Strengthening Industrial Heat Pump Innovation

Decarbonizing Industrial Heat

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Strengthening Industrial Heat Pump Innovation
Decarbonizing Industrial Heat

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MANAGEMENT SUMMARY

Industrial processes are currently responsible for 20 % of total greenhouse gas emissions in Europe. In order to stay within the 1.5°C scenario of the Paris Climate Agreement, measures to reduce these greenhouse gas emissions from industry are urgently needed. This paper highlights the role heat pump technologies can fulfil in realizing significant reductions in CO_2 emissions arising from industrial process heating. Industrial heat pumps are a highly energy efficient, cross-cutting technology to provide process heat. Driven by electric power, heat pumps are a key electrification technology which are able to replace a large share of fossil fuelled industrial process heating. The research institutes involved in RD&D of heat pump solutions propose a European industrial heat pump program, designed to accelerate the implementation and further development of this low carbon technology. Unlocking the benefits of heat pump technology requires a set of coherent measures. This includes creating a regulatory framework that facilitates the acceptance of industrial heat pumps, setting up a European information and knowledge base on heat pump technologies and process integration as well as the establishment of an RD&D program that supports the strengthening and growth of industrial heat pump applications.

“Limiting the global mean temperature rise to below 2°C with a probability of 68 % would require an energy transition of exceptional scope, depth and speed”

International Energy Agency
Perspectives for the energy transition

1. INTRODUCTION

The consumption of fossil fuels and the associated emission of greenhouse gases (GHG) are widely attributed to being the dominant cause of observed global warming. To limit the global warming within 1.5°C, the transition to a sustainable energy system is needed.

For Europe to achieve its ambition of net-zero GHG emissions by 2050, radical changes to the current energy supply in the industrial sectors are necessary. A focus on the industry is needed as it is currently responsible for 25 % of final energy consumption (FEC)[1] and 20 % of the GHG emissions[2] (not including indirect emissions attributed to external energy supply) in EU-28 countries. The majority (66 %) of industrial energy use is for process heating purposes[1,3], meaning that the sustainable supply and efficient use of heat should be at the forefront of any decarbonization strategy for industry.

Industrial heat pumps can play an important role in improving the energy efficiency of industrial processes, while simultaneously driving a switch from fossil fuels to renewable electricity as an energy source. This paper proposes industrial heat pumps as a technology for decarbonization of the low temperature (<200°C) heat supply within industry. Considering the process heat in this temperature range as the main market for industrial heat pumps, there are two distinct segments, depending on the temperature level:

- Applications up to 100°C which can be covered by mature heat pump technologies
- Applications in the range of 100°C to 200°C for which heat pump suppliers and technical developments are required to meet the market needs

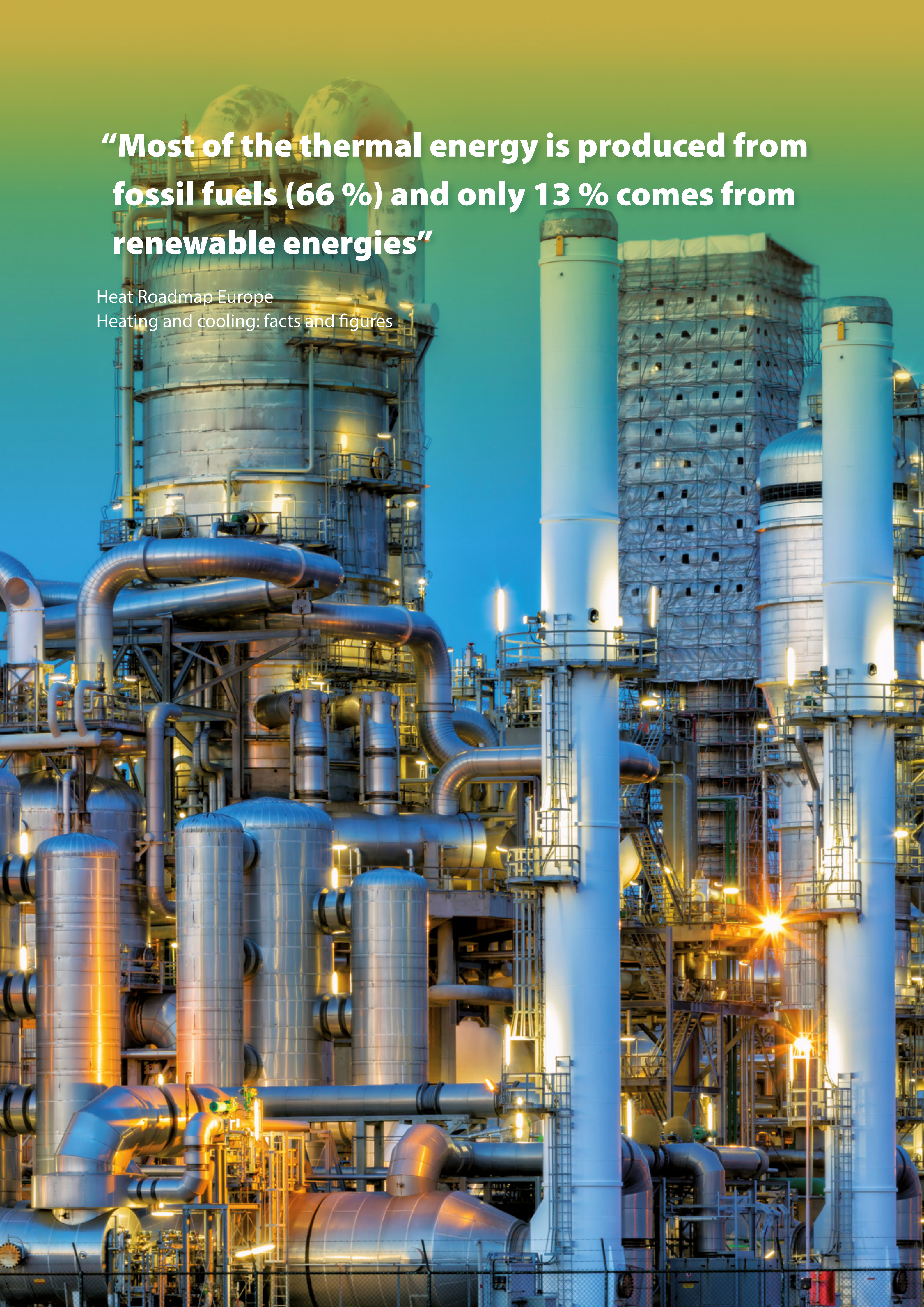
The implementation of industrial heat pumps aligns closely with the strategic priority of EU-2050 to build a competitive EU industry and circular economy as key enabler to reach carbon neutrality[4]. Furthermore, it will support the EU's 2030 targets to increase energy efficiency by 32 % and reduce emissions by 40 %, while fostering industrial competitiveness, and creating opportunities for growth and jobs[5].

This whitepaper describes the current heating demands of industrial processes and quantifies its current contribution to EU's overall CO_2 emissions. It explains the working principle of heat pumps and gives an illustration of the integration of heat pump technology in industrial heating processes, demonstrating how heat can be generated in a circular and sustainable manner. The energy saving and CO_2 emission reduction potential of industrial heat pumps is estimated based on the current and near future available industrial heat pump technologies. Starting from the current status of industrial heat pump technology and implementation, the required steps to unlock this vast emission reduction potential are described.

The paper concludes with recommended actions that will strengthen the technical and economic position of industrial heat pumps, accelerate its implementation, and contribute to the targeted CO_2 emission reduction potential.

“Most of the thermal energy is produced from fossil fuels (66 %) and only 13 % comes from renewable energies”

Heat Roadmap Europe
Heating and cooling: facts and figures



2. INDUSTRIAL HEAT

The industrial sector is responsible for the production of numerous intermediates and end use products, with large scale input of raw materials and energy. Despite a reduction in the energy consumption per unit added value (i.e. energy intensity) in the last decades, total industrial energy use has increased due to disparately higher production output.

Figure 1 presents an overview of the industrial energy demand in the EU by broad application. The bulk of the energy consumption is driven by the demand for thermal energy, responsible for 2390 TWh/a[3] or 81 %[1,3] of the total energy demand. The thermal energy use can broadly be divided into four end-use categories: process heating, process cooling, space heating and space cooling. The demand for process heating is dominant, accounting for 66 % of the total final energy demand. Figure 1 also presents an overview of this industrial process heat demand by temperature level. This paper makes a distinction between low temperature (<200°C) and high temperature (>200°C) process heat responsible for 37 % and 63 % of the total process heating requirements respectively.

The fuel source that is used to fulfill the process heating demand is also depicted in Figure 1. The choice of fuel or heating technology used for a given process depends on a number of factors, such as the structure of a specific industrial sub-sector or in which country the process is located. The current industrial process heat demand is primarily (78 %) covered by fossil fuel sources. Gas is the largest fuel source (36 %), with still large shares of coal (20 %) and oil (8 %) being used. The CO_2 emissions resulting from the use of these fossil fuels for process heating by industry is estimated to be 552 Mt/a,[3,6] comparable to car emissions within EU-28 (550 Mt/a)[7]. Relatively small shares are covered by more sustainable sources such as biomass (11 %) or electricity (3 %).

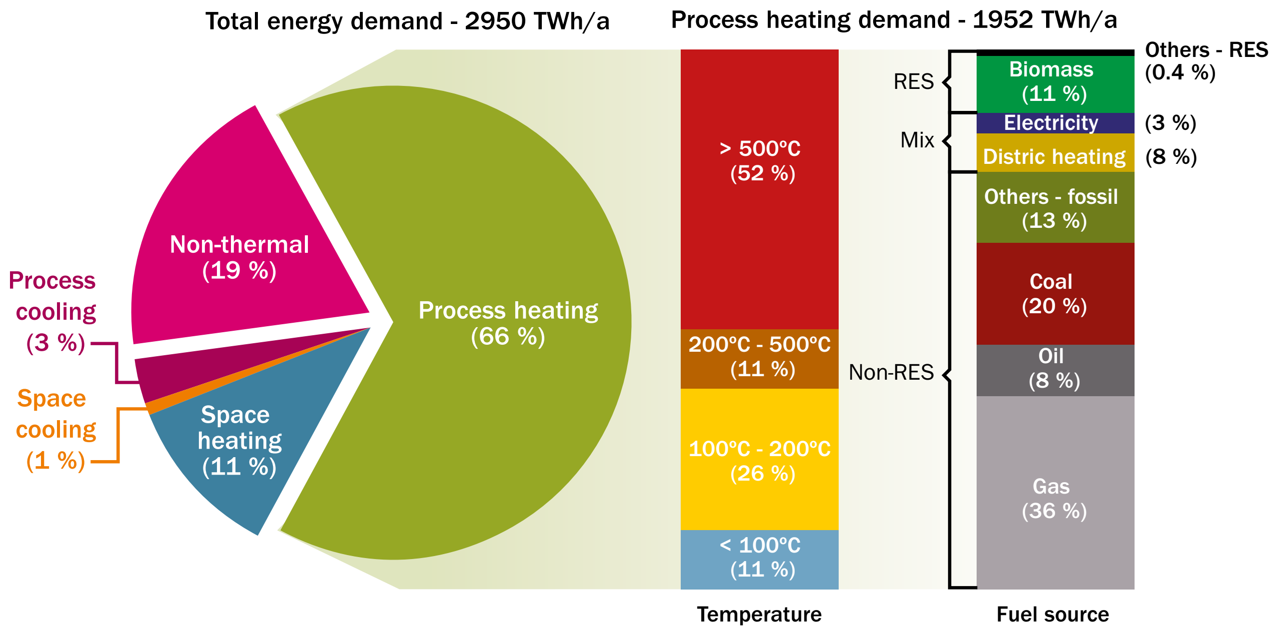


Figure 1: *Breakdown of the final energy demand in European industry by broad application (left) and process heating demand by temperature level (centre) and energy source (right) (RES = renewable energy sources)*
Data source: [1,3]

"Medium temperature heat-pumps (functioning well above 100°C), would present a viable alternative for must-run medium temperature boilers and will lower overall energy demand from industry as these are expected to be – just like the low temperature heat-pumps – more efficient than electric, hybrid or dual-system boilers"

McKinsey & Company
Energy transition: Mission (im)possible for industry?

3. ADDED-VALUE AND APPLICATION OF INDUSTRIAL HEAT PUMPS

Wide spread application of industrial heat pump technology promises to provide added value to the European community on numerous fronts. Specifically, unlocking the potential of this technology will achieve the following main outcomes:

- Transition multiple industrial sectors to a sustainable heat supply
- Provide large reductions in primary and final energy consumption as well as CO_2 emissions
- Offer a lower cost process heating alternative to end-users when compared with competing or existing technologies
- Drive technical innovations, stimulating the creation of numerous jobs and contributing significantly to growth of the European economy

The rest of this section is dedicated to outlining the manner in which application of industrial heat pumps facilitates these outcomes. Additionally, limited examples of industrial heat pump applications are provided to demonstrate the added value which the technology already provides.

Heat pumps for process heating

Industrial heat pumps are a technology which can upgrade the temperature of a waste heat source such that it can be re-used within a process, with the input of electric power. They are a cross-cutting technology option which can be implemented in both new and existing process operations. A simplified comparative energy flow diagram can be seen in Figure 2 for two industrial processes, one which uses a fossil fuel source and another which uses a heat pump for the process heating requirements.

The process driven by fossil fuels requires 110 % of the heat required by the process, as approximately 10 % of the heat is lost after combustion to the ambient in flue gases. After the heat is used in the process, the temperature is too low to be reused and therefore, the entirety of the process heat (100 %) is released into the ambient.

For the process using a heat pump, the heat discarded to ambient is reduced to 25 % of the process heat demand. With 75 % of the total waste heat reused by upgrading the temperature level through the use of the heat pump, the process heat delivered (100 %) exceeds the electricity input (25 %) by a factor of 4.

This value, i.e. the ratio of the heat delivered, to the electricity input, is known as the coefficient of performance (COP) and is an important parameter characterizing the efficiency of the heat pump. This value will usually be in the range of 2 to 5, depending on the waste heat and process heat temperatures. Therefore, rather than simple use and disposal of energy in the original process, implementing a heat pump achieves a large degree of energy circularity, increasing the overall efficiency of the process.

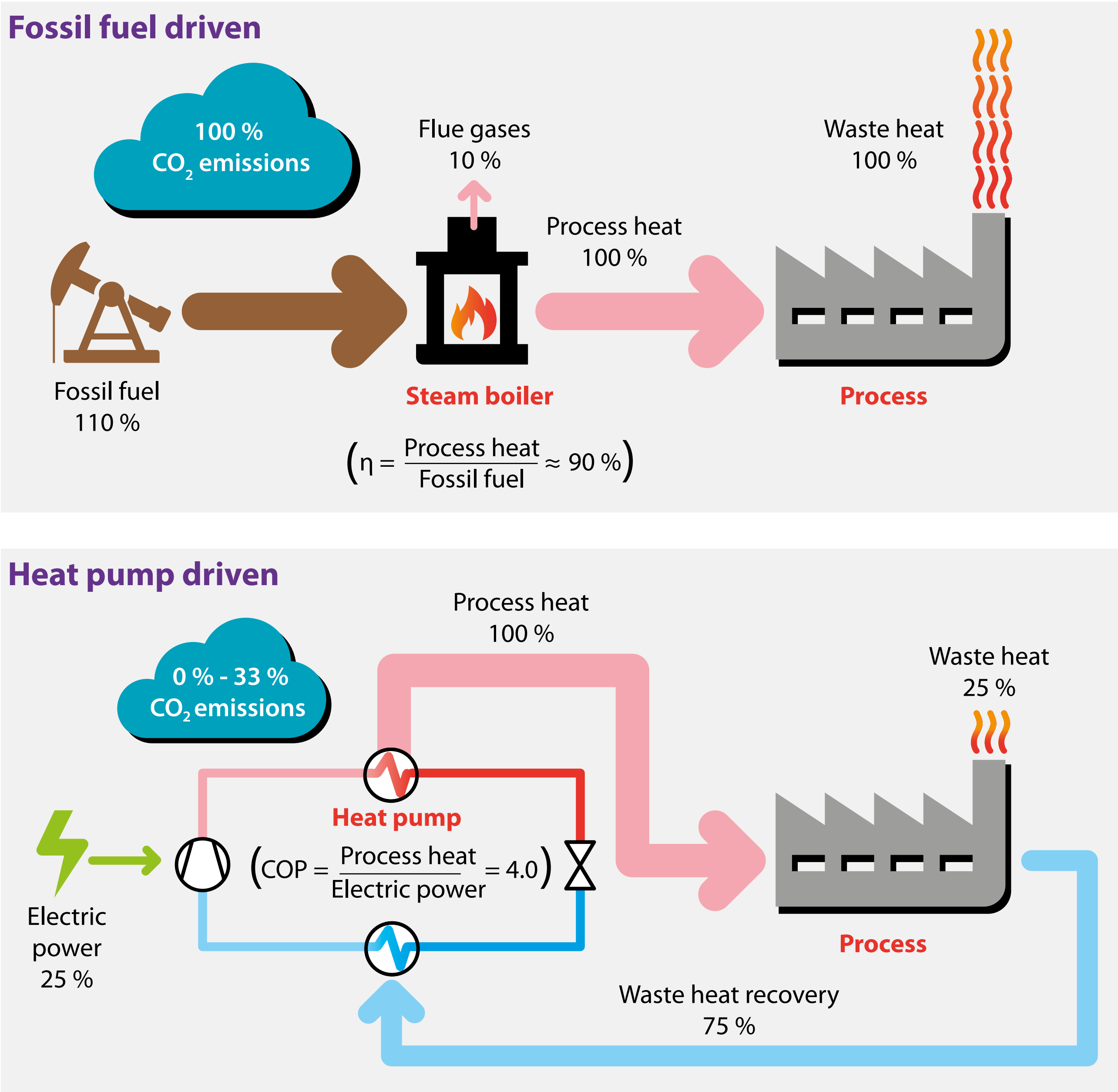


Figure 2: *Comparison of fossil fuel driven and heat pump driven industrial process schemes.*

With 100 % share of renewables in the future electricity mix, heat pumps become a technology with zero CO_2 footprint. Regardless of this, with the current electricity mix and due to the high efficiencies (COPs) in which heat pumps operate, implementing this technology will directly lead to a reduction in both final and primary energy consumption and CO_2 emissions. This is illustrated in Figure 2. With the implementation of a heat pump, emissions are reduced to 33 % (67 % reduction) of those of the process driven by fossil fuels, based on the current European average CO_2 emission intensity for electricity production[8]. In the case the electricity system is fully decarbonized, the emissions for the heat pump driven process reduce to zero (100 % reduction). It is clear, that with increasing shares of renewables in the electricity mix, implementation of heat pumps becomes a robust, no-regret option for industry.

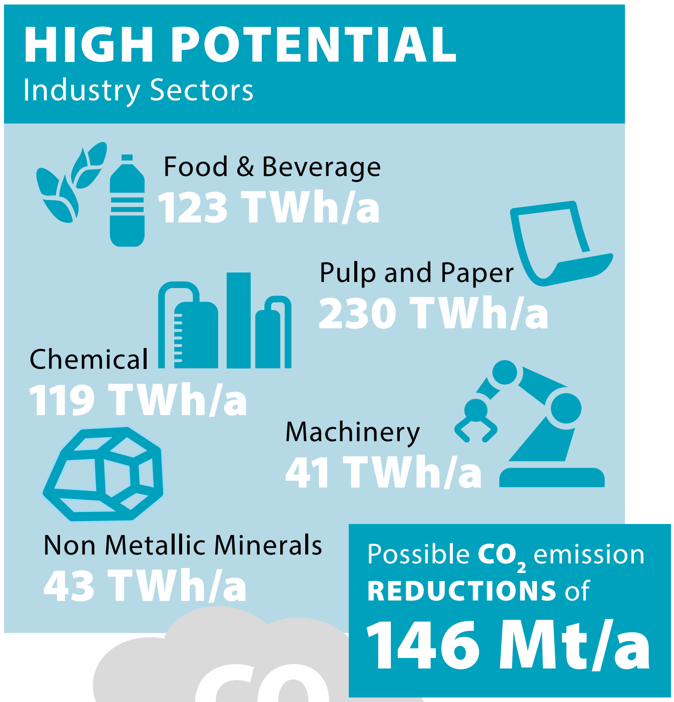
Application potential

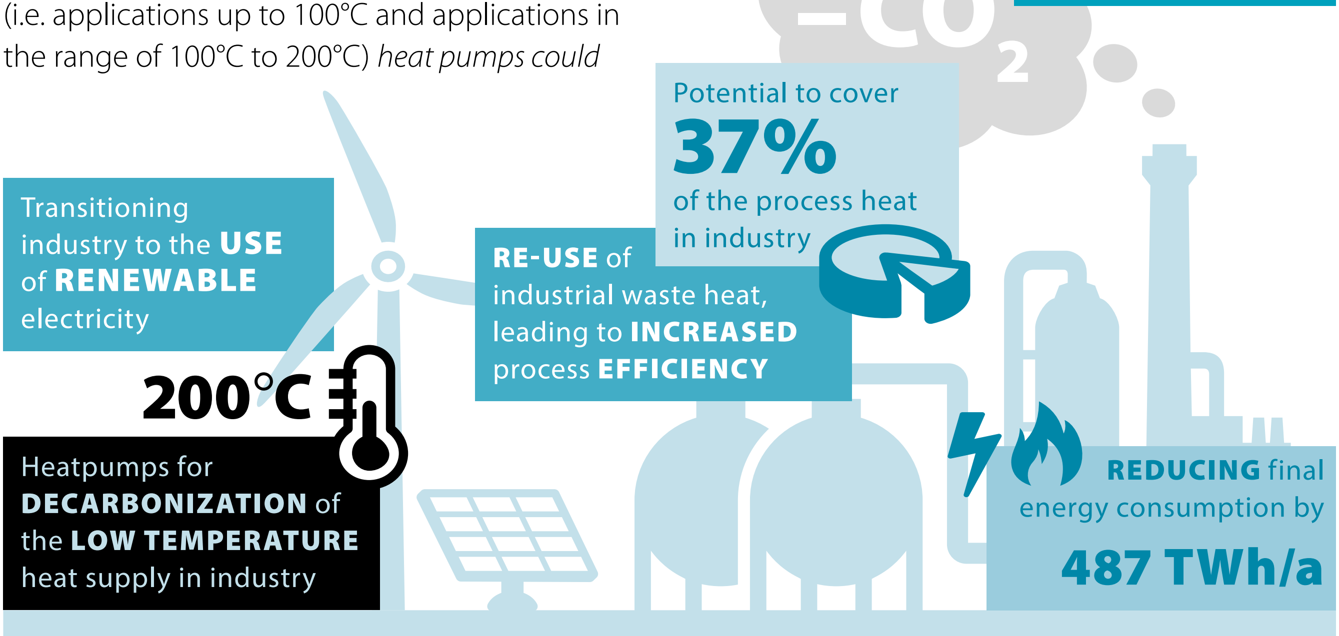
Developments in the last decades have enabled heat pumps to provide process heat up to 100°C with proven technical concepts and components. Despite the availability and potential of the technology, it is currently not utilized extensively by the industry. Even for new capacity and applications at these low temperatures, fossil fuel fired process heating equipment is the standard. Regardless of the lack of uptake of the technology, heat pumps for temperatures up to 100°C have the potential to cover 222 TWh/a or 11 % of the process heating demand in European industry. This could lead to CO_2 emission reductions in the order of 51 Mt/a.[3,6]

At present, there are a limited number of suppliers able to provide systems for temperatures higher than 100°C. In general, these systems are not considered to be mature technology. In the case that heat pumps also become a mature technology for the supply of heat in the temperature range of 100°C to 200°C, an additional 508 TWh/a or 26 % of the total process heat demand can potentially be emission free, with potential additional CO_2 reductions in the order of 95 Mt/a.[3,6]

Combining the two market segments, (i.e. applications up to 100°C and applications in the range of 100°C to 200°C) *heat pumps could deliver 730 TWh/a or 37 % of the process heat in industry*, with a corresponding CO_2 emission reduction potential in the order of 146 Mt/a.

Being a cross-cutting technology, heat pumps will be applicable to multiple industrial sub-sectors. Assuming that heat pumps can reach temperatures of 200°C, they will have high potential for the pulp and paper (230 TWh/a) food and beverage (123 TWh/a), chemical (119 TWh/a), non-metallic minerals (43 TWh/a) and machinery (41 TWh/a) sectors.[3,9]





Heat pumps in the food sector

The first heat pump applications are being applied in the food and beverage sector, which traditionally has the most experience with this technology as refrigeration equipment. The need for simultaneous heating and cooling in the food industry is itself a driver for first heat pump applications. Cooling of products will produce waste heat at temperatures above ambient, which can be upgraded using a heat pump to satisfy the process heating requirements. Coupling process heating and cooling needs through the use of a heat pump will result in high process efficiencies and low operational costs. As such, this solution is gaining traction in the market. It is expected that the experience gained from the use of heat pumps in this way can be transferred to utilise a multitude of waste heat streams in both the food sector as well as in other industrial sectors.

How does a heat pump work?

Technically, heat pumps are a piece of process heating equipment which can upgrade the temperature of a waste heat source such that it can be reused in the process with the input of electrical energy. Whilst there are numerous technical and thermodynamic possibilities for realizing heat pumps, the market is dominated by vapor compression cycles, the same technology as used almost exclusively for (household, domestic, industrial) cooling and refrigeration applications.

Figure 3 shows a simplified technical process layout of a vapor compression heat pump. The arrows which are overlaid by the heat pump components, depict the flow of energy to, from and through the system. In order to transfer the energy from a waste heat source to produce process heat, a working fluid or refrigerant is present within the system, which undergoes various processes and state changes as it is circulated through the various components. In the lowest temperature (and pressure) part of the system, the evaporator, waste heat is transferred to the refrigerant, transforming it from primarily a liquid state to a vapor. This vapor is then compressed to a high pressure and temperature using the compressor, which requires mechanical work and therefore an electrical input. The high temperature (and pressure) vapor releases heat to be used within the process in the condenser, in-turn transforming the refrigerant to a liquid. The high pressure liquid refrigerant is reduced to a low pressure (and temperature) using an expansion device, where it enters the evaporator, and the process repeats once more.

As seen by the energy flow depiction, the process heat generated by the heat pump is the sum of the electrical input and the heat input from the waste heat source. An important characteristic of heat pump systems is that the process heat output is usually a factor of 2 to 5 times larger than the electrical energy input. The ratio of the heat output to the electrical energy input, known as the coefficient of performance (COP), is an important metric which indicates the efficiency of a given heat pump. Whilst the COP is dependent on numerous factors, it can be concluded that it typically will reduce as the temperature difference between the available waste heat and the required process heat increases.

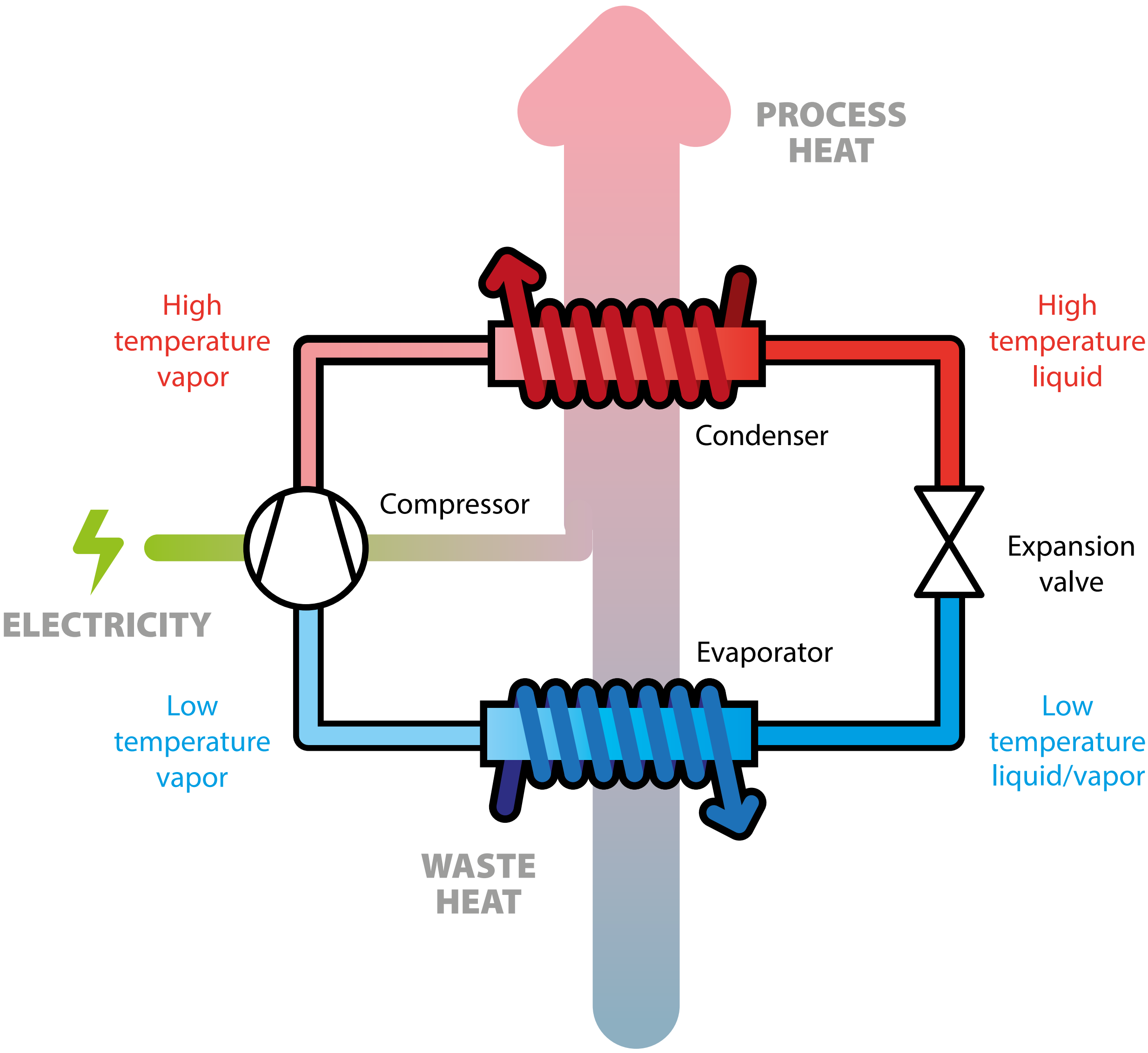


Figure 3: *Technical process layout of a vapor compression heat pump with the energy flow depicted*

Business case for industrial heat pumps

The decision to invest in a heat pump is generally determined by assessing the trade-off between the capital expenditure (investment) needed to purchase and install the heat pump versus the reduced operational (energy) costs resulting from the heat pump investment. The simple payback period is commonly used to assess this trade-off. Payback periods demanded by industry are typically in the range of 1 to 2 years, although this can be extended to the range of 2 to 5 years under certain circumstances.

The capital costs of a heat pump include the cost of the heat pump itself, the associated ancillary equipment costs, and costs associated with installation and integration, including labour. There is no general rule of thumb for the capital cost or specific investment cost (cost per unit heat output) of a heat pump. The cost of the heat pump itself depends on numerous factors, most notably the heating capacity, temperature levels, and the process and waste heat mediums. Integration costs are also highly variable depending on, for example, the complexity and required modifications to the process. This is especially the case for existing processes. Despite the multitude of different factors, the specific investment cost generally decreases with increasing system size.

Ultimately, the business case for an industrial heat pump will be dependent on the achievable operational cost savings. The achievable COP of the heat pump will be an important parameter in determining the operational cost savings from installing a heat pump. A higher COP results in a lower electricity consumption for a given heat pump application. The cost of this electricity for operation of the heat pump should be compared to the alternative energy source which the heat pump would replace. This is not always trivial, as the cost of various energy sources is highly variable on a site, regional, country or even temporal basis.

In general, heat pumps will be an attractive option in scenarios where the electricity price is low relative to the cost of the alternative energy source (e.g. natural gas). To illustrate the variation in energy prices on a country basis, Figure 4 shows the ratio of electricity to gas prices in numerous countries for small scale industrial end-users. Whilst these numbers are reasonably indicative for each country, the final ratio for each end-user will depend on the total energy use, as well as the relative amounts of gas and electricity required. The figure shows that the price ratio varies significantly on a country basis, from less than 2 in the case of Norway, Finland and Sweden to over 4 in the case of Belgium, the UK, Italy and Germany. This variation in electricity and gas prices can be a significant barrier to industrial heat pump uptake in some countries. For instance, applications which have a payback period of 1 year in Norway, may have a payback period which exceeds 10 years in Germany under the current conditions.

Considering the future business case for industrial heat pumps, with the current EU climate targets, it may be expected that natural gas will be subject to increasing costs resulting from the associated taxes on CO_2 emissions. Possible process heating utilities which are able to fulfil the requirements of EU-2050 targets include electrical heaters, biomass-based boilers, heat pumps, electro-fuels (such as green hydrogen) or natural gas in combination with carbon capture. Comparing these alternatives, it has been shown that high temperature heat pumps, with COPs as low as 2, are competitive in levelized cost of heat with biomass boilers and natural-gas based boilers under consideration of a CO_2 tax of 50 €/tonne[11].

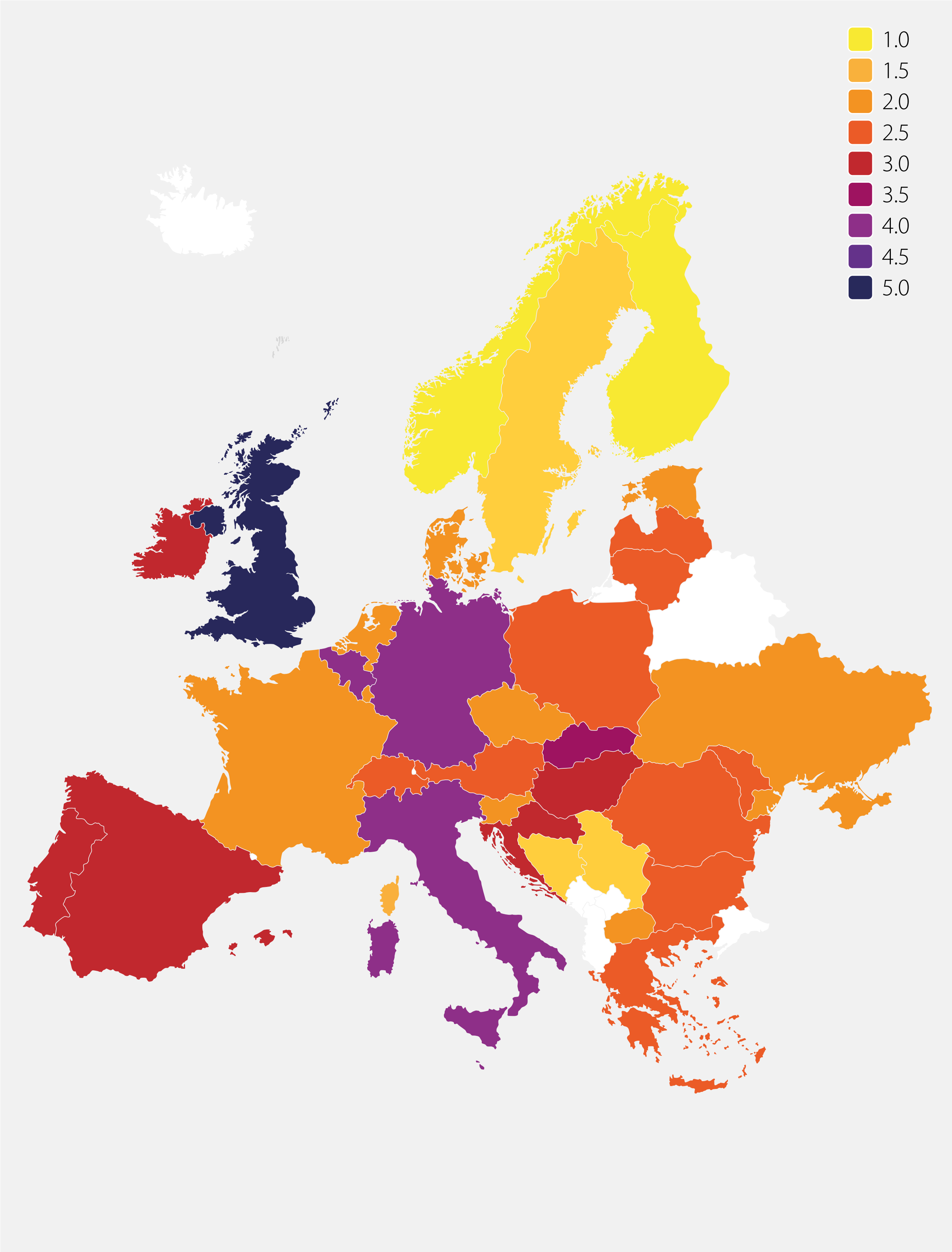


Figure 4: *Comparison of current electricity to gas price ratio in European countries for small scale industrial end-users (2 GWh/a to 20 GWh/a electricity, 3 GWh/a to 28 GWh/a gas)*
Data source: [10]

Industrial heat pump value chain

The European heat pump sector employs a well-trained workforce in R&D, component and heat pump manufacturing, installers, and service and maintenance. A recent European Heat Pump Association report described the industry as an economic force and provider of local labor[12]. The expansion of the sector to establish products and solutions for industrial applications will further drive innovations, stimulating the creation of numerous jobs and contributing significantly to the European economy. Under the assumption that an industrial heat pump market can be established within Europe with a market rollout of 5 % total potential per year (37 TWh/a), total turnover for the entire value chain is estimated to be in order of €2.3 billion/a, leading to the creation of 14,500 new jobs. Technology export will facilitate the creation of further revenue and jobs.

In a time of economic recovery post coronavirus, stimulating the creation and rollout of the industrial heat pump market will promote a secure and stable economy. This action will align economic recovery with EU's climate and sustainability goals and prevent further lock-in scenarios for fossil based technologies.

Integration of heat pumps in industrial processes

An electrically driven heat pump is process equipment, which is configured with compressors, heat exchangers, valves, vessels and piping. The modular nature ensures that the technology is flexible and it may be developed and installed for a broad range of applications, capacities and temperature levels. This, however, also indicates that there are several potential solutions for a given application, and that the right choice will depend on performance, efficiency, investment, technology readiness level, and regulations.

Compared to conventional steam-based systems heated by fuel combustion in a boiler, heat pump technology offers highly different options, ranging from intrinsic integration into a given process, integration at the process unit level, or as replacement for a central heating system.

Intrinsic integration into a process can require little additional process equipment and at the same time achieve the highest COP, as high as 20 units heating per unit electricity consumed. However, at the same time it may lead to significant changes to the process and conditions, the feasibility of which may need to be assessed.

By installing a dedicated heat pump at the process unit, it is possible to operate at lowest possible temperature lifts and reach a high COP for a range of processes. The COP is highly dependent on the actual temperature levels of the heat source and sink, and may reach up to 8, when the temperature lift is 20°C.

A central heat pump solution substituting an existing heating installation will require fewer changes in the process. This solution will have a lower COP because the generation of steam for the central utility system requires a higher temperature that is sufficient for all processes. This solution is likely to be implemented in the first instance when considering retrofitting heat pumps to existing processes.

Examples of existing industrial heat pump applications

Whilst not currently being the reference heating technology, numerous instances of heat pumps in an industrial setting exist.

We have included the following examples of existing industrial heat pump applications to showcase their positive impacts on energy savings and CO_2 emission reductions.

Hutten slaughterhouse

A prime example of process electrification through the use of heat pumps is seen in the Hutten slaughterhouse in the Netherlands (see Figure 5). Low temperature process heat is delivered by a heat pump which utilizes and upgrades the temperature of heat rejected from the refrigeration plant of the facility. The remaining high temperature heat demand is produced from an electric boiler. The combination of the technologies, has eliminated the use of all fossil fuels for the site.[13]

Figure 5: *Heat pump installation at Hutten slaughterhouse*

Mohrenbrauerei brewery

A similar solution is in operation at the Austrian brewery Mohrenbrauerei which has installed a 370 kW heat pump including a heat storage unit. The heat pump saves the burning of 1.8 GWh/a of fossil fuels and had a payback period of less than 6 years.[14]

Arla Videbæk dairy

A Danish dairy, Arla Videbæk, has installed a heat pump for preheating in a spray drying unit (see Figure 6). The heat pump has a COP of 4.5. It has been shown to save 4.6 GWh of fossil fuels and more than 1,400 tonnes of CO_2 emissions per year. The payback period was 1.5 years including subsidies, while it would have been 2.3 years without.[15,16]

Figure 6: *Heat pump installation at Arla Videbæk dairy*

Marienhütte steel and rolling mill

At the Austrian steel and rolling mill Marienhütte in Graz, two large heat pumps were installed (see Figure 7), that are able to supply heat at a temperature up to 95°C with a heating capacity of 6 MW to 11 MW. They use waste heat from the steel and rolling mill at a temperature of about 30°C to 35°C as heat source that would otherwise be dissipated to the environment. Through the installation of the heat pumps, the burning of 46 GWh of fossil fuels can be avoided, resulting in annual reductions in CO_2 emissions of 11,700 tonnes.[17,18]

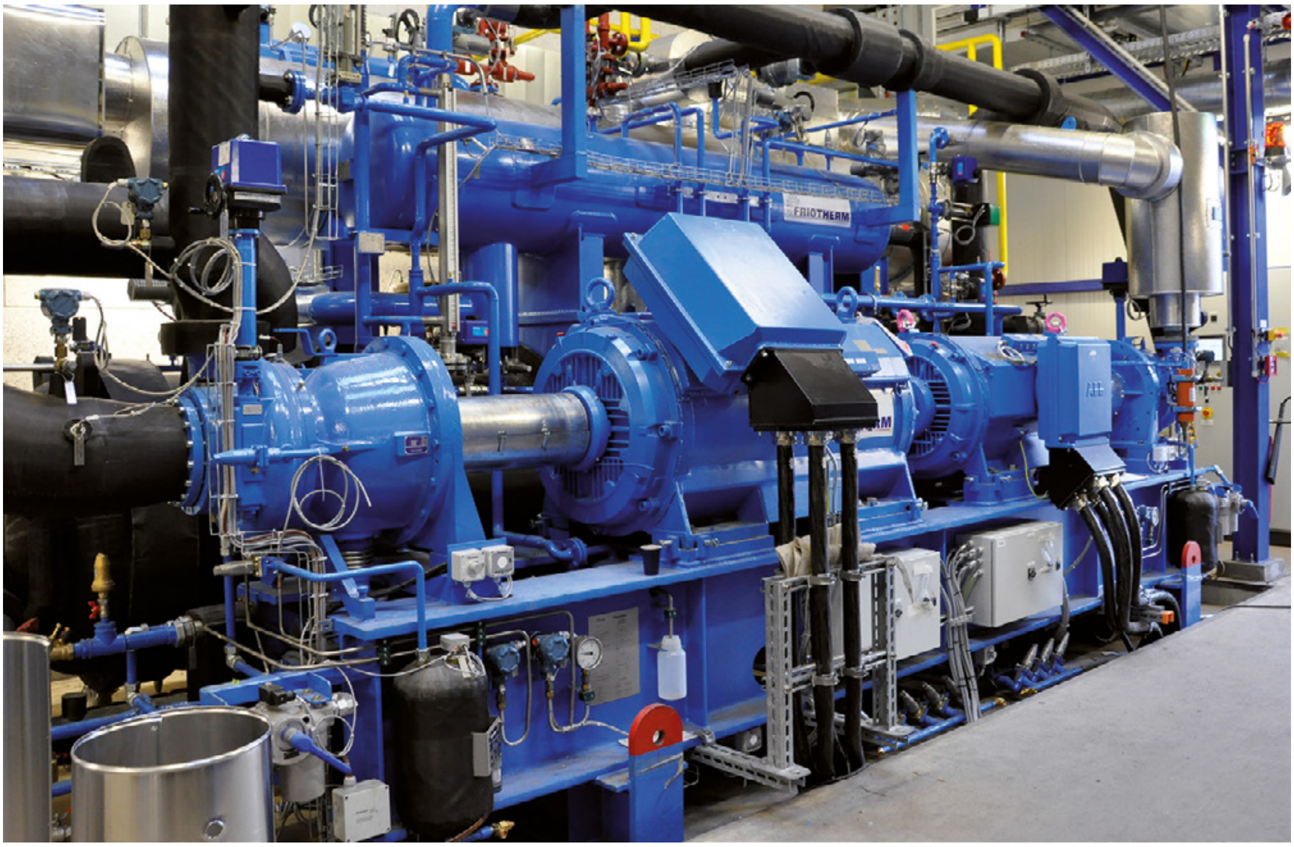


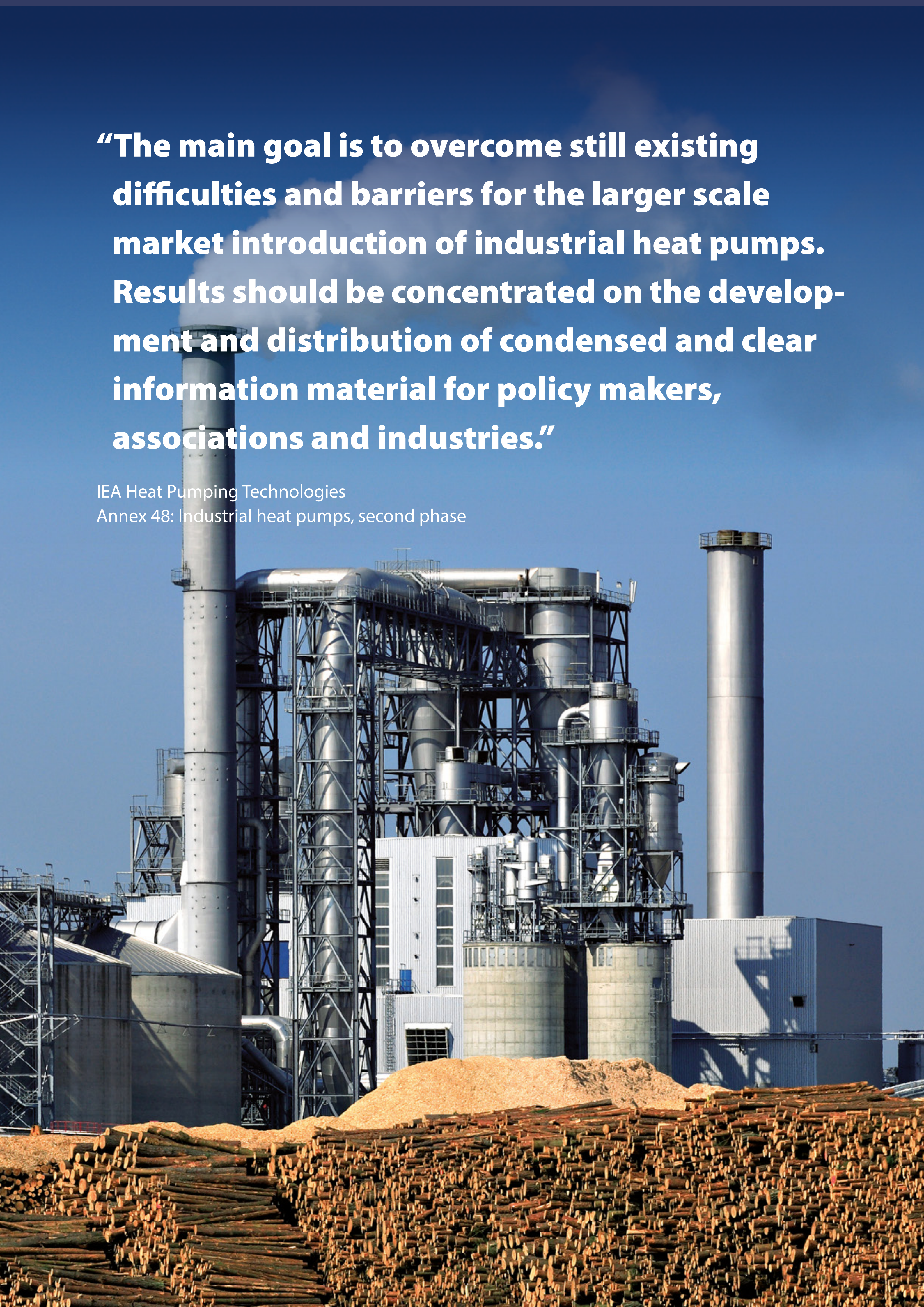
Figure 7: *Heat pump installed at the Marienhütte steel and rolling mill Source:* [17]

Tine dairy

The Norwegian dairy producer Tine has integrated a heat pump for combined heating and cooling for all processes in their factory. The plant does not use any fossil based heating, thereby reducing the greenhouse gas emissions to zero. The energy consumption is reduced by 40 % or 5 GWh per year. The heat pump has a heating capacity of 940 kW with a heating COP of 5. The system won the "Heat Pump City of the Year Award 2019" in the category "Decarb-industry".[19]

Appenzell – Industrial symbiosis

Heat pumps also accommodate industrial symbiosis. In Appenzell, Switzerland, the excess heat from a data centre is used as heat source for a high-temperature heat pump used in a neighbouring cheese factory to produce process heat (>90°C), hot water and heat for buildings. This saves the mountain cheese factory around 1.5 GWh of natural gas per year.[20]



"The main goal is to overcome still existing difficulties and barriers for the larger scale market introduction of industrial heat pumps. Results should be concentrated on the development and distribution of condensed and clear information material for policy makers, associations and industries."

IEA Heat Pumping Technologies
Annex 48: Industrial heat pumps, second phase

4. BARRIERS TO INDUSTRIAL HEAT PUMP APPLICATION

Existing Barriers

IEA HPP-IETS Annex 35/13 "Application of industrial Heat Pumps"[14,21], which concluded in 2014, was initiated to actively contribute to the reduction of energy consumption and GHG emissions through the increased implementation of heat pumps in industry. The Annex's final report indicated that despite the benefits and availability of industrial heat pump technology, implementation is limited for a number of reasons. As presented in 2014, these barriers are still valid today, the main ones being:

- The integration of heat pumps in industry requires knowledge of both the capabilities of heat pumps as well as the underlying process in which they can be applied. Currently, there are limited installers and decision makers which possess this *combined knowledge*.
- Many end-users have a *lack of awareness of their heating requirements* or consumption, meaning identifying heat pump integration opportunities is laborious or largely time consuming.
- In some cases, the technology is available, but *high payback periods* lead end-users to conclude that no feasible business case exists for installation of a heat pump. The high payback periods can be attributed to high initial capital costs, or to an unfavourable price of electricity relative to the alternative fossil source.
- In many cases, the *technology* for a specific application is *not available*. For instance, the process temperature level is higher than what can be delivered by commercially available heat pump technology.

Additional barriers to those presented above include :

- There is a *limited number of manufacturers* of heat pump equipment, particularly for higher temperature applications. In most cases, this can be attributed to manufacturers having limited understanding of the market and application potential. In other cases, it can be attributed to manufacturers viewing development of products for the (high temperature) industrial market as a high-risk project with a long payback time, even if they are established in the market for lower temperatures.
- End-users are subjected to uncertainties in the boundary conditions (gas, electricity, CO_2 price) which determine the business case for a heat pump. This *uncertainty hinders the decision making* process when implementing a new technology.
- There have been *limited cases to demonstrate and prove the reliability* of novel heat pump technology in an industrial environment. A limited amount of demonstrations over short time periods is not sufficient to introduce a new technology to the market.

Current situation of RD&D on industrial heat pumps

This whitepaper has shown that there is a large application potential for industrial heat pumps, but also a variety of processes and boundary conditions into which the heat pumps must be integrated. To achieve optimal performances (e.g. technical, economic, environmental) across a broad range of applications in industrial processes requires the development of a range of technologies to cover the market potential.

Furthermore, there is a market segment, namely for the temperature range of 100°C to 200°C for which products and technical solutions still have to be developed and demonstrated. For these reasons, the research institutes involved in the preparation of this whitepaper are striving to advance heat pump technology for industrial applications in national and international RD&D projects.

Currently, the development of heat pumps for the process industry is driven by scattered national initiatives which are very much targeted towards local industry sectors.
The main motivation for these development projects is typically focused towards operational cost saving potential, which results from the energy savings. On a European level, the low priority of industrial heat pumps on the research agenda means that only a limited number of projects (FP7, Horizon2020) containing heat pump developments have been undertaken in recent years.

Below, a list of RD&D projects within Europe is given, which demonstrates that it is possible to unlock the potential of industrial heat pumps with the right initiatives and entrepreneurial spirit:

Nationally funded projects

1. SkaleUp (SINTEF): Heat pump solution for combined process cooling (0°C to 4°C) and process heating (90°C to 110°C) with a combined COP of 2.8, resulting in the reduction of CO_2 emissions to near-zero.
2. LowCapex and FUSE (TNO): Demonstration of heat pump technology on an industrial scale (2 MW), producing process steam at temperatures between 120°C to 150°C from waste heat at 60°C to 90°C with efficiencies above 50 % of the theoretical maximum. The heat pumps developed within these projects have the potential to reduce emissions between 20 % to 35 % compared to the reference scenario. (Figure 8)
3. Efficiency in Industrial Processes (SCCER: Swiss Competence Center for Energy Research): The goal is to create energy efficient technologies and components which can be applied in many different processes such as steam and heat generation and applied to numerous industries, allowing for energy savings between 20 % to 50 % with respect to common technologies. www.sccer-eip.ch
4. SuPrHeat (DTI/DTU) – Development and demonstration of three pilot scale (500 kW) high temperature heat pump technologies based on natural refrigerants, for supplying process heat up to 200°C. The project also develops methods for heat pump integration in existing plants and new process equipment for dairies, slaughterhouses, breweries and other industry sectors.
5. SteamHP – Steam-based heat pump systems (DTI): Development, demonstration and long-term testing of a highly efficient evaporator using a turbo-compressor, which is based on an automobile turbo-charger.

European funded projects

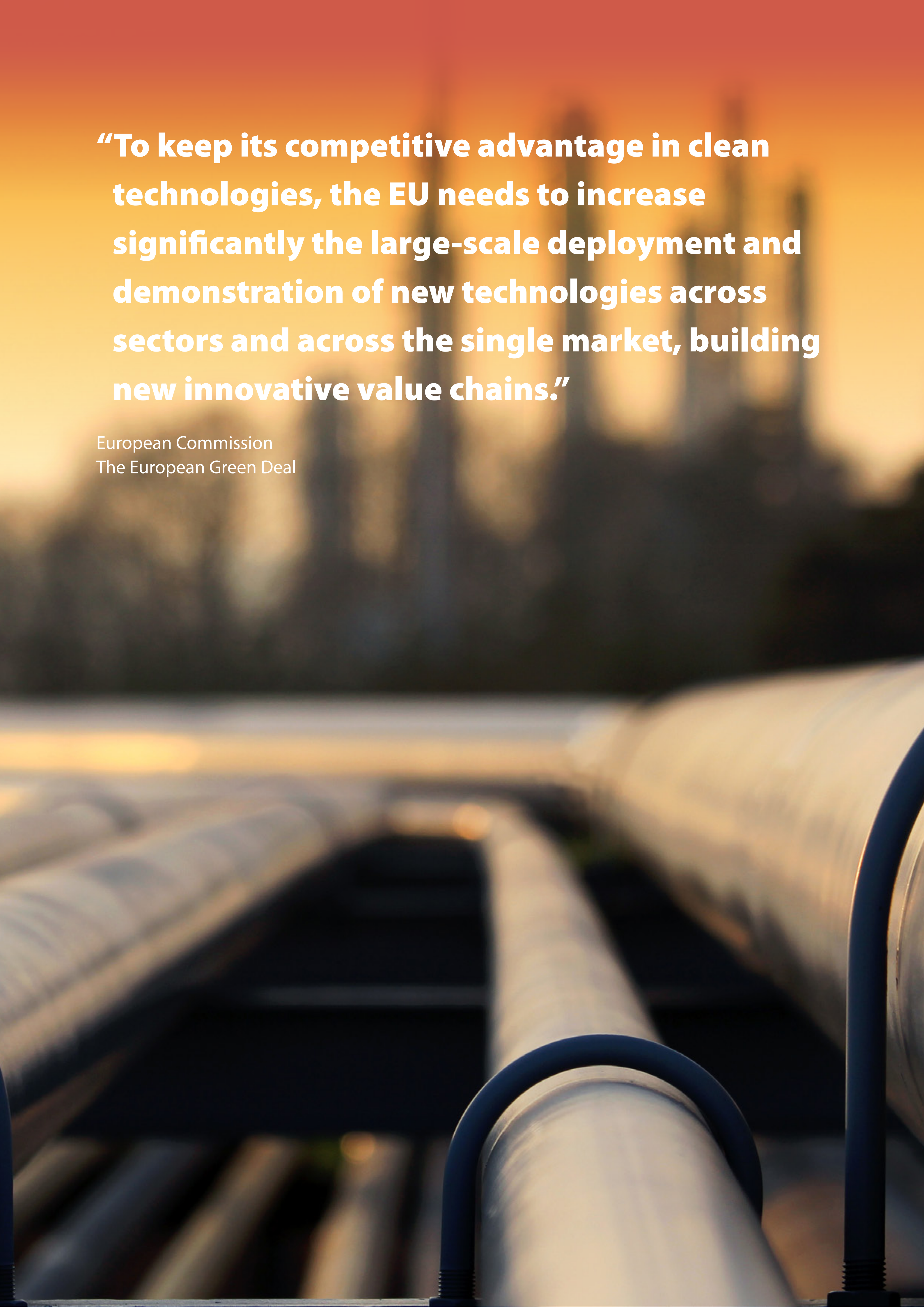
1. BAMBOO (AIT): Development and demonstration of a heat pump steam generator for low pressure steam up to 150°C. www.bambooproject.eu/project
2. DryFiciency (AIT): Demonstration and integration of three high temperature heat pump technologies in the production plants of starch, brick and waste treatment processes. The heat pump technology can produce heat at temperatures up to 160°C, reducing CO_2 emissions by up to 75 %. (Figure 9). www.dryficiency.eu

3. CHESTER (TECNALIA): Assessment of the possibility of storing low price electricity as heat at a high temperature with a heat pump, and then producing electricity at the highest price periods, by employing the stored heat to produce electricity by means of an ORC generator. The CHESTER high temperature heat pump must reach temperatures around 140°C in order to charge the phase change material of the thermal energy store, which stores heat at 133°C. www.chester-project.eu/

Whilst the current approach to RD&D on industrial heat pumps has led to impressive individual results, it is limited in the ability to ensure the technology reaches a level of maturity to achieve the meaningful CO_2 reductions, which are otherwise possible. Undertaking heat pump developments on a project by project basis, mainly through nationally funded incentives, prevents coordination of essential development activities, the sharing of critical knowledge and continuity of development. A more programmatic approach on a European level is needed to address these issues.

Figure 8: *Heat pump developed within the framework of the LowCapex project (NL)*

Figure 9: *Heat pump developed within the framework of the DryFiciency project (AT)*



"To keep its competitive advantage in clean technologies, the EU needs to increase significantly the large-scale deployment and demonstration of new technologies across sectors and across the single market, building new innovative value chains."

European Commission
The European Green Deal

5. AMBITIONS FOR INDUSTRIAL HEAT PUMP IMPLEMENTATION AND DEVELOPMENT

The research institutes involved in the preparation of this whitepaper have set out the following ambitions and objectives for the period 2020 to 2025, which will lay the foundation for a developed industrial heat pump market and establish industrial heat pumps as a mature technology for increased application areas.

The key ambitions are as follows:

- Heat pump technology is established as the reference (low carbon) technology for heat supply <100°C, with at least 500 large scale (1 MW to 10 MW) units installed in industry and other relevant application areas. (TRL9)
- Demonstration of 25 full-scale (1 MW to 10 MW) industrial heat pumps to supply heat in the range of 100°C to 150°C, installed at end-user locations in various sectors and countries. (TRL8)
- Up to 5 pilot scale (with ±100 kW heating capacity) demonstration projects to validate the technical feasibility of industrial heat pumps to supply heat beyond 150°C. (TRL6-7)
- Development of 3 technologies at a laboratory scale (1 kW to 10 kW), demonstrating the technical feasibility of heat pump concepts to supply heat at temperatures above 200°C. (TRL3-5)
- Establishment of 3 new refrigerants, which are suitable for use in heat pumps supplying heat in the range of 150°C to 250°C, which have been demonstrated in parallel with natural working media alternatives.
- Establishment of multiple knowledge, component and system suppliers for industrial heat pumps, which are able to supply the market with technical solutions that can deliver heat up to 150°C.
- Industrial heat pumps which are an integral part of standard process equipment (dryers, distillation units, other processes) have become commercially available.
- Realization of 5 projects in the framework of Horizon Europe, which have resolved the key market barriers that have so far prevented industrial heat pumps from achieving wide-scale implementation.
- Industrial heat pumps are high on the European R&D agenda and are recognized as key technology for the EU-decarbonization strategy of industrial heat demand below 200°C.
- Establishment of uniform testing standards for determining the performance of industrial heat pump units.

“Today, the costs of some of the advanced low-carbon energy carriers and technologies remain high, and their availability is limited. A massive research, coordinated and innovation effort, built around a coherent strategic research and innovation and investment agenda is needed in the EU within the next two decades to make low and zero-carbon solutions economically viable and bring about new solutions not yet mature or even known to the market.”

European Commission
A clean planet for all

6. THE WAY FORWARD

The following coherent set of actions is proposed to be taken up by the European Commission to stimulate industrial heat pump applications and to strengthen and accelerate the EU-wide research, development and demonstration of industrial heat pump technology, in order to unlock its CO_2 emission reduction potential.

Creating a fair regulatory framework that facilitates the acceptance of industrial heat pumps

It has been demonstrated in several projects that industrial heat pumps are viable alternatives for zero-emission heat supply. Various energy transition roadmaps[22-25] consider heat pumps for industrial applications and district heating as a key technology in future energy scenarios. A rapid transition to a sustainable energy system requires a stable and technology-independent regulatory framework that internalizes the costs of CO_2 emissions. Current scenarios continue to focus on the introduction of natural gas-based combustion through subsidies and tax benefits, as this is seen as a viable short-term alternative. It must however be understood that this leads to technological lock-in, even though long-term solutions, i.e. industrial heat pumps, are already available and can be equally competitive under technology-independent regulatory conditions. A review of the regulatory frameworks is needed with regard to the tax burden and to focus on promotion of industrial heat pumps as a long-term sustainable alternative to industrial heat supply.

Establishing an information and knowledge base to support the integration of industrial heat pumps at all levels of the value chain

The potential of industrial heat pumps must be understood by various stakeholders involved in the implementation of heat pumps, including manufacturers, consultants, planners, end-users, process engineers, decision makers, and politicians. In addition, there must be a sufficient knowledge base to support a wide deployment of industrial heat pumps, such as education materials, training courses, process integration and optimization methods, standards and guidelines.

Development of an EU-wide program which enables cutting edge research, development and demonstration projects with industrial heat pumps

Industrial heat pump technologies can become the preferred heat supply technology for a wide range of applications with supply temperatures below 100°C. For the technologies with supply temperatures between 100°C and 200°C, the focus should lie on development and demonstration, while higher temperatures require research activities. Demonstration projects should aim to break down application barriers and solve problems with upscaling and the widespread use of large heat pump systems. Additional R&D activities should focus on performance improvements and the development of strategies for the energy transition to fully renewable process heat systems, including heat pumps. These RD&D projects require cross-industry collaborations covering the entire range from research and development to manufacturing and final application in an international context.

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