Craft Brewery IHP Screening Tool

Final Report

ET23SWE0062

Prepared by:
Harry Gao, TRC
Matthew Stevens, TRC
Glen LaPalme, TRC
Marian Goebes, TRC

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Disclaimer

Abbreviations and Acronyms

Acronym	Meaning
ASHP	Air-source heat pump water heater
BBL	Barrel of beer
COP	Coefficient of performance
DAC	Disadvantaged communities
DOE	Department of energy
DHW	Domestic hot water
EE	Energy efficiency
ET	Emerging technology
GHG	Greenhouse gas
HP	Heat pump
HRC	Heat recovery chillers
IHP	Industrial heat pump
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
kWh	Kilowatt-hour
PA	Program administrator
PG&E	Pacific Gas & Electric
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SGHP	Steam-generating heat pump
SMB	Small and medium businesses

Acronym	Meaning
TPM	CalNEXT Technology Priority Map

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Introduction

In California in 2022, 957 operating craft beer breweries produced 3,551,344 barrels of beer.[1] The total annual energy usage of the beer industry to brew and package beer was 60 GWh of electricity and five million therms of natural gas. Industrial heat pumps (IHPs) could help breweries reduce energy usage, costs, and greenhouse gas emissions during the brewing process. However, there are several barriers to implementing IHPs, including a lack of awareness in the technology, long payback periods, increased operating costs, and lack of program support. This screening tool will help inform breweries of viable retrofit opportunities and the proposed benefits of industrial heat pumps, helping breweries take the first step in overcoming some barriers.

While other heat pump assessment tools are available online, none focus specifically on craft breweries. Experts often consider the industrial sectors as the most difficult to decarbonize, but breweries require low-temperature sources of heat, so they represent an excellent opportunity for switching to heat pumps or other efficient electric heating sources. The project team created this tool to encourage tasting rooms, craft brewery owners, operators, and project developers to start thinking about IHPs for processes, and to motivate them to collect site data to better understand the level, duration, and timing of heating and cooling loads that could help enable them to incorporate heat pump technology.

This screening tool project team focused on craft breweries, which the Brewers Association defines as small independent brewers with less than 6,000,000 barrels (BBL) of beer annual production and less than 25 percent ownership by non-craft brewer alcohol industry members (Brewers Association, 2024). The Brewers Association further subdivides craft breweries into two sizes as shown in Table 1 below. The project team designed the screening tool to be applicable for both sizes.

Table 1. Brewers Association Data

Market Segment	Annual Production (BBL)
Microbrewery	< 15,000
Regional brewery	15,000–6,000,000

This screening tool project aligns with the "Process Loads" category of CalNEXT's Technology Priority Map (TPM). Within the "Process Loads" technology family, this project aligns with three areas: Industrial Refrigeration, Food Processing (process heating and cooling), and Steam & Hot Water Systems. CalNext gives these technology areas medium priority in the TPM, and the project is aligned

[1] Brewers Association Stats and Data, 2022. https://www.brewersassociation.org/programs/brewers-association-events/

with the California Technical Forum's business goal of implementing tools to meet the resource needs for the Cal TF Custom Initiative.

Objectives

The project objective was to develop a Craft Brewery Industrial Heat Pump Screening Tool to assess the viability of potential industrial heat pump (IHP) installations for small and medium business (SMB) craft breweries. The tool should help decision-makers answer some of the following questions:

- Where might a heat pump be viable?
- What technologies might be suitable?
- Do similar installations exist?
- Which technologies and equipment are available on the market for these load types (brewing heating and cooling, domestic hot water, bottle pasteurization, space heating and cooling, etc.)?
- What field data are necessary to improve assessment confidence?

Methods & Approach

The project team used a literature review and interviews with three local California craft breweries to create a screening tool and draft report in response to the above objectives. The literature review helped provide the framework of assumptions for the tool and the interviews added nuance and understanding of real brewery needs.

Literature Review

The project team reviewed conference proceedings, academic papers, briefs from federal agencies, and investor-owned-utility (IOU) sponsored reports to understand the following:

- Applications of industrial heat pumps in craft breweries
- Equipment and operational data required to create a robust screening tool
- Information about available heat pump offerings and relevant policies in California

Craft Brewery Interviews

Next, the project team developed an interview guide to better understand the needs of craft breweries and sharpen the effectiveness of our screening tool. The project team designed the guide with three main sections, detailed below:

- **Perceptions of heat pumps**, to characterize craft breweries' perspective on the usage of industrial heat pumps.
- **Facilities and operations,** to collect additional information on assumptions needed for the screening tool.
- **Feedback on tool,** to improve the usability and practical effectiveness of the tool.

The team used existing industry connections to identify key staff members at breweries, completing interviews with the energy managers and engineers at three different breweries. All three of the breweries qualified as "regional breweries" as defined in Table 1, on the low end of the production range.

Screening Tool

Finally, the project team developed a tool based on our findings from the literature review and interviews. It includes three main sections, shown below, with additional details on its design covered in the Description of Screening Tool section below.

- **The main calculator:** This allows breweries to input their own energy costs and operating processes, select the technology that they are interested in, and review the energy outputs to understand the benefits of heat pumps.
- **Individual heat pump equipment calculators:** For a more detailed look at specific heat pump technologies, breweries can select between air-source heat pump water heaters, steam-generating heat pumps, and heat recovery.
- **Other energy efficiency measure suggestions:** If breweries are interested in other energy efficient equipment besides heat pumps, this chapter contains preliminary payback and process specific unit savings of opportunities for the brewing industry.

Detailed Findings

Literature Review

This literature review begins with a brief background on California's current energy policies that led to this study's inception, followed by a more detailed discussion of how breweries can use IHPs. The team used our findings from the literature review to conceive the industrial heat pump screening tool that is the focus of this project.

Electrification and Decarbonization Policies Relevant to Brewing in California

Legislation and regulation at all levels of government — local, state, and federal — have been enacting and enforcing electrification policies. Heat pump applications, however, are still in the preliminary stages of market adoption and government interventions. Because of this, legislators' efforts to incentivize heat pump adoption currently lack the specificity and nationwide consistency common to more mature energy-efficiency measures. Specific IOU policies, resources, and funding opportunities related to industrial heat pumps include:

- **Statewide/IOU 3rd Party Implementation Programs:** Third-party programs throughout California offer various rebates for residential and commercial heat pump retrofits. These retrofits primarily cover domestic hot water heat pumps and some small-scale air source HVAC heat pump retrofits. There are currently no industrial heat pump IOU rebates offered; however, custom incentives are available in certain programs which interested parties could use for IHPs.

- **Fuel Substitution Policy:** Decision 19-08-009 in 2019 directed the California Energy Division to produce a technical guidance document for fuel substitution measures, which primarily involves switching from natural gas to an electric energy source. The technical guidance document includes a step-by-step guide for calculating source energy savings and CO_2 offsets for fuel substitution projects. This policy allows programs to baseline fuel substitution measures to consistently estimate and claim eligible savings from fuel substitution measures. Many other states lack a similar mechanism for valuing and incentivizing fuel substitution projects.

- **California Energy Commission Grant**: The purpose of this solicitation — GFO-22-301 – Commercialization Industrial Decarbonization — was to fund technology development and demonstration projects of promising pre-commercial technologies to accelerate industrial decarbonization and increase overall energy efficiency to reach statewide goals set by SB 32 (Statutes of 2016, chapter 249), SB 100 (Statutes of 2018, chapter 312), and SB 350 (Statutes of 2015, chapter 547).
- **California Industry Assistance Credit**: The CPUC created this credit program for eligible industrial facilities to reward them for taking early action to reduce energy use and greenhouse gas emissions. The credit is part of California's greenhouse gas reduction program. The specific policies, rules, and formulas are in the December 2014 CPUC Decision (D.)14-12-037, as modified by D.15-08-006, D.16-07-007, and D.21-08-026.
- **U.S. Department of Energy's (DOE) Loan Program**: This is working to support industrial decarbonization throughout the United States to achieve the nation's climate goals. Accelerated by incentives in Bipartisan Infrastructure Law and the Inflation Reduction Act (IRA), consumer pressure, and first movers in the private sector, industrial decarbonization will be important for the shift to a net-zero economy by 2050.

While trending in the right direction, the industrial heat pump market in California is still very young. Some notable barriers still exist from a policy perspective, including a relatively sparse number of rebates and programs available to customers and an energy rate structure that leads to a high ratio of electricity to natural gas costs. While the focus of this project is to create a screening tool for craft breweries to better incorporate IHPs in their brewing process, the results of the research can also provide insights to utilities and legislators on opportunities to help foster a positive climate for IHPs in breweries.

Industrial Heat Pumps in Craft Breweries

Broadly, the brewing process involves heating water, boiling a wort solution, rapidly chilling a boiling solution to (or below) room temperature, and then keeping it chilled at or below room temperature. **Error! Reference source not found.** below typifies the process.

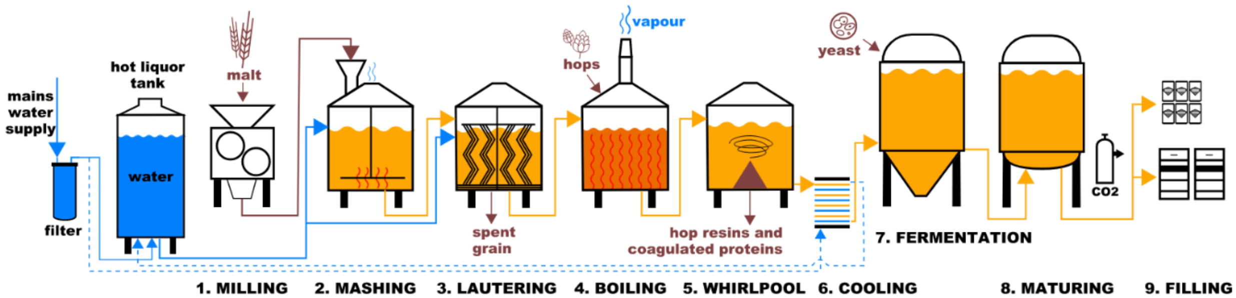

Figure 1: Typical Brewing Process Flow Diagram.

Source: Raffa, Bennet, and Clemon 2022

Currently, very few breweries incorporate IHPs in their brewing process, but the research team identified many potential configurations and applications. The large number of potential configurations and applications are a direct result of high variability in craft breweries facilities, equipment, operations, and throughput. For example, in the "Field Assessment of Energy Use in Craft Breweries in San Diego" (EPRI 2022), two breweries had the same nominal equipment size of thirty barrels (bbl) yet had a large disparity in operation and annual production: 10k vs. 40k bbl.

Heat pumps work by absorbing and concentrating heat from the heat source and rejecting it to the heat sink at a higher temperature. Input energy in either thermal or electrical forms drive heat pump technology. This screening tool focuses on electrically driven technology that uses a closed cycle mechanical vapor compression system which operates by compressing and then expanding a working fluid frequently referred to as a refrigerant. The calculation of a heat pump's ideal (Carnot-cycle) coefficient of performance (COP), an efficiency metric, is:

$$COP = T_{out}/(T_{out}-T_{in})$$

where T_{out} is the temperature the heat pump delivers heat at, and T_{in} is the temperature the heat pump receives heat. The COP of a heat pump is directly related to the heat delivery temperature and the lift in temperature from the input to the output. Both T_{out} and T_{in} are temperatures of the heat pump system, not the incoming heat source, or outgoing heat sink streams. A corollary of this equation is that, for the same T_{out}, the COP increases as T_{in} increases, and for the same T_{in}, COP increases in response to a smaller delta between T_{out} and T_{in}.

For this screening tool, the team categorized the applications of IHPs in craft breweries into three main end uses: water heating, steam generation, and heat recovery/chilling. The three end uses also generally correspond to three types of industrial heat pumps. For water heating, the project team considered air-source heat pump water heaters; for steam generation, steam-generating heat pumps; and for heat recovery/chilling, heat recovery chillers, as shown in Table 2.

Table 2. Recommended Heat Pump Types by Brewery Process

Brewery process	Recommended heat pump type	Rationale
Water heating	Air-source heat pump water heaters	Existing and commercially available. Can function as a drop-in replacement for gas-fired equipment. Heat source is independent from other process steps.
Steam generation	High-temperature heat pumps	Needs to operate higher than 100°C for steam generation. Existing and commercially available. Can function as a drop-in replacement for gas-fired equipment.
Heat recovery/chilling	Heat recovery chillers	Advantageous when there are simultaneous heating and cooling loads. Can concentrate low-grade heat to higher temperatures with more end uses.

There are slight differences in functionality for each of the heat pump types. Firstly, air-source heat pump water heaters (ASHPWH) use ambient air as a heat source and hot water output as the heat sink. These can be unitary systems, where all components are contained within a single piece of equipment and draw heat from their immediate surroundings, as seen in typical residential and light commercial heat pump water heaters. Or they can be split systems, which draw heat from a remote coil typically located outdoors, as seen in larger commercial and industrial systems.

Next, high-temperature heat pumps (HTHP) are frequently split systems and use either the ambient outdoor environment or a low-grade waste heat as the heat source, outputting heat at temperatures higher than 100°C. In this screening tool, the project team only examined steam-generating HTHPs because many craft breweries already employee steam jacketed equipment for process heating and do not have other end uses for high temperature heat. Depending on the temperature of the heat source, an HTHP may have multiple stages with different refrigerants to operate at higher efficiencies than a single stage system.

Finally, heat recovery chillers (HRC) are a technology that can be employed when there are simultaneous heating and cooling loads. A typical chiller used in the brewery industry absorbs heat from a glycol-water working fluid and rejects the heat to the outside ambient environment. An HRC would capture that waste heat and feed it back into the process as a low-grade heat source which can be used for preheating or as an intermediate, low-grade heat-source input in higher-temperature processes such as steam generation.

Error! Reference source not found. below shows the various potential applications for the above-mentioned heat pump technologies (ASHPWH, HTHP, HRC) in brewing. Green boxes denote heat pump technologies, blue boxes and arrows represent heat sources, red arrows and boxes denote end uses (heat sinks). Figure 2 demonstrates that there are a variety of heat sources and end uses for each technology and that they overlap across technologies. For example, ambient air could be the heat source for either ASHPWHs or HTHPs, each of which have multiple end-uses for their outputs. ASHPWHs have four different potential end uses for the hot water and HTHPs have three different potential end uses for the steam while both technologies can be used to supply heat to the hot liquor tank for brewing. Breweries that serve beer brewed in-house and have a restaurant incorporated into the facility are commonly referred to as brewpubs. Brewpubs have additional hot water end uses associated with supporting the restaurant such as sanitation, dishwashing, and restrooms (see "Brewpub DHW" in **Error! Reference source not found.** below).

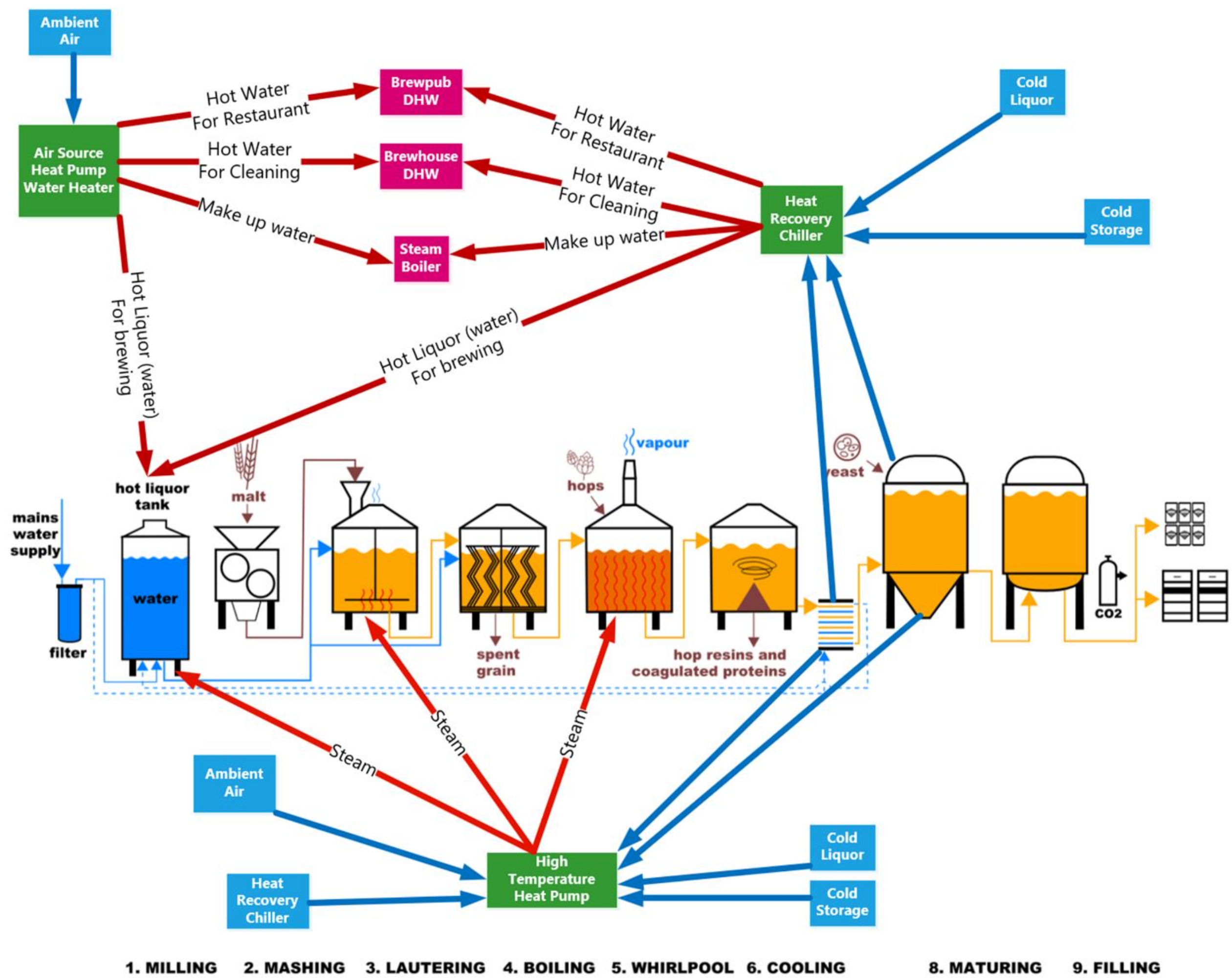

Figure 2: Heat Pump Technologies, End Uses, and Heat Sources.

The many uses for IHPs provide ample opportunities for breweries. However, breweries face several hurdles in the current market. Many brewery staff are still uninformed about even the existence of heat pumps. Even if they are aware of heat pumps, it can be challenging for them to assess the benefits of adoption without prior experience with the technology. Additionally, it is a complicated process for each brewery to assess the right HP technology or combination of technologies that fit within their individual constraints including physical space and incremental cost. The craft brewery IHP screening tool is intended to help them overcome these hurdles.

Interview Findings

Following the literature review and the initial development of a prototype tool, the research team reached out to California breweries to collect information on their perceptions of heat pumps, facility, and operational data to inform the screening tool's calculations, and then to collect direct feedback about tool design and functionality.

Heat Pump Perceptions

Craft brewery respondents were unanimous in their perception of heat pumps. While they were aware of heat pump technology, they had no practical experience using it. All three breweries reported that they were not aware of any of their competitors using heat pumps in the brewing process either, indicating that the heat pump market has yet to penetrate into this particular industry. Respondents were open to the prospect of installing heat pumps because of their familiarity with energy efficiency and the importance of cost savings. Their main concern was the return on investment, with two of the three breweries showing wariness on an expected long wait for the rate of return. Other concerns included having adequate space for a heat pump, reliability, and the potential need to upgrade their electric panel to handle additional usage. Interviewees were very interested in an IHP screening tool that would allow for an initial exploration of some of their trepidations. The project team does not anticipate that our tool or IHPs in general can alleviate all barriers or concerns raised by brewers, but it sheds light on capabilities and limitations of IHP technology.

Screening Tool Assumptions and Feedback

The research team also used the interviews to inform the baseline assumptions of the tool, to add features that interviewees suggested would make the tool more helpful, and to refine calculations for inputs and outputs. For example:

- All interviewees placed a high value on being able to calculate energy and cost impacts on a per-bbl basis as well as annualized energy and cost data.
- One brewer provided typical hot water set points for domestic hot water used for cleaning and other non-process end uses, helping the project team select default values for the ASHPWH tab.
- Brewer feedback on units of measure used most frequently (Fahrenheit, dollar/barrel) enabled the project team to make the tool accessible and approachable.
- The team used data provided during interviews to help select default equipment for the heat pump sizing.

Description of Screening Tool

Our literature review revealed that in addition to the wide range of overlapping heat sources and end uses for each of the heat pump technologies, there are the complicated differences in each brewery's existing equipment, available facility infrastructure, operational behaviors, and electrification or sustainability goals. Interview findings allowed the research team to refine the screening tool into a more practical and effective option for craft breweries interested in industrial heat pumps. Leveraging this information, the team created a tool that helps demonstrate the potential energy and emissions impacts as well as the estimates of cost impacts from select cases. However, these are preliminary estimates meant to be verified by a design professional, should a brewery choose IHP installation. The main goal of this screening tool is to introduce breweries to IHPs and expose the possibilities available to breweries if they choose to employ IHPs. Third-party program implementers may also use this tool to perform site audits for heat pump applications and identify standard energy efficiency measures.

Data and Assumptions of the Screening Tool

The execution of the screening tool required several assumptions about both the baseline and heat pump technologies. For the heat recovery chiller tab, the project team used the "Industrial Heat Pumps for Steam and Fuel Savings" brief (Department of Energy 2003) as the framework for the calculations. The project team also assumed that each of the process streams on the heat sink and heat source side were water rather than create additional fields for specific gravity of the wort and potential mixture ratios of glycol. The team made these assumptions to keep the calculations and required inputs simple and more user-friendly. During the interviews, the project team found that some breweries did not use any glycol in the wort heat exchanger because they employ cold liquor tanks to exchange heat between pre-chilled water and hot wort. Additionally, the project team compared the baseline heating method and the heat recovery chiller against a typical steam jacketed kettle supplied by a natural gas boiler. This means that the heat recovery chiller begins with a significant efficiency advantage due to the nature of steam systems which can frequently operate at a thermal efficiency in the proximity of 50 percent (Inveno Engineering 2019).

While the team intends for brewers to complete their calculations primarily on the "Comparison Calculations" tab, we also include individual technology tabs. Each of these tabs contain additional assumptions. For instance, on the ASHPWH and SGHP tabs, the team assumed that equipment met the required heat source input conditions, and that equipment sizes were comparable to the baseline water heater and boiler sizes. The team considered a standard-efficiency natural gas water heater operating at 80 percent efficiency[2] for the default values on the ASHPWH tab and compared it to a Trane Ascend air-to-water heat pump. The project team assumed a well-maintained, natural-gas-fired steam system for the baseline in the SGHP tab and used a Kobelco SGHP that operates at a COP of 2.7[3] as the default COP.

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[2] 80 percent is the minimum standard set by the DOE.

[3] A COP of 2.7 represents when 45°C water is supplied as the heat source. If higher-temperature water is supplied, such as if most of the incoming water has been pre-heated through heat recovery, then a higher COP should be assumed.

For more accurate calculations, tool users can also calculate their facilities' average loads. The team provides step-by-step instructions within each of the individual equipment tabs for users to calculate average load estimates based on bill data or meter data. If the user is interested in a more simplified estimate of energy and cost impacts, they can use the default average load estimates that the team provides as a starting point.

The team excluded system dynamics as the intent was, to the extent possible, to compare existing equipment with potential IHP replacements. The project team gathered emissions data from the EPA Emissions & Generation Resource Integrated Database, which covers both stationary combustion of natural gas and the emissions rate for the California grid as a whole. Additionally, the screening tool assumes that only electrically powered heat pumps will be employed, in support of California's electrification and emissions reduction goals and moving away from fossil fuels.

Screening Tool Framework

With these assumptions in mind, this next section provides an overview of the framework for the screening tool that the project team developed as the primary deliverable for this project. We designed the tool in the form of a decision tree document to help guide breweries to potential technology applications and an Excel spreadsheet with sheets for calculation estimates for each technology type. Users can input relevant operational data values or estimates such as temperatures, volumes, and energy costs, to tailor the estimates to an individual brewery.

The team split the screening tool framework into two figures shown below. Figure 3 and Figure 4 show the framework for determining the data needed to calculate the savings for each case. Starting with Figure 3, a brewery selects an IHP technology that is in alignment with their goals, equipment needs, etc. Following the equipment sizing subprocess (Figure 4), the brewery then identifies the data needs for evaluating the technology of interest for their specific case. Finally, by following the calculations in the selected examples, the tool provides estimated ranges for energy, emissions, and cost savings.

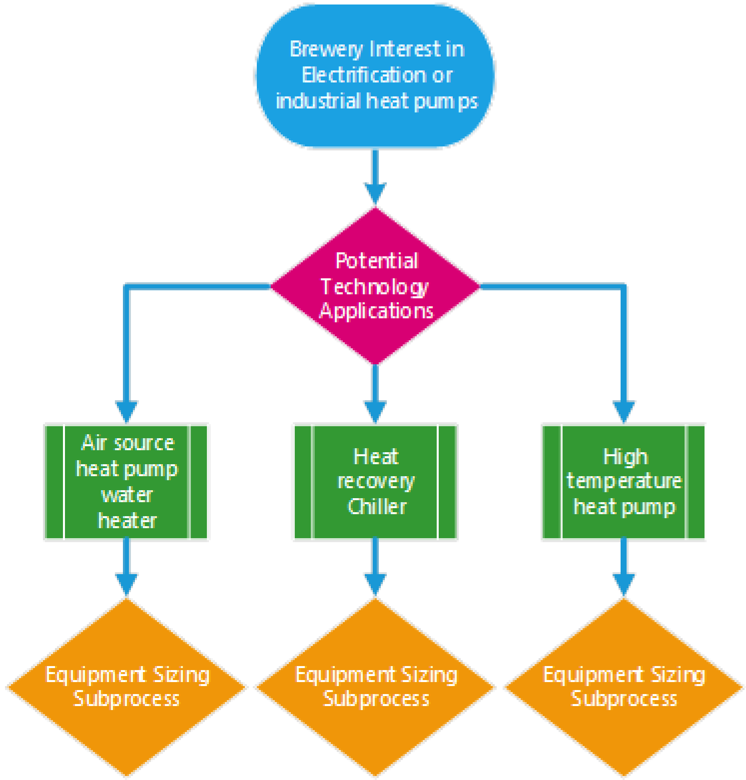

Figure 3: Data Needs Flow Chart, Part 1: Potential Technology Applications.

To calculate the savings for each of the selected cases, the following data is required from breweries:

1. End use product qualities and quantities (e.g., hot water, heating from 60°F to 140°F, 100 gallons per brew)
2. Baseline energy use associated with creating the end use product or equipment efficiency data (e.g., 85 kBtu natural gas per 100 gallons 140°F water)
3. Baseline emissions data for the associated energy use (e.g., 5.3 kg CO_2 per 100kBtu)
4. IHP equipment size and performance parameters at the points dictated by the end use product qualities and quantities (e.g., COP of 2.6 at an 80°F temperature lift to 140°F with an input of 100kW)
5. IHP energy use associated with creating the end use product (e.g., 10kWh)
6. IHP energy use emissions data (e.g., 0.69 kg CO_2 per kWh)
7. Energy cost data for each fuel type (e.g., $0.40/kWh, $2.08/therm, time of use rates, and rate schedules)
8. Operational data for end use product (e.g., 500 brews per year, boiler hours of operation)

Figure 4 shows some of the data breweries may need when considering an IHP for their facilities. If a brewery decides to move forward with IHP installation, they should contact a sizing professional. Based on the default assumptions used in the tool, the project team anticipates that all three heat pump applications will include emissions savings, but cost impacts are more varied (please refer to the tool itself for details). Ultimately, while outputs are heavily dependent on each brewery's specific situations, most breweries will see the most positive cost impacts for heat recovery chillers, followed by air-source heat pumps and steam generating heat pumps.

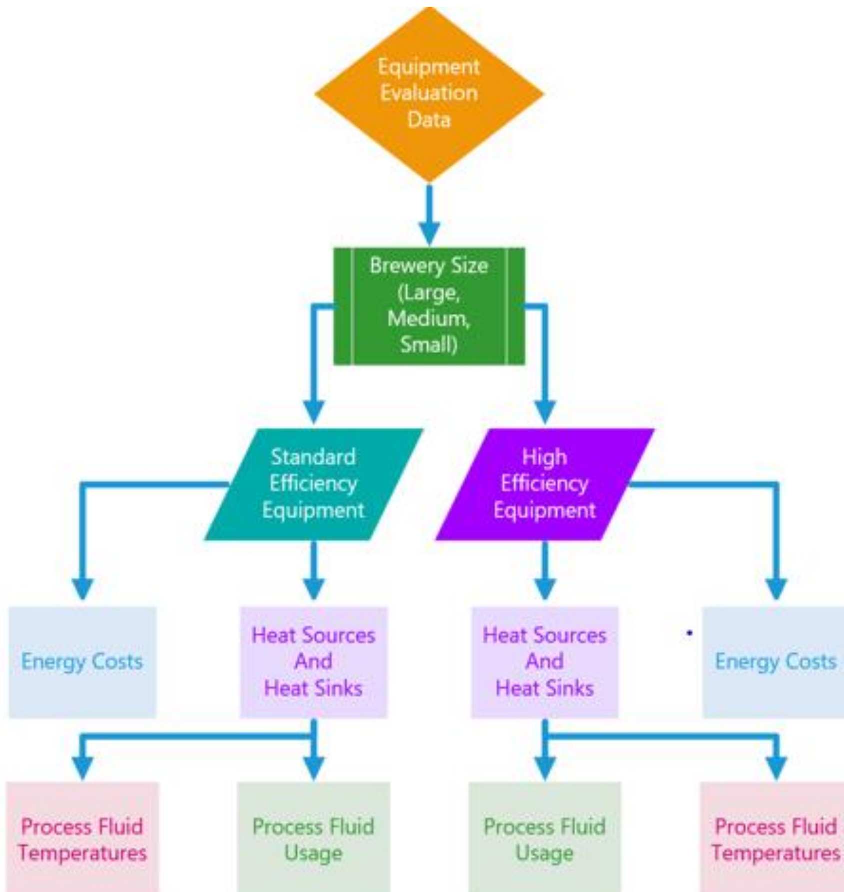

Figure 4. Data Needs Flow Chart, Part 2: Equipment Sizing Subprocess.

Tool users can obtain IHP equipment size and performance parameters from existing equipment manufacturers, if readily available, or for the selected application and alongside equations for an ideal heat pump with appropriate simplified assumptions for real world applications, shown in Figure 5. The team collected other site and equipment data during interviews with selected craft breweries, as discussed in the next section.

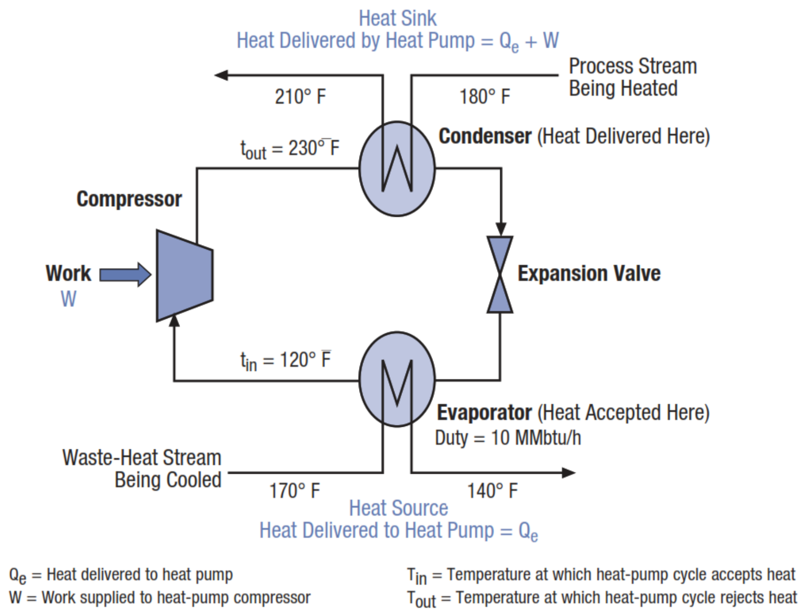

Figure 5. Heat Pump Operating Parameters Diagram.

Other than the technical assumptions made above, it is also important to note that the project team made considerable simplifications about the operational performance of heat pumps in the tool in order to accomplish the goal of informing a wider range of audiences on heat pump performance such as energy and cost savings. Some of the project team's simplifications are:

- The tool does not account for seasonal variation effects on heat pump performance.
- The tool does not account for potential down-sizing of the heat pump to meet load over a longer period of time.
- The tool assumes the heat pumps will be used to satisfy the same load at the same time as the combustion heating system under comparison. This may not be the most cost-effective operational method for breweries.
- The tool assumes a 70-percent load factor for ASHPWHs and SGHPs in the absence of actual energy usage data in the tool.

A brewery interested in taking the next step should contact an experienced design professional who can help with heat pump sizing and accompanying system designs.

Other Energy Efficiency Options for Breweries

Electrification is a critical path forward in California's carbon action plan for 2045, calling into importance the use of industrial heat pumps in breweries. However, California's top priorities are measures for energy conversation and demand response. For this reason, the team is including in this report an energy-efficiency measure checklist (Table 3). The list contains preliminary payback and process specific unit savings based on a Lawrence Berkeley National Laboratory study (Worrel, Galitsky, and Martin 2002). The list helps provide options for brewers either in addition to heat pump installation or as a complement to it.

Table 3. Estimated Savings and Paybacks for Energy-Efficiency Measures*

Primary Energy/Measure (process-specific)	Payback (years)	Savings (kBtu/barrel)
Boilers and Steam Distribution		
Maintenance	<1	4
Improved process control	<1	3
Steam trap maintenance	<1	3.4
Automatic steam trap monitoring	<1	<1
Leak repair	<1	6
Condensate return	>1	19 to 21
Insulation of steam pipes	1	6 to 28
Motors and Systems Using Motors		
Downsizing	2	1 to 2
High efficiency	1 to 2	1 to 2
Refrigeration and cooling		
Improved operations and maintenance	<1	4
System modifications and improved design	<3	5 to 8
Wort boiling and cooking		
High gravity brewing	<1	13 to 22

*Due to feedback from interviews that suggested most breweries require a quick return on investment, this table only includes measures that have a payback within two years. For the full table, please refer to the screening tool itself.

It is important to note that the research team was unable to find updated payback estimates to account for inflation or current energy prices. However, the research team included the values to provide a relative measure of comparison for the different energy efficient measure opportunities found at breweries. By realizing EE savings or recovering waste energy first, breweries could see lower heat pump capacity and cost requirements when considering heat pump installations. Additionally, including some of these improvements could lower the impact on the local grid and improve the project economics. If breweries are not yet ready for industrial heat pumps, they will still have some options to improve energy efficiency. To begin, they can check with their local utility and third-party program implementer for potential incentives and on-bill financing opportunities.

Conclusion

Overall, the project team created a tool that will help breweries and other users better understand the capabilities of industrial heat pumps in craft breweries. IHP technology is fairly new to the brewing industry, but our interviews showed that there is considerable interest. Our tool looks to bridge that gap.

Our literature review established that there are many configurations of IHPs. The project team categorized them into three main applications — water heating, steam generation, and heat recovery/chilling — corresponding with three types of heat pumps — air-source heat pumps, heat recovery chillers, and high-temperature heat pumps. The screening tool lets craft breweries and other interested parties learn about the general relationships of each heat pump technology's performance compared to typical combustion heating methods. It also gives decision-makers a base level of understanding of estimated equipment operating energy and cost impacts. It is important to keep in mind that this is a theoretical tool meant to provide a gateway into IHP technology; it is not meant to size heat pumps or choose specific equipment for breweries.

Based on the default assumptions used in the tool, the project team anticipates that all three heat pump applications will include emissions savings, but the cost impacts are more mixed, as can be seen in the tool itself. Ultimately, while outputs are heavily dependent on each brewery's specific situations, most breweries will see the most positive cost impacts for heat recovery chillers, followed by air-source heat pumps and steam-generating heat pumps.

References

Brewers Association. 2024. "Craft Beer Industry Market Segments." Accessed February 2024. https://www.brewersassociation.org/statistics-and-data/craft-beer-industry-market-segments/.

California Energy Commission. 2023. "GFO-22-301 – Commercialization Industrial Decarbonization (2022 CID Program)." Accessed March 2024. https://www.energy.ca.gov/solicitations/2022-10/gfo-22-301-commercialization-industrial-decarbonization-2022-cid-program.

California Public Utility Commission. 2021. "California Industry Assistance Credit." Accessed March 2024. https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency.

California Public Utility Commission. 2024. "Fuel Substitution in Energy Efficiency." Accessed March 2024. https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency.

Department of Energy. 2003. "Industrial Heat Pumps for Steam and Fuel Savings. A Best Practices Steam Technical Brief." Accessed February 2024. https://www.energy.gov/eere/amo/articles/industrial-heat-pumps-steam-and-fuel-savings.

Dryden, Amy, Andrew Brooks, Meghan Duff, Greg Pfotenhauer, Nehemiah Stone, Sean Armstrong, and Emily Higbee. 2021. "Getting to All-Electric Multifamily ZNE Construction. Draft Final Project Report." EPC-15-097. Accessed September 2023. https://aea.us.org/wp-content/uploads/2021/11/Final_Report_15-097_Getting-to-All-Electric-Multifamily-Zero-Net-Energy-Construction_2021.10.22.pdf.

Electric Power Research Institute (EPRI). 2022. "Field Assessment of Energy Use in Craft Breweries in San Diego." ET18SDG1051 Report. Accessed February 2024. https://www.etcc-ca.com/reports/field-assessment-energy-use-craft-breweries-san-diego.

Inveno Engineering. 2019. "Steam System Thermal Cycle Efficiency." Best Practice No. 66. Accessed April 2024. https://www.best-practice-no66-steam-system-thermal-cycle-efficiency.ashx (swagelok.com).

Raffa, Laryssa Sueza, Nick S. Bennett, Lee Michael Clemon. 2022. "Opportunities for Energy Efficiency Improvements in Craft and Micro-Breweries." *Proceedings of the ASME 2022 International Mechanical Engineering Congress and Exposition*. October 30–November 3. Columbus, Ohio. Accessed February 2024. https://nondestructive.asmedigitalcollection.asme.org/IMECE/proceedings/IMECE2022/86687/V006T08A021/1157184.

U.S. Energy Information Administration. "Electric Power Monthly." Accessed May 2024. https://www.eia.gov/electricity/monthly/.

U.S. Energy Information Administration. Natural Gas Cost, Accessed May 2024. https://www.eia.gov/dnav/ng/hist/n3035ca3m.html.

U.S. Environmental Protection Agency (EPA). eGRID, "Emission Factors for Greenhouse Gas Inventories." Accessed May 2024. https://www.epa.gov/system/files/documents/2023-03/ghg_emission_factors_hub.pdf.

Worrel Ernst, Christina Galitsky, and Nathan Martin. 2022. "Energy Efficiency Opportunities in the Brewery Industry." https://eta-publications.lbl.gov/sites/default/files/lbnl-50979.pdf.

Yarasolav Chudnovsky. 2023. "Challenges Priorities, and Opportunities for Industrial Heat Pumping Technologies." ACEEE Industry Summer Study – Industrial Heat Pumps Workshop. July 11, 2023. Detroit, Michigan. Accessed March 2024. https://www.aceee.org/sites/default/files/pdfs/IHPWorkshops_2023/Yaroslav_Chudnovsky_-_DOE.pdf.