Tool Documentation

INDUSTRIAL ENERGY EFFICIENCY AND DECARBONIZATION TOOLKIT

USER GUIDE FOR FACILITY SANKEY TOOL

Table of Contents

Introduction

The Facility Sankey Tool (FST) quantifies and visualizes a facility's energy and emissions using a Sankey Diagram (Figure 1). An interactive Sankey Network Diagram enables users to gain insights into patterns, trends, hotspots, and distributions of energy and emissions at a facility. Using this visualization, the assessment team can identify large end-uses and prioritize them during their assessments. The tool helps break down the total facility emissions into subcategories of energy, process, and fugitive emissions, which can be broken down further into individual equipment/process for a component-level analysis (Figure 1). Further, the tool aids to estimating product emissions intensities on an allocation-based approach that aligns with the best practices of ISO 14067: 2018 Greenhouse gases — Carbon footprint of products[1]. Facilities can employ the quantity (kilograms, cubic meters, etc.) and revenue ($/product, gross revenue, or revenue %) to allocate emissions for various products and co-products.

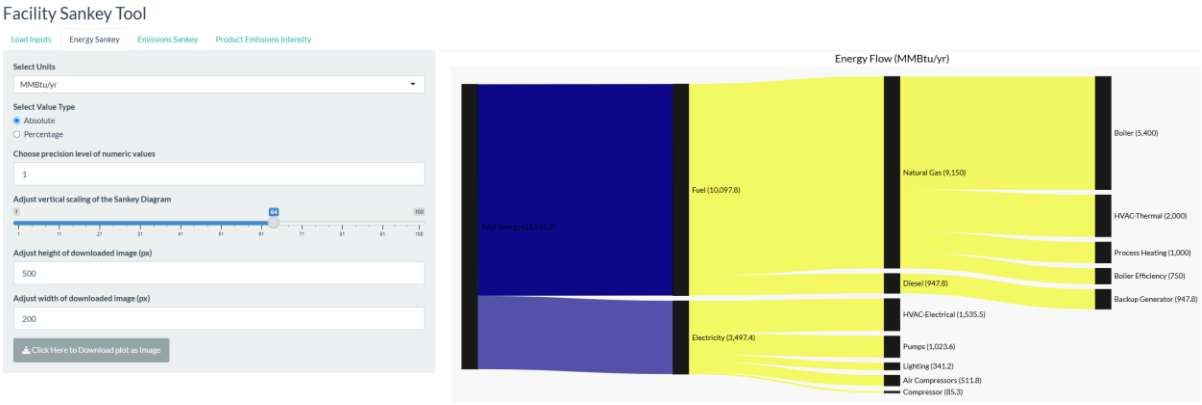


Figure 1: Facility Energy Sankey flow for a representative facility (MMBtu/yr)

The tool is designed to determine baseline energy and emissions but can be employed to run different scenario analyses based on user inputs. One such scenario analysis with this tool can be employed to compare a facility's baseline energy with energy post-implementation of assessment recommendations. Moreover, for emissions, future years can be modelled by varying the "year of analysis" input, which can help give a snapshot into the future emissions of a facility under varying grid emissions intensities.

This guide outlines the tool's working principles and provides step-by-step guidelines on how to use the tool.

[1] https://www.iso.org/standard/71206.html

How to Use the Tool

The tool is split into two components:

1. Input Sheet (Excel-based)
2. Visualization Application (Web-based)

The Input Sheet takes data on the facility's end-uses and energy consumption to compute the emissions, whereas the Visualization Application converts this quantitative data into a Sankey Diagram. This section outlines how to navigate and use each of the two components.

FST – Input Sheet

Types of Input: The inputs cells are color-coded using a 'light-yellow' shade (see below).

Input Cells

Energy Inputs

1. **Complete Energy Use Breakdown Table**

Source	Energy Category	Energy Source	Units	Annual Consumption
HVAC-Electrical	Energy	Electricity	kWh	450,000

These tables serve as the main input array for energy calculations. Please follow the following steps to fill this table:

- **Source:** Specify the name of the end-use equipment/process which is energy end-use at the plant site. Examples may include boilers, process heating, process cooling, pumps, compressors, and HVAC systems, among others.
- **Energy Category:** Tab will be available for use in future updates.
- **Energy Source:** Enter the energy source the end use operates on. Examples may include coal for a boiler, electricity for pumps, natural gas for process heating and so on. In addition to the pre-loaded energy sources, more can be added in the 'Energy Source' table (see below) in the 'Emissions Inputs' sheet.

Emission Factors for Energy Sources						
Energy Source	**CO_2e Intensity (MT CO_2e/)**					
Title	Source	KJ	kWh	MMBtu	GJ	therm
Electricity	2023 eGRID	5.1E-08	1.8E-04	5.4E-02	5.1E-02	5.4E-03
Natural Gas	EPA	5.0E-08	1.8E-04	5.3E-02	5.0E-02	5.3E-03
Propane	EPA	6.0E-08	2.1E-04	6.3E-02	6.0E-02	6.3E-03
Petroleum Coke	EPA	9.7E-08	3.5E-04	1.0E-01	9.7E-02	1.0E-02
Distillate or Light Fuel Oil	EPA	7.0E-08	2.5E-04	7.4E-02	7.0E-02	7.4E-03
Coal	EPA	9.1E-08	3.3E-04	9.6E-02	9.1E-02	9.6E-03
Diesel	EPA	7.0E-08	2.5E-04	7.4E-02	7.0E-02	7.4E-03
Motor Gasoline	EPA	6.7E-08	2.4E-04	7.1E-02	6.7E-02	7.1E-03

Source: https://www.eia.gov/environment/emissions/co2_vol_mass.php

- **Units:** Select units for the selected energy source.
- **Annual Consumption:** Enter the annual consumption of the fuel for specific end use in the units selected previously.

2. **Save and Close file.**

Emission Inputs

1. **Select Electricity Emissions Factor**

The electricity emissions factor is used to calculate emissions related to electricity consumption at a facility. The tool provides two options to select this emission factor, as described below:

a. Option A – Enter Custom Emissions Factor

This option allows users to enter custom/market-based emissions factors for electricity, where available, for the calculations. This value can be supplied through the local utility company, or it can be a company's own value based on internal calculation. This value must be entered into the units of 'MT of CO_2e/kWh'.

b. Option B – Select State and Grid Emissions Factor

This option uses the available emission factor for the selected state & year and applies that to the emissions calculation associated with electricity.

i. Select State and year of analysis

STATE (select from dropdown)	YEAR (select from dropdown)
CA	2021 (Current eGRID)

This input determines the grid emissions factor to be used in the emissions' calculations. Current emissions rate is based on eGrid Database[2], whereas future forecasts are based on average emissions rate from NREL Cambium Database, using the mid-case with tax-credit phase-out scenario. More on NREL Scenarios can be found at Cambium 2022 Scenario Descriptions and Documentation[3].

ii. Specify Clean Electricity Share

Clean Electricity Share (For facilities with onsite renewables or Clean Power Procurement)	0%

Clean electricity is the percentage of electricity used at the facility that was supplied using zero Energy and sources. Onsite renewables, Renewable Energy Certificates (RECs) and Power Purchase Agreements (PPAs) are some of the sources that can contribute to the clean electricity share.

This percentage adjusts the emissions factor extracted from the Grid Database by the ratio as specified, so that the emissions factor is accurately representative of the facility's perspective.

This share may be determined by the following equation:

$$Clean\ Electricity\ Share(\%) = \frac{Annual\ electricity\ supplied\ by\ clean\ sources}{Annual\ total\ electricity\ consumed\ by\ the\ plant} \times 100\%$$

2. Enter Process and Fugitive Emissions (Optional)

Source	Emission Category	CO_2e Emissions - Process or Fugitive (MT CO_2e/yr)
Process Emissions	Process	90

This table serves as the main input array for the process and fugitive emissions. Please follow the following steps to fill this table:

[2] https://www.epa.gov/system/files/documents/2023-01/eGRID2021_summary_tables.pdf
[3] https://www.nrel.gov/docs/fy23osti/84916.pdf

- **Source:** Specify the name of the end-use equipment/process which is a source of process or fugitive emissions.
- **Emission Category:** Select the emissions category for the source.
- **Annual Emissions:** Enter annual emissions for the respective source.

3. Add emission intensity for additional fuels (optional)

Enter any additional energy sources and their emissions factors to be used in emissions calculations for the energy inputs.

Emission Factors for Energy Sources						
Energy Source	**CO_2e Intensity (MT CO_2e/)**					
Title	Source	KJ	kWh	MMBtu	GJ	therm
Electricity	2023 eGRID	5.1E-08	1.8E-04	5.4E-02	5.1E-02	5.4E-03
Natural Gas	EPA	5.0E-08	1.8E-04	5.3E-02	5.0E-02	5.3E-03
Propane	EPA	6.0E-08	2.1E-04	6.3E-02	6.0E-02	6.3E-03
Petroleum Coke	EPA	9.7E-08	3.5E-04	1.0E-01	9.7E-02	1.0E-02
Distillate or Light Fuel Oil	EPA	7.0E-08	2.5E-04	7.4E-02	7.0E-02	7.4E-03
Coal	EPA	9.1E-08	3.3E-04	9.6E-02	9.1E-02	9.6E-03
Diesel	EPA	7.0E-08	2.5E-04	7.4E-02	7.0E-02	7.4E-03
Motor Gasoline	EPA	6.7E-08	2.4E-04	7.1E-02	6.7E-02	7.1E-03

Source: https://www.eia.gov/environment/emissions/co2_vol_mass.php

4. Add conversion factors for additional units (optional)

Enter any additional units that are pertinent to the analysis.

Energy Conversion Factors	
	MMBtu
KJ	9.5E-07
kWh	3.4E-03
GJ	9.5E-01
therm	1.0E-01
MMBtu	1.0E+00

5. **Save and close the file**

Results

The Excel workbook's outputs are depicted using the cell color as shown below, please do not update these output cells. Apart from the values copied from the input sheets, the additional calculated results are described below:

Output Cells

1. **Total Energy (MMBtu/yr and MWH/yr)**

   This is the calculated total energy for each end-use specified in the energy inputs tab.

2. **Percentage of Total Energy**

   This is the percentage of the current end-use to the total facility energy.

3. **Total Emissions**

   This output combines all emissions from all categories.

4. **Percentage of Total Emissions**

   This output identifies the proportion of emissions from the specific end use in terms of the total emissions.

FST – Visualization Application

The visualization component of the tool is hosted online and can be accessed here. The user interface for the visualization application is shown in Figure 2.

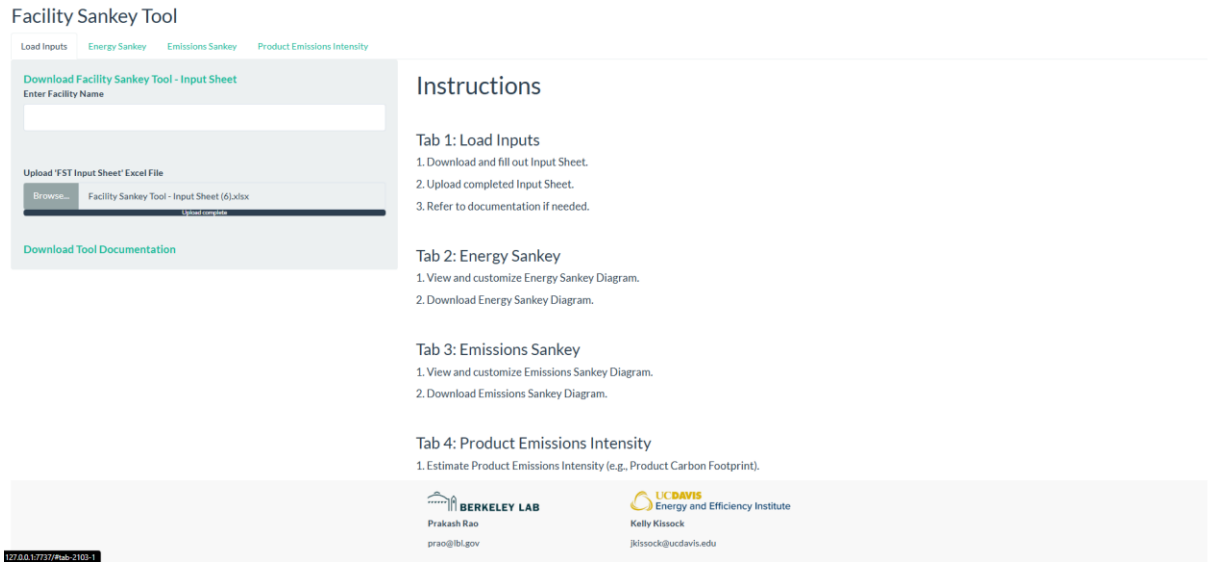
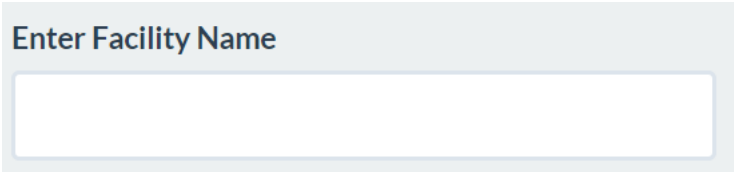


Figure 2: FST Web Tool – User Interface

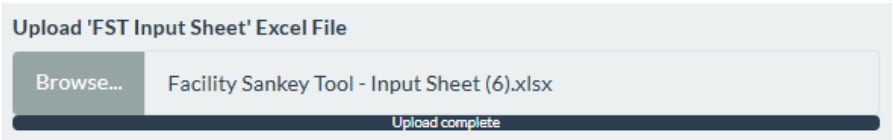
Load Inputs

1. **Enter Facility Name**



In the sidebar panel on the left, enter the name of your facility in the "Enter Facility Name" text box. This input is used to formulate the caption for the energy and emissions flow diagrams.

2. **Upload 'FST – Input Sheet' Excel file**



Click the "Browse" button next to the "Upload FST Input Sheet Excel File" label to upload the filled out 'FST Input Sheet' to the web tool.

3. **Download Tool Documentation**

   Download documentation for the tool.

Energy Sankey / Emissions Sankey

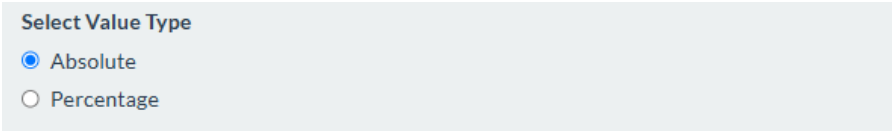
1. **Adjust the bars of the Facility Energy and Flow Diagram**

   Click and drag each node to customize and adjust the chart visually.

2. **Select Units**

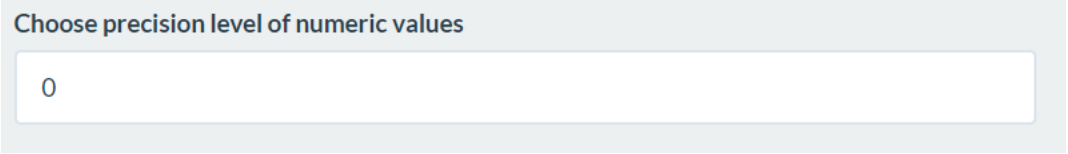
   Select the appropriate units from the "Select Units" drop-down menu. The available options are "MT CO_2e/yr." and "lbs. of CO_2e/yr.".

3. **Select Value Type**



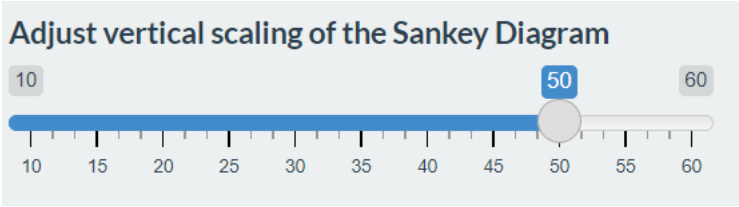
   Choose if results should be shown in absolute values or percentage terms.

4. **Select the precision Level of numeric values**



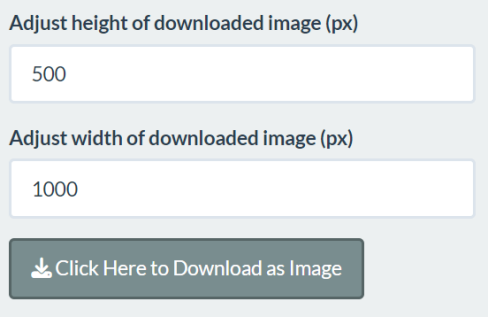
   Choose the level of precision by adjusting the numeric input "Choose precision level of numeric values". This precision level is used to determine how the values are rounded off. Increasing this number increases the precision of values and vice versa.

5. **Adjust Vertical Scaling of the Facility Energy and Flow Diagram**



   Depending on the number of end-uses entered, the vertical scaling of the diagram might need adjustment. This slider input can be used to alter the vertical scaling of the diagram.

6. **Download Facility Energy and Flow Diagram**



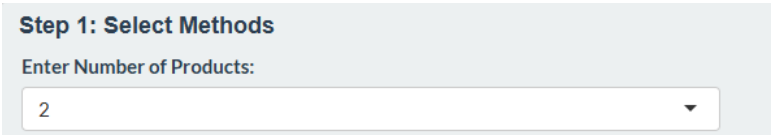
To download the Diagram as an image, click the "Click Here to Download as Image" button. You can adjust the size of the downloaded image by adjusting the inputs for height and width in pixels.

Product Emissions Intensity

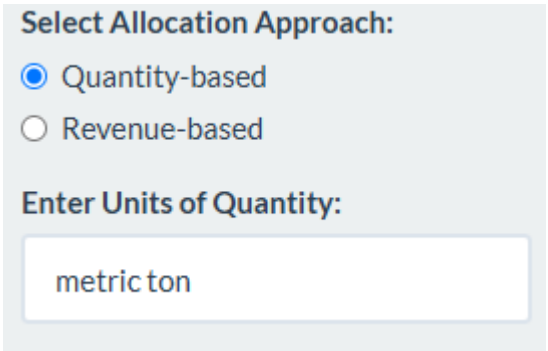
The "Product Emissions Intensity" tab is divided into two sub-sections, namely, Steps 1 and 2. Step 1 involves selecting the number and characteristics of products, such as quantity and revenue. For the purposes of this user guide, two products are analyzed in the following example.

Step 1:

1. Enter number of products that need analysis

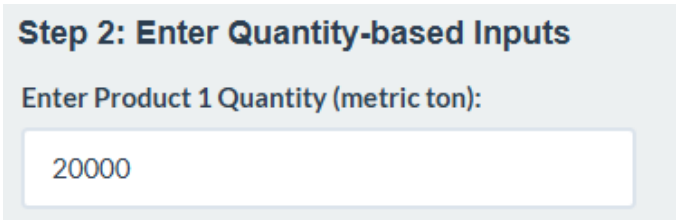


2. Select one approach (i) Quantity-based, or (ii) Revenue-based.
    a. Quantity-based Approach
        i. After selecting the quantity-based approach, users could enter any units of quantity that their products are relevant to. Some other examples are cubic meters (m^3), kilograms (kg), or pounds (lbs.).

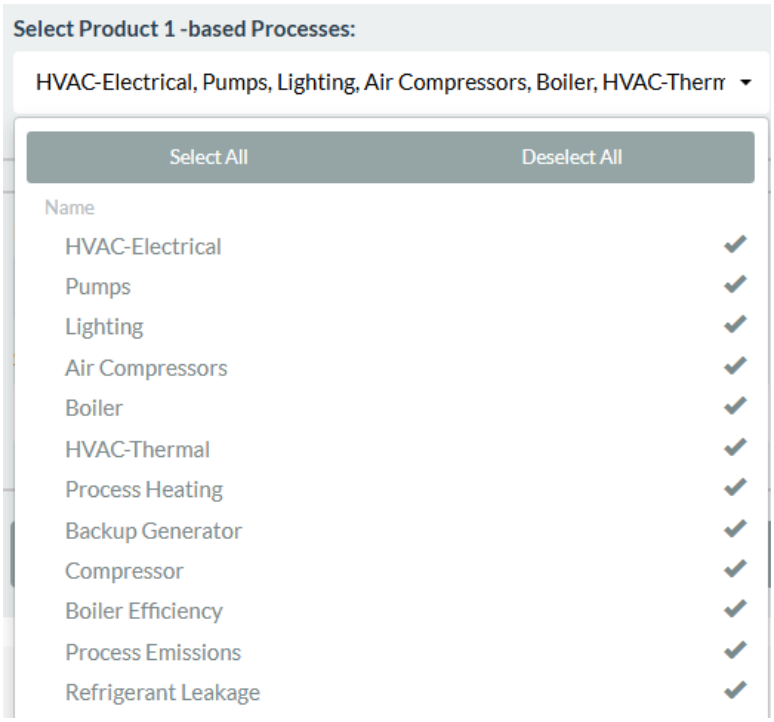


        ii. Enter the quantity of inputs based on the user selected units for Products 1 and 2. For example, Products 1 and 2 quantities are entered

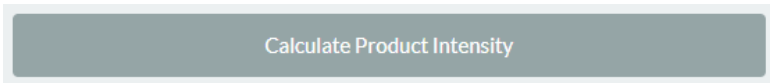
as 20,000 and 30,000 metric tons, respectively. (Note that Product 2 figure is not shown in the figure below).



iii. Select the number of processes that are relevant to the production of corresponding products. The figure below provides an example of processes selected for Product 1. The processes are based on the input excel sheet "Source" column. Users could select or deselect relevant processes.



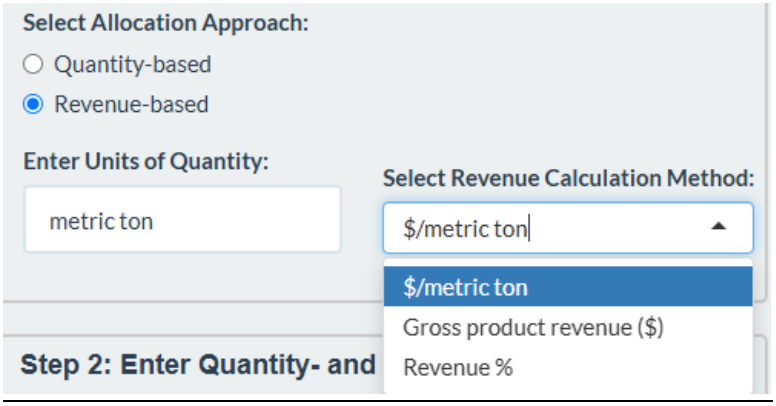
iv. After choosing the products processes and entering their quantity values, users could press the "Calculate Product Intensity" button.



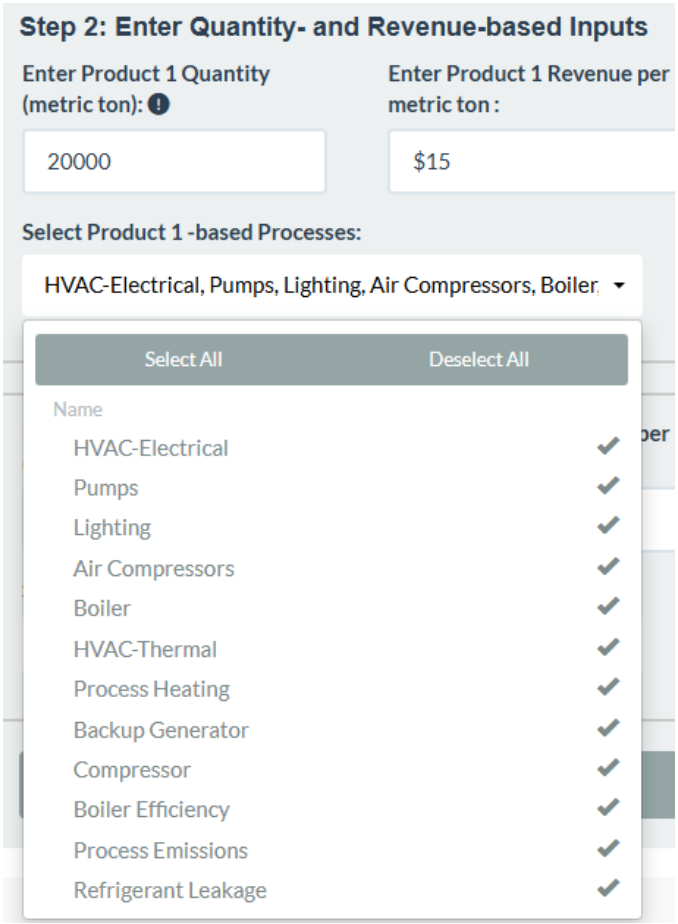
b. <u>Revenue-based Approach</u>

i. For the revenue-based approach, there are three major calculation methods. Users could enter $/unit of product that calculates total revenue based on the product of $/unit and units of quantity. The second option is to enter gross product revenue for each product. For the two methods, the tool calculates the share of revenue for each

product and applies them against the total emissions for each product. Finally, users could select revenue % that creates an allocation percentage for respective products.



ii. In Step 2, users would require entering corresponding product quantity followed by their revenue per unit product – in this case $15/metric ton of Product 1 – as inputs. Similarly, users could select what processes are applicable in producing Product 1 from the dropdown menu as shown in the figure below.



iii. Alternatively, users could also enter gross product revenue or revenue % if that is the calculated method selected in Step 1.
iv. After choosing the products processes and entering their quantity values, users could press the "Calculate Product Intensity" button.

Output

The output from the online tool is a Facility Energy and Flow Diagram showing the facility's energy and emissions broken down into its energy sources and end-uses (Figure 3 and Figure 4).

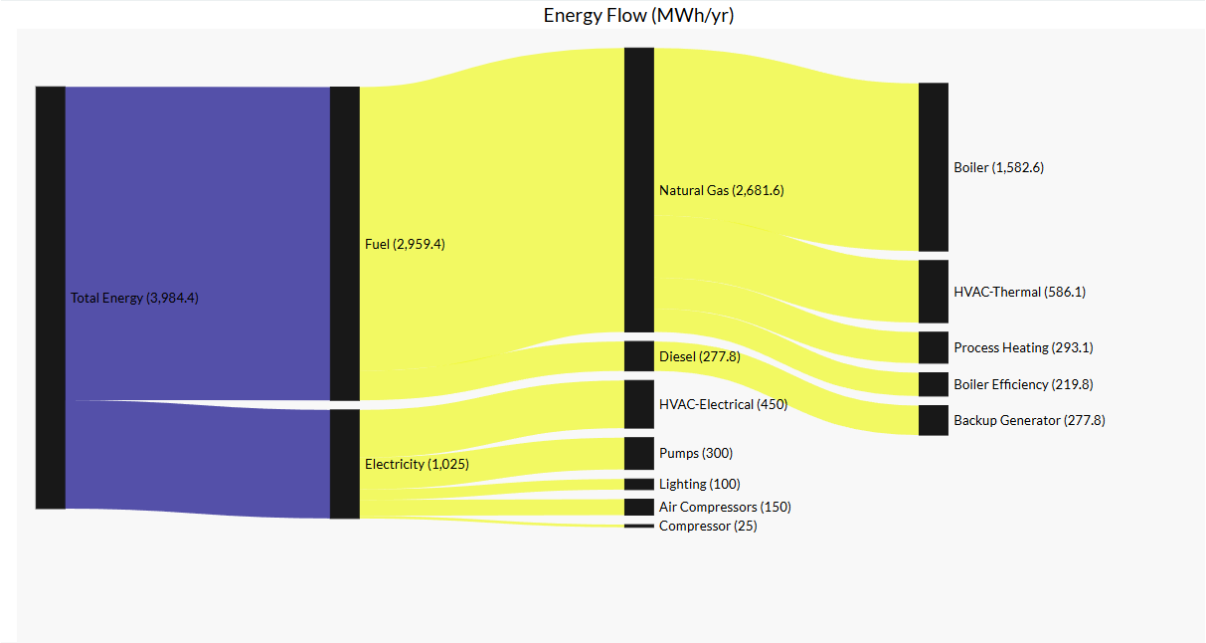
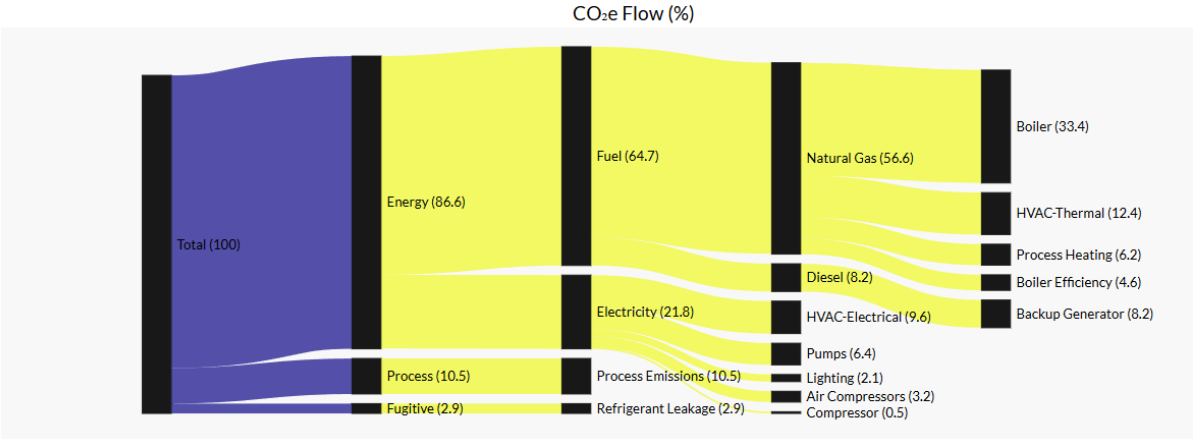


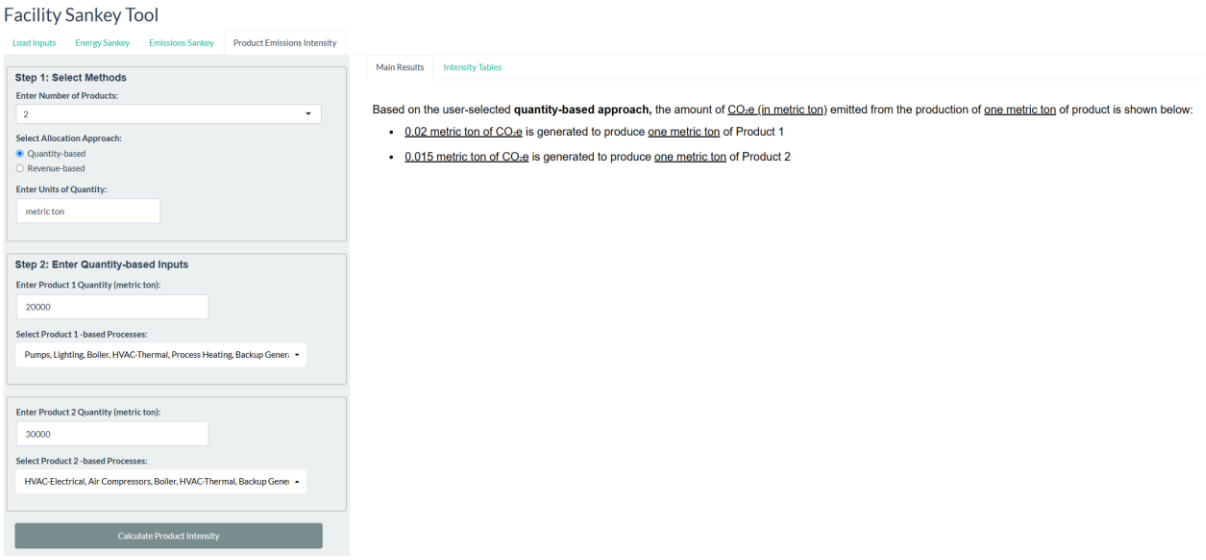
Figure 3: Facility energy flow diagram



Emission Factors Used

Title	Factors	Units	Source
Diesel	7.03e-02	$MTCO_2e/GJ$	EPA
Electricity	1.83e-04	$MTCO_2e/kWh$	2023 eGRID
Natural Gas	5.29e-02	$MTCO_2e/MMBtu$	EPA

Figure 4: Facility emissions flow diagram (tool output)



Product Emissions Intensity

Main Results | Intensity Tables

Product	Quantity-based Emissions ($MTCO_2e$)	Quantity-based Emissions Intensity ($MTCO_2e$/metric ton of Product)
1	396	0.020
2	460	0.015

Download Table Data (.xlsx)

Figure 5: Product Emissions Intensity (Quantity-based Approach) Tool Output

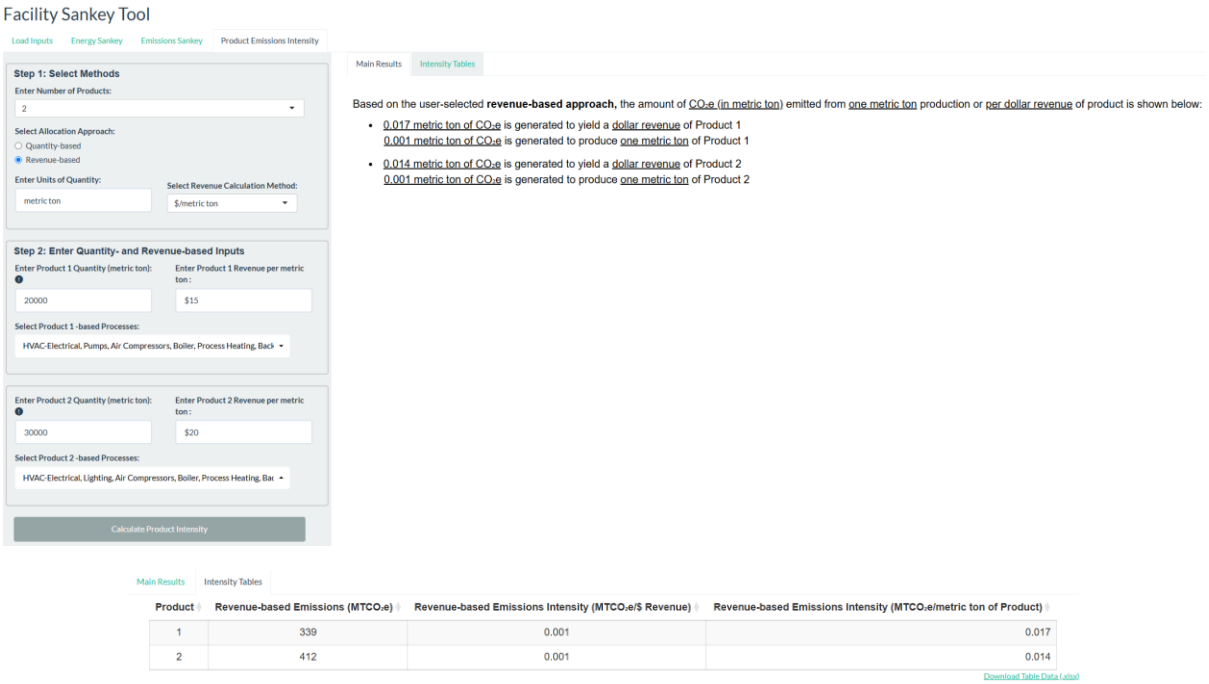


Figure 6: Product Emissions Intensity (Revenue-based Approach) Tool Output for "$/metric ton" selected calculation approach

Product	Quantity (metric ton)	Source	Associated Products	Total Emissions ($MTCO_2e$)	Share of Revenue-based Emissions	Product-level Emissions ($MTCO_2e$)	Revenue-Based Emissions Intensity ($MTCO_2e$/metric ton)	Revenue-Based Emissions Intensity ($MTCO_2e$/$)
1	20000	HVAC-Electrical	1 and 2	82	0.33	27	0.0014	0.00009
1	20000	Pumps	1	55	1.00	55	0.0027	0.00018
1	20000	Air Compressors	1 and 2	27	0.33	9	0.0005	0.00003
1	20000	Boiler	1 and 2	286	0.33	95	0.0048	0.00032
1	20000	Process Heating	1 and 2	53	0.33	18	0.0009	0.00006
1	20000	Backup Generator	1 and 2	70	0.33	23	0.0012	0.00008
1	20000	Boiler Efficiency	1 and 2	40	0.33	13	0.0007	0.00004
1	20000	Process Emissions	1	90	1.00	90	0.0045	0.00030
1	20000	Refrigerant Leakage	1 and 2	25	0.33	8	0.0004	0.00003
2	30000	HVAC-Electrical	2 and 1	82	0.67	55	0.0018	0.00009
2	30000	Lighting	2	18	1.00	18	0.0006	0.00003
2	30000	Air Compressors	2 and 1	27	0.67	18	0.0006	0.00003
2	30000	Boiler	2 and 1	286	0.67	190	0.0063	0.00032
2	30000	Process Heating	2 and 1	53	0.67	35	0.0012	0.00006
2	30000	Backup Generator	2 and 1	70	0.67	47	0.0016	0.00008
2	30000	Compressor	2	5	1.00	5	0.0002	0.00001
2	30000	Boiler Efficiency	2 and 1	40	0.67	26	0.0009	0.00004
2	30000	Refrigerant Leakage	2 and 1	25	0.67	17	0.0006	0.00003

Figure 7: "Download Table Data" to download excel sheet that contains detailed Product Emissions Intensity (Revenue-based Approach) Output for "$/metric ton" selected calculations approach. Excel sheet data is more comprehensive than summary data on the website.