Industrial Heat Pumps: it's time to go electric

Contents

Executive summary | 3

1 **Industrial heat and the opportunity for heat pumps** | 4

The size of the prize | 5

Industrial heating applications | 6

What is a heat pump and how does it work? | 8

What are the key benefits of industrial heat pumps? | 8

2 **Leveraging changing market conditions** | 10

Improving market trends | 12

Growing policy support | 14

Developing technological innovation | 14

3 **Opportunities to unlock the full potential of heat pumps** | 16

Couple applications and sectors | 17

Investigate Heat-as-a-Service | 20

Provide grid balancing services | 21

Consider grid connection costs | 22

Take advantage of refurbishment | 22

Create targets and advocate for heat pumps | 22

4 **Conclusion: Seize the opportunity** | 23

Executive summary

Electrification is one of the most promising and scalable solutions to decarbonize heat, especially for light industry. When coupled with the procurement of clean energy, it offers a genuine opportunity to transition to a low or zero-carbon heating system. Heat pumps are a particularly promising means to turn heat electric as they are the only technology capable of achieving thermal efficiencies well over 100%.

Industrial heat represents approximately 29% of total world energy demand and its decarbonization is therefore an essential feature of any credible pathway to net zero emissions. At a time of geopolitical instability and volatile gas markets, the case for reducing dependence on fossil fuels for industrial heat is increasingly compelling.

The fact that heat pumps can achieve such high efficiency gains can yield significant reductions in overall energy use, operational costs and emissions. Heat pumps also enable circular solutions where one company's waste heat can be upgraded and used by another company. While heat pump technology is not new, its full potential as a source of low-carbon heat is becoming increasingly better understood. However, at the time of writing, there has been relatively low uptake within industry due to suboptimal return on investments, high capital expenditure costs, a lack of policy support, potential power grid capacity restrictions and technical features that limit their applicability to low-temperature heat uses (up to 200°C).

Fortunately, there is growing commercial viability for heat pump installation – notably in light industry, where there are typically lower temperature heating requirements. Several market trends are improving the business case for electrification, including reducing electricity-to-gas price ratios, growing uptake of carbon pricing mechanisms and increasing costs of carbon. Innovation in heat pump design has also yielded cost reductions and efficiency gains that have made higher-temperature heat applications more commercially available to a wider range of applications.

Equally, some barriers remain: switching to electric heat by replacing fossil-fuel heat sources with heat pumps is not straightforward. Heat pumps often involve high up-front capital expenditure and companies need to integrate unfamiliar technologies into their facilities and work across internal functions to identify the most appropriate business models and financing mechanisms. Key actions that companies can take to improve the business case for heat pumps include:

- Use scenarios for utility and carbon prices to understand the lifetime costs of all options and the policy and market risks associated with fossil fuel-based heat;
- Pursue opportunities to make use of variable electricity tariffs and potential revenue generation opportunities by providing grid-balancing services;
- Embrace alternative business models and financing mechanisms such as Heat-as-a-Service;
- Seize opportunities to minimize disruptions and capital costs, by installing heat pumps during planned outages, and at sites with no or limited additional grid connection costs.

1 Industrial heat and the opportunity for heat pumps

1 Industrial heat and the opportunity for heat pumps

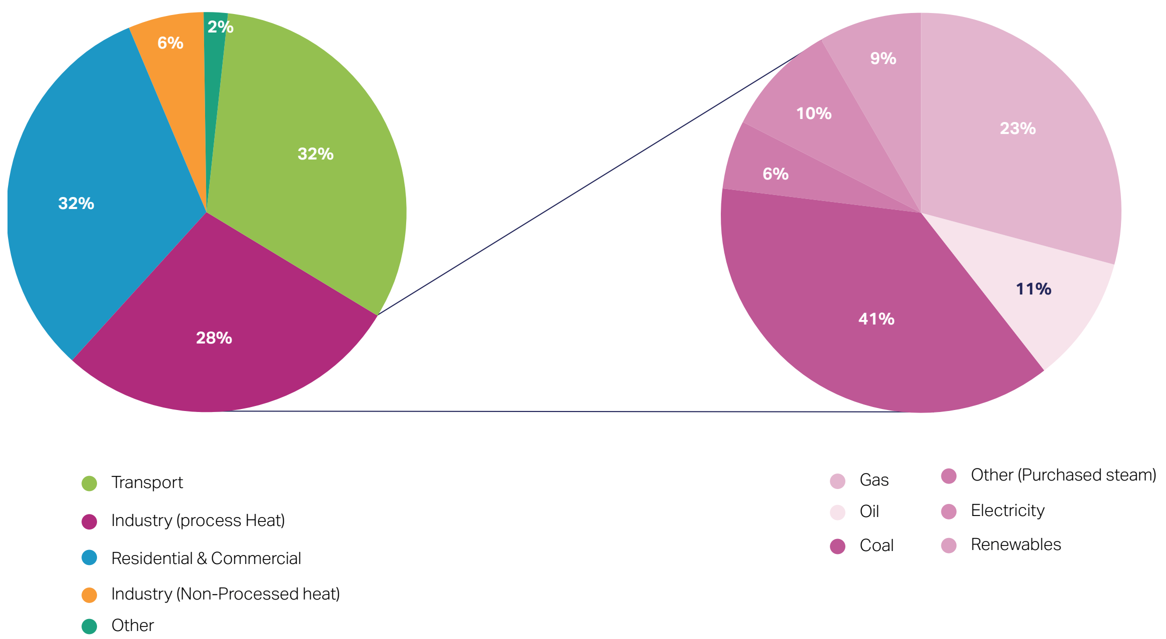
The size of the prize

Businesses and households alike still largely depend on oil, coal and gas for their energy needs: more than 80% of the energy used worldwide comes from these sources today.[2] Almost 50% of all final energy used goes into heat applications – across industry and the built environment. As Figure 1 shows, 29% of world energy demand is for industrial heat applications alone – the vast majority of which is generated with fossil fuels. Process heat is used across all industries, from making steel and cement to manufacturing food, pharmaceuticals, paper and textiles.

In 2019, industry worldwide used about 23,700 TWh of energy for heating purposes. For comparison, annual electricity consumption, including that consumed to generate heat, amounted to 25,000 TWh. Industrial heat demand is predicted to continue to rise in the coming decades, although this growth could be even greater if the expected efficiency improvements assumed in these analyses are not delivered.[5]

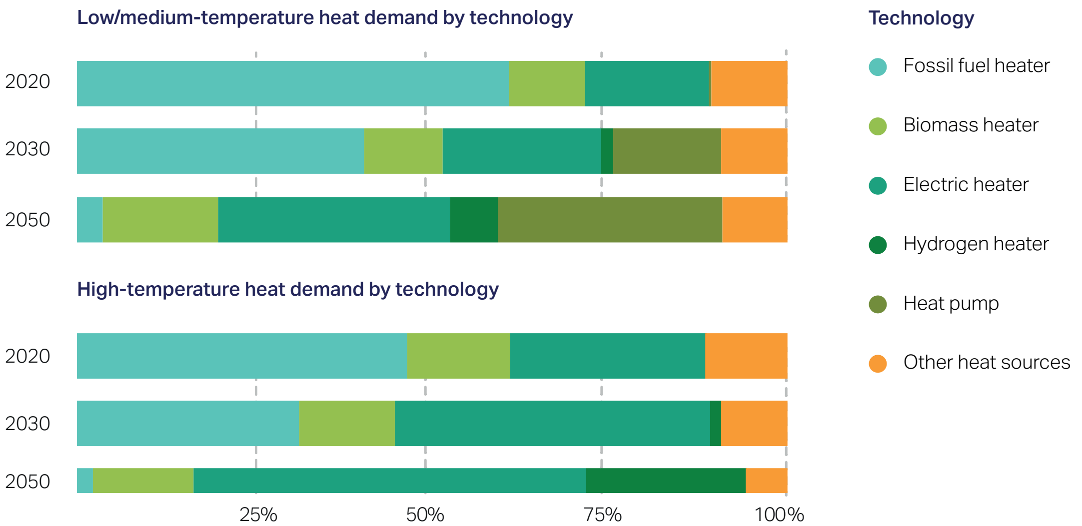
The electrification of industry using low or zero carbon power presents a significant opportunity for decarbonization and is an essential feature of a 1.5°C-aligned pathway to net-zero emissions, although the future heat source mix will differ significantly between industries. In light industry where heating temperature requirements are moderate, such as for manufactured goods, electricity (via electric heaters and heat pumps) will satisfy 40% of heat demand by 2030 and 65% by 2050, compared to 20% for hydrogen and 15% for bioenergy in 2050.[6]

Figure 1: Industrial heat use relative to global final energy consumption and heat production by fuel source, 2018[3]



Industries such as iron and steel, cement and chemicals will have lower electrification possibilities because of their need for high-temperature heat. Typically, these industries rely on the use of fossil fuels as feedstock due to the high energy density, energy flux requirement and physical design of the facilities. Furthermore, heavy industrial facilities are capital intensive with long project lifetimes (25+ years). Operators are disinclined to replace large, capital-intensive equipment, which comes with the additional burden of lengthy downtimes when installing different facilities, revenue losses, operational changes and a need to retrain staff.

Figure 2: Share of heating technology for light industry in the IEA Net Zero scenario[7]



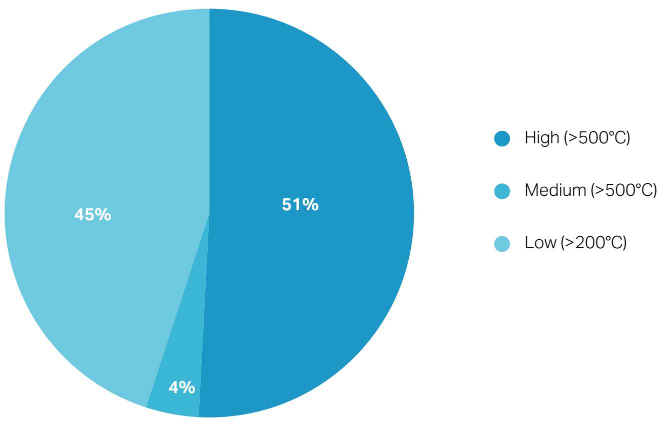
Industrial heating applications

Industrial heating applications vary widely in their operating temperatures as dictated by different industrial processes, classified as follows:

- Ultra-low (<100°C)
- Low (<200°C)
- Medium (200-500°C)
- High (>500°C)

No single technology can electrify heating applications across all these temperatures. Heat pumps are now emerging as the most promising heating technology for lower temperature applications. Heat pump technology for ultra-low heat applications (up to 100°C) is mature and therefore presents a credible opportunity for near-term action in electrifying up to 11% of global heat demand.

Figure 3: Global industrial heat use by temperature with ultra-low and low combined into the low category, 2016[8]



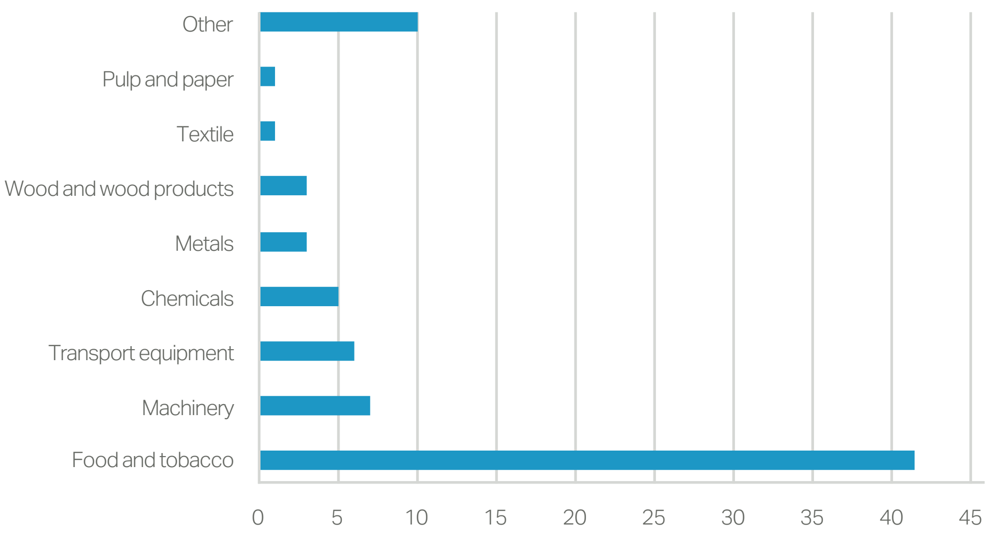
This accounts for 222 TWh in the European Union alone.[9] Heat pumps suitable for use in low-heat applications (up to 200°C) are also becoming increasingly commercially available following research, development and demonstration work to improve pump efficiencies at higher temperatures.[10] Taking the European Union as an example, it would be possible to apply the technology to supply up to 37% of industrial process heating (730 TWh).[11]

The sector with the greatest uptake of heat pump use so far has been the food, beverage and tobacco sector, as demonstrated in Figure 4, where 41 heat pumps have been installed in this sector across a sample of 77 global industrial heat applications in 2019.[13] Given that this sector represents more than one-quarter of all low-temperature heat demand, it will likely continue to see the greatest use of heat pumps.

A more recent trend is to install heat pumps at sites that require simultaneous low-temperature heating and cooling in a combined heating and cooling solution. The efficiency of such a solution is very high, given it connects waste heat/cooling loads on-site and displaces a heating and a cooling solution – each with their own energy demand and conversion losses – with a single solution for both.

Industrial heat pumps remain less common in industries that rely on both high-temperature and low-temperature processes at a given facility, such as chemicals.

Figure 4: Sample of industrial heat pump applications by sector globally, 2019[12]



What is a heat pump and how does it work?

Simply put, a heat pump is the reverse of a refrigerator in that it transfers available heat from a colder place (heat source) to a warmer place (heat sink) by compressing a refrigerant (or working fluid) to increase the temperature to a more useful level, typically by using electrical energy. They are highly energy efficient compared to existing conventional heating options because heat pumps deliver more thermal energy than electrical energy is used to drive the pump leading to large energy savings. Conventional heating options, by comparison, always have an efficiency below 100% – meaning they always output less thermal energy compared to the energy input. The efficiency of a heat pump is directly related to the temperature increase required – also known as temperature lift. The greater the temperature lift between the source and the sink, the lower the efficiency (coefficient of performance – COP). It is this phenomenon and the availability of suitable refrigerants that limits their commercial application above approximately 150°C at the time of writing.

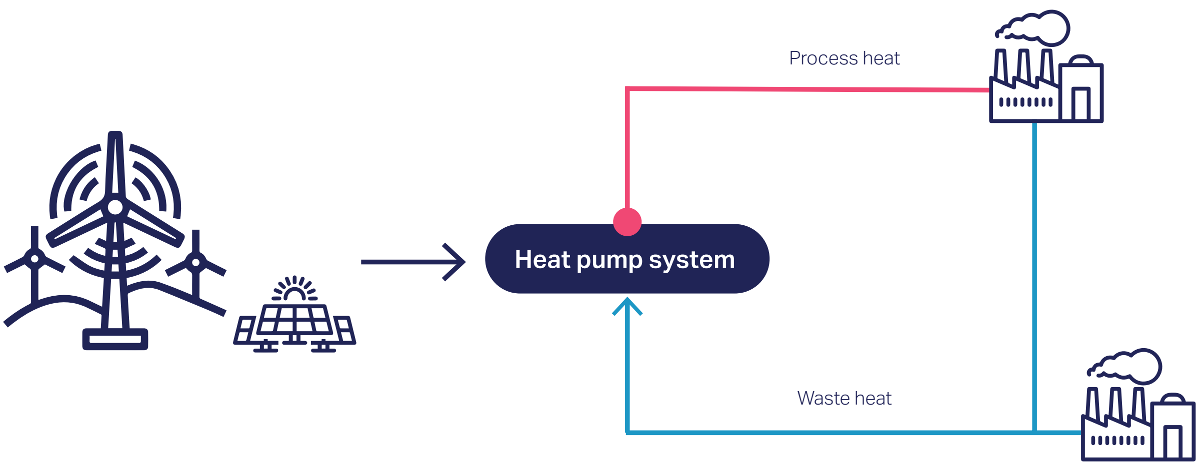
However, further efficiency gains through additional research and development are expected to allow applications of higher temperatures to become more commercially available.

The **coefficient of performance (COP)** describes the efficiency of a heat pump. A COP of two means that it delivers two times more thermal energy than the electrical energy put in. A COP of five means that it delivers five times more energy than the electrical energy put in.

What are the key benefits of industrial heat pumps?

1. Heat pumps reduce overall energy use due to high thermal efficiencies, especially for low-temperature heating applications and when waste heat sources can be upgraded – see Figure 7 below.
2. Heat pumps can reduce carbon emissions by displacing fossil fuels with a renewable heat source (i.e., ambient heat from the ground, air or a waste heat source) and by using electricity sourced from an increasingly low-carbon grid to drive the pump. The heating application can be zero-carbon by twinning the increased electricity consumption using certifiable zero-carbon power.
3. Heat pumps are a more scalable technology compared to bioenergy, which is finite due to limitations on land and water availability. Alternative options, including geothermal and solar thermal solutions, might not be available due to local climatic conditions and/or require large amounts of physical space at industrial sites.
4. Heat pumps increase security of supply by reducing the reliance on (often) imported fossil fuels.
5. Electrification with heat pumps can enable additional revenue-generating opportunities by providing grid-flexibility services.
6. Heat pumps can introduce product quality improvements where a precise temperature is easier to maintain with a fully electric solution versus heat from combustible fuels.

Figure 5: Industrial heat pump using waste heat in industry – whether from a business' own processes or from nearby third parties



CASE STUDY: ENGIE – REPLACING A GAS STEAM BOILER

Context

Multinational utility and energy services provider Engie worked with a dairy factory in France to replace its two 5.5 MW gas boilers with heat pumps.

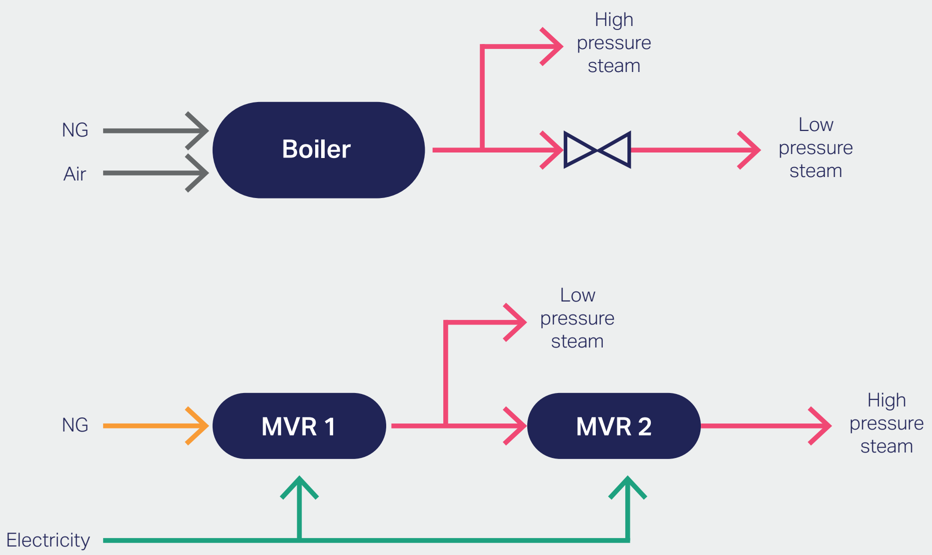
Activity

Engie optimized a mechanical vapor recompression (MVR) heat pump to produce low-pressure steam at <95°C and high-pressure steam at 100-140°C by using an on-site waste heat stream.

Key benefits

- The optimized design has yielded a high efficiency of 400% (COP of 4). This has reduced CO_2 emissions by 3,000 tons per year.
- It also lowered electricity consumption three times more than would have been possible if the boiler had been replaced with an electric boiler.

Figure 6: Replacing natural gas (NG) boilers with the factory's own waste heat via a heat pump



② Leveraging changing market conditions

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While the use of heat pumps for industrial heat presents an exciting opportunity, some key barriers have so far limited its widespread development:

- Sub-optimal return on investment in markets with high electricity prices relative to natural gas prices, combined with high capital expenditure needs, has meant that electrification with a heat pump could be commercially challenging;
- Volatility in energy prices in some environments has made investment decisions difficult when considering upgrading an industrial facility;
- The lack of policy support, historically low costs of carbon and continued fossil fuel subsidies have meant that conventional gas boilers have remained an economical choice for industrial heat applications;
- Limitations in technological capabilities have historically restricted heat pump applications to (ultra) low-temperature heat only.

Evolutions in energy markets, policies and technology will help address these barriers and influence how fast industrial end-users can deploy heat pumps.

To encounter more favorable investment conditions for heat pumps, it is crucial that companies prioritize markets that are most conducive to heat pump deployment. WBCSD's joint-publication on Hot Spots for Renewable Heat with Bloomberg New Energy Finance provides indications of market conditions across the G-20.

Additionally, business cases should be built on market and policy conditions as they are expected to be over the lifetime of the asset, i.e., the next 15-25 years, not just the conditions as they are today. Companies locking themselves into fossil fuel solutions now will embed various risks into their operations, which are increasingly scrutinized by company management and investors. Many companies have also committed to assessing and reporting climate risks and the extent to which carbon costs, and oil and gas prices induce risks in the organization.

Companies could apply various scenarios to better understand lifetime costs of heat solutions, as done within the Task Force on Climate Related Disclosures where scenario analysis is applied to assess strategic resilience.

Companies should:

- Work with global procurement, utilities and sustainability teams to identify which markets offer appealing market and policy conditions today, and/or those that are expected to improve significantly in the coming 15-20 years.
- Agree with their finance and management teams on realistic scenarios for future utility and carbon costs.

This section elaborates on the direction of travel for key market and policy trends and highlights the technological innovation that will improve efficiencies, particularly at higher temperatures.

Credits: Engie

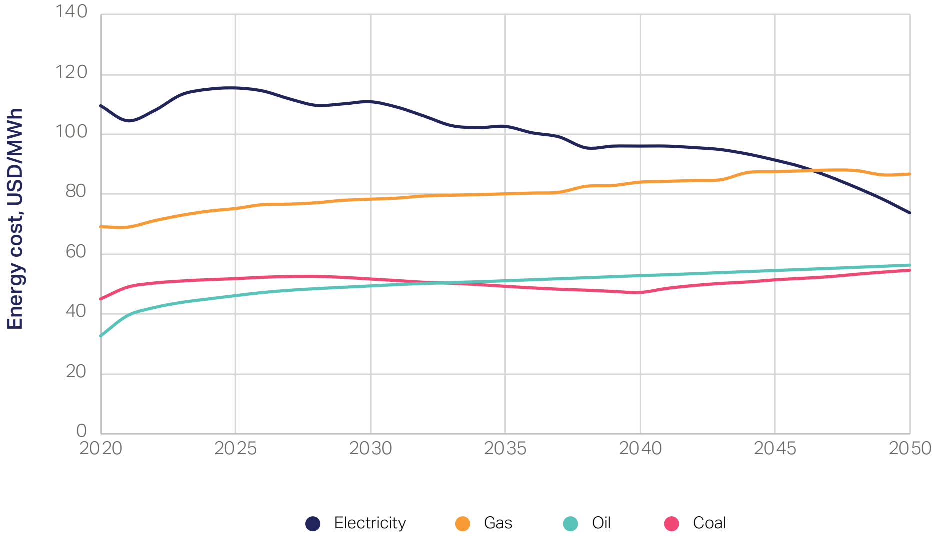
Improving market trends

Energy market analysis conducted by DNV in their 2021 Energy Transition Outlook, prior to the significant natural gas price increases immediately preceding and following Russia's invasion of Ukraine, identified several market trends that clearly favored the deployment of heat pumps at that time.

Natural gas prices were forecast to remain relatively stable between now and 2050, while electricity prices were to decrease along with a parallel decrease in the costs of renewable power generation. Taking Europe as an example in Figure 7, DNV estimated that energy costs for industry in Europe would decrease substantially for electricity – particularly from 2035 onwards, while natural gas would see a moderate increase. Crucially, the power-to-gas price ratio would decrease. Therefore, while electricity costs should remain higher on a per-unit basis, heat pumps would become an attractive commercial proposition given their efficiency is two or three times that of a natural gas boiler.

Overlaying the greater-than-predicted gas price increases further pushes the analysis in favor of heat pumps.

Figure 7: Energy cost for industry in Europe (including carbon tax)[14]

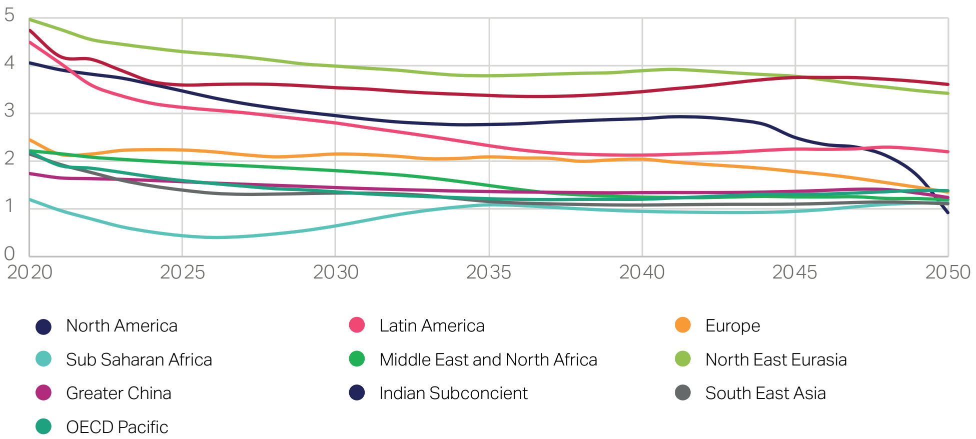


However, Figure 8 demonstrates significant regional variation. Electricity and natural gas costs can vary greatly, so the EU is not necessarily a representative example.

Those regions with a lower electricity-to-gas price ratio are more favorable for heat pump deployment due to lower operating expenditure costs.

Increasing costs of carbon and costs for carbon capture, where applicable, positively impact this ratio, making electricity more competitive.

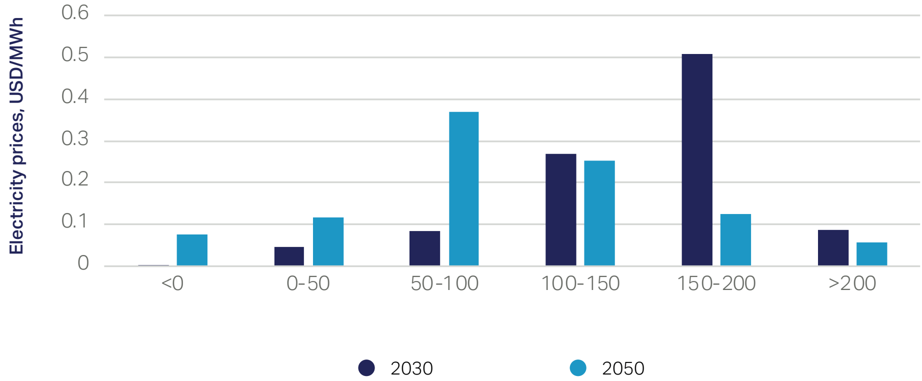
Figure 8: Electricity-to-gas price ratio (including carbon tax), by region[15]



Another market trend improving the business case for heat pumps relates to the increasing proportion of intermittent solar and wind generation technologies in the electricity mix. The changing dynamics of electricity markets will increasingly favor flexible power demand – that is power demand that shifts in line with the availability of wind and solar.

Periods of the day with negative electricity prices will be increasingly common, with predictions showing negative electricity prices for industry in 8% of the time by 2050 globally. Irrespective of the exact figure, this trend could greatly reduce operating costs of a heat pump and/or be an extra source of revenue for industry.

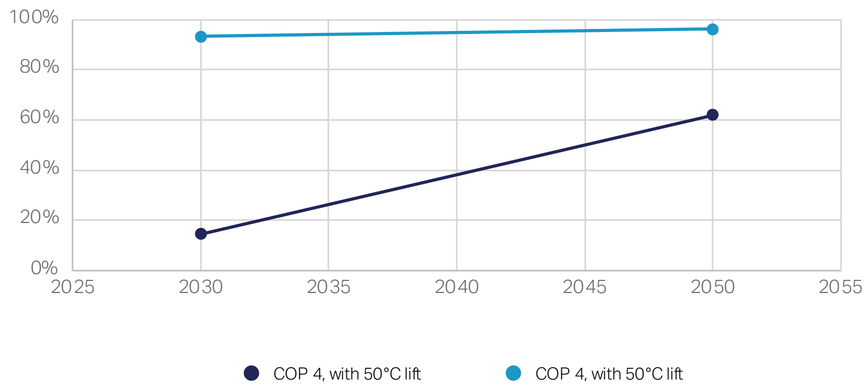
Figure 9: Yearly distribution of industrial electricity prices in Europe[17]



Taking the EU as an example, gas and power price predictions show that heat pumps with a COP of 2 (and presuming a 100°C lift) will be progressively competitive with gas-fueled heat from around 15% of the time by 2030 to more than 60% by 2050. Those with a COP of 4 (and a temperature lift of 50°C) should be more competitive over 90% of the time.

While these market trends indicate a movement towards a more favorable operating expense environment, the trends for reducing technology capital expenditure costs are also notable, driven by technological innovation, economies of scale and learning by doing. In the IEA's Sustainable Development Scenario, the average cost of a vapor compression heat pump is predicted to fall from 935 USD/kW in 2020 to 873 USD/kW in 2030 and 779 USD/kW in 2050.[18]

Figure 10: Yearly number of hours when electricity is more competitive than natural gas in Europe[17]



Growing policy support

The changing policy landscape can significantly alter the heat pump deployment rate through both incentive and coercive mechanisms. An example of a coercive policy is the presence of a cost of carbon. The growing numbers of carbon pricing systems and a general increase in costs both favor heat pump development and deployment. Figure 11 shows the cost per tonne of CO_2 emissions in the European Union. The higher the cost of carbon, the more economical industry will find heat pump installation.

Governments can also incentivize heat pump deployment by setting quotas and targets. This may be through national policies or, for example, through the REPower EU plan to increase heat pump deployment, with a target of 10 million newly installed heat pumps by 2027 and 30 million by 2030.

There are also many incentive-based policy mechanisms. Economic policies such as tax reform and reductions in fossil fuel subsidies may help make heat pump installations more economically attractive. Policies specifically targeting technological innovation, such as through innovation funding mechanisms, can also help drive improvements towards new and more efficient technologies.

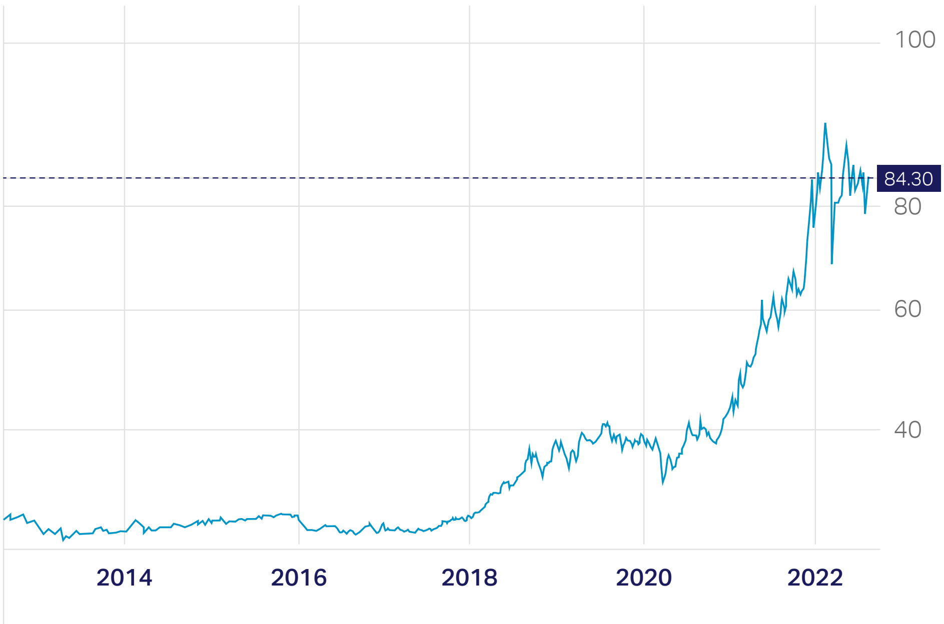
The direction of travel in the policy landscape is clear – many governments are introducing policies to make heat pumps more economically attractive in the near future. The International Energy Agency (IEA), the International Renewable Energy Agency and REN21 have published a report which summarizes renewable energy policies for heating & cooling. The IEA also publishes information on heat pump-specific subsidies and regulations across key markets.

Developing technological innovation

Improving the business case for heat pumps in the ultra-low to low-temperature ranges and continuing technological innovation in heat pumps to achieve higher temperatures will enable a wider range of industries to apply them.

Heat pumps typically use Hydro-Fluoro-Carbon (HFC) refrigerants as their working fluids. Increasing environmental regulation to drive down HFC usage, such as through the Kigali Amendment to the Kyoto Protocol, may drive further developments in more environmentally friendly and high-performance synthetic refrigerants.[20] These improvements may in-turn accelerate development of heat pumps capable of achieving higher-temperatures.

Figure 11: EU ETS allowances price in € (2012-2022)



Source: https://tradingeconomics.com/commodity/carbon

CASE STUDY: OLVONDO TECHNOLOGY – REPLACING A GAS STEAM BOILER

Context

Olvondo Technology is a Norwegian heat pump manufacturer. The company worked with a dairy factory in Norway to replace gas steam boilers that consumed 21.1 GWh in energy annually.

Activity

It installed four HighLift high-temperature heat pumps to produce steam at between 175°C and 184°C from a waste heat source of 25°C.

Key benefits

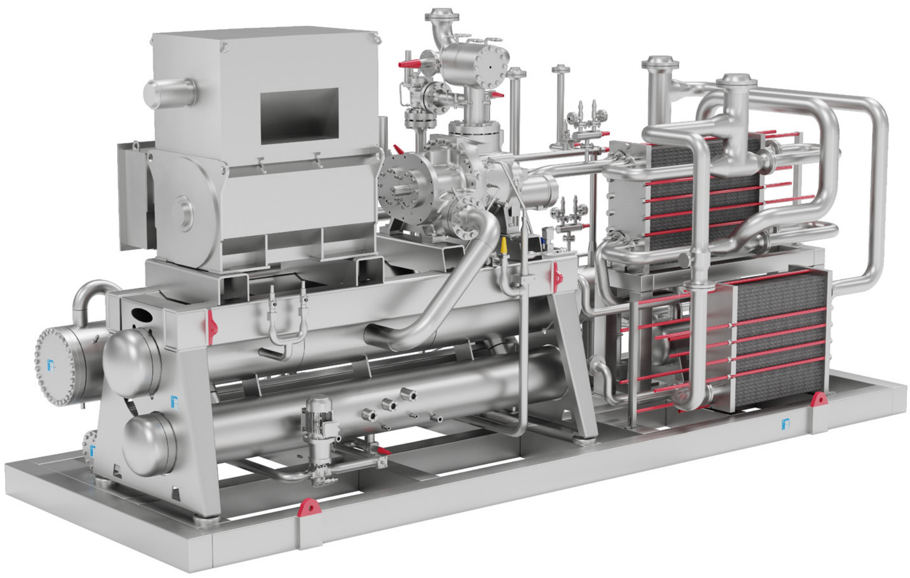
The installed heat pumps achieve a COP of 1.7-1.9. The resulting efficiency gains and electrification have yielded:

- Annual energy savings of 5 GWh;
- Annual energy cost reductions of 30%, with additional savings of USD$33,000 from secondary effects;
- A 66% reduction in CO_2 emissions;
- The consumption of 95% of the steam supplied.

Solutions that integrate heat pumps within standardized process equipment, such as in dryers and boilers for the food and beverage industry, can further accelerate their deployment by making them more easily accessible to end-users, reducing overall unit costs and space constraints.

Further technological development will introduce the ability to combine heat pump technology with thermal storage systems (for heating or cooling), akin to a domestic hot water tank, which can accumulate thermal energy provided by a heat pump and release it at a later moment in time. Thermal storage would enable more efficient use of waste heat, allow companies to take advantage of low electricity prices at certain times of day, and facilitate the provision of flexibility services in stabilizing grids (see next section) as heat generation does not have to take place exactly when power is expensive, or when excess heat is available.

Credits: Johnson Controls



3 Opportunities to unlock the full potential of heat pumps

③ Opportunities to unlock the full potential of heat pumps

Changing market conditions, technology innovation, policies and the emission reduction expectations of investors and consumers will all improve the value proposition of heat pumps. However, deploying sustainable heat solutions is not necessarily as simple as replacing gas-fired equipment with like-for-like sustainable solutions. To help make sustainable heat solutions commercially viable across an increasing number of use-cases and markets, companies may need to adapt their facility designs, adopt innovative business models and gather new skills and expertise.

Heat pumps may also present a significant shift in a business's operating strategy. Therefore, to embrace their introduction, it is critical that the sustainability, engineering, operations and finance functions understand the drivers, the benefits and the commercial and financing options to deploy heat pumps, include heat pumps in the corporate sustainability strategy and ensure their use in new builds and refurbishments.

To help build the business case for heat pump deployment, businesses should leverage the following six opportunities to maximize the value-add of heat pumps in industry.

Couple applications and sectors

As heat pumps transfer (residual) heat from cold sources to warmer sinks, they can upgrade low-grade waste heat from within or outside an industrial facility. Heat pumps thus enable the use of what is otherwise wasted, reducing energy input needs.

Waste heat often requires energy-intense cooling processes. Heat pumps offer an opportunity to link these cooling and heating demands. Businesses can leverage greater efficiencies within their facilities when meeting heating and cooling demands simultaneously, displacing energy use for both these processes with one integrated and more efficient solution.

Where there may be insufficient waste heat to use within an industrial facility, there may also be opportunities to improve returns and make heat pump applications more feasible by working with other local industries and/or governments to balance heat demand with waste heat supply. Organizations can jointly develop integrated heating (and cooling) solutions. Such a solution may benefit from more consistent demand profiles, higher efficiencies and economies of scale when it comes to investment costs and operating expenses.

As an example, many industrial sites and data centers have excess waste heat they cannot consume within their own operations. Businesses can consider collaboration opportunities with other energy producers and consumers or look for local government initiatives to create or grow district heating networks.

Companies should:

- Investigate the heat requirements and waste heat streams from stakeholders local to their production sites. If a manufacturing site is located alone within a rural environment, opportunities might be limited given that heat transfer is primarily economical at shorter distances. However, at industrial parks, or within towns and cities, a multitude of thermal loads could enable more circular, efficient and economical solutions.
- Commence high-level dialogues with local stakeholders to articulate joint needs, and engage with energy services companies to understand the feasibility and economic benefits of a common solution.
- Engage local government representatives to understand existing explorations into district heating solutions, and opportunities for business to tie into this network.

CASE STUDY: TRANE – COMBINING HEATING AND COOLING FOR HIGHER SYSTEM EFFICIENCY

Context

Trane is a manufacturer of heating, ventilating and air conditioning systems. They worked with an animal health product manufacturer in France to optimize its energy use and reduce carbon emissions by replacing an old boiler with a heat pump system.

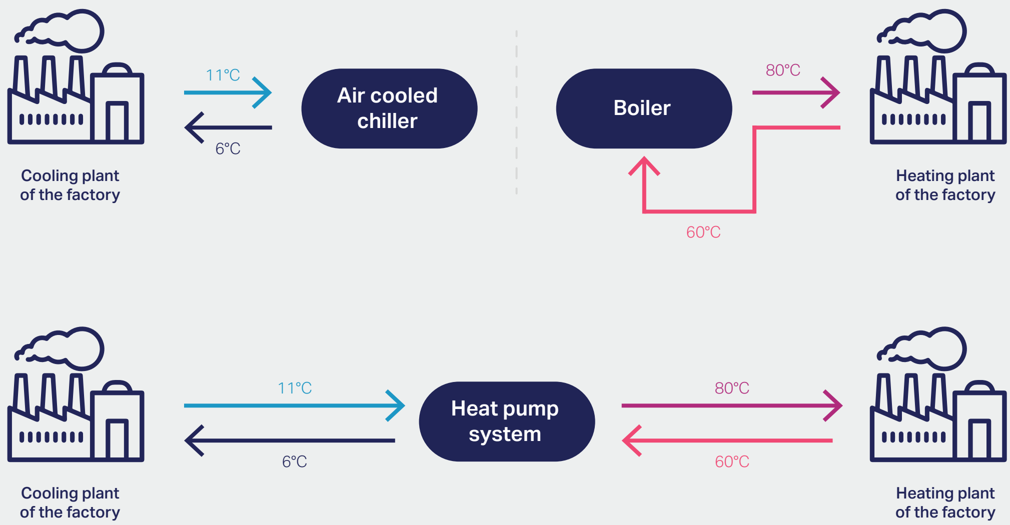
Activity

Trane installed a heat pump connecting heating and cooling applications. The heat pump recovers heat from a waste heat stream of 11°C and uses it to heat the required stream from 60°C to 80°C while simultaneously cooling the waste heat source to 6°C.

Key benefits

Traditionally, the best option to increase energy efficiency was replacing old equipment with a newer, more efficient version. However, combining cooling and heating can yield higher system efficiency. In addition to this, the electrification yielded a reduction in emissions.

Figure 12: Original and new factory design using a heat pump system



CASE STUDY: DALKIA – CONNECTING COOLING AND HEATING SYSTEMS

Context

Energy services provider Dalkia worked with a tire manufacturer to connect its cooling and heating systems across its buildings and industrial processes. Originally, it used natural gas to provide the heat requirements and met cooling requirements with cooling towers.

Activity

Dalkia installed a 900-kW heat pump to provide heat at temperatures of 55-85°C for the site's main heating network, while reducing the use of the cooling towers by using a portion of the waste heat as a sink for the heat pump.

Key benefits

The COP of the heat pump varies between 4.7-1.9. This has yielded:

- Gas savings of 3,550 MWh/year;
- CO_2 savings 633 tons per year.

CASE STUDY: GREEN ENERGY SOLUTION USING LOCAL RESOURCES

Context

Multinational utility and energy services provider Engie worked with the world's second largest brand of dairy products, headquartered in France, to enhance the value of the waste heat of its production processes.

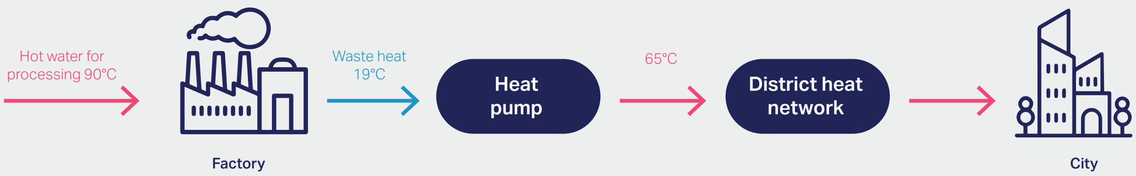
Activity

Engie developed a system that used low-temperature waste heat of 19°C from the production system to put heat of 65°C into a local district heating network with a 1.5 MW heat pump.

Key benefits

The use of this industrial waste heat source provides a sustainable heat source to a city of 30,000 inhabitants and has yielded a 50% reduction in CO_2 emissions.

Figure 13: Waste heat as a source for district heating



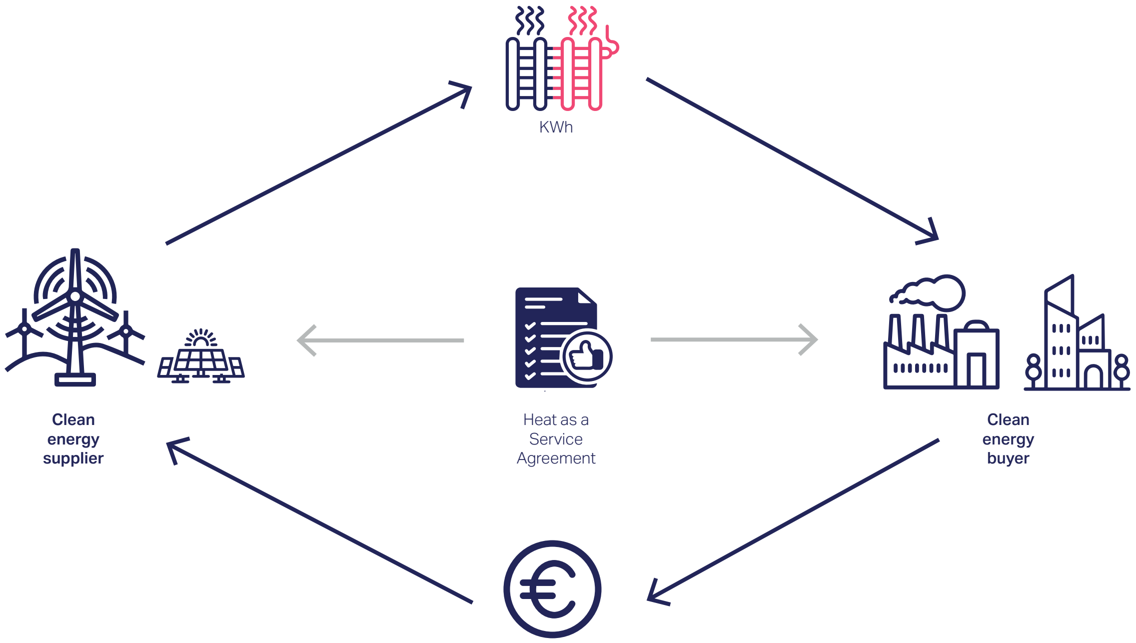
Investigate Heat-as-a-Service

While capital expenditures to install industrial heat pumps can be relatively high, a third-party energy supplier could potentially bear them. Akin to power purchase agreements, Heat-as-a-Service (HaaS) sees a third party fronting some or all of the required capital for new renewable thermal assets, with the industrial company paying for thermal energy supplies on a per-unit basis under a long-term offtake contract. The energy supplier invests in designing, building, operating and maintaining a solution tailored to the needs of the energy buyer. This allows companies to decouple their decarbonization journey from their capital allocation and hence removes a key barrier to heat pump uptake – the large up-front investment costs.

Companies should:

- Work with a cross-functional team to investigate what financing models are most suitable to the company. Whilst existing heat generating equipment is often owned and operated by the industrial company, an as-a-service contract might be more suitable for heat pump solutions which are likely to require new expertise for efficient operation as well as require significant capital investments.
- Identify global and local suppliers who can design a tailored sustainable heat solution, guarantee the performance of this solution over the lifetime of the asset, and bring the required capital needed to invest.
- Consult WBCSD's practical guidance on third-party financed solutions including Power Purchase Agreements and Heat-as-a-Service to understand how to maximize the value add of such solutions and how to best develop these long-term contracts across the company's asset base.

Figure 14: Schematic illustration of Heat-as-a-Service



Provide grid balancing services

The electrification of industrial heating requirements may allow businesses to benefit from providing flexibility services to electricity grids. Power grids need to operate in a perfect balance between supply and demand to prevent power outages and potential equipment damage. Historically, electricity companies have used dispatchable fossil fuel-powered plants to balance variations in electricity consumption, quickly increasing or decreasing generation as necessary. However, as variable and non-dispatchable renewable energy sources, such as solar and wind, provide increasingly more electricity, it will become more difficult to maintain this balance. Hence there is a growing role for grid balancing services provided by non-fossil fuel based but dispatchable supply and by the demand side.

The impacts on industrial companies are two-fold: they may be able to exploit significant reductions in electricity tariffs during periods of low demand. In addition, businesses willing to engage in demand response services with transmission system operators (TSOs) will need to temporarily reduce electricity consumption during periods of peak grid demand but gain from risk-free revenue streams provided by TSOs. Demand response services are typically coordinated through energy services companies or independent aggregators who liaise directly with TSOs.[21]

The flexible operation of heat pumps may allow businesses to take advantage of these opportunities. Many industrial sites have processes that they can schedule during periods of low grid demand without a decrease in overall output. While it is possible to unlock some flexibility across all manufacturing sites, those that manufacture goods in batches are particularly well placed to schedule production in line with low electricity tariffs and/or adjust consumption in line with the requirements of a demand response service. Batched manufacturing is common practice in, for example, food and beverage facilities – such as for different types of cookies or yoghurt in its various flavors.

The ability to combine heat pumps with thermal storage creates additional opportunities to unlock value and reduce overall utility costs as those two combined entirely decouple generation from demand.

Companies should:

- Work with local utilities, grid operators and/or energy consultants to understand power market dynamics across the markets in which they operate.
- Assess whether the production processes, and their associated heat demands, have inherent flexibility and how this could be unlocked.
- Build a business case for industrial heat pumps that takes into account time-of-use electricity tariffs (not average kWh prices) and any potential revenue opportunities coming from ancillary service markets.

CASE STUDY: TENNET – FLEXIBILITY FROM HEAT PUMPS FOR A SUSTAINABLE ELECTRICITY SYSTEM

Context

Dutch electricity transmission system operator TenneT has partnered with a variety of companies, including balancing service providers Sympower, Engie and Kraftwerk, to develop a pilot project that provides small-scale sustainable power generation in Norway that ensures sufficient and flexible capacity to balance future supply and demand.

Activity

The pilot project uses decentralized heat pumps across Norway to yield 0.5 GW to 1 GW of temporary flexibility by 2030.

Key benefits

The key benefits so far include:

- Maximizing carbon emissions savings by using as much electricity as possible when variable renewable sources are available and as little as possible when gas-powered stations are providing the required dispatchable power;
- Significant reductions in energy bills by responding to fluctuating energy prices on the spot, balancing and reserving electricity markets, and by providing additional revenue from selling flexible capacity and ancillary services.

Consider grid connection costs

The application of heat pumps will be best suited to sites where there is significant additional grid capacity. The electrification of industrial heat loads often comes with a sizable increase in power load. Grid connection costs and the associated peak power charges can reduce the cost benefits heat pumps provide. Considering heat pumps in conjunction with energy-efficiency improvements, as well as renewable generation and storage, can reduce grid-related costs.

Companies should:

- Approach their local grid operators to understand the grid's ability to absorb additional power loads, and if/what additional cost might look like to increase their connection capacity.
- Minimize increases in peak power demand, and hence avoid/negate associated costs by considering heat pumps in conjunction with additional on-site renewable generation, energy efficiency saving measures, energy storage solutions or investment in energy management systems that enable management of overall site electrical loads.

Take advantage of refurbishment

It can be time intensive to install heat pumps into the manufacturing process if production lines are complex and designed for specific products - often more so than replacing gas boilers with a like-for-like solution. Therefore, the business case for heat pumps is often most attractive for new facilities or when a heat pump retrofit is part of an extensive facility upgrade program.

Companies should:

- Plan strategically for the integration of heat pumps for new builds or during refurbishments of existing facilities. Operations, procurement and capital project teams should collaborate to avoid or eliminate additional downtime.
- Ensure timing considerations are adequately addressed in conversations with the supply chain or the energy services company that will supply the heat solution.

Create targets and advocate for heat pumps

Incorporating objectives for process heat electrification and the deployment of heat pumps into corporate sustainability strategies will help create demand signals for heat pumps. This has the potential to drive investment, leading to greater technological innovation and cost reductions.

In addition, companies can use their position and influence to increase awareness of heat pump technologies within their business, industry, region and beyond. In some regions and sectors, there is little public awareness of the technology and a lack of skilled technicians. In others, there is concern that heat pumps cannot provide the quality of heat necessary for companies to make the shift.

Companies should:

- Embed the role of heat pumps in their sustainability strategies to send clear signals to internal and external stakeholders.
- Consult libraries of case studies, for example, from the European Heat Pump Association, to help build an internal business case for heat pumps and address doubts and concerns that might exist within the organization.
- Use WBCSD's guidance on Integrated Energy Strategies to develop and implement a credible energy strategy and maintain buy-in across the organization.

4 Conclusion: Seize the opportunity

④ Conclusion: Seize the opportunity

Electrifying heat is a crucial challenge for industry and one that will have a significant impact on the speed of the transition to a net zero economy. Heat pumps present a solution available today to electrify heat at lower temperatures and will be increasingly relevant across many industrial heating applications, particularly in the light industrial sector.

While introducing heat pumps into industrial processes is not always straightforward, the time to act is now. Transitioning manufacturing operations away from fossil fuels will reduce reliance on volatile natural gas and oil costs, limit emerging policy risks and futureproof operations.

To ensure companies can unlock the full potential of industrial heat pumps, they should:

- Seek opportunities to couple heating and cooling applications within or outside an industrial facility and leverage existing waste heat streams;
- Pursue opportunities to make use of variable electricity tariffs and potential revenue generation opportunities by providing grid balancing services;
- Embrace alternative business models and financing mechanisms such as Heat-as-a-Service;
- Seize opportunities to minimize disruptions and capital costs, by installing heat pumps during planned outages, and at sites with no or limited additional grid connection costs;
- Use scenarios for utility and carbon prices to understand the lifetime costs of all options and the policy and market risks associated with fossil fuel-based heat.

At WBCSD, two dozen leading global companies from across the energy value chain are actively working together on low carbon heat in industry – building capacity to overcome barriers and unlocking value using new technical, commercial and financing solutions.

All companies, initiatives and sector stakeholders wrestling with similar challenges are invited to join this work to tackle these challenges together.

If you are interested in contributing to our work, please contact Rutger van der Zanden, Manager, Energy Transformation.

Appendix: Methodology

This paper is based on information from the literature, the DNV Energy Transition Outlook (ETO) and interviews with companies and research institutes active in the heat pump technology field.

Sources used for actual and forecast data

We have mainly based industrial heat demand, carbon, electricity and gas pricing on the DNV ETO model. The ETO presents results based on DNV's independent model of the world's energy system. It covers the period through to 2050 and forecasts the energy mix, supply and demand globally and in 10 world regions. In addition, we have used data from Eurostat and Heat Roadmap Europe. Appendix E in the ETO includes an overview of the data types used and its sources.

Literature sources

The main literature sources used for this paper are:

- Recognized organizations active in heat pump technology, such as the European Heat Pump Association (EHPA);
- Recognized organizations active in energy sector, including the International Energy Agency (IEA), DNV, TNO Netherlands;
- Recognized companies, manufacturers and suppliers involved in heat pump technology, for example, MAN Energy Solutions.

Interviews

We have also garnered information through interviews conducted by DNV with WBCSD member companies, other companies and research institutions active in the heat pump technology domain. We have verified this information with recognized literature sources, as mentioned above, to ensure the reliability of the facts.

Case studies

We have derived the case studies from documents exchanged by the interviewees with DNV and selected those that show the potential of heat pumps in promising applications. Neither DNV nor WBCSD was not able to review the data provided in these case studies.

Endnotes

[1] Bloomberg New Energy Finance (BNEF) and WBCSD (2021). Hot Spots for Renewable Heat: Decarbonizing Low- to Medium-Temperature Industrial Heat Across the G-20. Retrieved from: https://www.wbcsd.org/Programs/Climate-and-Energy/Energy/New-Energy-Solutions/Resources/Hot-Spots-for-Renewable-Heat

[2] Our World in Data (n.d.). "Energy Overview". Retrieved from: https://ourworldindata.org/energy-overview.

[3] Bloomberg New Energy Finance (BNEF) and WBCSD (2021). Hot Spots for Renewable Heat: Decarbonizing Low- to Medium-Temperature Industrial Heat Across the G-20.

[4] Ibid.

[5] International Energy Agency (2021). Net Zero by 2050. A Roadmap for the Global Energy Sector. Retrieved from: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050ARoadmapfortheGlobalEnergySector_CORR.pdf

[6] International Energy Agency (2021). Net Zero by 2050. A Roadmap for the Global Energy Sector.

[7] International Energy Agency (2021). Net Zero by 2050. A Roadmap for the Global Energy Sector

[8] BloombergNEF (2019). Industrial Heat Pump Primer

[9] Fleiter, T., Elsland, R., Rehfeldt, M., Steinbach, J., Reiter, U., Catenazzi, G., et al. (2017). "Heat Roadmap Europe. Profile of heating and cooling demand in 2015 – Data Annex". Retrieved from http://www.heatroadmap.eu/deliverables.php

[10] Ibid.

[11] Ibid.

[12] BloombergNEF (2019). Industrial Heat Pump Primer

[13] According to Annex 35 of the International Energy Agency's Application of Industrial Heat Pumps. Retrieved from https://iea-industry.org/app/uploads/annex-xiii-part-b.pdf.

[14] DNV (2021). Pathway to Net Zero Emissions: Energy Transition Outlook 2021.

[15] Ibid.

[16] Ibid.

[17] Ibid.

[18] IEA, Cumulative capacity and capital cost learning curve for vapour compression applications in the Sustainable Development Scenario, 2019-2070, IEA, Paris https://www.iea.org/data-and-statistics/charts/cumulative-capacity-and-capital-cost-learning-curve-for-vapour-compression-applications-in-the-sustainable-development-scenario-2019-2070

[19] European Partnership for Energy and the Environment (EPEE) (2022). "EU can be more ambitious in rolling out heat pumps to reduce dependency on Russian gas". Retrieved from: https://epeeglobal.org/wp-content/uploads/2022/03/EPEE-Statement-on-REPoweEU-Heat-Pump-Roll-out-acceleration.pdf.

[20] European FluoroCarbons Technical Committee. "Regulations Affecting HFCs". Retrieved from https:/www.flurocarbons.org/regulations/regulations-affecting-hfcs/.

[21] Sympower (2022). "The differences in demand response – balancing services explained". Retrieved from https://sympower.net/the-differences-in-demand-response-balancing-services-explained/.

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ABOUT WBCSD

WBCSD is the premier global, CEO-led community of over 200 of the world's leading sustainable businesses working collectively to accelerate the system transformations needed for a net zero, nature positive, and more equitable future.

We do this by engaging executives and sustainability leaders from business and elsewhere to share practical insights on the obstacles and opportunities we currently face in tackling the integrated climate, nature and inequality sustainability challenge; by co-developing "how-to" CEO-guides from these insights; by providing science-based target guidance including standards and protocols; and by developing tools and platforms to help leading businesses in sustainability drive integrated actions to tackle climate, nature and inequality challenges across sectors and geographical regions.

Our member companies come from all business sectors and all major economies, representing a combined revenue of more than USD $8.5 trillion and 19 million employees. Our global network of almost 70 national business councils gives our members unparalleled reach across the globe. Since 1995, WBCSD has been uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues.

Together, we are the leading voice of business for sustainability, united by our vision of a world in which 9+ billion people are living well, within planetary boundaries, by mid-century.

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