CalMTA Request for Ideas: RFI Submission Questions

Idea Name: Industrial Heat Pumps in California

Submitter Name: Andrew Hoffmeister

Company Name: American Council for an Energy Efficient Economy (ACEEE)

Address: 529 14th Street NW, Ste. 600. Washington, DC 20045

Email: ahoffmeister@aceee.org

Phone: 203-585-7015

Project Submitter Type (Manufacturer, National Laboratory, Utility/Program Administrator, Non-profit Organization, Consulting Firm, Other): Non-profit organization

Is your idea a: (Technology, Practice, and Other __________[specify]) Technology.

Product description & benefits

1) Please describe the technology or practice. (2,000 characters)

The de-fossilization of industrial process heat is critical to decarbonization. Production and use of process heat accounts for approximately 51% of on-site industrial energy consumption in the United States. Electricity supplies less than 5% of that energy demand, while carbon-intensive fossil fuels, primarily natural gas make up the rest. Electrifying the generation of process heat while also enabling waste heat recovery is possible for a substantial majority of applications through industrial heat pumps (IHPs).

ACEEE research has shown that IHPs have the potential to cut the energy use associated with process heat by up to one third and enable CO_2 savings between 30 and 43 million tons per year in key industrial subsectors including chemicals, food and beverage, and pulp and paper manufacturing. According to NREL data, these subsectors combined for over 50 million MMBTUs of energy consumption in 2016 in California. Expanding to all low and medium temperature applications, long-term savings could be as much as 300 million tons per year.

IHPs are powered active heat recovery systems. By increasing the temperature of waste heat and transferring it to where it can be reused they replace purchased fossil fuel energy typically used to produce steam that drive heat-intensive processes in such industries. IHPs operate on basic refrigeration cycle principles: instead of generating heat through combustion of fuel, they compress refrigerants that transfer heat from lower to higher temperatures. IHPs require external energy sources – either electrical, mechanical, or thermal heat – to drive them. The most common configuration is an electric motor-driven heat pump.

IHPs are a critical technology for the clean energy transition for industry because they can help displace carbon intensive, long-lifetime boiler systems, de-fossilize the generation and use of industrial process heat, recover otherwise wasted heat, and deliver non-energy-benefits.

2) Describe how the technology or practice saves electricity or natural gas, reduces peak demand, and/or reduces GHG emissions. (800 characters)

IHPs save gas and reduce GHG emissions by displacing fossil fuels through electrification. IHPs typically transfer 2-3 times more heat than the energy required to drive them, so they can outperform even efficient fossil boilers. In addition, redesigning thermal processes to accommodate IHPs can reduce heating needs from existing steam systems. IHPs save gas by replacing boilers, offsetting fuel costs and steam infrastructure (especially at greenfield facilities), redesigning heat and cooling flows[1], and reusing waste heat. These savings will increase as the grid decarbonizes.

3) Are there additional benefits that your technology or practice will provide? If so, please describe these benefits. (800 characters)

IHPs provide several energy and non-energy benefits. IHPs can simultaneously meet process heating and cooling needs in some applications (e.g., food processing). IHPs can also create water and cost savings by avoiding the need to send waste heat to cooling towers. They can sometimes debottleneck processes increasing production. IHPs can enable wider plant level electrification and other decarbonization measures and technologies, including thermal storage and low-carbon fuels. Manufacturing and implementation of IHPs will create meaningful, long-lasting jobs, as well as accrue benefits from reducing emissions and pollutants in and near marginalized communities, where manufacturing is typically located.

Target market description

4) Describe the target market sector and customers that will benefit from your technology or practice in California. For example, commercial, industrial, single family residential, multifamily residential, agricultural, etc., and, if applicable, key subsector. Be sure to specify whether it will benefit hard-to-reach customers, low-to-moderate income markets, disadvantaged communities, etc. and how. (800 characters)

Industry is a primary beneficiary of IHPs. Emissions reductions and cost savings are essential to a clean energy transition. IHPs are suited to providing low to medium temperature process heating. IHPs are a cost-effective pathway to decarbonization of this economically critical but hard-to-abate sector. Supporting IHP manufacturing and implementation creates equitable, long-lasting jobs in marginalized communities. Food and beverage manufacturing will particularly benefit, especially with new SCAQMD NOx regulations for the subsector.

California's ambitious climate goals can only be reached by decarbonizing hard-to-abate sectors. California could become a leading state in enabling IHP manufacturing and rapid decarbonization.

5) Where, specifically, is the technology or practice available? Is it available to consumers in California? Please provide an example of a specific outlet or service provider, if possible. (800 characters)

We have limited insights into IHP use in the United States. Market implementation has lagged behind the EU and elsewhere. From IEA's technical HTHP annexes, we know of technological capability in various industrial applications, but there is limited product availability in the U.S., and few public demonstrations. IHP equipment at process heat temperatures below ~80°C are available from various

[1] Thermal demands are typically thought of based on boiler technology. When thermal integration analyses are performed, it is often the case that the actual temperature requirements of processes are much less than end-users believe.

manufacturers. Several manufacturers and start-ups are developing new products for the U.S. market including several seeking funding from DOE under various Inflation Reduction Act programs. We anticipate some product announcements in the first part of 2024. IHP manufacturers and component providers agree on the potential for expansion of the North American market. To take advantage of this market, end-users will need to be ready to implement IHPs as they become available and as federal and state programs launch.

6) Describe how the technology or practice is (or will be) delivered to the market. For instance, will it be available for direct purchase by the consumer through traditional retail establishments, or will it be available only through installation by a licensed professional, or something else? Is there a well-established distribution channel that can be used, or would one need to be developed or adapted? Also include any information about potential partnerships or partnership opportunities, including those with community-based or environmental social justice organizations, that would support the advancement of the technology or practice, if applicable. (4,000 characters)

Transformation of the IHP market is required for the technology to be able to achieve industrial decarbonization at scale. This must include efforts in the supply chain to establish the necessary infrastructure to connect various disparate actors and funding sources. For example, engineering firms, installers and maintenance staff need to be trained. Numerous barriers to meeting supply and stoking demand exist that must be mitigated to achieve the potential created by IHPs. Steps to larger scale deployment include:

- Building coalitions to align on barriers, consistent messaging, priorities, and pathways for mitigating barriers. A new national coalition is the IHP Alliance, which is composed of ACEEE, National Electrical Manufacturers Association (NEMA), and the Renewable Thermal Collaborative (RTC). The Alliance is committed to transforming the domestic IHP market through various means of advocacy and research. For additional information on the IHP Alliance, follow this link to the launch announcement. The state should leverage the IHP Alliance for its network of stakeholders, technical expertise, and policy insights.
- Assessing the market to identify best-fit industries and opportunities by temperature range, technology models and geography.
- Pilots at different industries in various applications. Pilots give proof of concept and build market knowledge base for both suppliers and end-users.
- Thermal analyses carried out by experts and third-party engineering to determine pinch points and best fit applications.
- Partnerships between federal agencies, state agencies, utilities, regulators, and energy engineering firms. Partnerships will be needed to support vendor continuity (maintenance and service) and deliver technical assistance.

California funding should leverage existing value chains to support expansion and repurposing of existing production facilities (specifically HVAC manufacturers) to rapidly expand IHP and component manufacturing.

Federal policies and programs to support manufacturing, implementation, and technical assistance, include DOE’s: Technical Applications Partnerships (regional hubs offering expertise in the use and operation of technologies including IHPs); Industrial Assessment Centers (engineering universities that conduct no-cost energy assessments and upgrade recommendations); and the Better Plants Program (helping manufacturers implement technologies and practices to decarbonize). Federal funding is also emerging that can support IHP deployment, including the Defense Production Act, the Inflation Reduction Act, and the 48C manufacturing tax credits (both for manufacturers and implementers), and USDA grants and loans for IHP use in rural applications. Additional information on federal funds to support IHP deployment can be found here.

7) What is your best estimate of current market adoption of the technology or practice? For instance, how many units or what percentage of the target market(s) have already adopted the technology or practice? (1,200 characters)

Our best large-scale estimate of current market adoption of countrywide IHPs is from the International Energy Agency's 1994 Annex 21 Global Environmental Benefits of Industrial Heat Pumps. Although the U.S. is participating in Annex 58, which will be released in 2024, these figures are not yet publicly available. In 1994, the number of plants by subsector with IHPs installed was 20% for pulp and paper, 20% for corn milling, 5% for inorganic chemicals, and 10% for petroleum refining. Additional figures can be found here. However, these percentages will have changed significantly since 1994 due to reduced natural gas prices.

ACEEE is working with NEMA to complete a survey of IHP manufacturers to determine new estimates for current market penetration. Responses to this survey will provide greater insight into the current IHP market and regionality.

Market adoption barriers

8) What is keeping the market from adopting your technology or practice? Please list the key market barriers. (2,000 characters)

On the IHP supply side, the barriers include:

- Large manufacturers are not operating domestically at scale. Currently available IHP products are primarily in the EU and Japan. Incentivizing large market players to produce IHP components and systems in the U.S. will require demonstrated market potential and demand, representing a perceived risk for both suppliers and implementers.
- Limited current vendor support for international product. Because the majority of IHPs and their components are manufactured in the EU and Japan, there can be limited technical and maintenance support.
- Need for engineering workforce to support implementation and integration at end-user facilities. Adequate workforce is needed both in terms of technician installers as well as thermal integration engineers.
- Workforce gaps—In discussions with industrial facilities, labor groups, and IHP manufacturers, workforce availability continues as a major barrier in pursuing industrial electrification and meeting product demand. IHPs need to be supported by well-known vendors with sufficient workforce capacity to offer technical support and continuity of product assistance.
- Intellectual property and codes and regulatory constraints exist for IHP including availability of foreign products and components. Importing foreign products is a pathway through which IHP pilots can be created more expeditiously. However, there are UL certification and intellectual property constraints on importing such products. Uncertainty exists around the

regulatory certainty of availability of refrigerants with high global warming potential (GWP) or that are toxic and/or explosive.

On the IHP demand side, the barriers include the following:

- Lack of demonstrated energy/GHG and cost savings. Because of limited domestic product availability, end-users have little IHP experience. Misconceptions exist at the facility level about process temperatures requirements, meaning that savings are often underestimated without extensive thermal analysis.
- Resource adequacy. Industrial electrification will require significant amounts of new, low-GHG electricity. Utilities have yet to plan to accommodate these increases with transmission and distribution infrastructure buildout. They will also need to accelerate the greening of the grid to ensure that electrification reduces GHG emissions.
- Economic constraints for end-users. IHPs require large capital investments, especially in retrofit applications where thermal systems need to be redesigned. Electricity is relatively expensive in California. This means that the spark-spread, or electricity to natural gas price ratio is relatively high. Attractive IHP paybacks will require state and utility technical and financial assistance. This is especially the case for small and medium sized manufacturers, who should not be left behind in the clean energy transition but may require additional support.

9) What limitation(s), if any, does the technology or practice have that must be overcome? What are the technical barriers, if any? (4,000 characters)

IHP technology readiness level differs by application, heating capacity, and temperature. Below 80° C, applications such as paper de-inking, food concentration, dairy processing, and chemical bio-reactors have proof of market potential. Between 80° and 100° C, for applications such as paper bleaching, food pasteurization, and chemical boiling, IHP use is commercial and competitive, but large-scale deployment has not yet been achieved. Between 100° and 140° C, IHPs for applications including paper drying, food evaporation, and chemical concentration are in first-of-a-kind commercial applications in relevant environments. For higher temperature processes, excluding high temperature steam production, IHPs are at a lower technology readiness level, typically in early to large prototype stage or on pre-commercial demonstration. High temperature heat pumps for supply temperatures higher than 160° C will need additional compressor and refrigerant evolution.

Concerns also exist with refrigerant availability and use under U.S. EPA and state-based regulations. This is especially the case for high global warming potential (GWP) refrigerants, including per- and polyfluorinated substances (PFAS) and fluorinated gasses. Some IHP models in use in the EU and elsewhere use such refrigerants. Natural refrigerants, such as ammonia and butane are seen as potential pathways to reducing reliance on high GWP refrigerants but will need additional guidance and training for use. IHP suppliers will want certainty of their ability to manufacture product in the U.S selected refrigerants. This means that clear, concise, and consistent policy is needed to regulate refrigerants and indicate the path for future action.

Retrofitting heat systems with IHPs can be challenging because of the need to reengineer existing equipment and processes that are highly complex and integrated. Early IHP wins may be at new manufacturing facilities that have been incentivized by federal policy, especially those that intend to be fueled by 100% carbon free electricity without the installation of any natural gas or steam infrastructure.

Energy and cost savings will differ by individual applications, as every industrial facility differs. There are few off the shelf solutions possible with IHPs. Other potential technical hurdles include plant layouts, as sometimes waste heat streams and heat needs are not conveniently co-located within large facilities. There may also be waste heat streams at temperatures unsuitable for lift or cooling to usable applications within facilities.

10) Beyond the standard or base case technology or practice, what are the alternative competing products or services (direct and indirect), and how does your technology or practice compete with them? (2,000 characters)

Natural gas fired boilers and steam systems are the primary competing technology to IHPs. In addition to producing significant emissions, these systems have high costs of maintenance and operations including insurance, water-treatment and permitting. These fossil fuel-based systems require large amounts of space in industrial facilities. They also typically have very long lifetimes, meaning that facilities that operate them are locked into their associated emissions and costs for long periods of time. However, natural gas and steam infrastructure is sometimes needed for higher temperatures than IHPs can currently meet. Such systems are also typically integrated into current industrial processes and will take time and capital to replace. A role for natural gas boilers will likely exist in thermal systems in the near future with IHPs for cycling and reliability.

Natural gas prices are low compared to electricity, especially in California. As marginal electricity costs come down (as more renewable generation comes online), cost parities will improve. Also, as companies look to set and meet decarbonization targets, many will look at fuels such as renewable natural gas (RNG) for which prices are significantly higher. Many agricultural facilities use propane due to limited natural gas infrastructure in rural applications. Replacing propane, which has high price volatility and availability risks, creates potential for cost and emissions savings.

Electric boilers. Although electric boilers can replace the use of any natural gas and electrify industrial processes, the energy efficiency wins they enable are not nearly as great as those created by IHPs. Electric boilers are often more expensive to operate than IHPs because of high electricity cost without these efficiency savings. Emissions reductions created through electric boilers depend entirely on grid decarbonization. However, they can often reach higher temperatures than currently available IHPs. Therefore, electric boilers may have a role of boosting temperatures for higher-temperature processes when paired with IHPs and/or thermal storage.

Combined heat and power (CHP). CHP systems produce both electricity and heat, reducing the need for supplemental electricity and some fuels used for process heat. CHP benefits include increased energy security and energy efficiency gains. They are also very cost competitive with IHPs because of the low cost of natural gas and electricity savings. However, costs associated with CHP systems will likely increase substantially. This is especially the case in modeled scenarios with rising natural gas prices, and even more so if factoring in the likely use of RNG.

11) What type of market interventions, assistance, or support do you think are necessary to overcome the identified barriers? (2,000 characters)

Significant efforts in workforce development and job creation are needed to address gaps in both supply and demand. Trainings need to be created that leverage federal programs including DOE's Technical

Assistance Partnerships and others. These needs include development of the technician/installers, thermal integration engineers workforce, and operator training in IHP operation and the handling of refrigerants.

Pilots, demonstrations, and market assessments will be critical to mitigating any barriers associated with perceived risk, and knowledge gaps. Pilots can be run through utility programs but should be connected with both state and federal funding sources. Statewide market assessments should include temperature ranges of applications, and evaluations of potential market penetration. State-based energy assessments should include identification of IHP opportunities and connect end-users with technical assistance resources.

Policy consistency and transparency on regulatory constraints is needed on components (including non-ASME certified pressure vessels, piping, and heat exchangers), as well as on unconventional refrigerants. Refrigerants especially will require clarity of future regulation in order to enable foreign manufacturers to operate domestically.

California needs to plan for industrial process electrification needs to preempt potential issues with electricity adequacy in parallel with building and transportation electrification.

California will need to offer incentives or other financial mechanisms for end-users looking to implement IHPs to reduce the first-cost capital cost barrier associated with thermal integration analysis and redesign of processes to implement IHPs.

12) Do you have any additional information that would help the CalMTA evaluate your proposed idea? (800 characters)

These responses were written and submitted with the full support of both RTC and NEMA. Contact information for those organizations can be found in the response to the subsequent question.

Industrial heat pumps represent one of the most promising near-term opportunities for decarbonizing California industries. Achieving this potential will require coordinated efforts spanning the value chain. Federal government and industry are working to develop important supporting resources that the state can leverage, but getting this benefit will require the state to develop a comprehensive plan. IHPs should be considered a type of renewable energy technology because they recover and recycle waste heat, and can be driven by renewable, carbon-free electricity.

13) If available, please provide names and links to any recently completed studies, workpapers, measure packages, whitepapers, industry publications, articles, interviews, and other supporting documentation related to this idea. (2,000 characters)

IHP Alliance Contact Information:

ACEEE: Andrew Hoffmeister - ahoffmeister@aceee.org

RTC: Blaine Collison - blaine@dgardiner.com

NEMA: Steve Griffith - steve.griffith@nema.org

- USDOE Industrial Decarbonization Roadmap: https://www.energy.gov/industrial-technologies/doe-industrial-decarbonization-roadmap

- ACEEE IHP report: https://www.aceee.org/research-report/ie2201
- ACEEE IHP website landing page: https://www.aceee.org/industrial-heat-pumps
- ACEEE IHP Market Transformation paper: https://www.aceee.org/sites/default/files/pdfs/ssi23/2-62%20SSI%20Nadel%20final.pdf
- RTC industrial electrification report: https://www.renewablethermal.org/electrifying-us-industry/
- RTC suite of three Heat Pump Decision Support Tools: https://www.renewablethermal.org/heat-pump-decision-support-tools/
- RTC Playbook for Decarbonizing Process Heat in the Food & Beverage Sector: https://www.renewablethermal.org/food-bev-playbook/
- Australian Alliance for Energy Productivity's online heat pump estimator: http://www.heatpumpestimator.com/
- LBNL Electrification of U.S. Manufacturing With Industrial Heat Pumps report: https://eta-publications.lbl.gov/sites/default/files/us_industrial_heat_pump-final.pdf