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FINAL REPORT

JULY 7, 2026

Industrial Heat Pump Technology and Market Assessment



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July 7, 2026

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under Project 23809

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EXECUTIVE SUMMARY

Industrial heat pumps are emerging as a practical and increasingly important pathway for reducing energy use and emissions in industrial and institutional facilities served by Peoples Gas and North Shore Gas. These systems upgrade waste heat or use electricity to deliver useful process heat with efficiencies significantly higher (COP highly dependent on integration, but roughly around 3 to 5) than conventional combustion equipment (COP < 1), offering a compelling means of reducing natural gas consumption and advancing long-term decarbonization goals. Multiple national and statewide assessments highlight the role of electrified process heat in future industrial energy systems, particularly as the electric grid continues to transition toward lower-carbon generation. Within Illinois, where industry accounts for a meaningful share of statewide emissions and where long-term policy targets call for a fully carbon-free power sector, interest in electrified heat solutions is expected to grow.

A review of current industrial heat pump technologies shows that commercially available systems in the U.S. can now provide hot water up to approximately 248 °F (120 °C) and, in several cases, low-pressure and medium-pressure steam. These offerings represent a notable advancement over prior years and include products from major international and domestic vendors with established U.S. presence. Many of these systems are already widely deployed in Europe and Asia, and U.S. manufacturers are rapidly expanding product lines, capacity ranges, and temperature capabilities. For the types of moderate-temperature process loads common in food and beverage, chemical production, pulp and paper, and institutional facilities, these technologies can reduce site energy demand by a factor of two to five when properly integrated.

The market assessment conducted for this study finds that the Peoples Gas and North Shore Gas service territories include a relatively small but diverse industrial base, with substantial gas consumption concentrated among large users. Within these customers, the greatest near-term opportunities for heat pump adoption lie in food processing, chemical production, and large institutions such as hospitals and universities. These facilities often have thermal networks, simultaneous heating and cooling loads, or processes operating in temperature ranges compatible with today's industrial heat pump equipment. Technical potential across the sectors analyzed exceeds 43 million therms of natural gas use. However, due to current equipment costs, electricity-to-gas price ratios, and site-specific integration challenges, the near-term economically feasible potential is estimated at roughly 1 to 2 percent of large-user consumption.

Several barriers currently inhibit adoption. Many facilities in Illinois face unfavorable electric-to-gas spark ratios (in the range of 3.4 to 4.1) that require high heat pump performance to reach cost parity with natural gas systems, and capital costs remain higher than for combustion equipment. Space constraints, electrical service upgrades, and limited familiarity with heat pump technologies further restrict implementation. Additionally, the limited number of U.S. industrial reference installations—particularly for steam applications—contributes to uncertainty among engineering firms and plant operators. These challenges were reflected in customer outreach during the study, where low awareness and competing operational priorities limited participation in proposed pilot evaluations.



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Nonetheless, for a small percentage, the findings indicate that industrial heat pumps offer meaningful near-term opportunities for select industrial and institutional users and can play an important long-term role in reducing regional emissions as technology costs decline and electricity becomes cleaner. Realizing these opportunities will require targeted education for customers and design firms, development of integration guidance and screening tools, and support for demonstration projects that document real-world performance. Incentives and coordinated program design—especially for applications requiring enabling infrastructure or steam-generating heat pumps—will be vital to improving economics and building confidence. Over time, these activities can help create replicable case studies, expand market expertise, and accelerate broader adoption across the Peoples Gas and North Shore Gas territories.



INTRODUCTION

Introduction to Industrial Heat Pumps (IHPs)

IHPs are emerging as one of the most versatile and impactful technologies for decarbonizing process heat—the single largest use of energy in U.S. manufacturing—by recovering and upgrading waste heat and electrifying heat supply with much higher efficiencies than combustion systems. Multiple recent assessments converge on the same signal: IHPs can deliver substantial energy and emissions reductions across food and beverage, chemicals, pulp and paper, and other moderate temperature processes, particularly as the grid decarbonizes. The utility of IHPs can be seen in its value to Illinois' industrial sector, which comprises 18% of the states total emissions¹. Given Illinois' legislated mandated² trend to decarbonize by targeting a 100% carbon-free power sector by 2045 and using 100% renewable energy by 2050, IHP's could play a vital part.

The U.S. Department of Energy (DOE) *Industrial Decarbonization Roadmap*³ places industrial electrification—including heat pumps—alongside efficiency, low carbon fuels, and carbon management as a core pillar for cutting industrial emissions on a path to net zero by midcentury. The roadmap highlights process heating (Figure 1) as a crosscutting priority and identifies food & beverage and chemicals among the sectors where electrified heat solutions can meaningfully reduce emissions.

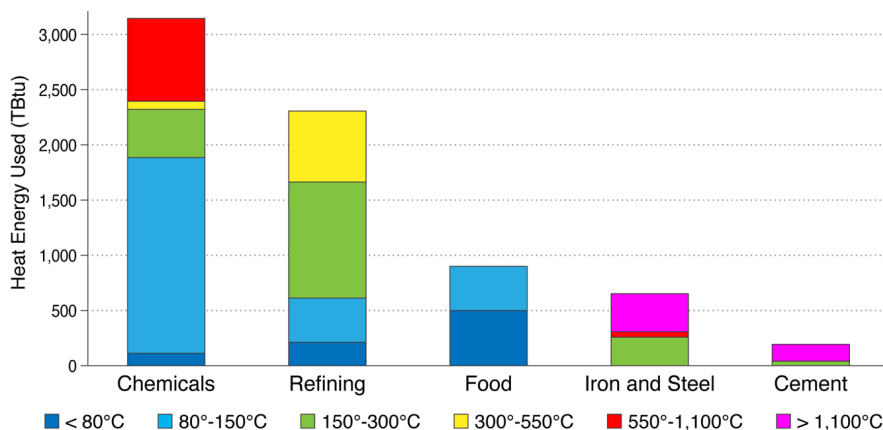


Figure 1: Distribution of Process Heat Temperature Ranges by Industrial Sectors (2014)

Other sources reinforce the applicability of IHPs. The American Council for an Energy Efficient Economy (ACEEE) estimates that moderate deployment in high process heat sectors could cut up to ~32% of net energy use and CO₂ emissions for applicable loads, with attractive paybacks in favorable power–gas price environments.⁴ State and utility consortia (e.g., CalNEXT⁵ and MN CARD⁶) also find that a significant share of U.S. industrial thermal demand falls within current heat pump temperature capability (roughly up to 150 °C/302 °F), underscoring a large technical potential for electrified process heat when systems are properly integrated.

Given the strong interest and support, the question remains that despite the interest there has been very limited implementation of IHP technology. With few exceptions, there are almost no



IHP installations in Illinois. This topic is outlined in further detail below, but the factors that contribute to lack of adoption include economics, application challenges, electrical readiness and uncertainty.

IHP Technology and Applications

At its core, a heat pump moves heat from a lower temperature source (such as as dryer exhasut at 140°F) to a higher temperature sink (drying at 200°F) using mechanical work—typically an electric motor driving a compressor—rather than creating heat by combustion. That shift enables coefficients of performance (COP), defined as ratio of energy output to energy input, well above one (often 2–5+ in industrial applications), translating into a potential for large primary energy and emissions savings, especially as electricity carbon intensity falls. Industrial systems use familiar heat pump concepts extended to industrial processes:

- Higher lift (temperature difference between source and sink) and delivery temperatures, commonly 70–150 °C (158-302°F) today, with R&D pushing higher,
- Larger capacities (hundreds of kW to multi MW), and
- Tailored integration with process streams (e.g., waste heat sources, preheating, steam generation or boiler feedwater, and multi effect configurations).

IHPs appear in several configurations: closed cycle mechanical (the most common, using a refrigerant loop), open cycle/mechanical vapor recompression (MVR) for evaporators and distillation overheads, and hybrid/thermal driven variants.

While the practical envelope is expanding, today's commercially-available IHPs most economically target low to moderate temperature process heat and applications with recoverable waste heat at meaningful flow and temperature. Illustrative sweet spots include:

- Food & beverage: pasteurization, blanching, wort heating, bottle washing, hot water/steam for sanitation, drying and dehydration with heat recovery.
- Chemicals: distillation reboiler duty via MVR, solvent recovery, reactor jacket heating/cooling integration.
- Pulp & paper/textiles: whitewater and condensate heat recovery, drying with recirculating air streams.

Temperature lift—the difference between source and sink temperatures—strongly influences COP and economics; higher lifts mean lower COPs and larger compressors. Process designs that minimize lift (e.g., with pinch analysis, heat-exchanger network adjustments, or staged heat pumps) yield markedly better performance and cost outcomes. Integration engineering is case-specific and not “plug-and-play.”

IHPs are generally not capable of addressing very high temperature processes (e.g., >200–300 °C) in applications such as primary metals, cement, certain chemical industries, high temperature kilns, or cracking units. Ongoing R&D on working fluids, multistage cycles, turbo-compressors, and materials that are pushing deliverable temperatures upward, but processes requiring these temperatures are unlikely to benefit from electric IHPs.



Technology benefits

Energy & operating cost performance.

Well-matched IHP applications can reduce site energy use substantially because a COP of 3–4 implies 3–4 units of delivered heat per unit of electricity input. System modeling shows source energy savings potential in the targeted sectors; field and prototype results are documented aligning with these gains under realistic duty cycles. In this context, site energy is the energy consumed at the facility by the equipment, as recorded by the gas and electric utility meters. Source energy is the sum of all energy inputs required to power the equipment: the energy used on-site (site energy) plus the energy required to produce, transmit and distribute that energy to the site. The spark ratio (or spark spread)—the ratio of electricity to gas price per unit energy, is a key determinant of operating cost economics, but even where electricity is more expensive per unit energy, the effect of COP can offset that disadvantage.

Emissions and air quality. IHPs allow facilities to recover waste heat and shift heat loads to electricity, thus reducing on-site combustion and associated criteria pollutants. Local emissions and air quality improvements are possible as loads shift to electricity—transferring emissions from the site to the grid. While current grid carbon intensities are often high, as grid carbon intensity declines, emissions will drop over time. In general, energy efficiency approaches offer the highest immediate emissions reduction, while electrification of heat may drive decarbonization over a longer period.

Process integration and product quality. Beyond energy and emissions reductions, industrial users may realize process control benefits such as reduced cycling of boilers resulting in tighter temperature control, reduced thermal stresses, and productive reuse of waste heat. One practical strategy involves preheating of process wash water or boiler feedwater. Commercially available air-to-water heat pumps, requiring system integration, can reduce gas use without forcing wholesale process redesign, but often results in lower COP than heat pumps with integrated waste heat recovery.

Workforce and maintenance. Compared with combustion systems, IHPs typically require different skills (refrigeration systems and controls). Maintenance aspects of industrial heat pumps are different and may be somewhat higher. Pilot demonstrations and workforce training will be crucial elements to lowering adoption barriers and growing local service capabilities.

Current state of the market and trends

Across Europe and parts of Asia, industrial deployments are mounting, largely driven by higher gas prices, energy resilience and carbon policies. The U.S. market drivers are different and IHP adoption lags but is being evaluated considering sustainability and economic factors. Technical advancements and vendor innovation in High Temperature Heat Pumps (HTHPs), for example, multi-stage compression, oil-free turbomachinery, MVR and low-GWP refrigerants are broadening feasible temperature ranges and applications.

Studies for California's CalNEXT program review the statewide technical potential and identify immediate demonstration niches (e.g., central hot-water generation for cleaning/sanitation). In



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Minnesota, a CARD project concludes that IHPs could replace up to approximately 32% of industrial natural gas for process heat in the state, while acknowledging that the current spark gaps make the economics challenging. That finding is salient for the markets served by Peoples Gas and North Shore Gas (PG/NSG) where many industrial subsectors resemble Minnesota's mix.

Policy drivers have varied significantly over recent years, with Federal leadership under the Inflation Reduction Act (IRA 2022) being limited in the next administration. DOE's 2022 roadmap focused RD&D around industrial electrification and prioritizing sectors with high process heat demands but has been curtailed since initiation. Currently, utility and state initiatives are the key policy drivers, with strategies including research programs, opportunity mapping, field trials, and generating measure packages that can feed directly into efficiency and electrification portfolios. Policies can address the need for industry education, design firm engagement, and technology transfer for pilot plants to become replicable offerings.

Industry consortia and research institutions can support the effort through solid engineering and applied knowledge. GTI Energy offers thorough understanding of both gas and electric systems and related costs, and along with others (EPRI, ACEEE and RTC) has provided technical updates, described prototype case studies, and offered application guides that help utilities and end users gauge feasibility. Technology, market and policy insights are useful for utilities like PG/NSG when prioritizing outreach to industry sectors with the highest probability of near term success.

Market barriers

The key barriers to broader market adoption include the following:

- **Energy Costs:** Current gas vs electricity costs are such that electricity is relatively expensive vs gas on a per-unit energy value. Even with the high energy efficiency and reduced energy use, the operating costs of IHPs are often equal or even higher than gas technologies. Approaches to this barrier include targeting the highest COP applications, using incentives, and rate designs that reward off-peak operation or thermal storage.
- **Electric demand charges:** Also referred to as capacity charges, these are fixed fees per kW of electric demand from the regional grid operator to ensure sufficient electricity is available to meet peak demands on the grid. Since IHPs can significantly increase a facility's peak electric demand, the resulting increase in monthly capacity charges can also be significant.
- **Capital Costs:** Installation costs are much higher than traditional gas technologies. With limited penetration of IHPs in the U.S. markets, the equipment costs are relatively high. If the existing equipment has useful remaining life, it is very difficult to justify replacing it.
- **Applications and installation:** Many of the existing plants do not have readily available space for a retrofit given that the footprint of IHPs is generally larger than current boilers. In addition, integrating the heat pump source and sink can be challenging if they are physically distant in the plant and if the heat source and sink are not concurrent in time.



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- **Electrical readiness:** In many cases, the plant electrical equipment, possibly the main plant transformer, along with electrical feed and switchgear, needs to be upgraded. For the electric grid, the utility may need to upgrade feed to the plant or that area of the distribution network.
- **Lack of Awareness and Uncertainty:** Plant personnel and design firms often lack IHP experience, and installation complexity can add to uncertainty and increased costs. Given the above factors, even with emissions reduction benefits and Illinois' legislated direction, plants are hesitant to invest in long-term assets that don't show clear payback. Demonstration pilots with thorough M&V, design guides, and training help bridge capability gaps.

Relevance to the Peoples Gas / North Shore Gas service territories

For industrial customers in Peoples Gas (PGL) and North Shore Gas (NSG) territories, IHPs represent potential pathways to reduce gas consumption and emissions. The region's sector includes industries identified as favorable for IHP applications: food & beverage plants, chemical production, institutional campuses with thermal networks and hospitals with simultaneous heating and cooling loads.

As the U.S. grid continues to decarbonize and as equipment suppliers offer IHPs with higher temperature and capacity, the feasible application envelope will expand. It is believed that targeted demonstrations in key industries with near-term focus should provide repeatable prototypes for systems designers and end users. For utilities, this is an opportunity to evaluate incentives, offer design assistance and education so that early adopters become reference sites that accelerate broader market uptake.

Project objectives

The stated project objectives were outlined as follows: GTI Energy will carry out a technology and market assessment study for industrial heat pumps (IHPs) with the potential to reduce energy use across Peoples Gas and North Shore Gas service area for their Industrial customers.

The study includes the following components:

1. **Introduction to IHP:** Provide a brief introduction to IHP and why it is becoming important. A brief description of this technology's benefits to industrial customers and society will also be provided.
2. **Technology Review:** Identify IHP types with potential for integration into industrial applications, primarily focusing near-term, demonstration-ready systems that achieve the higher temperatures needed by industry and systems that can efficiently recover waste heat from high temperature industrial processes. Document available (current and near-term) IHP vendors and their technologies in the USA which can be offered to Peoples Gas industrial customers.
3. **Market assessment:** Perform analysis of where IHPs are a likely fit, based on temperature capability, capacity and integration potential, prioritizing the industries and applications with the highest potential.



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4. Territory Potential: Leveraging user information from Peoples Gas and North Shore Gas and learnings from Tasks 1 and 2, identify what customers are best positioned to adopt the technology based on industry classification, processes, economics and demonstrated commitment to Energy Efficiency and Decarbonization goals.
5. Final Presentation and Report: Document findings with Final Report, including PowerPoint presentation summarizing results.



TECHNOLOGY REVIEW AND APPLICATIONS

IHP Technology

This section reviews the current state of industrial heat pump (IHP) technologies, with an emphasis on commercially relevant equipment, temperature ranges, performance fundamentals, and integration patterns that matter for industrial end uses in the Peoples Gas/North Shore Gas service territories. It consolidates vendor capabilities observed in the U.S. market, distills practical rules of thumb for engineering design (e.g., temperature lift, COP, staging), and documents application archetypes—ranging from combined heating/cooling to steam generation—together with illustrative case examples. The intent is to bridge the gap between high-level technology potential and the specific installation configurations most likely to succeed in food & beverage, chemicals, pulp & paper, and institutional/healthcare facilities across the region.

Industrial heat pumps at a glance -Working principle and industrial positioning

Industrial heat pumps move thermal energy from a lower-temperature source (e.g., process waste heat, cooling tower water, ambient air) to a higher-temperature sink (e.g., hot water or steam serving process loads), using primarily electricity to drive a compressor. In industrial contexts, IHPs are valued less as simple “heaters” and more as active heat-recovery machines or electrified boiler/steam alternatives with substantially higher system efficiency than direct resistance or combustion, especially where recoverable waste heat is available. Two illustrative concepts are shown in Figure 2.

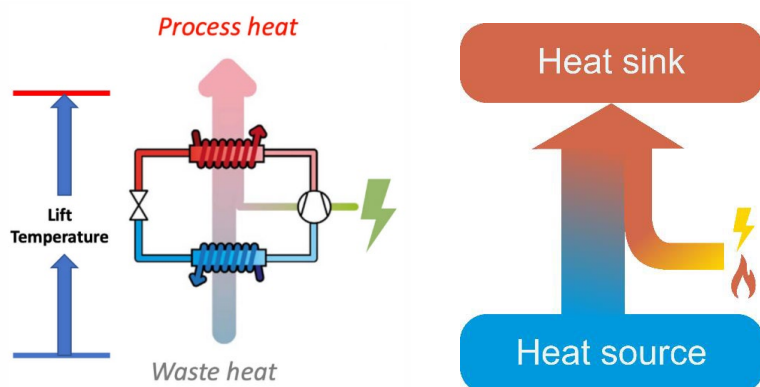


Figure 2: Illustrative Concepts of Heat Pumps, source ACEEE (left), IEA Annex 58 (right)

IHPs offer key benefits with relevance for industrial customers:

- Energy and emissions impact: When appropriately matched to processes, IHPs can reduce end-use energy input by a factor of 2–5 (reflecting attainable COPs), cut on-site combustion, and enable low- or zero-carbon heat as the grid decarbonizes. Figure 3 below⁷ shows a comparison of a plant using a conventional fossil fuel boiler vs a heat pump with a COP of 4. For these conditions, the energy required for the plant process is reduced by more than 75%. The resultant emissions vary based on the grid emissions



factor and range between 0% of conventional combustion equipment (for a grid with 100% renewable energy) and 37% (based on US average grid emissions of 823 lb/MWh).

- Commercial maturity at moderate temperatures: Many IHP offerings are market-ready in the low- to moderate-temperature bands required by common industrial operations (sanitation hot water, pasteurization, wash systems, low-pressure steam). Higher-temperature products are advancing quickly via multi-stage cycles and new compressors/refrigerants)
- Vendor commitments and U.S. presence: Multiple OEMs have U.S. footprint and offer service support.

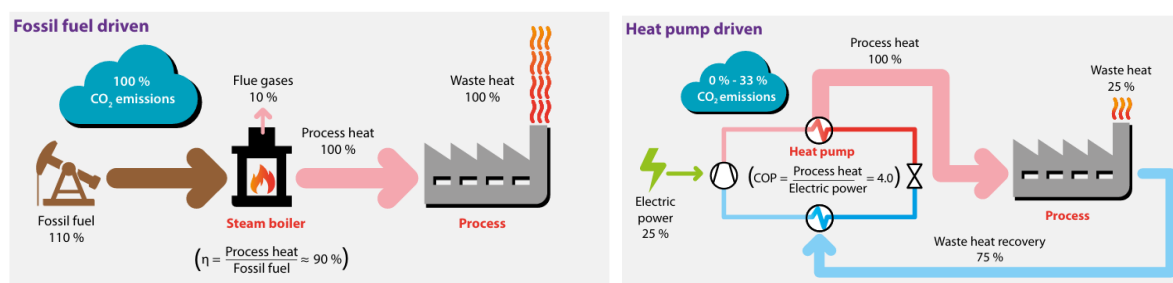


Figure 3: Energy and Emissions Comparison for Conventional Boiler and Heat Pump

Classification and temperature capability

IHPs can be categorized as open cycle or closed cycle systems (Figure 4):

- Open cycle: *Mechanical vapor recompression (MVR)* and *thermal vapor recompression (TVR)* are particularly relevant for separations/drying where the process vapor itself is compressed to raise its condensation temperature (e.g., distillation overheads, evaporators).
- Closed cycle: *Compression heat pumps* use a working refrigerant loop to extract heat from a source stream and reject it to a sink stream at a higher temperature; *sorption/heat activated systems* exist but are less common in the U.S. and are often limited in the achievable temperature ranges.

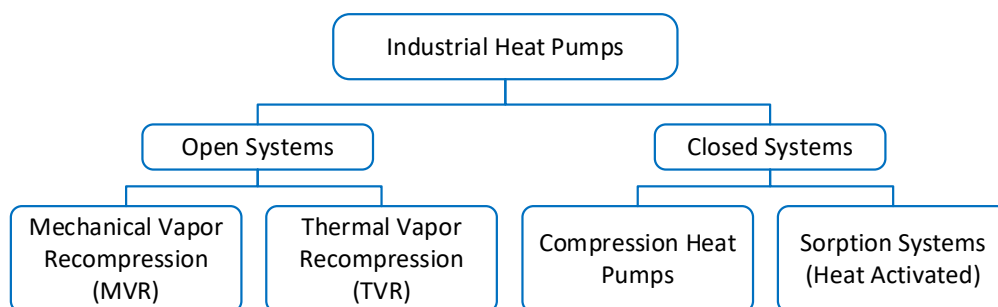


Figure 4: Types of Industrial Heat Pumps⁸



Temperature bands and definitions

Descriptions of high temperature and very high temperature vary in the heat pump literature, but the purposes of this study, temperature capability is defined in three useful bands aligned to current product landscapes and process needs:

- Conventional heat pumps: up to 85°C (185°F). The upper range of the conventional category is being expanded by some suppliers to approximately 95°C (203°F).
- High temperature heat pumps (HTHP): up to 120°C (248°F). This allows production of pressurized hot water and low-pressure steam.
- Very high temperature heat pumps (VHTHP): >120°C (>248°F). This is generally used for higher pressure steam, which is common in many industries.

These bands map well to the requirements found in food & beverage sanitation and cooking, Clean-In-Place (CIP) /hot water systems, low-pressure steam, and some chemical/paper duties.

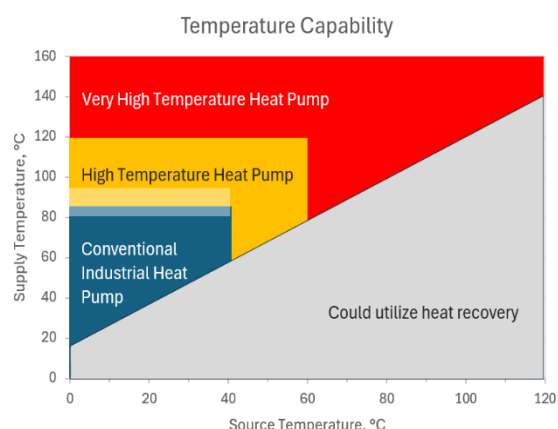


Figure 5: Temperature classification of high temperature heat pumps

Performance fundamentals that drive feasibility

The coefficient of performance (COP)—delivered heat divided by electrical input—is bounded by thermodynamics, with the Carnot efficiency being the theoretical maximum for the cycle. Actual performance of industrial COPs often clusters around 50% of Carnot (maximum theoretical efficiency any heat engine can achieve when operating between two specific temperatures), so the temperature lift (sink temperature minus source temperature) is the principal lever: lower lifts result in higher COPs, while high lifts degrade COP and require larger, costlier compressors and systems. Consequently, designing around higher source temperatures and/or lower sink setpoints is critical to economics. Two stage compression improves COP at higher lifts but adds cost/complexity; single stage designs are simpler and efficient when lifts are modest (e.g., $\approx 55\text{--}60\text{ K}$ / $100\text{ }^{\circ}\text{F}$).

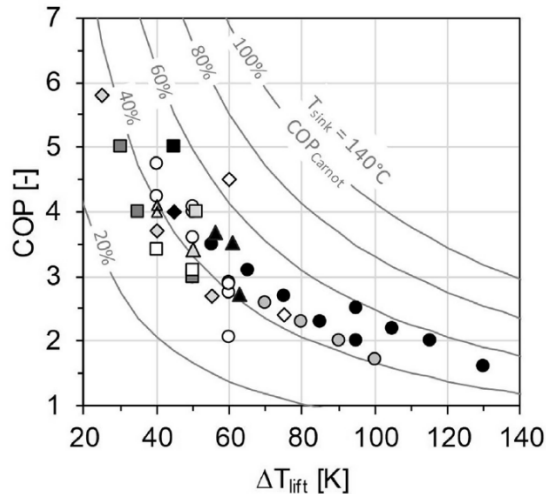


Figure 6: Historic COPs for IHP installations, source Arpagaus, 2018

Combined heating and cooling

In heat recovery chiller configurations with simultaneous heating and cooling, plants can realize effective “combined COPs” that exceed the heating only COP because the same compression work serves two loads at once (recovering cooling while delivering useful heat). Plants with year-round cooling plus domestic/process hot water needs—hospitals, large campuses, breweries, dairies—are prime candidates.

One example of how a heat recovery chiller could be implemented is shown in Figure 7. For this application, the heat recovery chiller provides both cooling of the chilled water loop and heating of the hot water loop. The OEM-provided performance data shows that at evaporator temperatures of 44/54°F and condenser temperatures of 130/140°F, the combined heating/cooling COP is between 5.2 and 5.9.

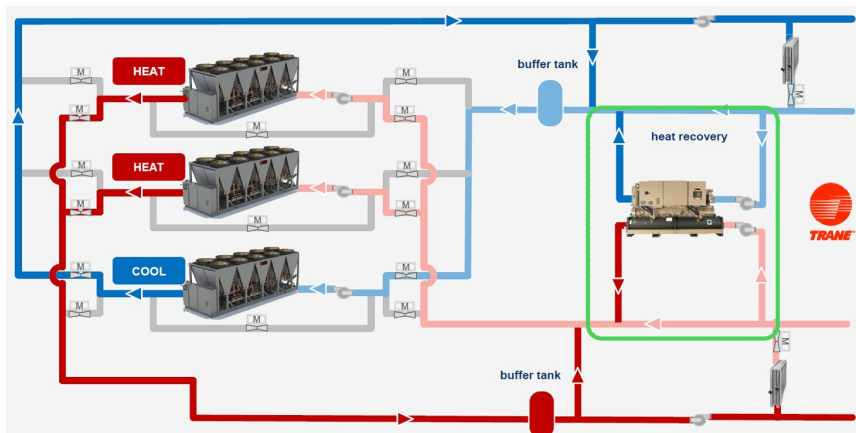


Figure 7: Heat recovery chiller shown integrated in building system (source: Trane)

U.S. vendor landscape and capability snapshots

This subsection complements the presentation prepared for Task 2, which presented in more detail the major U.S. vendors of IHPs. The focus was on suppliers with domestic service support



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and possibly domestic production. It should be noted that this review significantly limits the total number of potential vendors, as IHPs are more commonly applied in Europe and Asia. In addition, the listing focused on suppliers with experience beyond demonstration or pilot sites. This criterion was included so that technologies that are proven and mature are highlighted. One exception to the criterion is AtmosZero, included as their air-to-steam heat pump is unique, as well as being a domestic supplier with a demonstration site in progress.

For high temperature IHPs ($>85^{\circ}\text{C}$), the focus is on closed-loop units in the 0.5 to 10 MWth range (1.7 – 34 MMBtu/h). This is the most likely size range for food and beverage installations, for the chemical sector and hospitals. For moderate temperatures (up to 85°C), IHPs of all size ranges were reviewed. Larger units are potential solutions for larger thermal networks or district heating.

In summary, the section identifies IHP vendors with U.S. presence, focusing on temperature limits, capacity ranges, industrial alignment, and notable differentiators. GTI Energy performed an initial vendor screening, identifying those that had production-ready equipment and domestic support capability. A virtual meeting was held with each of the vendors, during which the equipment specifications and capability, along with installation experience was presented. The vendors reviewed, in no prioritized order, include GEA, Armstrong International, Trane, Multistack, Copeland, AtmosZero and JCI.

GEA

GEA has a long legacy in industrial refrigeration and heat recovery, with a substantial U.S. presence providing packaged units, compressors, and custom systems. Their offering is based on using ammonia (NH_3) as the core refrigerant, offering zero GWP and strong thermodynamic performance for industrial duties. GEA's standard offerings cover large thermal capacities across refrigeration and heat-pump modes, with established references in food processing and other process industries.

Product Portfolio Overview

GEA Systems North America - HRT



Figure 8: GEA Product Portfolio

For plants seeking >1 MWth capacities, ammonia safety practices are well understood in industry, and GEA's packaged or engineered solutions can deliver hot water into the $\sim 80\text{--}120^{\circ}\text{C}$ region and serve as the basis for steam-adjacent strategies (e.g., preheating feedwater) or MVR/evaporator integration.



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GEA ammonia heat pumps incl. Fusion

Overview portfolio GEA North America

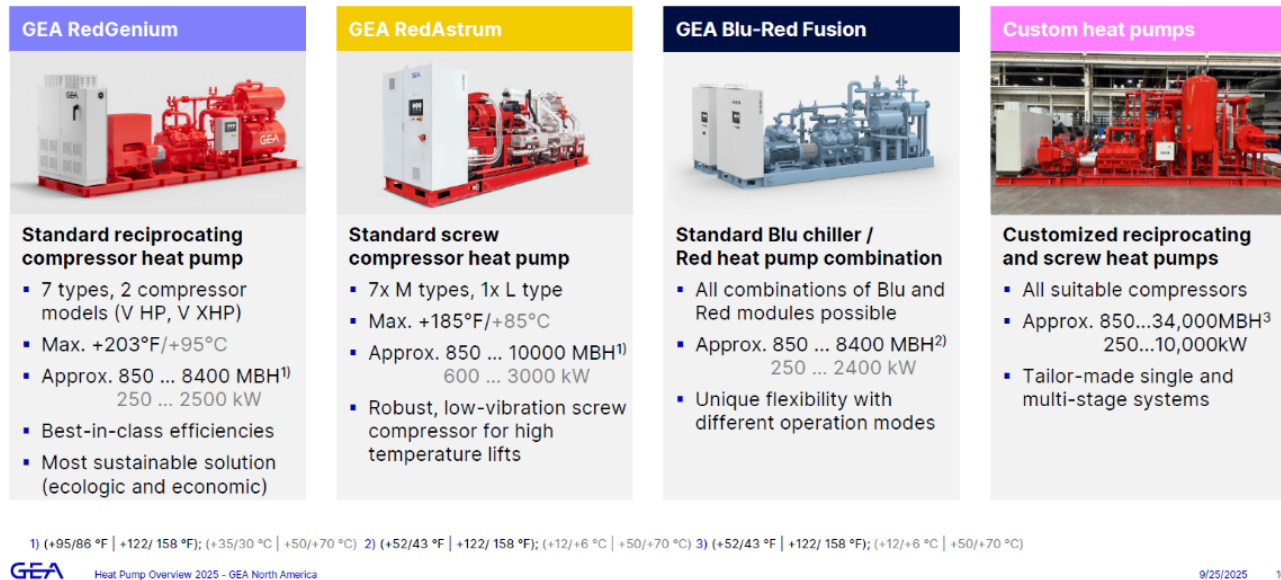


Figure 9: GEA – North America Product Portfolio

For installed base, GEA has a proven record in several industries, including food processing (including dairy and brewery) as well as district heating (thermal networks). A summary of their example cases is shown in Figure 10.

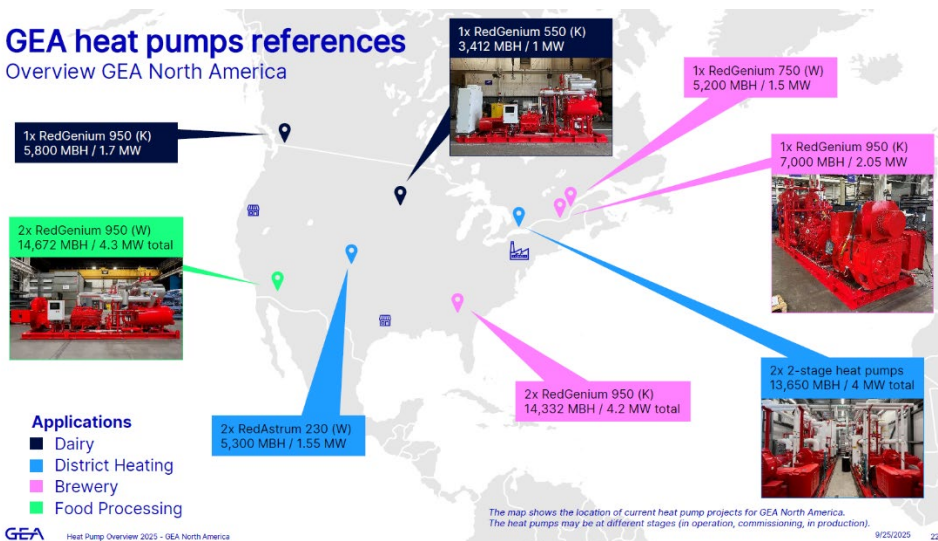


Figure 10: GEA Installed Heat Pump Reference Cases



Armstrong International

Armstrong is a century-old thermal systems company with deep steam expertise across chemicals, food and beverage, pharmaceutical, healthcare and building energy. It is expanding U.S. manufacturing in southwest Michigan to produce industrial IHPs, assisted by a grant from the DOE's Office of Manufacturing and Energy Supply Chains. Figure 11 below shows a photo of an Armstrong Industrial heat pump in their newly-expanded test facility.

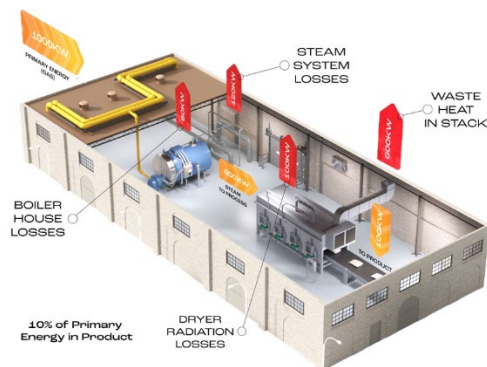


Figure 11: Armstrong IHP in the test facility

The current product line builds on a licensing agreement with CombiTherm of Germany where they have installed dozens of installations in Europe and India. The current product line focuses on hot water up to 248°F (120°C). In the near term, their product roadmap calls for expansion to low-pressure steam capability. The capacity range of 300–1,500 kWth fit well for typical food and beverage requirements.

Armstrong's "Circular Thermal" approach—balancing efficiency, waste-heat recovery, and heat pumps—aligns naturally with retrofit environments where steam networks already exist and feedwater/condensate preheat or low-pressure steam are attractive first steps. The company's expertise in managing thermal networks makes them a strong candidate for successful implementation.

Standard One-way Thermal System—Single Process User



Circular Thermal™ System—Single Process User

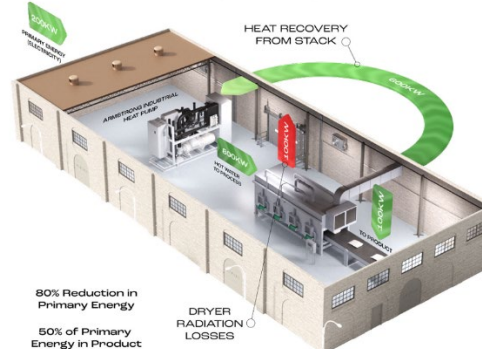


Figure 12: Circular Thermal Concept, showing conventional and Circular Thermal Approaches to heat recovery.

Trane

Trane's commercial heat pumps and heat-recovery chillers have historically targeted commercial building markets (temperatures up to ~165 °F/74 °C), as shown in Figure 13 below. The air-to-water heat pump uses ambient air as the source for providing hot water. If the needed building water temperatures are higher than the heat pump can provide efficiently, a water to water heat pump can be used in a cascade arrangement.

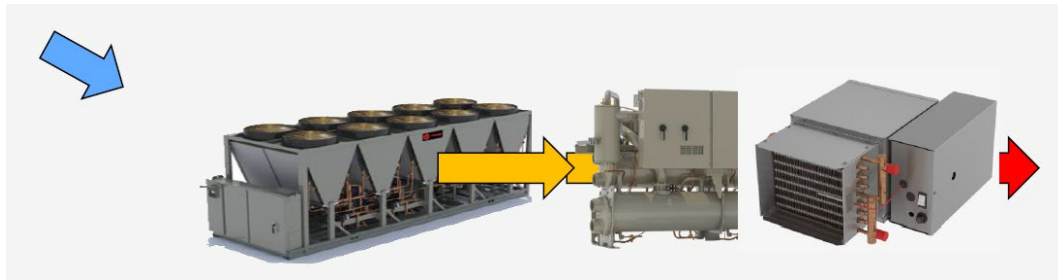


Figure 13: Trane Air-to-Air Heat Pump, Heat Recovery Chiller and Air handling components

Trane is currently developing higher temperature solutions, model RTZA, delivering water at 210°F (99°C), with 250°F (121 °C) roadmap targets. The RTZA is a dual-circuit heat pump rated for approximately 0.9 MWth. The larger CVZA units (to 10 MWth) support district-heating-scale hot water to 180°F with 80 °F lifts.

For industrial sites with hot water needs or simultaneous heating and cooling, the RTZA product line is a potential fit. For large district heating or central plants, for example university campuses or hospitals, Trane's heat-recovery platforms provide a practical path to high combined COPs with the potential of significant fuel savings depending on the overall COP, driven by lift and supply temperatures.

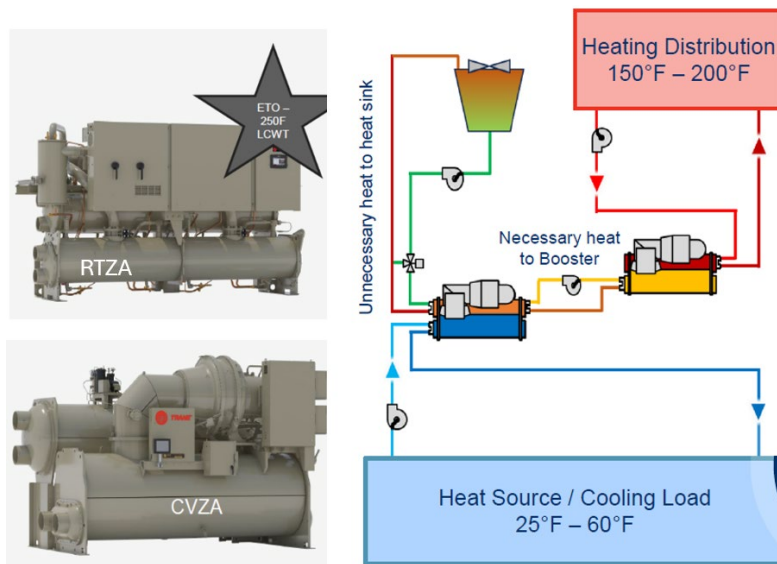


Figure 14: Trane models RTZA and CVZA; diagram of building system with heat recovery



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MultiStack

MultiStack is known to be a heat-recovery chiller specialist company and pioneered modular chillers, including TurboCor™ magnetic-bearing compressors, and dedicated heat-recovery solutions with scroll compressors capable of hot water up to 175–180 °F. Their units are smaller than others cited here with capacities to approximately 0.2 MWth per module (multiple modules can be interconnected). They cite hospital projects using heat-recovery chillers that have demonstrated COP of greater than 3.0 in heating and combined COPs of up to 7.0.

MultiStack is best matched to building-like industrial and institutional loads (CIP/wash, DHW, laundry, comfort reheat) where simultaneous cooling exists and steam is used primarily for domestic/process hot water rather than high-temperature duties.



Figure 15: Multistack Model DHRC

Vilter by Copeland

Vilter is well established in industrial refrigeration. The new VQ95 product targets process/district heating with 95 °C (203 °F) delivery and 1–5 MWth per skid with a balanced single-screw compressor using ammonia as the refrigerant. They are applying the product for district heating and other industrial sectors such as food and beverage, chemical and pharma. An initial product is being installed at a large water treatment facility in Canada.



Figure 16: Vilter VQ95

In October 2025, Copeland acquired SPH Sustainable Process Heat of Germany, a leader in steam-generating heat pumps. SPH has a number of commercial installations in Europe for low pressure steam and are part of a pilot project producing steam to 165 °C. This is a notable advance and opens possibilities for steam production in U.S. industries. Adding SPH to Copeland/Vilter's portfolio, adds capability to support hot-water and steam-generating needs. For food and beverage plants needing low pressure steam (commonly 15 psig or 2 barg) at temperatures of 120–130 °C, SPH-derived solutions offer direct pathways to displace low-pressure boiler duty when paired with appropriate heat sources (e.g., CHP jacket water,



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condenser heat). While at somewhat lower COPs, SPH equipment can provide steam to 5 barg (72 psig). Figure 17 shows SPH equipment installed in Spain and being used for 5 barg steam production.



Figure 17: SPH installation in Axilone, Spain for 6 barg steam (source: SPH)

AtmosZero

A newer entrant, AtmosZero's Boiler 2.0 is an air-to-steam heat pump designed as a drop-in boiler replacement, producing steam up to 150°C (302°F) which can operate, producing steam at ambient temperatures to 0°C. Given that the equipment uses an air-source heat pump, no interface for waste heat recovery is needed, offering installations that can minimize plant disruption.

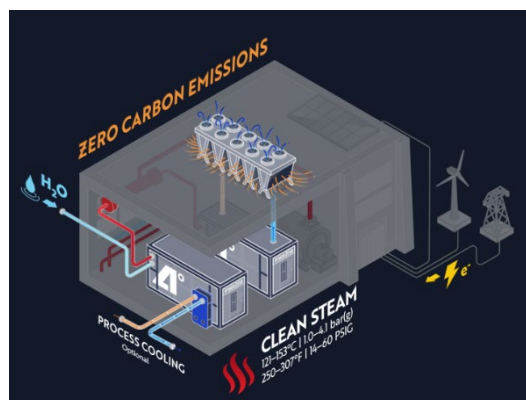


Figure 18: AtmosZero Boiler 2.0

The system uses newly-developed multi-stage compression with proprietary compressors. A publicized pilot at New Belgium Brewery in Ft. Collins, Colorado illustrates early adoption in the brewing sector.

For sites lacking a robust waste-heat source—or seeking a simplified retrofit path—an air-source steam HP can serve address steam loads while leveraging ambient energy, with performance dependent on climate and load profile.

COPs are generally lower than waste-heat driven solutions, likely ranging from 1.5 to 2.5. This



Figure 19: AtmosZero Boiler 2.0 installation at New Belgium Brewery, Ft. Collins, CO



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provides lower costs than electric resistance boilers, but are likely to have significantly higher operating costs than natural gas fired boilers.

JCI/York

JCI/York is a well-established manufacturer which offers a range of chillers, including air-source modular chillers, to larger water-to-water screw compressor chillers, to extremely large centrifugal chillers. Their equipment is well-known and used extensively in large building systems across the U.S.



Figure 20: York Heat Pump Product Offerings

JCI's large chillers are operable in heat-pump mode, but generally limited to 180°F hot water. While they may not achieve temperatures needed for industrial applications, York's scale and installed base can be leveraged where conventional temperatures suffice, likely in thermal networks or district heating.

Vendor fit matrix

Based on characteristics of the suppliers presented, a summary of the best-fit for various vendors is presented below.

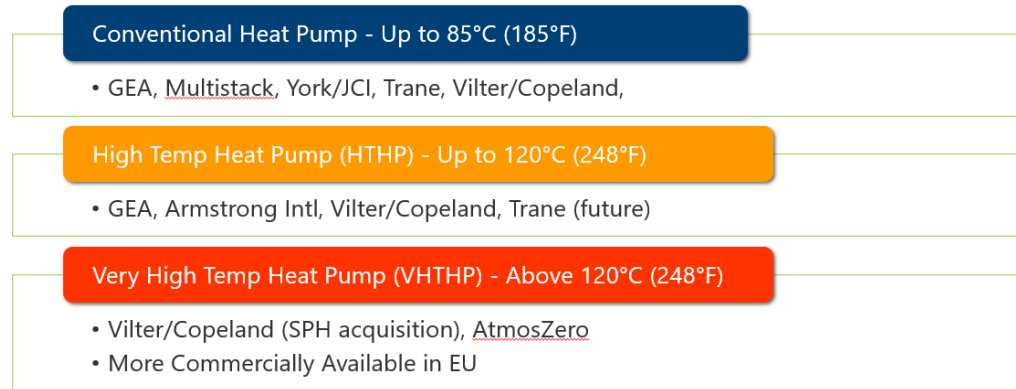


Figure 21: Vendor Fit Matrix

Recommendations include:

- For applications that accept ammonia as the refrigerant, key suppliers are GEA and Vilter/Copeland. They are the likely candidates for multi-MW duties and plants with ammonia familiarity, or where hot water $\geq 90^{\circ}\text{C}$ and steam-adjacent strategies make sense.
- For large-scale solutions such as district heating and thermal networks, key suppliers are Trane and York/JCI. They are experienced in dealing with large building and district heating applications and are offering practical solutions to address the opportunity.
- Steam-generating specialists: SPH under Copeland, AtmosZero, Armstrong and GEA are offering steam-generating capability. Sites with low or medium-pressure steam requirements and relevant heat sources (e.g., CHP, condensers) should benefit.
- Modular heat-recovery chillers: Trane, GEA, MultiStack offer solutions. These are best for simultaneous heating/cooling in institutions and industrial sites with substantial comfort or process cooling plus hot-water demand.
- Drop-in air-to-steam (AtmosZero): Attractive where waste heat is limited and a plant seeks a drop-in for a portion of steam. Challenges include lower COPs (energy costs will be higher than gas-fired boilers) and colder climates will further impact performance.
- Custom Engineered high temperature applications are offered by SPH under Copeland, Armstrong and GEA: These are suited to identify and develop specific process solutions given integration constraints. Custom designs, testing, and performance validation can be provided.

Applications

The following section addresses the potential applications for IHPs.

Processes and Temperature Requirements

Figure 22 identifies the key industries where IHPs can be applied along with the processes and required temperatures. The equipment capability and Technology Readiness Level (TRL) identified. Well-proven and mature installations are generally available up to 80-100°C.



Demonstrations of applications in the 100-140°C range are in process, but are not yet commonly in service. New technologies are being introduced for supply temperatures above approximately 140°C.

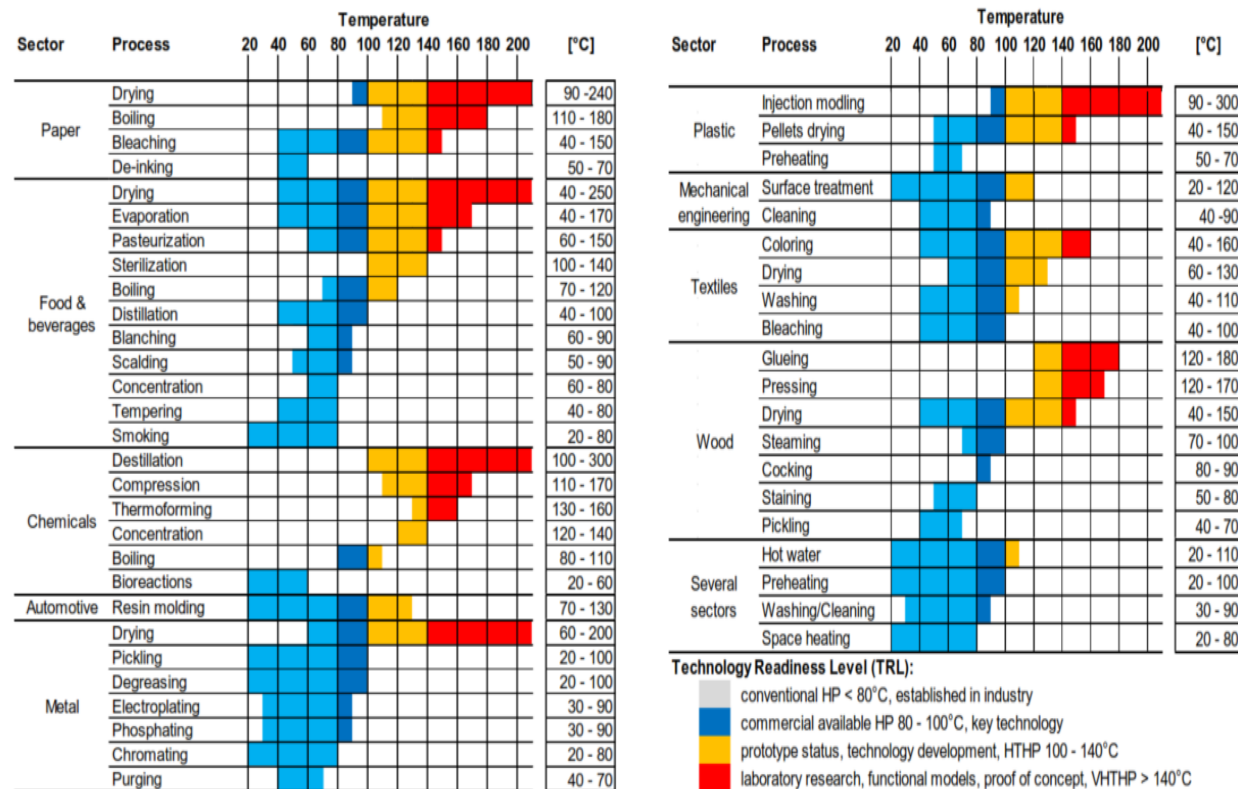


Figure 22: Applications, Temperature and TRL readiness for IHP application. Adapted from Arpagaus, 2018

A brief description of the processes most likely to utilize IHP's, many of which are already proven as scale in Europe or Asia and are technologically feasible in the U.S.

- Food & Beverage: pasteurization, clean-in-place and sterilization, other sanitation needs, hot water, blanching, drying/dehydration, steam for cooking/cleaning. Some flash drying, evaporation and pasteurization process are currently in the prototype development stages.
- Chemicals: distillation and concentration processes are highly energy intensive, but would benefit from high COPs using MVR technology. Reboilers could also be supported, as well as reactor jacket heating/cooling integration.
- Pulp & Paper: whitewater and condensate heat recovery, drying loops, generating low-pressure steam from waste heat.
- Healthcare/Institutions: large, simultaneous heating and cooling for thermal heating loops is a potential application. Hot-water needs (laundry, domestic hot water, sterilization) are ideal for heat-recovery chiller/heat pumps given the need for simultaneous heating and cooling.



Technology readiness

The previous chart, from a well-respected source, presents TRL levels based on capabilities of global suppliers. As presented earlier, the present study is based on U.S. suppliers and the TRL temperature capability is somewhat lower, as presented earlier in Figure 5.

- Commercial readiness is strongest for hot water up to 80–95 °C with conventional IHPs. The operating envelope of existing supplier's equipment is being extended through incremental improvements in their capabilities. In some cases, low-pressure steam could be generated for use in the process or further heated as required.
- High temperature heat pumps (100–120 °C and select steam cases) are currently being offered (e.g., GEA, Armstrong, SPH through Vilter/Copeland, AtmosZero) are growing U.S. presence, gaining operational experience and demonstrating higher TRLs.
- Very-high-temperature (>120 °C) steam and process heat are advancing via multi-stage compression, novel refrigerants, and steam-generating HPs. The economics are more challenging due to the higher temperature lifts, but pilot demonstrations are informing cost/performance for broader industry acceptance.

In summary, a lens of technology readiness by application shows strong near-term viability for hot-water up to 95 °C, in particular for applications of simultaneous heating/cooling. Higher-temperatures and steam for specialty processes are being demonstrated but may remain project-by-project requiring custom engineering solutions in the near term. Very high temperatures are largely in the research and development stage.

Screening criteria

The following guidelines are recommended for prioritizing opportunities:

- Waste heat availability and coincident with hot-water or steam needs for most of the operating hours.
- Moderate temperature lifts (preferably <100 °F), which result in higher COPs. For temperature lifts greater than 100 °F, the COP decrease is likely to result in unrealistically long payback periods.
- Simultaneous cooling and heating loads (ideal for heat-recovery systems) may provide the highest economic benefit, depending on the required temperatures.
- Corporate emissions goals and willingness to accept multi-year paybacks (≥3-5 years) are generally needed. In the current environment, where carbon emissions are not assigned a value, other benefits, for example, sustainability goals, are likely to be needed for projects to advance.
- Favorable spark ratio (electricity-to-gas price ratio ≤4) such that operating energy costs are less than directly firing with natural gas.
- Infrastructure: Sufficient electrical capacity for the units is needed, as adding transformers, switchgear and other electrical infrastructure is costly and result in delays. Physical space for the equipment, and proximity to the heat source and sinks is needed.



Conversely, barriers include high electricity prices vs. gas, capital intensity and space/power constraints. Low awareness and the limited number of U.S. reference installations are factors that utility technical assistance and pilot programs could directly address.

Engineering design guidance

Practical guidance for engineering and owner teams includes the following:

1. Begin the evaluation of heat loads and required temperatures. Quantify the heat source (flow rate, temperature, seasonality) and sink (setpoint, required turndown) to calculate the temperature lift. Target applications with lift of less than 60°C (approximately 100 °F) to unlock higher COPs and simpler machines. Multi-stage equipment is unlikely to be justified.
2. Exploit simultaneous heating/cooling where present. If the facility routinely runs chillers and has hot-water/steam demand, evaluate heat-recovery options first—the combined value often dominates simple payback calculations.
3. Use preheat to decarbonize steam progressively. Preheating feedwater/condensate can trim boiler firing without wholesale end-use changes and can be rolled out incrementally across multiple plants.
4. Right-size for base loads and add thermal buffers. IHPs perform best at steady loads—add thermal storage (buffer tanks for hot-water systems) to smooth profiles and maximize uptime and COP.
5. Plan electrical capacity and rate strategy. Confirm available power, feeders, and switchgear, and model the time-of-use (TOU) and demand charges. Where feasible, leverage thermal storage or load shifting to minimize peaks.
6. Be aware of refrigerants and codes. Ammonia, CO₂, hydrocarbons, and selected low-GWP synthetics are all in play at different temperature bands—each with safety, materials, and code implications that affect siting and maintenance plans. Coordinate early with EHS teams.
7. Commission controls for plant functionality. Integrate with existing boilers, chillers, and BMS/SCADA to keep each asset in its efficient operating region (e.g., avoid simultaneous reheat/cooling conflicts).

Key technical considerations for successful IHP integration

1. Thermodynamic matching and pinch analysis. Use heat integration studies or pinch analysis to minimize temperature lift and identify best-fit sources and sinks. This can be the difference between a COP of 2 and 4.
2. Duty cycle and load profile. Continuous or high-utilization loads (e.g., sanitation hot water, continuous evaporators) improve economics and right-size equipment.
3. Steam vs. hot-water strategy. Where feasible, shift end uses from steam to hot water (“de-steaming”) or use the heat pump to preheat boiler feedwater to reduce firing rates and gas usage. Where steam is essential, evaluate steam-generating heat pumps, either



single stage for low-pressure steam or in combination with MVR for higher-pressure steam.

4. Electrical infrastructure and rates. Anticipate transformer, switchgear and panel capacity. Evaluate demand charges and time-of-use structures to minimize electrical impact. Pair IHPs with thermal storage or load management to mitigate peak impacts.

Illustrative applications/ Case Studies

The following examples illustrate typical applications for IHPs. Some of the following are pilot or demonstrations. Others are concepts that were presented to customers for their evaluation.

Metals industry: *Dryer exhaust to hot water for drying*

A waste-heat recovery HP lifts energy from dryer exhaust to supply higher-temperature air/water for drying stages of a drying/heating process for electrical transformers. In this demonstration plant in Japan, 130 °C hot water supply is demonstrated, with the COP driven by exhaust temperature and humidity management. For effective operation, it was essential to address fouling of the furnace heat exchanger, manage condensation actively, provide upstream filtration for the furnace and economizers.

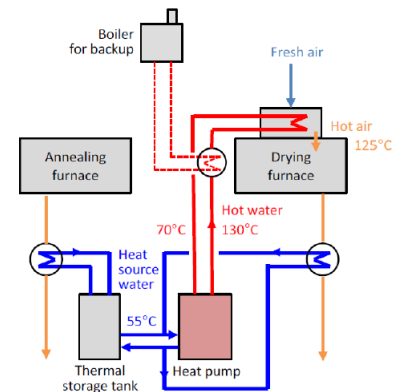


Figure 23: Hot water supply heat pump, Oyama factory, Takaoka Toko, Japan. Source Annex 58.

Materials Industry: *Low-pressure steam from dryer exhaust*

By adding a condensing economizer and applying a steam-generating heat pump, this concept shows how a plant can produce low-pressure steam for drying while also recovering water from the exhaust stream. COPs in the 3.7–4.3 range are achievable at appropriate temperatures and offer the capability of water recovery.

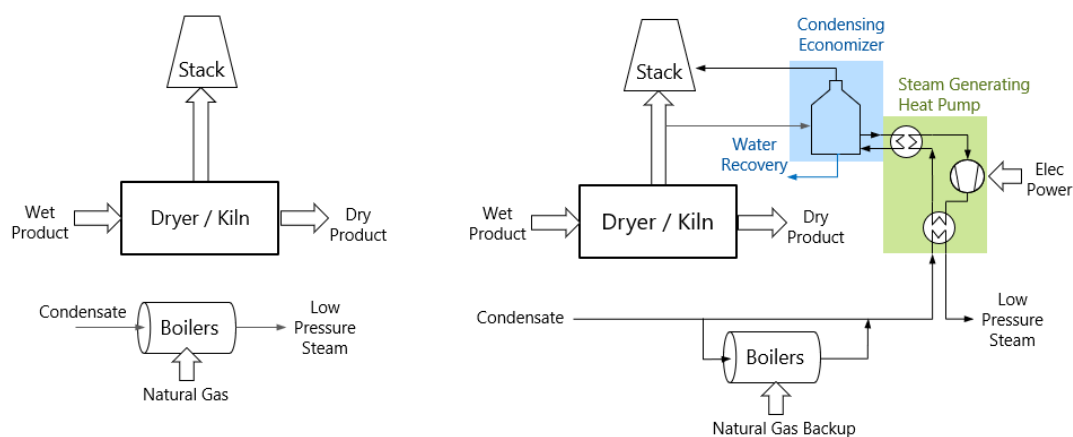


Figure 24: Low pressure steam from dryer exhaust. GTI Energy Proposal Concept.



Food production: Steam from combined heat and power (CHP) jacket water

In this concept, jacket water from a CHP unit serves as the heat source to generate medium-pressure steam for process use. The jacket water is currently used for intermittent building heating, while converting to steam offers year-round benefit. The plant could utilize low pressure steam in some processes, which would have increased the COP, but the facility preferred feeding the plant system at medium pressure. The modeled COPs of 1.7–1.9 reflect the higher lifts required to reach medium pressure steam. Staging with MVR can improve effective performance while matching plant pressures.

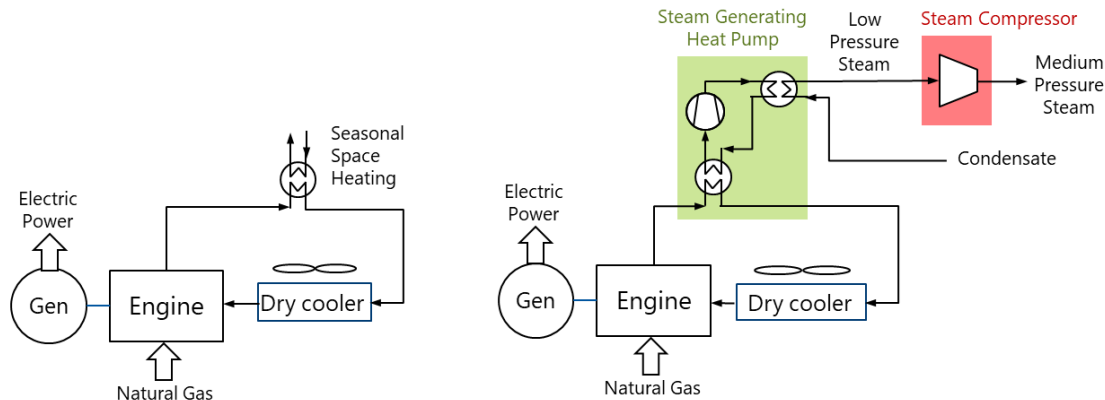


Figure 25: Steam from CHP jacket water. GTI Energy Proposal Concept

Chemicals: Heat Pump with MVR for steam

A concept in the chemical industry shows recovered vapor (sub-atmospheric) as the heat source, generating 3 bar steam using an high temperature heat pump. The steam is then boosted to 9 bar via MVR. This showcases the potential synergy between closed-cycle HP and open-cycle vapor recompression in separation/purification operations.

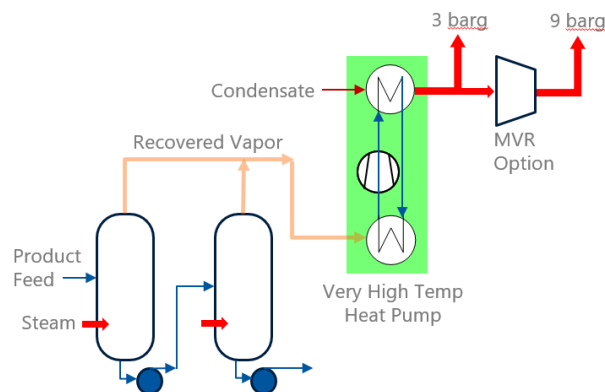


Figure 26: Heat Pump + MVR for steam production. GTI Energy Proposal Concept

**Food production:** Low pressure steam from CHP cooling

An installed project in the Netherlands (2023) used CHP cooling jacket water as source to produce low pressure (2 barg/15 psig steam) with 514 kWth capacity and a COP of 4.4. This example indicates that when source temperatures are favorable, steam generation at low pressures can be very efficient.



Figure 27: Low Pressure steam from CHP jacket water. Source: SPH Project Gelatine

Potato drying: Drying loop heat pump

This application uses a heat pump to provide hot air for a potato drying application. Waste heat is recovered from the exhaust while the supply dryer air is heated. Temperatures are relatively low with the resulting COP of this potential application between 2.4–5.1. The performance depends on the lift and the degree of heat recovery integrated into the drying loop (recirculating air, dehumidification strategies). Process control benefits such as temperature and humidity profile control may be factors, as valuable as the energy savings.

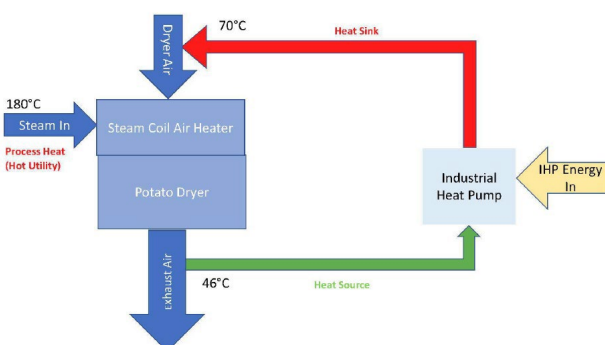


Figure 28: Potato Drying Loop. Source: ACEEE Industrial Heat Pumps: Electrifying Industry's Process Heat Supply

Wastewater treatment: Sludge drying with low pressure steam

A concept tested in Norway demonstrates low pressure steam (120 °C/248 °F) for sludge drying. Under most conditions, the process COP is 4.5. The process utilizes vapor compression technology and requires careful moisture/heat management to prevent liquid from entering the compressor. Aspects of the vapor compression equipment proved challenging and require further development before becoming commercially available.

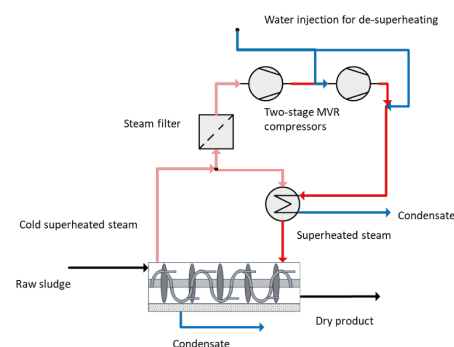


Figure 29: Wastewater Treatment: Sludge drying with low pressure steam. Source: IEA Annex 58

**Healthcare:** Heat Pump with steam compressor for medium-pressure steam

For hospitals with strong comfort cooling and sizeable steam loads (laundry/sterilization), this concept shows how a low-pressure steam heat pump using cooling tower water as the heat source can be paired with a steam compressor to provide medium pressure steam. This would potentially reduce boiler cycling runtime and improving overall plant thermodynamics.

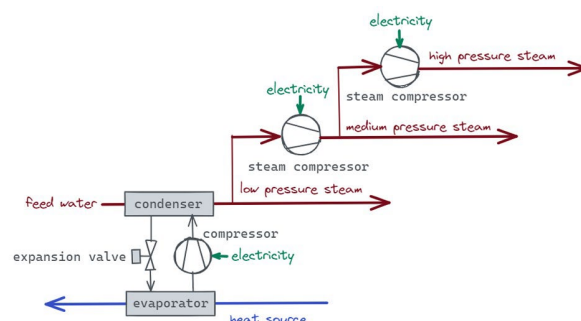


Figure 30: Heat Pump with Steam Compressor for medium pressure steam. Source: IEA Annex 58

Process benefits and risks

From the example applications presented, it is clear that IHPs show potential for many industrial processes. The potential benefits and risks can be summarized as follows:

Potential Benefits

- Energy and cost savings: Properly integrated IHPs can reduce site energy use by 50% or more for many moderate-temperature loads; combined heating/cooling applications can yield very high effective COPs and can improve OPEX under a given range of spark gaps.
- Emissions: Electrification plus waste-heat recovery lowers Scope 1 emissions and positions plants to benefit from grid decarbonization trajectories.
- Process performance: In some cases, tighter temperature control and tighter heat-integration can improve product quality and throughput.
- Water and air quality: Condensing economizers and closed-loop heat recovery can reduce stack losses/criteria pollutants and improve water reuse compared with fuel-fired units.

Potential Risks:

- Capital and OPEX Costs: At present, capital costs for IHPs are generally higher than fuel-fired equipment. Depending on relative gas and electric costs, OPEX savings may be minimal or in some cases costs may increase.
- Sensitivity to rates: In some cases, OPEX can be addressed by selecting appropriate loads, time of use (TOU) operation when possible and thermal storage to limit peak demand.
- Space and interconnection: IHPs generally require larger footprint than fuel-fired equipment. Interconnection between heat sources and sinks can be challenging depending if distances between the two are significant.
- Refrigerant safety and codes: Most common refrigerants do not impact significantly, with the exception of ammonia. If already in use, for example, in the refrigeration system,



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impact will be minimal. However, if the plant doesn't use ammonia, safety and code requirements could play a role.

- Skills mismatch: Traditional heating specialists may not have IHP experience or capabilities. Developing refrigeration & controls skills or service contracts, and leveraging vendor capabilities is needed to ensure reliable operations.



MARKET ASSESSMENT

Utility Customer Base

Overview of Utility Territories and Customer Base

The primary focus of the Industrial Heat Pump Technology and Market Assessment is whether heat pumps could be more widely applied in industrial settings. To provide additional context of the utility customer base, the following summarizes the Market Potential Study of Peoples Gas, which serves Chicago, and North Shore Gas, which serves Chicago's northern suburbs. Data sources include documents presented to the Illinois Energy Efficiency Stakeholder Advisory Group (SAG, September 3, 2024)⁹ and the Long Term Gas Infrastructure Plan (September 23, 2024).¹⁰ For these reports, the service territories were analyzed using a combination of utility data, baseline studies, and nationally recognized energy-use datasets. Both utilities serve mixed customer bases, though the distribution of residential, commercial, and industrial users differs substantially between the two systems.



Figure 31: Peoples Gas and North Shore Gas Service Territories

General Gas Consumption Patterns and Baseline Load Trends

Baseline gas consumption patterns—developed for forecasting adoption of efficiency measures—show:

- High reliance on natural gas for space and water heating across all customer classes.
- Process loads dominate therm consumption in industrial facilities.
- Weather-driven seasonal variability, especially in residential and commercial heating.

Residential Customer Characteristics

Residential customers represent the largest share of total customers in both PGL and NSG service territories. While industrial and commercial users consume more energy per account, the residential sector provides the scale that drives many energy efficiency measures.



Table 1: Peoples Gas and North Shore Gas Overall Customer Base and Energy Usage (2023)

	Number of Customers		
	Peoples Gas	North Shore Gas	Total
Residential	807,340	150,639	957,979
Commercial	77,425	13,858	91,283
Industrial	148	22	170
Total Count	884,913	164,519	1,049,432
	Gas Volume (% , Therms, GJ)		
	Peoples Gas	North Shore Gas	Total
Residential	42.8%	54.0%	
Commercial	42.6%	31.5%	
Industrial	14.6%	14.5%	
Therms	1,498,889,347	324,804,383	1,823,693,730
(GJ)	158,132,826	34,266,862	192,399,689

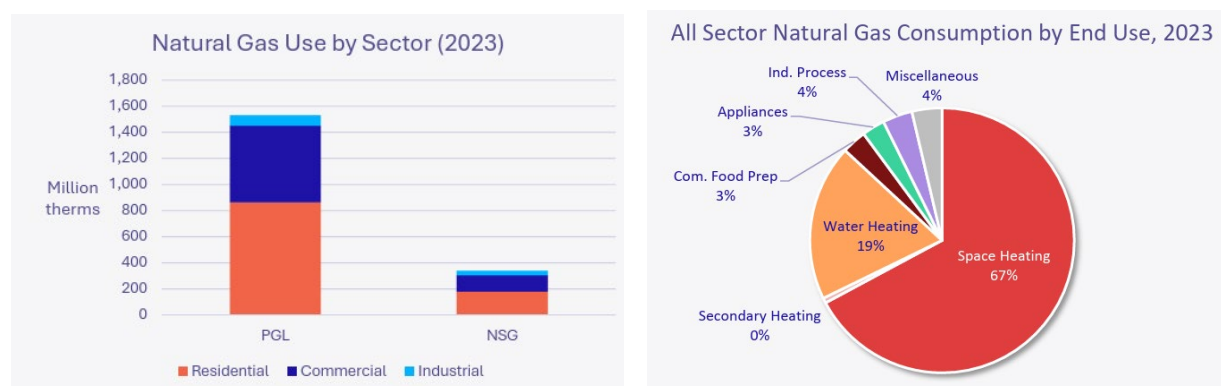


Figure 32: Natural Gas use by sector (l) Consumption by End Use (r).

Source: IL Energy Efficiency SAG, Sept 2023.

The market potential study includes residential end-use characteristics—space heating, water heating, and appliance usage—derived from a combination of utility data and national surveys and refers to earlier survey data (from 2020) used to inform adoption rates of energy efficient appliances. For example:

- Customers' willingness to adopt efficient equipment increases significantly when incentives reduce payback periods. In one example from the SAG follow-up notes, respondents exhibited 62.7% likelihood of purchasing a high-efficiency heating system when incentives lowered the payback to less than five years.
- Without incentives, uptake for the same measure was approximately 30%, highlighting the importance of program design in driving residential participation.

From this data, behavioral patterns are used to help determine the "realistic achievable potential" used in the study, largely focused on residential appliances.



Commercial and Industrial (C&I) Customer Characteristics

C&I customers represent relatively smaller portion of total accounts but a disproportionately large share of total therm usage. This is consistent with typical utility system load profiles and is confirmed by the foundational utility data used in the study's market characterization. Examples of C&I categories present in the study include:

- Office buildings
- Retail establishments
- Schools and municipal buildings
- Manufacturing facilities
- Warehouses and distribution centers

Baseline characteristics such as equipment saturation, square footage, operational schedules, and fuel-use intensity were drawn from Commercial Buildings Energy Consumption Survey (CBECS) and Manufacturing Energy Consumption Survey (MECS) datasets.

Industrial and Process Load Customers

Industrial users in the PGL/NSG territories include manufacturing sectors that appear in the Chicago region:

- Food manufacturing
- Metals and machinery
- Plastics and chemicals
- Transportation equipment
- Medical device fabrication

Compared with residential and commercial customers, industrial customers have larger, more concentrated process loads, typically associated with boilers, space heating, water heating, and occasionally industrial process heat systems.

The Energy Efficiency Potential Study notes the 2020 potential but includes Industrial within Commercial and notes that "some additional insight is gained in separating it, however, the loads are too small to meaningfully break individual segments/manufacturing types." The analysis presented as follows offers further insight into the industrial segments within Peoples Gas and North Shore Gas.

Large Customer Analysis

For this analysis, the Peoples Gas and North Shore Gas Efficiency Programs compiled a database of large users—those with usage of >400,000 therms/year. The database includes key customer data such as customer name, address, contacts, rates, annual usage, NAICS classification and other relevant information



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The customer data was extensively reviewed, updated and screened by PGL and NSG staff. It was shared with GTI Energy for further analysis under confidentiality agreement that no customer-identifiable data can be shared. The file and analysis will be provided to PGL/NSG for their internal use.

The analysis focused on NAICS classifications, which identify the industry sector. The number of customers and usage based on the classification is shown in Table 2. The data shows that the total number of customers and the majority of usage (over 80%) is concentrated in three general NAICS classifications: 300, 600 and 900.

Table 2: Peoples Gas and North Shore Gas Large Customers (>400,000 Therms/yr)

NAICS	Number of Customers			Therms Used (2023)		
	Peoples	North Shore	Total	Peoples	North Shore	Total
200	2	2	4	1,746,070	1,953,158	3,699,228
300	79	12	91	93,679,702	23,666,398	117,346,100
400	15	2	17	11,956,952	1,048,664	13,005,617
500	21	4	25	13,811,133	9,039,852	22,850,985
600	56	25	81	118,897,885	19,494,138	138,392,023
700	24	2	26	15,620,265	344,532	15,964,797
800	14	1	15	13,811,234	818,427	14,629,661
900	17	5	22	32,708,621	2,527,319	35,235,940
Total	228	53	281	302,231,862	58,892,489	361,124,351

The key sector description within the major groupings are shown below.

Table 3: NAICS Descriptions

NAICS	NAICS Description
311	Food Manufacturing
312	Beverage and Tobacco Product Manufacturing
316	Leather and Allied Product Manufacturing
322	Paper Manufacturing
324	Petroleum and Coal Products Manufacturing
325	Chemical Manufacturing
326	Plastics and Rubber Products Manufacturing
327	Nonmetallic Mineral Product Manufacturing
331	Primary Metal Manufacturing
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
335	Electrical Equipment, Appliance, and Component Manufacturing
336	Transportation Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Manufacturing
611	Educational Services
621	Ambulatory Health Care Services
622	Hospitals
623	Nursing and Residential Care Facilities
921	Executive, Legislative, and Other General Government Support
925	Administration of Housing Programs, Urban Planning, and Community Development



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Further refining the analysis, the NAICS sectors were grouped according to common industries showing the groupings in key sectors. The following table highlights the groupings of 300-series NAICS codes separated into general categories of Food Manufacturing, Paper, Chemical and Metals. The 300-series customers used a total of 117,346,100 therms, just under 1/3 of the large user consumption and 6.3% of the utility-wide gas usage.

Table 4: Usage of key industrial and large user sectors

NAICS	Summary Description	Therms (2023)		% of Large Use	% of Total Use
311-316	Bakery, Food Manufacturing, Chocolate, Brewery, Leather and Tanning	34,084,509	117,346,100	32.5%	6.3%
322-324	Paper, Corrugated, Asphalts, Paving	7,826,902			
325-327	Chemical, Pharma, Paint, Plastics, Cement and Gypsum	43,053,724			
331-339	Metals, Machinery, Electrical, Furniture and Medical Devices	32,380,965			
600	Colleges, Hospitals and Healthcare	138,392,023	173,627,962	48.1%	9.3%
900	Government	35,235,940			

The primary study objective was to assess IHPs for industrial applications. However, it was noted that a significant portion of PGL/NSG large customers are large institutions, so the scope of the analysis was expanded to include heat pumps for large commercial institutions (universities and hospitals) with thermal networks of either steam or hot water.

The sectors analyzed are shown graphically in Figure 33, in the following groups:

- NAICS 200, 400, 500, 700 and 800: These sectors comprised 20% of the large customers' consumption. IHPs are generally not suitable for these industries.
- NAICS 300: The manufacturing sector is the most likely to incorporate IHPs into their process heating applications. As noted previously, the analysis grouped the sectors in into four subsectors.
- NAICS 600 and 900: Large institutions could potentially use a IHP if they have a thermal network or large simultaneous loads, for example in hospitals or university campuses with a central heating/cooling plant.

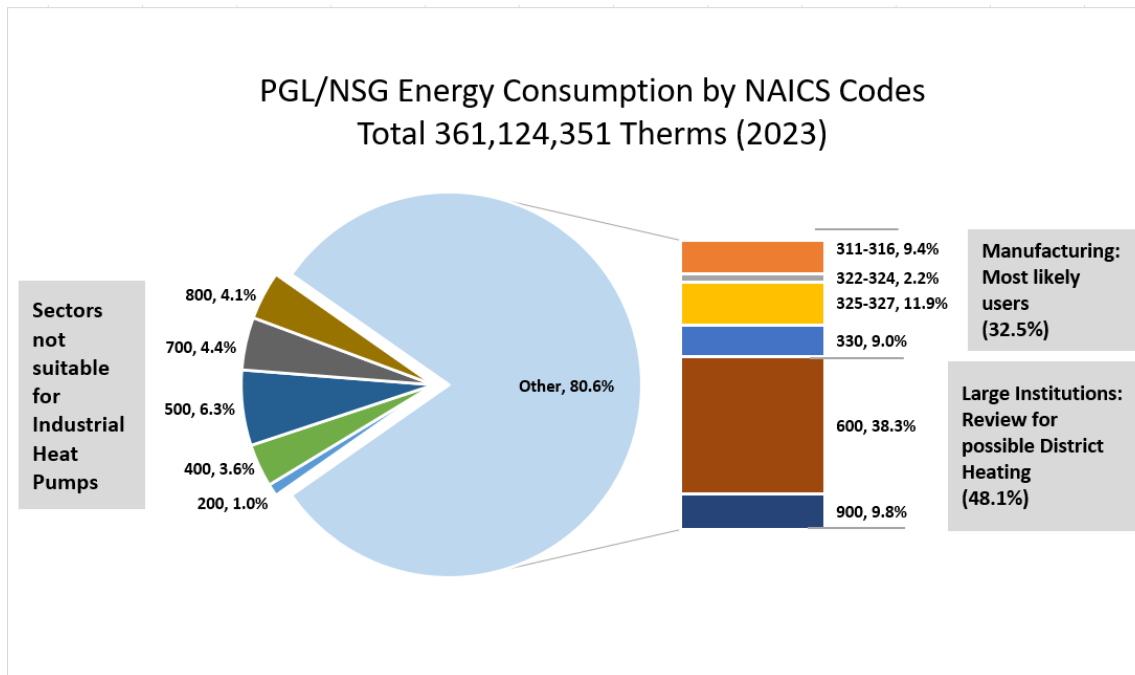


Figure 33: Energy Consumption by NAICS Codes

Energy Prices and Spark Gap

A determining factor in the operating cost benefit of IHPs is the relative cost of the electric energy used for the heat pump compared to the fuel (natural gas) that it is displacing. While heat pumps operate at COPs that range from 1.5 to 6.0, typical COPs are in the 2.5-4.0 range. Earlier, Figure 6, showed the COP trend for historical installations. Figure 34 details the trend. It can be seen that for temperature lifts of 60K (108°F), a COP of 3.0 is expected. Thus, for every unit of electrical energy input, the heating output is 3 times that. The gas efficiency should be accounted for as well, for example, for a gas-fired water heating system with an efficiency of 90%, the heat pump would output 3.3 times the energy of the gas input.

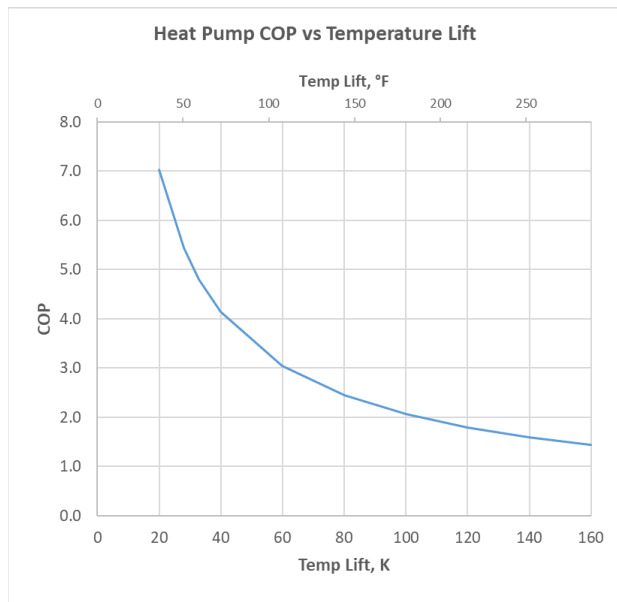


Figure 34: Heat Pump COP vs Temperature Lift

To determine the energy cost savings (or increase), the relative gas and electric prices need to be compared. A common approach is to determine the spark ratio (often referred to as spark gap



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or spark spread), which is the cost ratio of electric to gas on an equal energy basis. The electric cost (\$/MWh) and gas cost (generally in \$/MMBtu) are converted to common energy units.

The spark ratio varies significantly throughout the U.S., as both gas and electric costs are variable. Determining actual costs, accounting for electrical demand charges and time-of-use pricing adds a high degree of complexity. Clearly, utilizing the heat pump during off-peak hours would be beneficial from a cost perspective, but most industrial processes are continuous.

Average industrial spark ratios (EIA, 2024) are shown in the Table below. Illinois ranks 18th in the U.S., with average industrial electric price of \$0.0883/kWh and average industrial price of gas as \$6.37/MMBtu. As a point of reference, average electric cost for the Commonwealth Edison (ComEd) service territory (which aligns with PGL and NSG gas territory) is \$0.0736/kWh. The Illinois average spark ratio is thus 4.07 with the ComEd ratio 17% lower at 3.39.

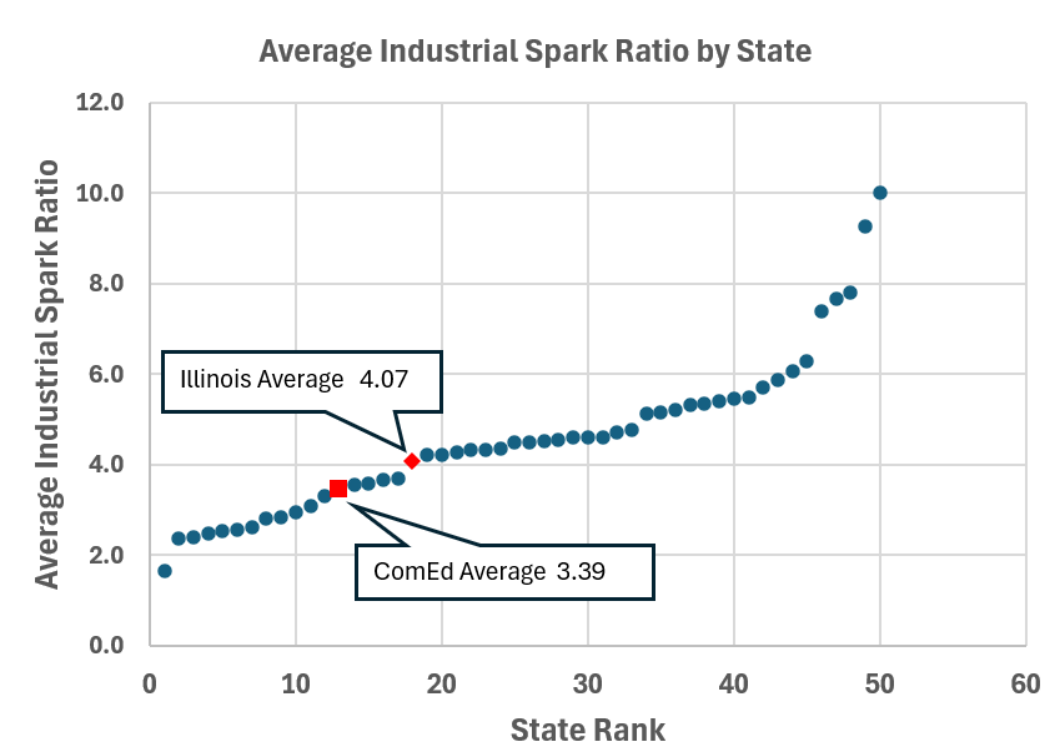


Figure 35: Spark Ratio by State Rank, including Illinois average and within ComEd

To compare the annual energy cost of a heat pump and gas-fired equipment, the spark gap, heat pump COP and efficiency of the gas-fired equipment are needed. Using a spark ratio of 3.4, the breakeven COP for a heat pump must be approximately 2.7 when replacing 80% efficient gas-fired equipment, and 3.0 when replacing 90% efficient gas-fired equipment. This is shown graphically in Figure 36 below. If a heat pump system can supply a higher COP, the energy costs will be reduced; if the COP is lower, the heat pump system will have higher energy costs.

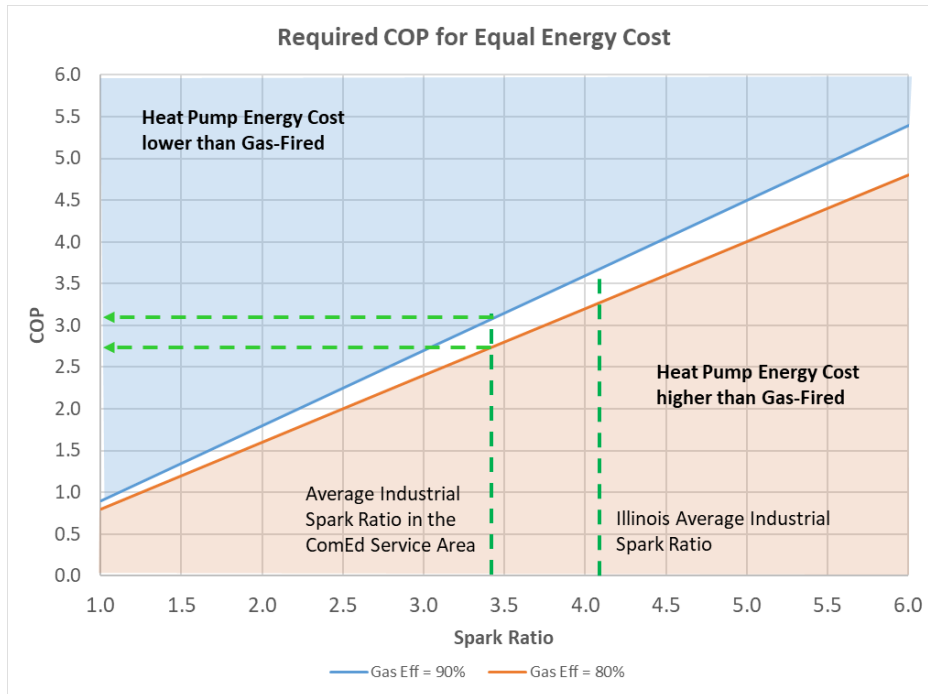


Figure 36: Required COP to achieve equal annual energy costs

It is important to note that the spark ratio analysis above is based on average energy costs and does not include demand charges, which can significantly affect the economic benefits. For example, demand charges in Chicago (June 2026-2027) will be \$10.01/kW-month. Thus, a plant running a continuous process that adds a 500 kWth IHP, operating at a COP of 3.0, would see an annual demand charge of \$20,010, significantly increasing the overall energy cost.

Site Emission Reductions

Reductions in a plant's emissions are highly site-specific, dependent on the achievable COP of the process and the emissions rate of the electric grid. One example, following Armstrong International's Circular Thermal approach, is shown in Figure 37 below. The simplified diagram shows the shift in gas usage to an IHP system producing 100 MMBtu of thermal energy for a process. The conventional natural gas boiler would require approximately 115 MMBtu of energy (based on a boiler efficiency of 87%) and would result in approximately 80 MMBtu of waste energy. The IHP system, assuming a COP of 4.0, recovers 75 MMBtu of energy and produces 100 MMBtu using 25 MMBtu (equivalent) of electric power.

The emissions of conventional natural gas boiler system would be 17,000 lbs of CO₂eq (115 MMBtu x 148 lb/MMBtu) and are relatively constant throughout the U.S. The emissions of the IHP depend on the local grid emission rate. For Illinois, served by RFCW, the eGrid rate for All Plants is 1072 lb/MWh and for Non-Baseload plants is 1959 lb/MWh. For the 25 MMBtu electric input (7.33 MWh), this results in emissions of 7860 and 14,400 lbs of CO₂eq. This results in emissions that are between 46-85% of the conventional natural gas system. For a life cycle reduction, future grid emissions should be taken into account, but is beyond the scope of this project.

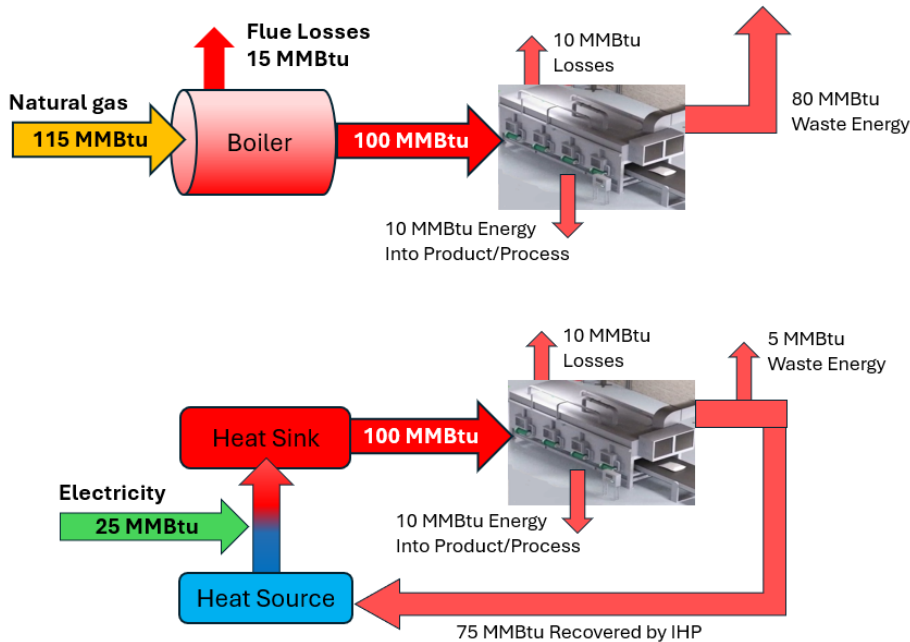


Figure 37: Comparison of Gas-fired and IHP Systems

Equipment and Total Installed Cost

While IHPs offer the potential of reduced operation costs and emissions, Capital cost (CAPEX) remains one of the primary barriers to widespread adoption in industry. Cost levels vary substantially depending on unit capacity, supply temperature, heat source quality and availability and other system integration or site-specific factors. While imprecise, costs are typically described in as:

- Equipment Cost: the heat pump unit and primary auxiliaries supplied by the vendor.
- Total installed cost: the fully installed, commissioned system including balance-of-plant, engineering, and construction.

Typical IHP Equipment Costs

Commercially available industrial heat pump equipment costs generally fall within the following ranges:

- Low temperature supply (60-90 °C) and low-lift (<60 °C): 400 to 1,000 \$/kW_{th}
- High temperature supply (90-120 °C) and medium lift (60-80 °C): 600-1,500\$/Kw_{th}.
- Very High-temperature supply (> 130 °C): prices less defined but estimate \$1,000-2,000 \$/kW_{th}.

These values typically include the compressor(s) and motor(s), packaged heat exchangers, system frame and basic controls. Other site-specific components and integration costs are separate. As a point of comparison, the equipment cost for IHPs can be 2 to 4x that of natural gas boilers.



Key factors affecting equipment cost

Several factors contribute to the equipment pricing:

- Temperature lift and supply temperature: Higher temperature lifts reduce COP as described previously and shown in Figure **. Higher supply temperatures, especially above 120 °C, are still in development requiring more robust compressor designs, specialized working fluids, with the requirement for higher-grade materials, all of which increase cost.
- Capacity and modularity – Small systems (<500 kWth) are often very expensive given fixed installation costs. Larger systems (>2 MWth and larger) benefit from economies of scale, but requirement for custom engineering can offset these savings compared to standardized modular offerings.
- Heat Source: Systems designed to recover waste heat (for example from cooling tower water or process exhaust streams) provide higher source temperatures and reduced lift requirements leading to increased COPs, but the required heat exchangers add complexity and increase integration costs.
- Refrigerant selection: For plants that are not using ammonia, safety and regulatory issues may increase costs. Low-GWP refrigerants capable of very high temperatures are often more expensive and less standardized, increasing vendor cost.

One OEM provided historical equipment costs demonstrating the impacts of temperature lift and unit capacity. As can be seen in Figure 38, the cost of the smaller units (300-500 kWth) is quite high, while large units (>1200 kWth) are significantly less expensive. Also, the impact of temperature lift can be seen, as higher lift temperatures lead to increased equipment cost. It should be noted that costs shown are helpful as trends, but to accurately estimate equipment costs, the application needs to be defined and suppliers approached for quotations.

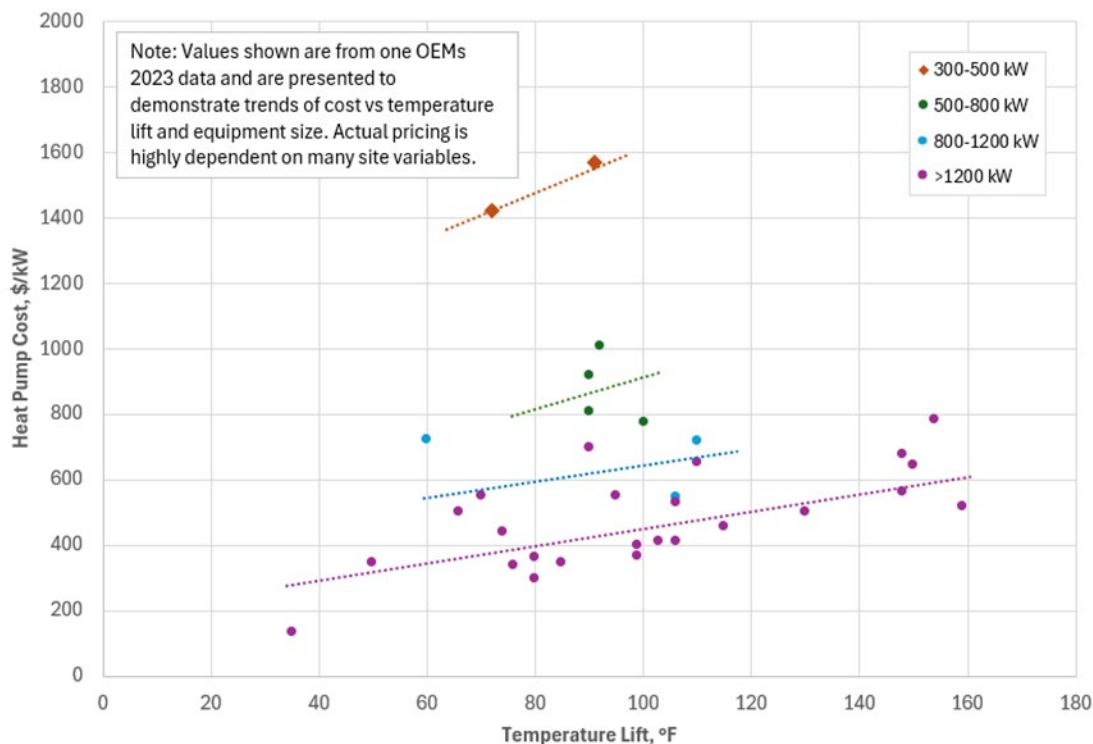


Figure 38: Equipment Cost: Impact of Capacity and Temperature Lift (Source: GEA)

Total Installed Cost:

Including all other costs (engineering, installation, integration and commissioning), the total installed cost is often a factor of 2 to 4 times the heat pump equipment cost. One supplier uses an estimated 2x equipment cost for retrofits. However, if additional process equipment is needed (heat exchangers, coils, kettles) or increased electrical demand above the plants current capacity, the total installed cost will increase further. Another supplier uses a factor of 2x for simple installations with more complex installations reaching 4x the equipment cost.

Experience gained from industrial installations is gradually reducing equipment costs due to standardization, improved capabilities for high-temperature systems, but other economic factors including inflation, tariffs and business uncertainty is playing a larger role. Given the wide variation of the installation cost, the range of total installed cost needs to be accounted for in project evaluation.

Territory-Wide Potential

Calculating the territory-wide potential of IHPs is imprecise, but to provide an order of magnitude estimate, the following approach was used: The potential was computed for two levels: technical potential and economic feasibility. The technical potential—the percentage of thermal process heat that could be provided by IHPs, was estimated based on published information for the sectors and refined by review of the companies in the large users database. For example, in NAICS 311-316 (largely food and beverage), a value for technical potential of 47% was used because most of the processes are within capabilities of current IHPs. In NAICS



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325-327 (chemical, pharma and others), the technical potential is moderate (30%) due to the process temperatures and the processes themselves. For NAICS 322-324 (paper, asphalts and paving) as well as NAICS 331-339 (metals), a value of 15% was used for the technical potential. In NAICS 600 and 900, the technical potential was estimated to be only 5%, as the only application for IHPs would be for district heating or thermal networks. With these estimations, the technical potential for the sectors shown is 43,648,000 therms.

For economic feasibility, an estimated factor was applied based on the current economic conditions: industrial gas and electric rates, policy drivers, and other factors. Because of the current spark ratio, the economic feasibility is estimated to be quite low—between 5-15%. Using this approach, the total economic feasibility for the large users is estimated to be 3,747,000 therms, approximately 1.3% of these customers gas usage.

Table 5: Territory-Wide Potential

NAICS	Summary Description	Therms (2023)	Technical Potential		Economic Feasibility	
			Estimated	Therms	Estimated	Therms
311-316	Bakery, Food Manufacturing, Chocolate, Brewery, Leather and Tanning	34,084,509	47%	16,019,719	10%	1,601,972
322-324	Paper, Corrugated, Asphalts, Paving	7,826,902	15%	1,174,035	15%	176,105
325-327	Chemical, Pharma, Paint, Plastics, Cement and Gypsum	43,053,724	30%	12,916,117	10%	1,291,612
331-339	Metals, Machinery, Electrical, Furniture and Medical Devices	32,380,965	15%	4,857,145	5%	242,857
600	Colleges, Hospitals and Healthcare	138,392,023	5%	6,919,601	5%	345,980
900	Government	35,235,940	5%	1,761,797	5%	88,090
Total		290,974,000		43,648,000		3,747,000

It should be noted that approach is sensitive to the assumptions and approximations presented. Further sensitivity studies could be performed to further understand and define the market potential.

Case Studies

Selection Criterion

The goal of this task was to identify companies and sites with a high potential for IHP application in their plants and companies that have sustainability goals such that IHPs would be evaluated. To identify companies with potential and likely interest, the Energy Advisors (EAs) from the Peoples Gas and North Shore Gas Energy Efficiency Programs were engaged. Energy Advisors are in contact with customers at the plant level and work with them to evaluate energy usage and find energy efficiency solutions.

As a first step in identifying likely case studies, the large user database was screened to eliminate customers whose processes were generally unsuitable for IHPs. This reduced the number of potential sites from 281 to 135. This list was distributed to the EAs for review and they responded by addressing questions in several areas:

- Database accuracy: Is the energy use realistic and is the business classified correctly?
- Application: Does the plant have waste heat and hot water needs? Is there simultaneous heating and cooling?



- Customer Interest: Does the customer have sustainability goals?

Based on the EAs review, they recommended whether to contact the customer for a more detailed evaluation. This reduced the potential list to 31 sites. From these, a more detailed evaluation was held, with the plan of performing 5 site visits to the following sectors:

Table 6: Planned Site Visits

Sector	Number of Intended Site Visits
Food Manufacturing	2
Chemical	1
Hospital	1
Large Institution	1

The EAs reached out to the appropriate engineering staff at the identified sites.

Site Selection Results

When contacting the identified customers, the EAs noted that interest was minimal. One presentation was made to a chemical company and they were open to a site visit, but required an NDA. The NDA was processed, but even after repeated attempts, the site visit couldn't be scheduled. Two food and beverage sites responded that they didn't think a heat pump would fit in their process.

Companies in the other sectors did not respond to the EAs outreach.

This anecdotal experience raises questions about the reason for lack of engagement, with likely explanations including:

- Outreach to operational rather than sustainability personnel: The personnel contacted were plant-level and generally deal with ongoing operational challenges rather than strategic upgrades. While open to energy savings options that reduce costs, most are very busy and hesitant to invest effort in evaluating new technologies when operational cost savings are not a guarantee unless the company has clearly defined sustainability goals. To implement IHPs, the company company contacts will need to be different—they should be the staff with energy saving and sustainability and emissions reduction goals.
- Lack of awareness of IHP options: given that food and beverage companies, several identified as having simultaneous heating and cooling, believed that IHPs didn't fit their processes, shows that plant personnel have limited understanding of how IHPs would be integrated into their processes and the potential benefits.



CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The findings of this Industrial Heat Pump Technology and Market Assessment indicate that IHPs offer strong technical value and credible near-term opportunities within the Peoples Gas and North Shore Gas service territories, but meaningful adoption will require targeted market development, economic support, education and sustained stakeholder engagement.

Across U.S. and international markets, industrial heat pumps have advanced rapidly in temperature capability, capacity range, and commercial readiness. Multiple OEMs now offer demonstration-ready systems capable of providing hot water up to 95°C and 120 °C and, in several cases, low-pressure and medium-pressure steam. This represents a notable shift from only a few years ago when high-temperature steam-capable products were limited to pilots. The technology review confirms that major vendors—including GEA, Armstrong, Trane, Vilter/Copeland (including the SPH steam-generating platform), AtmosZero, and Multistack—have U.S. presence and product lines suitable for many of the industrial and institutional applications within PGL/NSG territory. These offerings span hot-water systems, heat-recovery chillers, and increasingly steam-generating configurations.

The market assessment shows that, on a percentage of total consumption basis, Peoples Gas and North Shore Gas have a smaller large commercial and industrial base relative to many U.S. gas utilities. However, the territory includes a meaningful number of large institutions with thermal networks, including hospitals and universities, which closely match the highest-potential applications for IHPs. Within the industrial sector, the analysis of the large-user database highlights NAICS 300-series customers (food & beverage, chemicals, paper, and selected metals) as the most promising near-term candidates. These sectors align well with current IHP capabilities, which are strongest for moderate-temperature process heat, water heating, pasteurization, cleaning/sanitation, evaporators, distillation via MVR, reactor heating/cooling integration, and combined heating/cooling applications.

Despite the technical potential, the study finds that barriers remain predominantly economic and logistical. Industrial electricity prices relative to gas—expressed as the spark ratio—often require heat pump COPs above 3.0 to achieve operating cost parity with gas-fired systems. When electric demand charges are considered, the breakeven COP increases further. While many applications can achieve these performance levels, many sites face challenges due to:

- Unfavorable spark gaps
- Rising electric capacity charges
- High capital and installation costs
- Space constraints and integration complexity
- Electrical infrastructure limitations
- Low familiarity among plant personnel and engineering design firms

These barriers are amplified by the limited number of U.S. reference installations, particularly in industrial high temperature or steam applications. In PGL and NSG territories specifically, several



customer interactions indicate that low awareness and concerns about applicability remain significant hurdles, even among facilities with strong sustainability goals or clear simultaneous heating/cooling opportunities.

Overall, the assessment concludes that IHPs present meaningful decarbonization and efficiency opportunities for PGL and NSG industrial and large-institution customers, but adoption is likely to remain modest without targeted interventions, demonstrations, and market-building activities. Technical potential is substantial—estimated at more than 43 million therms—yet economically feasible potential is closer to 1–2% of large-user gas consumption under current conditions. Strategic actions are required to shift this trajectory.

Recommendations and Next Steps

To capture the most promising opportunities and overcome current deployment barriers, the following actions are recommended:

1. Grow Stakeholder Interest and Awareness

Broader understanding of IHP technology and its application is essential among industrial decision-makers, including plant engineers, sustainability managers, operations leaders, and capital planning teams. Needed steps:

- Develop targeted outreach explaining how IHPs integrate into actual industrial processes.
- Provide clear guidance on identifying “best-fit” process conditions—moderate lift, waste heat availability, and simultaneous heating/cooling.
- Share case studies and benchmark data to demonstrate where IHPs have succeeded in comparable facilities.

Early awareness-building will help address misconceptions surfaced during this project, particularly among plants that dismissed IHP applicability despite having favorable loads.

2. Technology Transfer and Design Firm Engagement

Engineering design firms and EPC contractors play a critical gatekeeping role for industrial customers. Many lack experience with industrial heat pumps, particularly steam-capable systems. Needed steps:

- Convene technical workshops for engineering firms, OEMs, and plant staff.
- Develop design aids, integration schematics, screening tools, and example specifications.
- Partner with OEMs to host hands-on demonstrations and site walk-throughs.

This activity reduces perceived technical risk and increases the likelihood that IHPs will be identified early in project scoping.

3. Field Demonstrations and Pilot Support

Demonstration projects are the single most important action to accelerate adoption. Strategically selected pilots across high-potential sectors such as food & beverage, chemical



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processing, hospitals, and large institutions with thermal networks would demonstrate viability.

Key elements include:

- OEM-supported engineering and performance validation
- Metering and M&V to document COP, therm savings, operational impacts, and economics
- Public-facing results to serve as regional reference sites

Successful pilots will materially reduce uncertainty around economics, integration complexity, and operational performance.

4. Incentives, Program Development, and Economic Support

Given current spark ratios, IHPs often require incentives or custom support to reach competitive paybacks. Possible actions:

- Develop custom incentive pathways for industrial IHPs, including steam-capable equipment
- Allow incentives for enabling infrastructure (e.g., controls, integration engineering, heat-recovery plumbing)
- Coordinate with ComEd on joint electric-gas program offerings for electrically driven systems

Coordinated program design will allow early adopters to proceed with confidence while the market matures.

Summary

Industrial heat pumps represent a viable and emerging decarbonization pathway for segments of the PGL/NSG customer base—particularly food & beverage, chemicals, and large institutions. While technical potential is significant, economic and awareness barriers currently suppress adoption. Focused action on education, design support, demonstrations, and incentives will be essential to realizing the near-term opportunities and preparing the market for broader uptake as technology prices fall and electric grid carbon intensity continues to decline.



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