Decarbonizing Industry with Heat Pumps

Context

Industry accounts for more than 25% of U.S. energy use (including feedstocks) and energy-related carbon dioxide (CO_2) emissions, which must be reduced to achieve national and international climate goals. Among climate stabilization experts, decarbonization—replacing fossil fuels with electricity from low-carbon sources like wind, solar, and hydropower—is a widely accepted goal.

Industry offers some of our best opportunities for decarbonization. The generation and use of process heat accounts for 51% of on-site industrial energy use, so it's a prime target for energy and CO_2 emissions reduction. Today, less than 5% of the energy for generation of process heat comes from electricity. Instead, that energy comes from fossil fuels. There are thousands of industrial operations, and process heat is a cross-cutting use of energy where industrial heat pumps (IHPs) can significantly reduce energy and greenhouse gas (GHG) emissions.

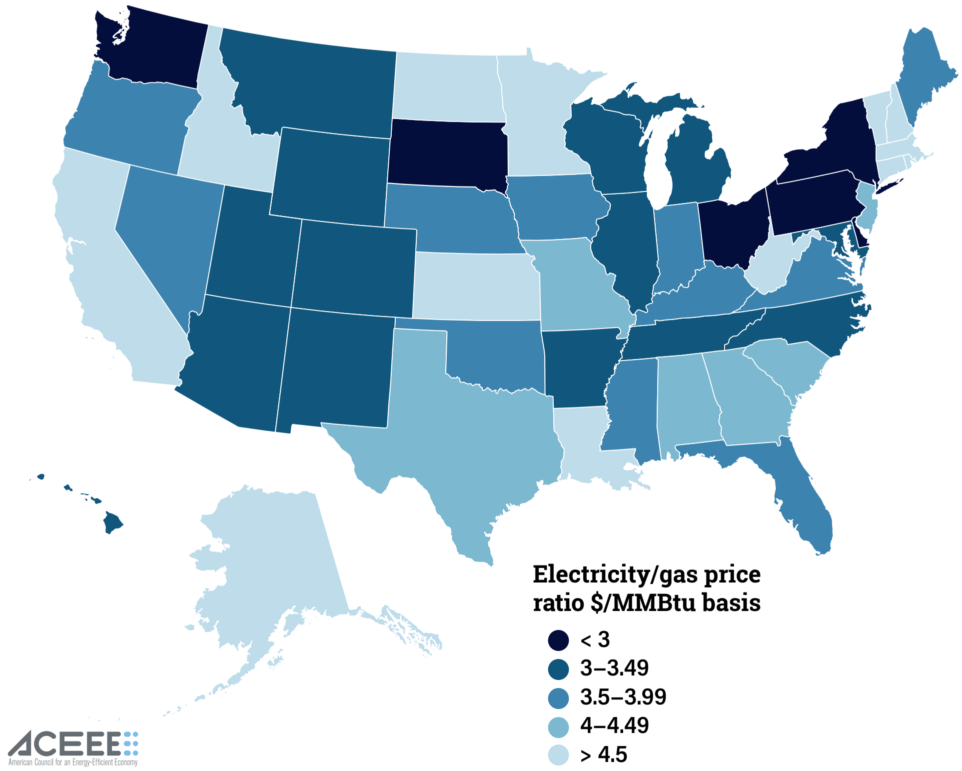
In fact, our research shows that IHPs can cut the energy use associated with process heat by up to one-third. IHPs could provide much of the process heat needed in the pulp and paper, food, and chemicals industries, helping to make drastic cuts in those industries' emissions. And we can do this soon with the right incentives and policy levers.

Industrial heat pumps are not new. They were developed and commercialized in the United States from 1980 to 2000, but the arrival of inexpensive natural gas in the United States cut into their economic favorablity, and adoption stalled. Now, more than a quarter-century later, the urgency of the climate crisis and advancements in IHP technology (some IHP types can now can now reach twice the previous maximum temperature, up to 160°C), make them an eminently logical solution for cutting industrial GHG emissions. Corporate appetite for sustainable energy and GHG reduction is yet another argument for implementing IHPs without delay.

Policy's Role in Enabling IHP Adoption and Scaling

The low price of natural gas in many states compared to electricity is currently the largest economic obstacle to IHP adoption. In many cases, IHPs have paybacks of less than 2 years (a common threshold for acceptability in industry), especially when the electricity/natural gas price ratio is less than 4. In regions of the country with ratios higher than 4, the gap between the electricity and natural gas prices would need to be offset. Even when the ratio is less than 4, incentives would accelerate adoption.

Electricity to gas price ratio



For prospective buyers of IHPs, another obstacle is the uncertainty of investing in something that is not yet common, especially because IHPs are a capital expense that may last 20 years or more. Policymakers can minimize perceived risk through economic incentives like refundable tax credits and direct payments and by supporting the development of a workforce skilled at installing and servicing IHPs (with the added benefit of creating jobs).

Expanding pilot and demonstration projects with IHPs will help convince stakeholders that this technology is not only viable but also advantageous. Because IHPs are not yet widely available in the United States, we need to attract global suppliers to pilot these technologies with U.S. industrial companies that have ambitious carbon reduction goals and spark a domestic market. The market and vendor capabilities for IHPs are most developed in Europe and Japan, where industrial companies see IHPs as part of their plan to reach aggressive sustainability and GHG reduction goals.

Policy approaches need to be supported by a coherent, predictable policy framework to reduce investment uncertainty, improve economics, and spur adoption across the whole distribution of heavy industrial companies and not just leading users.

The Carbon-Cutting Potential of IHPs

Earlier studies showed that moderate deployment of IHPs could avoid emissions of 12–25 million metric tons/year of CO_2 (equivalent to emissions from 2.6–5.4 million passenger cars). ACEEE's new report delves deeper, looking at how and where IHPs could deliver energy and GHG savings while creating multiple nonenergy benefits like cleaner air, jobs, and a more reliable electrical grid.

Because they use a high proportion of process heat below 200 °C (the temperature range reachable by IHPs), three industries—food, chemicals, and pulp and paper—are top candidates for IHP deployment.

Across the breadth of these three industrial groups, IHPs could:

- → Save 427–518 TBtus/year (26–32%) in source energy (net, after subtracting electricity use) depending on the scenario. This is the equivalent energy use/year of 2.7–3.1 million homes.
- → Avoid emissions of 30–43 million metric tons (MMT) CO_2e /year in 2022, equivalent to the emissions of 6.5–9.4 million cars/year.
- → Use 5 gigawatt-hr/year of additional electricity to run the IHPs, facilitating electrification. A gigawatt is the electricity needed to run a medium-sized city.

To realize that potential, we must overcome multiple hurdles, especially price-advantaged natural gas. To mitigate technical risk, we need more research and development of IHP methods, protocols, databases, integration, and knowledge infrastructure to continually improve reliability, further reduce energy and GHGs, and drive the scale of application. We need local workforces that can install, maintain, and service IHPs so that industrial companies feel comfortable investing in them. Multiple states are working on decarbonization roadmaps featuring electrification, and IHPs should play a fundamental role. Policymakers can accelerate IHP adoption with economic incentives, support for pilots and growth of domestic support capabilities, and development of a skilled workforce; such efforts will have the added benefit of creating jobs.

Categories for Enablers

Drivers

- Shift to low-carbon investments, financing
- Increasing demand for low-carbon products
- Development of a coherent, predictable policy framework

Technology
- ► Capability awareness
- ► Smart manufacturing
- ► IHP design choice
- ► Scale-ups and demos
- ► Protocols & tools

Collaboration
- ► Broad partnerships
- ► Clearinghouse data
- ► Protocols, methods
- ► Shared precommercial intellectual property

Field Support
- ► Integration
- ► Vendor support
- ► Technical assistance

Policy
- ► Defrayed electric cost
- ► Support for demos
- ► Incentives at clusters
- ► Support for middle tier
- ► Incentives for adoption

Technical Details

Rationale for IHPs at the Operational Level

There are thousands of industrial unit operations, and process heat is a cross-cutting use of energy across common operations (e.g., separation, drying, evaporation) where IHPs can significantly reduce energy and GHGs. The following sectors and unit operations were selected for this study:

Paper
pulp mill digester; multi-effect evaporator; non-integrated paper mill pulper

Food
wet corn milling steepwater and high-fructose corn syrup starch conversion; potato processing hot-air dryer

Chemicals
ethyl alcohol for fuel applications from dry mill production; ethylene (above ambient) debutanizer reboiler; process water stripper reboiler

Pictured below: Steam Grow Heat Pump SGH 120/165 from Kobelco at CRIEPI (Central Research Institute of Electric Power Industry) in Japan (Photo credit: Cordin Arpagaus, Switzerland) © Cordin Arpagaus

The combined impact of these unit operations—using the Mechanical Vapor Compression IHP as an example—is as follows:

Paper and pulp: The unit operations studied represent 43% of the sector's process heat demand.

- → IHPs could potentially save 42%–57% of the process heating demand.
- → For all 338 facilities, IHPs could supply an estimated 3,370 MW of process heat.
- → Up to 6,507 GwH/yr (MMkWhr/yr) of additional electrical demand needed.
- → Carbon savings could be 3.8 MMT CO_2e/yr (5.7 MMT CO_2e/yr in 2050 with lower grid emissions factors), equivalent to the energy use of 478,700 U.S. homes in 2020.

Food: The unit operations studied represent 10% of the sector's process heat demand.

- → IHPs could potentially save 10%–37% of the process heating demand, if fully implemented.
- → For all 78 facilities in the subsector, IHPs could supply an estimated 535 MW of process heat.
- → Up to 1214 GwH/yr of electrical demand would be needed to run the IHPs.
- → Carbon savings could be 0.5 MMT CO_2e/yr (0.9 MMT CO_2e/yr in 2050), equivalent to the energy use of 63,000 U.S. homes in 2020.

Chemicals: The unit operations studied represent 16% of the sector's process heat demand.

- → IHPs could save 80% of the process heating demand analyzed, if fully implemented.
- → For all 218 facilities in the subsector, IHPs could supply 6673 MW of process heat.
- → Up to 9057 MMkWh/yr of additional demand needed.
- → Carbon savings could be 9.0 MMT CO_2e/yr (11.7 MMT CO_2e/yr in 2050), equivalent to the energy use of 1.13 million U.S. homes in 2020.

For example, in the paper digester case, to achieve a 2-year payback, a capital cost adder of 10%–70% would be needed, depending on IHP type and the electricity/natural gas price ratio. In some states this price ratio is already less than 3, but in more than 80% of the states the ratio is above this marker. Here, policy incentives would help companies consider IHP options favorably when they consider industrial boiler replacement.

To read our full report, "Industrial Heat Pumps: Electrifying Industry's Process Heat Supply," visit aceee.org/research-report/ie2201. Learn more about ACEEE's industrial work at aceee.org/program/industry.

*About ACEEE: **The American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.*