Industrial Electrification Through Heat Pump Adoption for Process Loads



Industrial heat pump (IHP) development started in the 1980s. The systems have great potential to decarbonize industrial thermal processes, but they have not seen extensive use in the US. For example, the 2018 Minnesota Energy Efficiency Potential Study found that the industrial sector had the second highest potential for natural gas savings. One of the largest opportunities in the sector is process heating – which is 13% of all industrial potential savings. The primary goals for this market assessment were to identify and evaluate best candidates for moderate- to high-temperature heat pump applications and determine steps needed to establish market adoption of these technologies.

IHP System Characteristics

IHPs that can produce hot water to just below water boiling temperatures are available using a variety of refrigerants. Many manufacturers have systems with supply temperatures from 212°F (100°C) to 300°F (149°C) using multiple stages of compression and supply temperatures >300°F (149°C) can be produced using a booster steam compressor. About half of process heat loads require too high of a temperature for commercially feasible IHP units. Large customers are more likely to have optimal applications for heat recovery, while small customers are more likely to have suitable process loads for lower temperature or air source applications.

Stakeholder Interviews

The interviews revealed growing interest in IHPs, particularly driven by corporate sustainability goals and greenhouse gas reduction targets. While plant managers were generally unfamiliar with IHP technologies, especially for high-temperature applications, they expressed strong willingness to explore pilot projects when aging equipment or sustainability initiatives were present. Manufacturers and consultants were well-informed and noted increasing market traction, particularly in Europe. Utilities are beginning to support industrial electrification through custom programs and pilot funding, though there was no consensus on whether prescriptive or custom rebates would be most effective.

IHP Evaluations

The site surveys of six industrial plants found that hot water heat pumps provided better economics than steam heat pumps when applied to the same heating process. However, in all cases, both types of IHPs had higher energy costs than the current gas systems that they would replace. This is due to the relatively high spark gap for Minnesota which ranked 41st of the 50 U.S. states. However, excluding electric demand charges brings COP_h above the spark gap, suggesting that thermal storage, demand management strategies, or modified rate structures could make certain installations financially viable.

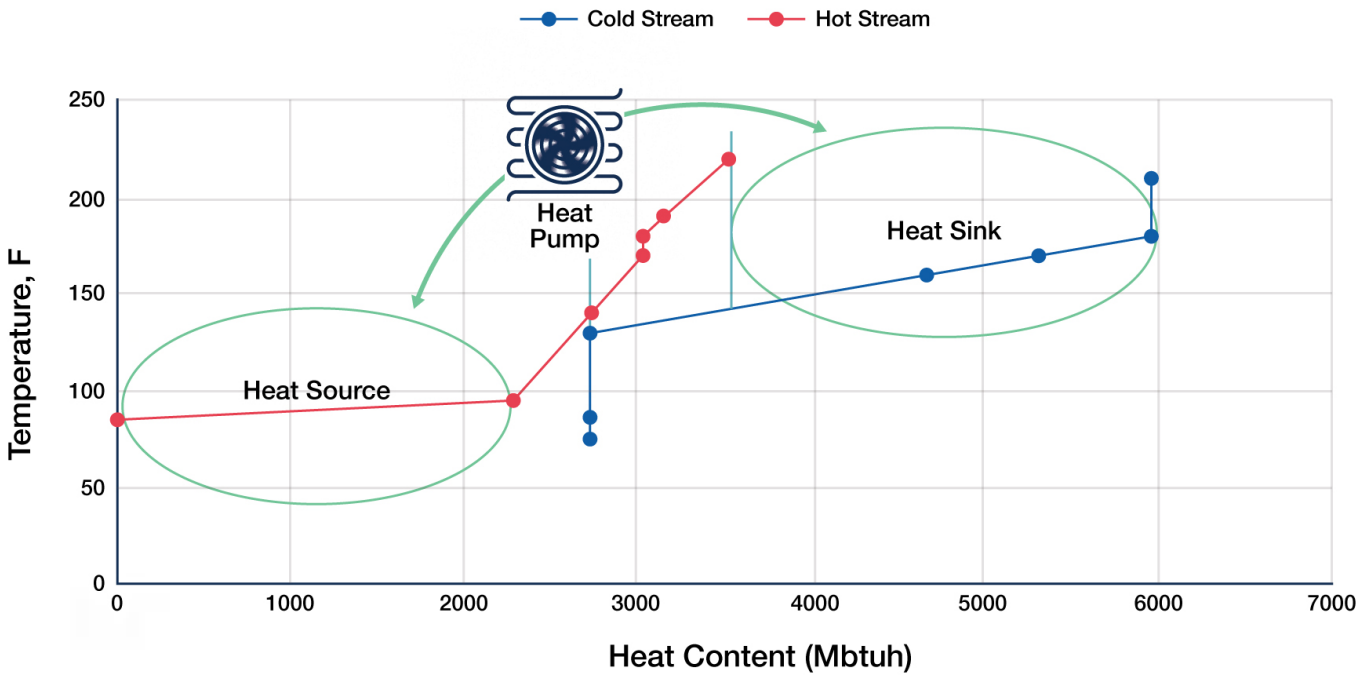
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Market Potential

The market potential analysis indicated that industrial heat pumps IHPs have the potential to replace up to 32% of Minnesota's industrial natural gas consumption, equivalent to approximately 12.6 million Dth annually. Food processing, pulp and paper drying, and chemical manufacturing emerged as the most promising sectors, with food processing alone accounting for nearly half the total technical potential. However, with current Minnesota industrial gas and electric rates, only 4.7% of industrial gas use is economically viable for heat pump replacement, and just 2.4% is considered maximum achievable under current market and policy conditions.

Roadmap to Market Adoption

We identified five-steps to help achieve greater adoption of IHPs. Identification of high-potential sectors, improved screening tools, and broader education efforts are essential to overcome current barriers and unlock the full potential of industrial heat pumps in Minnesota. Demonstration projects will be a key step to build confidence and showcase successful applications. The sites should ideally be widely applicable, economically viable, and capable of replacing a significant portion of heating loads. Two Minnesota utilities have approved demonstration projects. In addition, refined metrics, rate innovation, program bundling, and enhanced customer services — create a pathway for utilities to accelerate industrial electrification.



Pinch analysis composite curve showing overlapping thermal profiles of hot and cold process streams. Red lines represent heat sources, and blue lines represent heat sinks needing heating. Green arrows and circles indicate potential for heat pump integration, where low-temperature waste heat from cooling processes can be upgraded to meet hot water or steam needs. The chart helps visualize temperature lift requirements and opportunities for energy recovery using industrial heat pumps.

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