UC SANTA BARBARA
The 2035 Initiative

Frequently Asked Questions

What is "The Clean Heat Climate Opportunity" Scenario Explorer?

This webtool allows users to interact with and visualize the results of our recent report, *The Clean Heat Climate Opportunity: A Roadmap for Electrifying Low- and Medium-Temperature Industrial Heat*. We provide abbreviated summaries of our analysis below, but refer to the report for more details on our results, methods, and conclusions, as well as discussion of policy implications!

How to Use the Tool

How should I interpret the results?
The tool uses publicly available data and the results are modeled based on research from peer-reviewed papers and subsequent assumptions. The results are meant to illustrate trends, relative impacts, and potential outcomes under different scenarios rather than exact forecasts. While the tool provides valuable insights, it does not capture every local condition, operational constraint, or real-world complexity. Results should be complemented with local expertise and additional analysis where possible.

Can I compare different scenarios or locations?
Yes. Users can select different technology scenarios, cost metrics, scenario cases, pollutants, and more to estimate how emissions and economics might change. These selectors are located on the left side pane of the tool.

There's a facility present in the state/county view, but the state/county is grey on the map. Why isn't the data showing up?
Filtering criteria must yield at least two facilities in an area for modeling data to display. Our research does not make claims about individual facilities, so we exclude economic data for geographies with a single facility. "N/A" means that there are fewer than two facilities with results to display in the area.

Where are current industrial electrification projects?
Our map shows the results of our modeling. ACEEE has publicly available data highlighting industrial electrification projects - check out their great work here.

Where can I find a list of the top emitting facilities for a given state?
A ranked list of the top emitting facilities can be found on the right side pane. Note that this is a static list that does not respond to selected filters on the left side pane.

Methods & Data Sources

What types of facilities and industrial processes are included in the tool?
This study focused on industrial sectors that use amounts of process heat in the low-to-medium temperature range (<200°C), which includes the chemicals, food & beverages, and pulp & paper sectors. Within these sectors, we created process archetypes for 32 NAICS subsectors, which are visible in the "Filter Facilities" dropdown.

In these 32 subsectors, we sampled GHGRP-reporting facilities from 2023. This limits the study to facilities with 25,000 metric tons of CO2e emissions annually. From this, we identified facilities with "in-scope" process heat, which includes low-to-medium temperature heat from non-byproduct, non-CHP sources. These are the processes that are electrified in our electrification technology scenarios. See the *Clean Heat Opportunity* report for more details.

What is a process archetype?
Each process archetype models energy and mass flows to characterize how a typical plant operates in a given subsector. Archetypes let us simulate how changes to plant operations – such as replacements of fuels and technologies, improvements in process-level energy and mass efficiencies, recovery and reutilization of waste heat, and efficiency improvements to process heat systems – can affect the overall energy requirements, operating costs, and direct and indirect emissions of industrial plants. This also allows us to estimate the proportion of heat demand in a typical facility that comes from LMT processes, higher temperature processes, CHP units, and byproduct fuels.

What do the "Technology Scenarios" mean?
Each technology scenario models different ways of providing process heat at a manufacturing facility, with differing combinations of technologies and efficiency measures. The technology scenarios are summarized in the table below.

Technology Scenario Name	Process Heat Steam Source	Direct Process Heat Source	Energy Efficiency Measures	Notes
"Baseline"	Natural gas boiler	Direct Combustion Units	No	Business as usual, process heat (steam and direct-fired units) generated via fossil-fuel combustion
"Drop-In Electrification"	Electrode boiler	Electric resistance ovens and dryers	No	Business as usual facility, steam is generated via electrode boilers, direct-fired units electrified
"Drop-In Electrification Max Efficiency"			Yes	Steam and direct process heat systems optimized for efficiency; steam is generated via electrode boilers, direct-fired units electrified
"Advanced Electrification"	Air-source high-temperature heat pump		No	Business as usual facility, steam is generated via air-source HTHPs, direct-fired units electrified
"Advanced Electrification Max Efficiency"			Yes	Steam and direct process heat systems optimized for efficiency, steam is generated via air-source HTHPs, direct-fired units electrified

How is energy efficiency modeled?

We create scenarios that layer **energy efficiency measures** ("Max Efficiency"). The energy efficiency scenarios also model opportunities for waste heat recovery and valorization using **WHRHPs**. Using our process archetypes, we can identify where waste heat sources are typically available and at what temperatures. Importantly, we assess where waste heat is still available *after* primary steam and other LMT heat electrification — we do not harvest fossil-fuel based waste heat.

What are the "Optimistic", "Conservative", and "Average" cases?
We model three cases for each technology scenario: "Optimistic", "Conservative", and "Average." These cases differ in the assumptions used for parameters such as equipment efficiency, equipment costs, fuel prices, and operations & maintenance costs.

The optimistic case uses 'best case' cost and efficiency assumptions for electrification technology scenarios, and 'worst case' assumptions for the Baseline technology scenario. The conservative case is reversed, using 'worst case' cost and efficiency assumptions for electrification technology scenarios and 'best case' assumptions for the Baseline technology scenario. For the "Average" cost outcomes, we averaged inputs and calculated outcomes using the averages.

How are costs estimated?
The basis of the cost estimate is our assessment of facility-level in-scope process heat demand, which derives from our process archetypes. Accounting for unit efficiencies at the relevant temperatures, distributions losses, energy efficiency measures, and more, we can use the in-scope process heat demand figure to estimate the size of the units that a facility requires under different technology scenarios.

Given the size of a unit, we estimate the up-front and operating costs for each technology scenario. Up-front expenses include installation and equipment costs. Operating costs include the cost of electricity or natural gas, as well as operating & maintenance costs.

For more information on cost estimates and details such as energy price data, capital equipment scaling formulas, cost metrics, and more, see the *Clean Heat Opportunity* report.

How are present-day emissions measured?
We used the following data sources to measure present-day emissions for facilities:

- Total GHGRP-reported baseline CO2e emissions (2023)
- Total NEI-reported baseline SO2 emissions (2020)
- Total NEI-reported baseline NOx emissions (2020)
- Total NEI-reported baseline PM2.5 emissions (2020)

Only a subset of facilities report copollutants to NEI (739/934 or 80%). In the aggregate copollutant results, we imputed copollutant amounts for these missing facilities by deriving emissions factors from the NEI-reported baseline in reporting facilities for each fuel. We then multiplied these NEI-derived unit-fuel emissions factors by the unit process heat demand to get a baseline estimate for the nonreporting facilities. Only the NEI-reported copollutant emissions are shown at the facility details level.

How are cumulative emissions measured?
In the Baseline technology scenario, our estimates assume that present-day on-site emissions will remain constant through 2050. This is a simplifying assumption to illustrate potential emissions reductions.

In the electrification technology scenarios, we model partial replacement of on-site fossil fuel demand with electricity. On-site emissions are replaced by grid emissions, which we estimate by multiplying the UCSB-modeled change in electricity demand for each scenario by grid emission factors (CO_2e/kWh). For 2025, we used eGRID emission factors; for 2026–2050, we applied factors from NREL's Cambium *Mid-case with 95% decarbonization by 2050*. Note that eGRID regions cross state boundaries, so these estimates have limited spatial resolution.

Some on-site process heat is considered to be out-of-scope, which includes heat from high-temperature processes, byproduct fuel sources, and CHP units. Out-of-scope onsite emissions were taken from unit-level GHGRP data.

Grid criteria pollutant emissions were estimated similarly, multiplying the UCSB-modeled change in electricity demand by grid emission factors (kg/kWh). For 2025, we used eGRID subregion factors; for 2026–2050, eGRID 2025 factors were scaled using the clean-electricity fraction from NREL's Cambium *Mid-case 95% decarbonization* pathway. Out-of-scope onsite criteria pollutant emissions were estimated using NEI-derived unit-fuel emission factors (EFs). These EFs were constructed by allocating each facility's NEI-reported emissions across combustion units based on unit heat shares and converting the allocated emissions to unit-fuel EFs. Because this method relies on facility-level NEI totals, assumes proportional allocation by heat demand, and does not capture non-combustion $PM_{2.5}$ sources or facility-specific control technologies, the resulting onsite pollutant estimates should be interpreted as approximate. As above, eGRID regions cross state boundaries, so these estimates have limited spatial resolution. See the *Clean Heat Opportunity* report for details.

Any questions or feedback?
Please contact us at 2035initiative@iee.ucsb.edu to ask questions, share feedback, or report technical issues.