



# Heat Pumping Technologies

## MAGAZINE

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Envelope of Heat Pumps

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### Topical Article

## Roll-Out of Large-Scale Heat Pumps as A Key Factor for The German Energy & Heat Transition

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*From less than 1 GW to more than 90 GW installed thermal capacity in less than 25 years: For the climate-neutral transformation of German district heating networks and the decarbonization of process heat, large-scale heat pumps are no-regret measures. This is one of the key findings of a 2023 study by Berlin-based think tank Agora Energiewende and Fraunhofer-Institution for Energy Infrastructures and Geothermal Systems IEG. However, to unlock their full potential and accelerate the market ramp-up, several measures need to be taken. The main fields of action are 1) adaptation of German energy policies and regulations, 2) further industrialization and automation of heat pump manufacturing, and 3) reduction of bureaucracy in the planning, approval, and building process.*

### Introduction

Germany has set itself the binding target to become fully climate-neutral by 2045. Since the demand for space heating and hot water in the building sector and the supply of process heat in the industry sector together account for more than half of the final energy demand in

Germany, their decarbonization plays a key role in the German energy transition. Yet, currently, about 80 % of the heat demand in buildings and industry is met by fossil fuels. [1]

At the same time, most of the demand for heat is in the low-temperature range below 200 °C, which includes the whole building sector, all district heating, and about a third of the industrial heat demand [2]. Specifically, the demand for heat up to 200 °C accounted for 43 % of Germany's final energy consumption in 2021, more than 75 % of natural gas consumption (around 494 TWh), and more than one-quarter of greenhouse gas emissions (around 215 million t CO<sub>2</sub>-eq) [1, 3, 4] (see Figure 1).

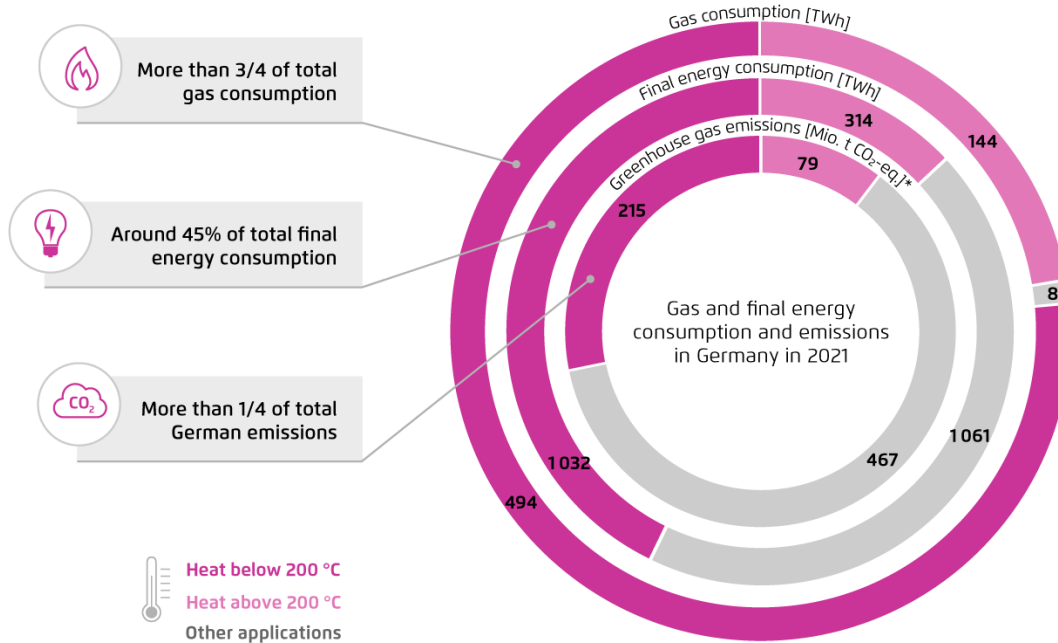


Figure 1: Heat demands up to 200 °C: high potential for reducing emissions, gas, and final energy consumption (Agora Energiewende based [1]. Emissions based on the breakdown by fuel type according to [1] and emission factors according to [3], not weather-adjusted. Own assumptions regarding the breakdown by fuel type across the different temperature levels based on [4]).

Modern large-scale high-temperature heat pumps can already efficiently reach those temperature levels. More and more original equipment manufacturers (OEMs) are entering the market with products that can easily achieve coefficients of performance (COP) of 2.5 or more (depending on the temperature spread between heat source and heat sink). However, only a relatively small number of large-scale heat pump projects have been realized in Germany so far, and the market is only slowly gaining momentum. The opportunities and

challenges associated with a broad market ramp-up in Germany are illustrated in this article by (1) looking at the energy scenarios for heating networks and large-scale heat pumps to achieve the German climate targets by 2045, (2) showing the potential of large-scale heat pumps and renewable heat sources; (3) comparing that to the status quo of the heat pump market; and lastly (4) developing recommendations for action.

### Fast ramp-up of large-scale heat pumps is key for the transformation of the district heating sector

In 2021, German district heating networks had a total installed thermal capacity of around 71 GW, with a share of large-scale heat pumps – here defined as plants with a rated thermal power of 500 kW or more – near 0.0%. Since then, the share has risen by a small fraction. [5] At the same time, different studies and scientific analyses indicate that for the full decarbonization of the German energy system, the fast ramp-up of large-scale heat pumps is a key factor. In the “Long-term Scenarios for the Transformation of the Energy System in Germany” from November 2022, which was developed by an expert group of research institutes on behalf of the German Federal Ministry for Economic Affairs and Climate Action, the future district heating system is dominated by large-scale heat pumps. The study, which has been updated since, models five different scenarios to reach climate neutrality with different pathways on how to get there. In all five scenarios, at least 90 GW of installed thermal capacity of large-scale heat pumps are needed in 2045, which would produce more than 70% of the total energy supply in district heating networks. [6] (see Figure 2).

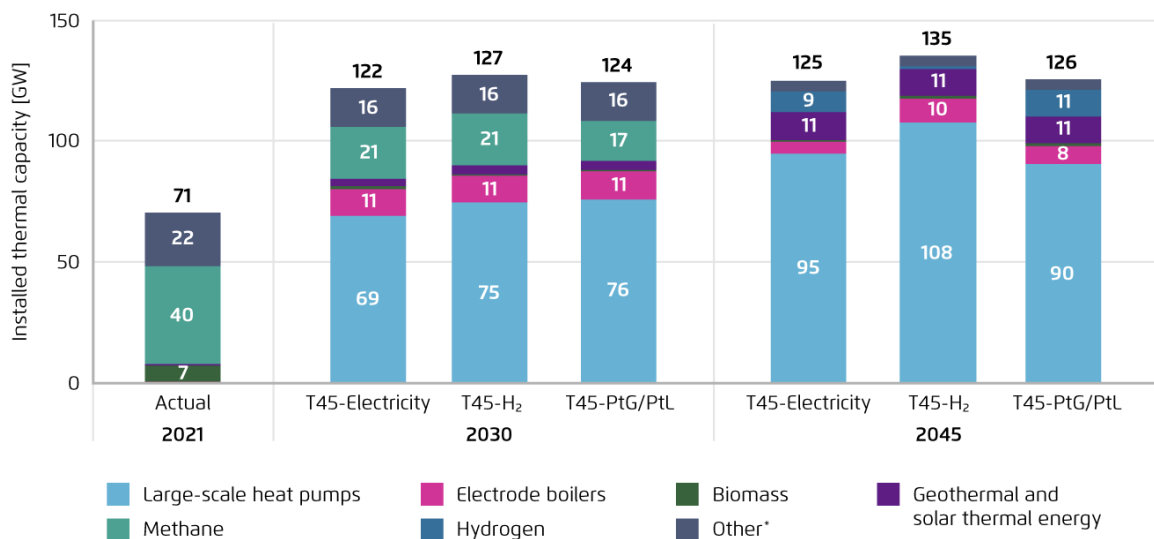
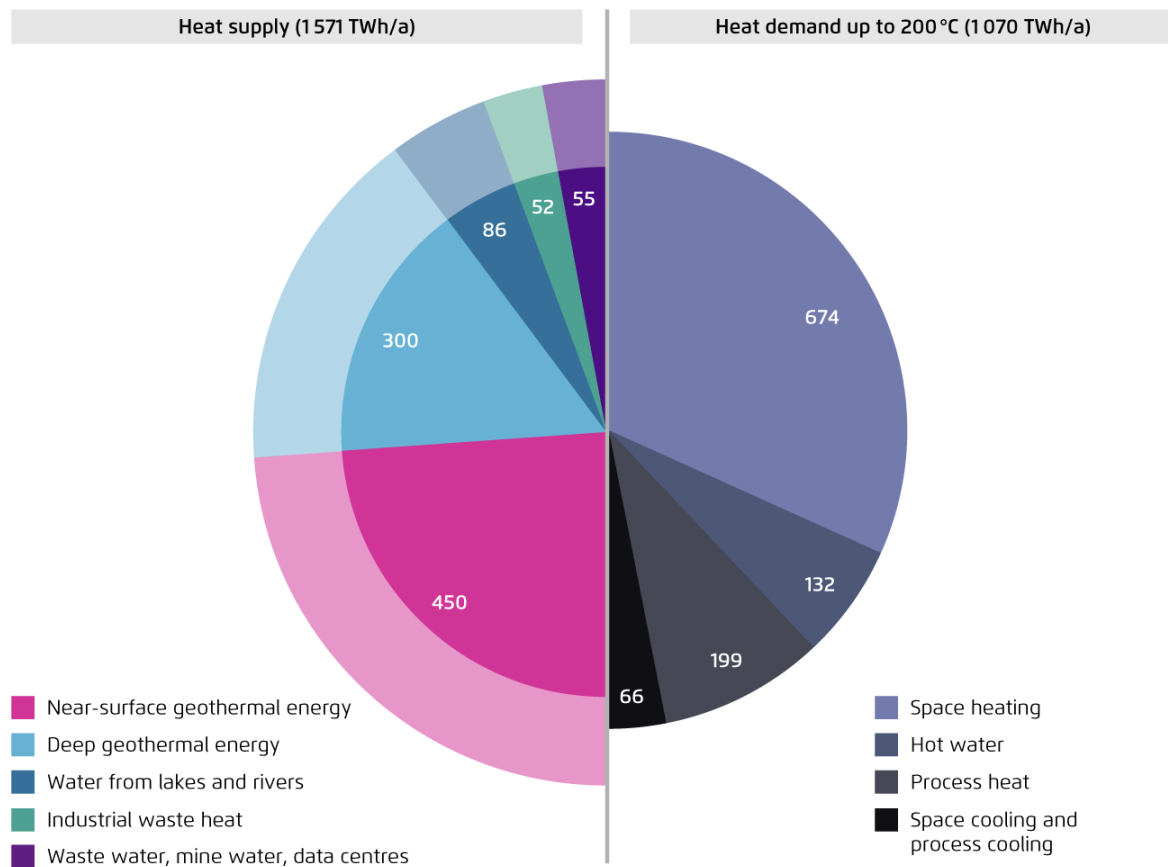


Figure 2: Projections from German Long-term Scenarios (version of Nov 2022) for installed thermal capacity in the German district heating sector (\* lignite, coal, waste, and other fossil fuels) [6, 7].

Translated into actual investment in energy infrastructure, these figures require, on average, around 340 - 410 new large-scale heat pump projects with an installed heating capacity of 4.0 - 4.9 GW and 800 km of new heat pipes each year until 2045. As a rough estimate, this would correspond to new investments of at least €3.1 billion – €4.4 billion per year in the German district heating sector, not taking investments in the industry sector into account. [7] This is a big challenge, and the required private-sector capital needs to be mobilized by creating appropriate conditions for investors. Besides planning security and economic incentives, this also includes the provision of sufficient public funding. In 2022, the German government started a new federal funding scheme for efficient heating networks (Bundesförderung für Effiziente Wärmenetze - BEW). This programme is equipped with €3 billion until 2026 and could roughly mobilize investments of about €7.5 billion in total (when assuming a funding rate of 40%). Hence, to satisfy the actual demand, as shown in [7] and [8], and to lift private investments to the needed level, an increase and extension of funding will be crucial.

**Potentials are high, and technology is mature**

The possibilities of large-scale heat pumps, both technologically as well as looking at available heat sources, are enormous. In the long term, the entire heat demand up to 200 °C (including process heat in industry) in Germany can be met by heat pumps. A meta-analysis of different studies shows that the potential heat supply by climate-neutral heat sources that can be utilized by heat pumps exceeds the entire heat demand up to 200 °C in Germany, and that is without even taking ambient air as a heat source into account. Near-surface and deep geothermal energy offer by far the greatest potential, followed by lakes and rivers, industrial waste heat as well as wastewater, coal mine water drainage and data centers (see Figure 3).



*Figure 3: Comparison of the potential heat supply via heat pumps (excluding ambient air) and the heat demands up to 200 °C in Germany (Fraunhofer IEG, 2023) [7].*

In addition, the technology of large-scale heat pumps is mature and reliable. Large-scale heat pumps have a long operation history in other countries (e.g., for district heating in Scandinavia), and state-of-the-art products already can reach temperatures which are suitable for district heating networks and many industrial processes (see Figure 4). Furthermore, large-scale heat pumps provide these temperatures efficiently, with COPs of above 2.5 in most cases (assuming an efficiency rating of 50 % and depending on the actual temperature spread between the heat source and the heat sink). For industrial processes, there are efficient combinations of large-scale heat pumps and mechanical vapor recompression systems available to provide steam.

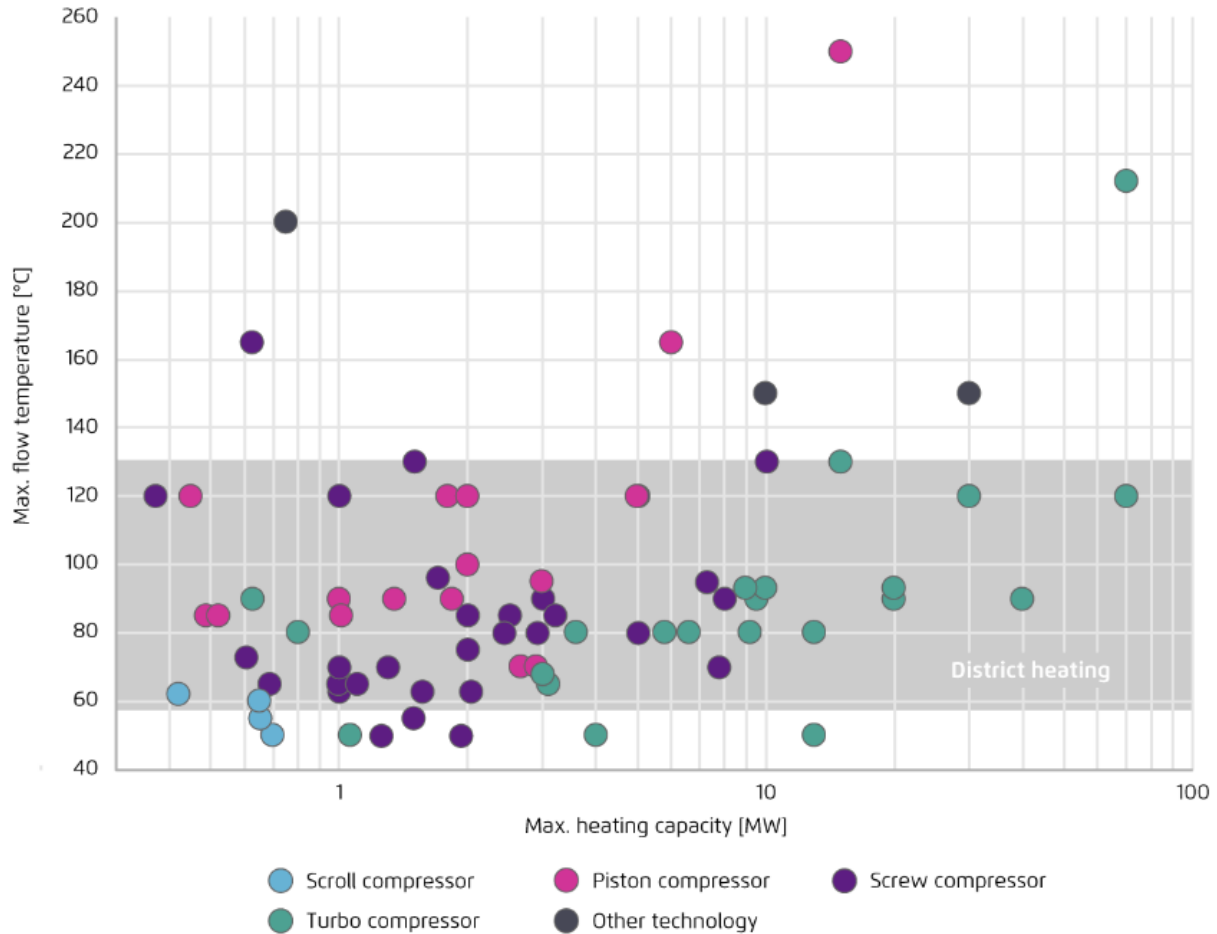


Figure 4: Maximum flow temperatures and thermal capacities of large heat pumps on the market (Fraunhofer IEG, 2023) [7].

### Status quo: Small number of large-scale heat pumps in operation, but with rising demand

As of December 2023, at least 45 large-scale heat pumps with a total installed thermal capacity of around 130 MW are in operation in Germany, and additionally, around 1,000 MW are currently under construction or in planning (based on own market research by Fraunhofer IEG) [7]. In addition, OEMs report rising requests for new feasibility studies or project inquiries. However, only a small percentage of those projects are actually commissioned. Some major challenges that hinder the realization of large-scale heat pump projects in the current market phase include:

- Insufficient economic viability due to comparatively high electricity and low gas and CO<sub>2</sub> prices;
- Lack of municipal heat planning in many places, lack of heat registers, and hence little knowledge and high uncertainties about the technology and its profitability;
- Relatively small production volumes at OEMs and highly individual projects with elaborate planning and approval procedures.

**Conclusion and recommendations for action**

To successfully roll-out large-scale heat pumps while at the same time allowing supply chains and implementation capacities to grow without creating bottlenecks, an intelligent mix of price signals, support measures, and regulation is needed. The necessary measures can be categorized along three central fields of action.

Firstly, a coherent overall framework must be established. Therefore, all stakeholders, including policymakers, OEMs, as well as utility and district heating companies need to start a dialogue to develop a clear vision and to agree on joint strategic goals for the roll-out of large-scale heat pumps in Germany. Furthermore, price signals are crucial – here, the ratio of electricity-to-gas-price is decisive. Effective carbon emissions pricing is one important step to level the playing field in favor of climate-friendly energy sources. In addition, electricity in Germany continues to be subject to higher taxes, levies, and surcharges than fossil gas. A further reduction of these disincentives, for example, by lowering the electricity tax to the European minimum level, can remedy this situation. To meet the demands of a more and more flexible energy system, incentives for a flexible and grid-friendly operation of large-scale heat pumps should be established (such as time-variable grid fees), and grid connections need to be realized faster.

Secondly, the potential for innovation and cost reduction in production must be exploited consistently and quickly. Main fields of innovation are to reach higher levels of standardization of the products themselves and their main components, as well as further automatization and scaling of the manufacturing processes. Especially in the range from 1 MW to 10 MW, the availability of standardized solutions is central to a successful and quick market penetration, not only in Germany but all over Europe. Apart from that, there also is considerable potential for innovation in compressors – the key component of heat pumps. New refrigerants, more flexible operating modes, and higher target temperatures are some important features to make large-scale heat pumps fit for future district heating systems.

Thirdly, the transformation of heat grids, i.e., the expansion, new construction, and gradual lowering of flow temperatures of heat grids, must be structurally accelerated. Therefore, in Germany, subsidy schemes must be improved and harmonized. In particular, the parallel management of subsidies under the long-standing Combined Heat and Power Act (KWKG) and the new BEW funding program currently leads to misdirected incentives. Furthermore, municipal heat planning is very important to identify areas with a grid-bound heat supply. As

of January 2024, heat planning is mandatory in Germany. Municipalities with more than 100,000 inhabitants are required to establish heat plans by mid-2026 and all other municipalities by mid-2028. Ideally, the heat planning would then be developed into an integrated energy distribution strategy to create clarity for the entire sector coupled energy infrastructure. Implementing these heat plans also requires a bundle of adjustments and simplifications in planning and approval procedures. Reducing bureaucracy and enhancing digitization would help to reduce the necessary workforce for these processes as well as to shorten the current project duration significantly.

For more information on this, we recommend our study on the “Roll-out of large-scale heat pumps as a key factor for the German energy & heat transition” [7].

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