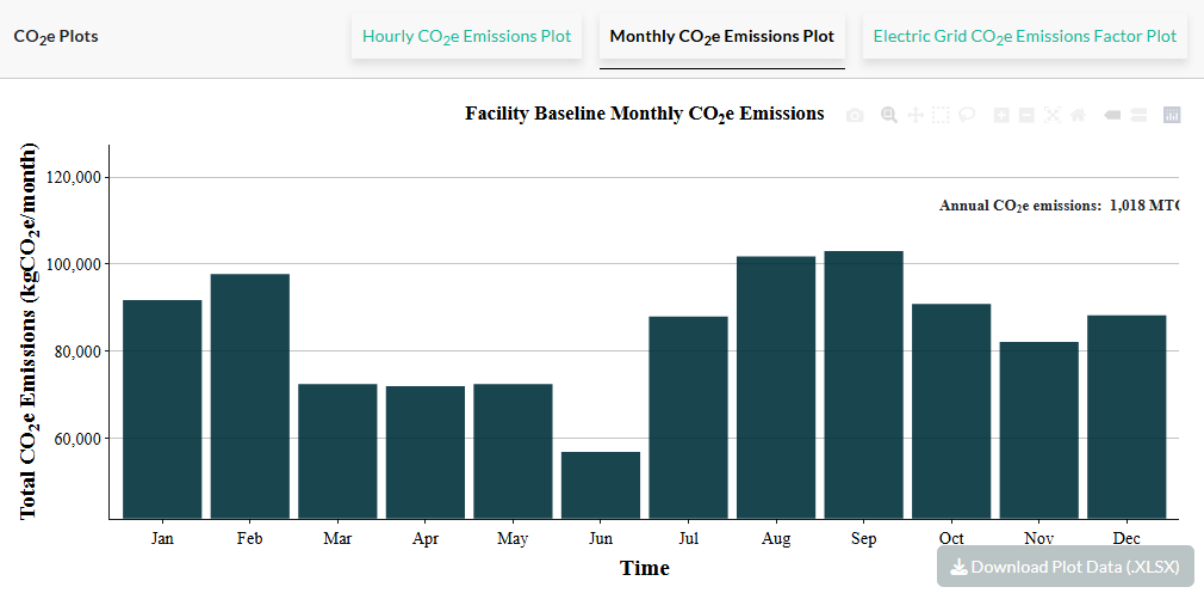

Figure 44: Facility's Monthly Emissions

Steps 3a and 3b: Your Rate Structure and Schedule Info

This section outlines various cost parameters that can affect electricity costs. Two major entities are electricity usage and demand costs. The costs could be based on the time-of-use tariffs, such as on-peak, off-peak and part-peak periods. Further, demand costs could also be based on maximum demand in the corresponding months. These various selections could be made to match the user's utility rate structure and procure accurate results for the tool. See Figure 45 below to understand various default rate values in the tool. For this exercise, we select that the usage and demand parameters have time-of-use components, and the time-of-use periods only have on and off-peaks. Further, we select a monthly maximum demand charge on top of on-peak and off-peak demand charges.

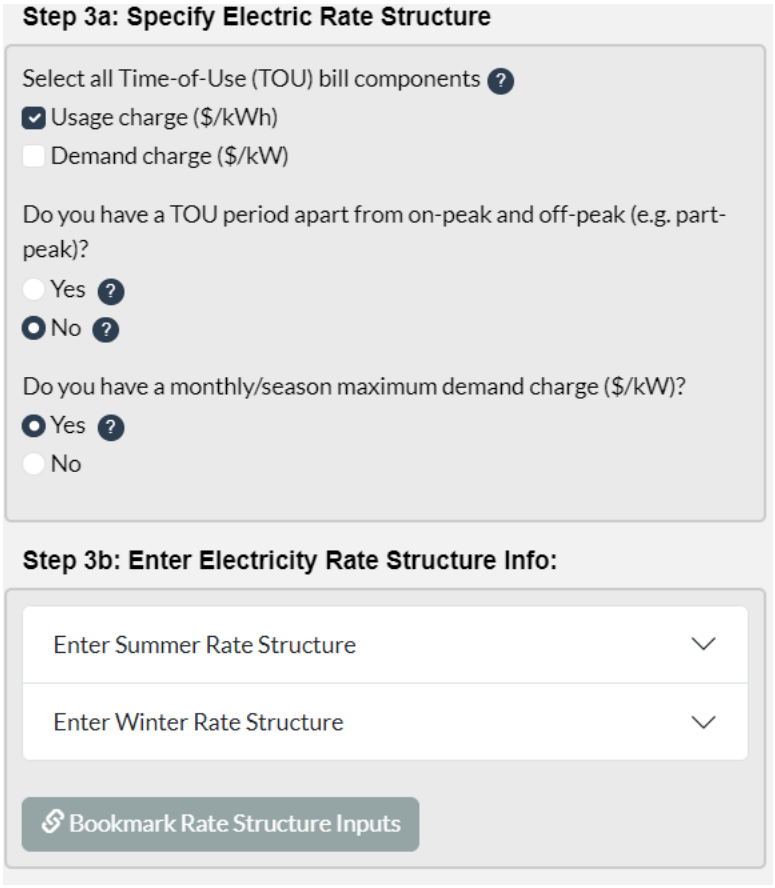

Figure 45: Steps 3 in the process. This step pertains to the rate structure selection and rate inputs.

After making the selections in Step 3a, we move towards Step 3b to enter our rate prices for the structure we have selected in Step 3a. We utilize the default inputs in the tool that are provided for ease of usage while learning and operating the tool. The default inputs for the summer and winter are shown in Figure 46.Please enter the summer and winter beginning and ending months, followed by the time-of-use hours. Then, enter the on- and off-peak rates and the maximum demand charge. The tool can also remember all the rate structure inputs through the "Bookmark Rate Structure Inputs" button. On clicking the button, the tool creates a URL that can be entered in any browser to restore the inputs entered in the tool. This makes it easy for the user to return and start at the point where they left their previous session.

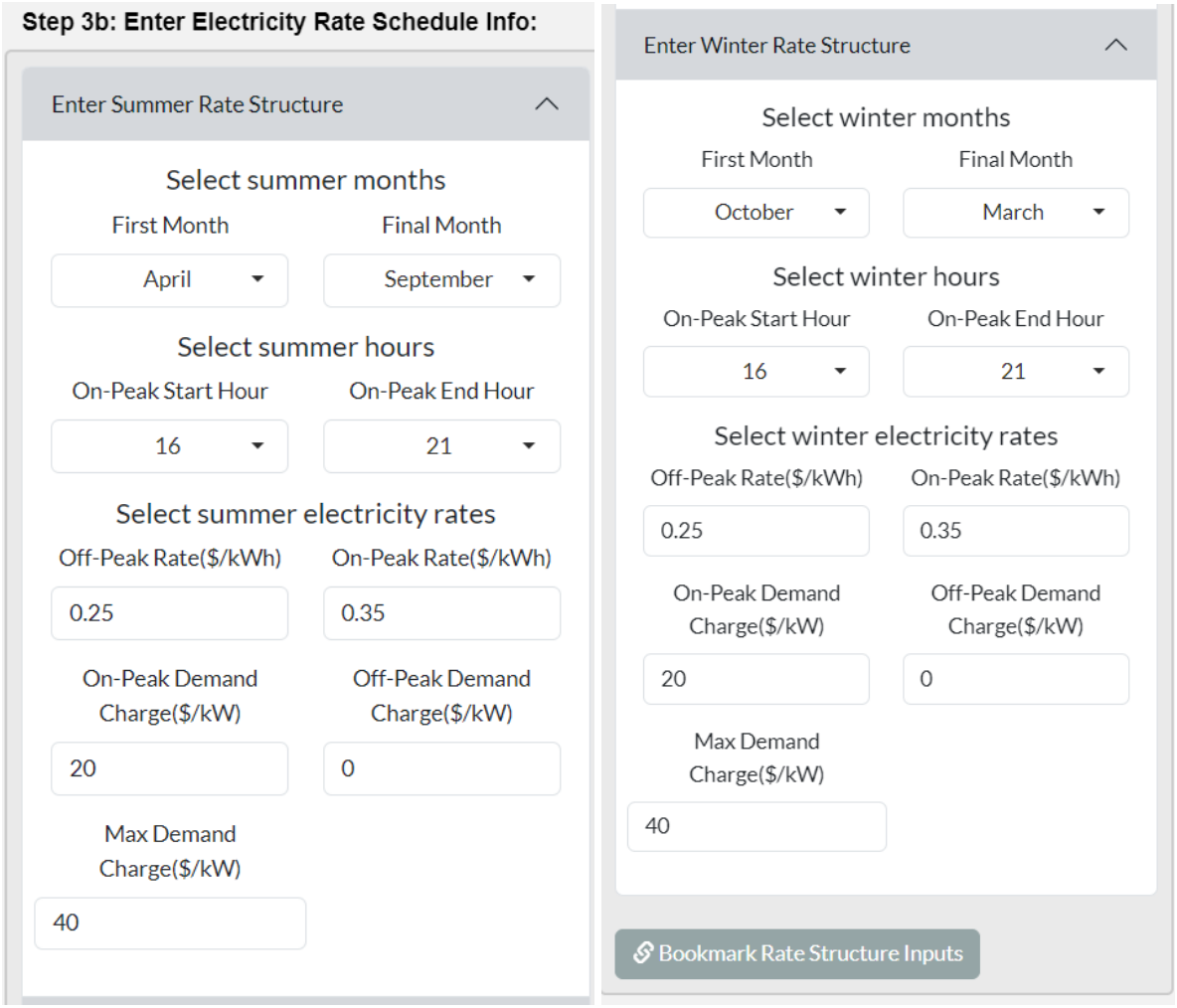

Figure 46: Summer and Winter Rate Structures

Step 4: Enter your Load Management Inputs

Users could either add, shed, or shift their load. The options for adding and shedding the load are contained within the same radio button while shifting the load is in the second radio button. In the example, we add a new load of 50 kW between 12:30 PM and 2:30 PM. To shed the load, please enter the load with a negative value. Further, to shift the load, add the load data followed by periods to shift from and shift to. Click the generate plot button after entering the desired inputs (Figure 47). This furthers the tool operation by updating all the existing charts with baseline and modified load.

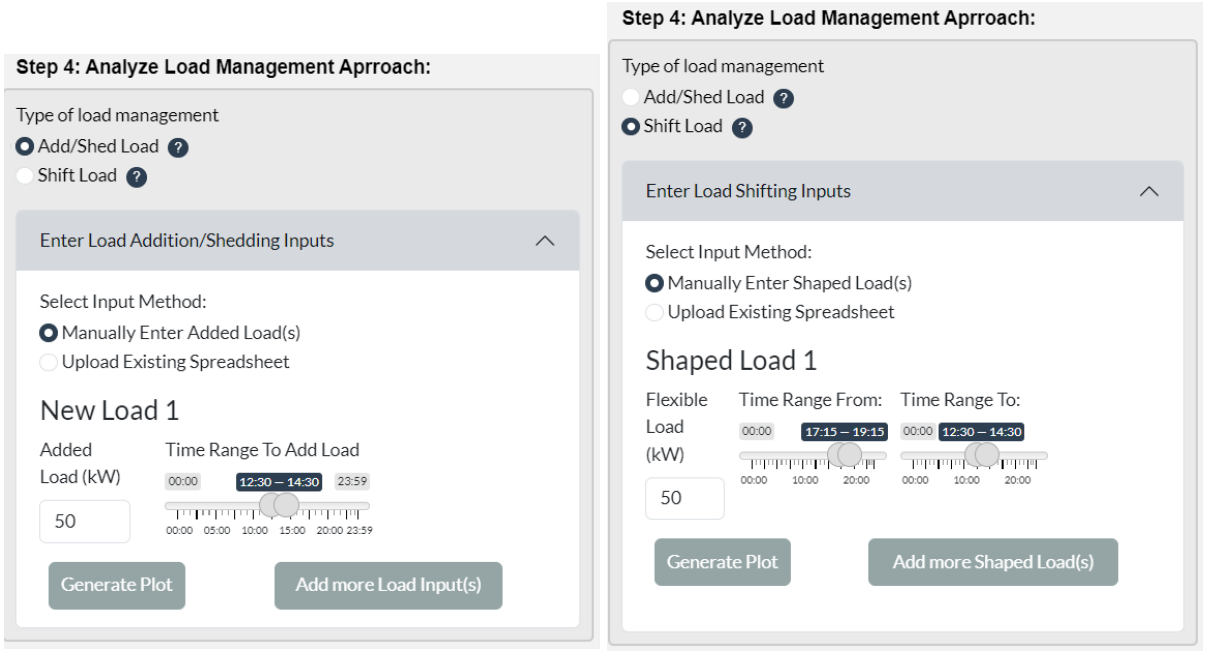

Figure 47: Add or Shift Load Options based on the selection made in the radio buttons

Step 5: Interpret Results

The generated plots will have modified loads represented by red lines in. On top of the existing information, there is a modified load and emissions line chart. Further, there is also a monthly baseline and modified emissions bar chart. Adding a load would increase energy consumption and GHG emissions. The new data can be downloaded using the "Download Plot Data (.xlsx)" below the corresponding graphs.

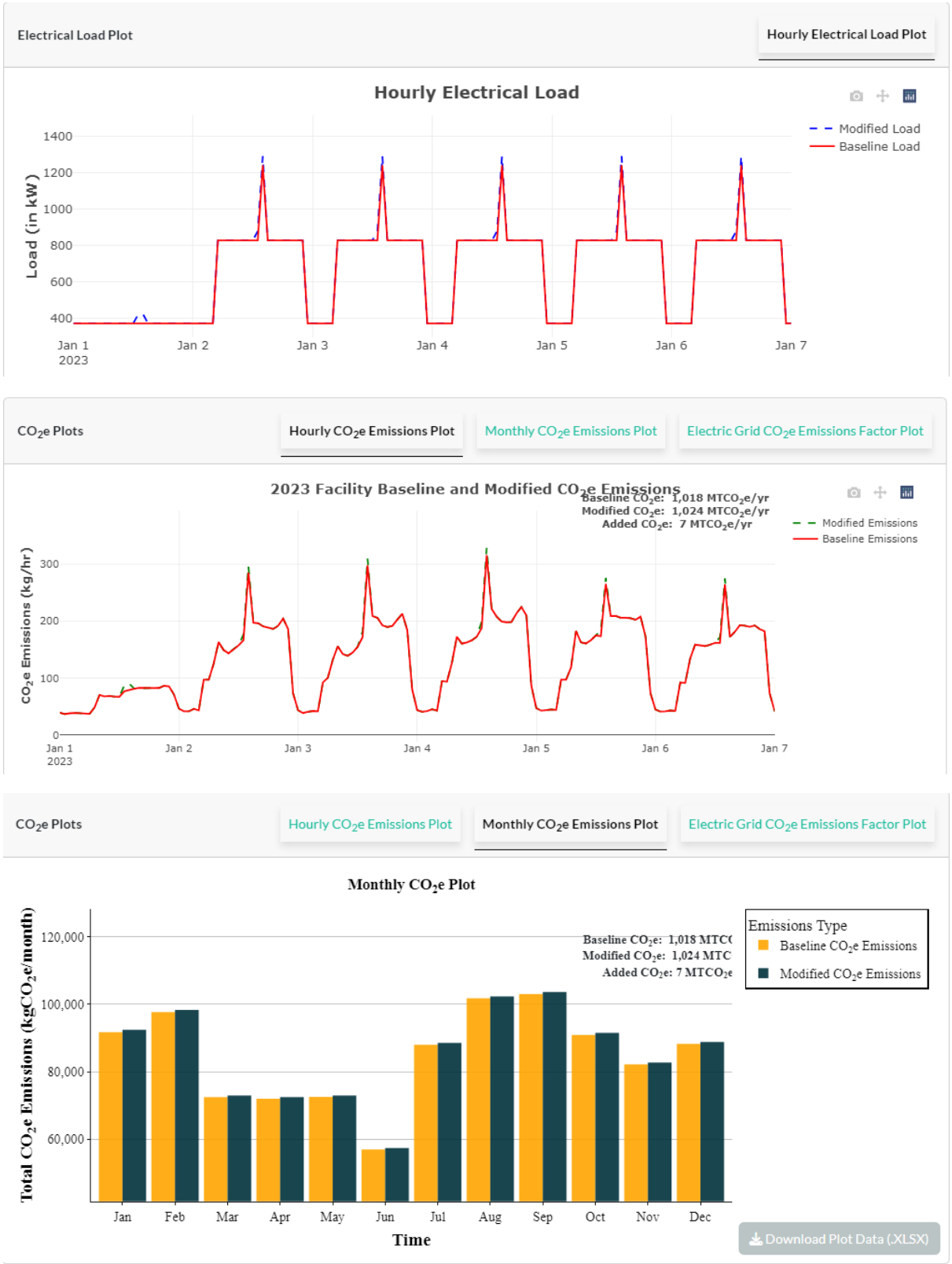

Figure 48: Added Hourly Load, Hourly and Monthly CO_2e Charts

On the third row of the graphs, there are three tabs about the cost plots for the selected dates, calendar year, and LCAC plot based on each month. The costs will change depending on whether the load has been added or shifted. These plots help realize the cost impacts of the

added or shifted loads. The first chart refers to the baseline and modified usage and demand costs for the added load of 50 kW each month. To see the data, the user could hover around the bar charts or download the data through the "Download Plot Data (.xlsx)" button below.

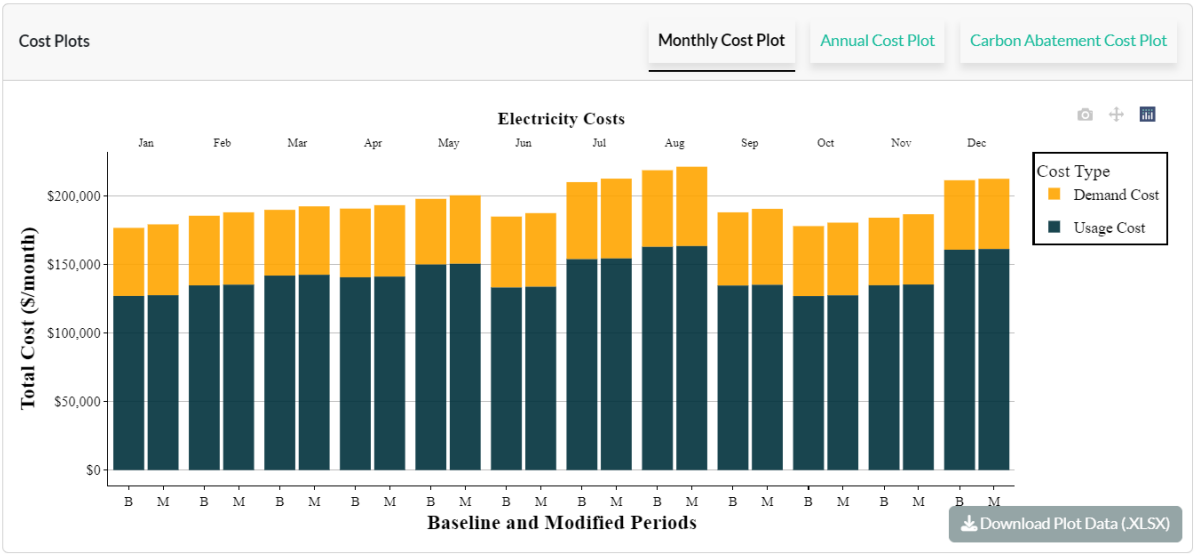

Figure 49: Selected Dates Cost Plot

The second plot is the annual cost savings plot for usage and demand costs. Based on the input selection of adding, shedding, or shifting loads, users will be provided with these bar charts with annotations that specify whether there are cost savings or increments.

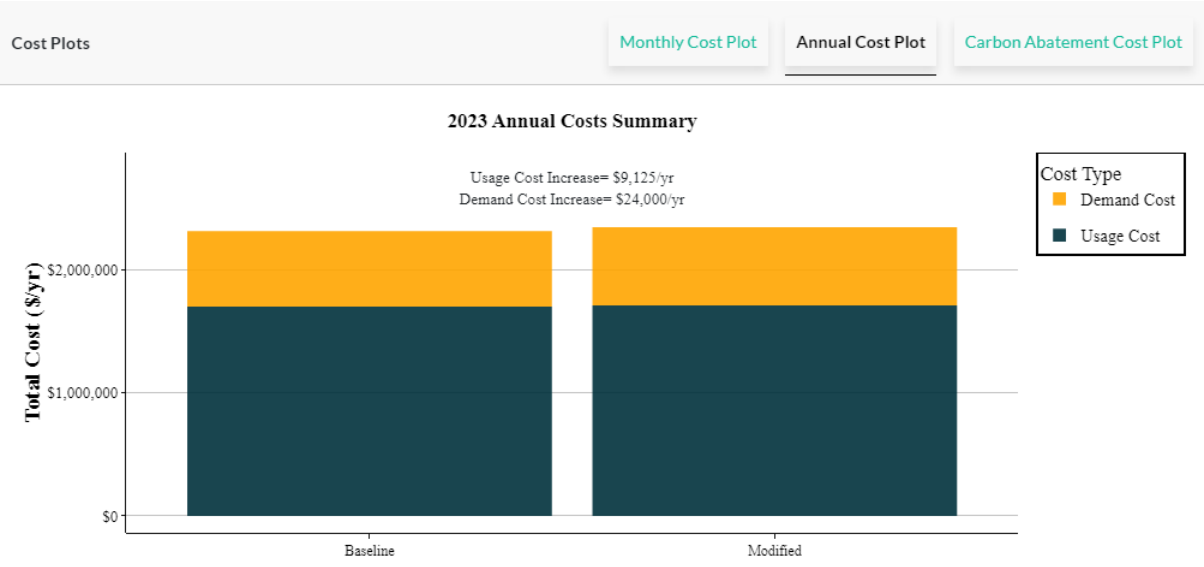

Figure 50: Annual Cost Plot

Finally, the user is provided with the abatement cost plot that pertains to the $/ton value for all selected months in the calendar year. Please note that if you add a load, the carbon abatement cost plot will not display because adding a load would not reduce carbon emissions. In the figure below, we shed a 50-kW load for the same period to obtain the results in the figure below. The diagram also neatly states the annual CO_2e and cost implications.

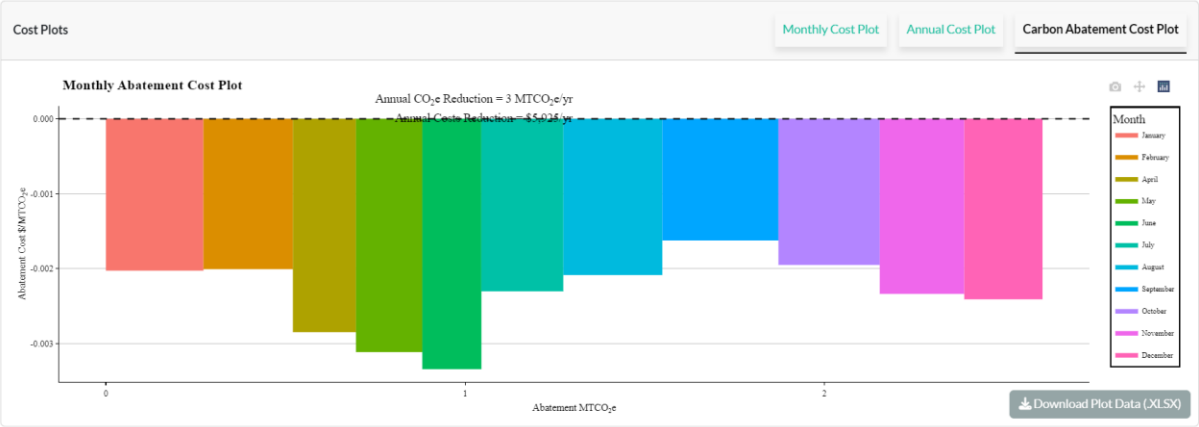

Figure 51: LCAC Plot for the Shed Load

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2. Miller, G. J., Novan, K., & Jenn, A. (2022). Hourly accounting of carbon emissions from electricity consumption. Environmental Research Letters, 17(4), 044073. https://doi.org/10.1088/1748-9326/ac6147
3. Nandy, P., Botts, A., & Wenning, T. (2022). Demand Response in Industrial Facilities (ORNL/SPR-2021/2299; Better Buildings, Better Plants). Oak Ridge National Laboratory. https://info.ornl.gov/sites/publications/Files/Pub184294.pdf
4. Summerbell, D. L., Khripko, D., Barlow, C., & Hesselbach, J. (2017). Cost and carbon reductions from industrial demand-side management: Study of potential savings at a cement plant. Applied Energy, 197, 100–113. https://doi.org/10.1016/j.apenergy.2017.03.083