ROADMAP FOR NEAR-SURFACE GEOTHERMAL ENERGY

Geothermal heat pumps for the "Energiewende": potentials, barriers and recommendations for action

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The present study was carried out by Fraunhofer IEG, Fraunhofer Research Institution for Energy Infrastructures and Geothermal Energy IEG, with the support of the Bundesverband Geothermie (BVG), the Bundesverband Wärmepumpe (BWP) and the Erdwärme Gemeinschaft Bayern.

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Foreword

Near-surface geothermal energy: the future for building heating and cooling

The use of near-surface geothermal energy can, with its diverse and scalable applications, make an efficient contribution to a climate-friendly and price-stable heating market of the future. Renewable geothermal energy primarily offers the possibility of heating and cooling residential and non-residential buildings in a climate-friendly manner. For example, one kilowatt hour of electricity can provide up to five kilowatt hours of geothermal energy. Climate-neutral heating in this manner can be achieved in a future energy market which is 100 percent renewable. In the warmer seasons, geothermal energy technology can also be used for particularly efficient passive cooling of buildings. By storing solar heat in the ground, a seasonal energy balance is achieved.

The land consumption and emission load of the near-surface geothermal plants are extraordinarily low, shown by regularly collected data of the German Federal Environment Agency on the emissions balance of renewable energies. The use of geothermal energy produces neither particulate matter nor nitrogen oxides. The low noise emissions remain in the boiler room or the buildings energy centre.

Another fundamental advantage of using geothermal energy came to the fore this year, significantly increasing the demand for geothermal heat pumps. Near-surface geothermal energy is a domestic heat source with a base-load capability that can be used independently of international crises and raw material imports by utilising the natural heat flow available in any location, at any time of day, at any time of year.

Near-surface geothermal plants also stabilize the European energy system by making particularly efficient use of renewable electricity, especially during power peaks in the winter months. Geothermal heat pumps provide the grid operator with a high degree of flexibility; this grid-stabilizing effect is not only relevant to energy policy, but also to security policy.

In recent decades, near-surface geothermal energy has proven to be an efficient and reliable technology, but due to state-subsidies for fossil fuel technologies and cheap energy imports, geothermal heat pumps have not been able to establish themselves in the German heating market. However, the urgently overdue transformation of the heating market can be achieved in the medium term through the targeted adaptation of funding and condition frameworks. One of the most urgent challenges is the shortage of skilled workers, too.

The study presented by the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Energy IEG shows the outstanding potential of near-surface geothermal energy and offers options for its environmentally-friendly use.

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In Germany, the "Wärmewende" is lagging far behind the "Stromwende". While wind and solar power already provide more than half of the electrical energy sustainably in good years, renewable heat sources such as biomass, solar thermal and geothermal energy cover significantly less than a fifth of Germany's heat demand; despite the fact that heat accounts for the largest share of Germany's energy conversion at 56%. A successful "Energiewende" requires major and immediate changes in the heat sector. Politicians, administrators, businesses and citizens must set the course for the future today, so that sustainable technologies can gain momentum. The most promising approach is to integrate heat pumps into the energy system. Six million heat pumps by 2030, and 12 million heat pumps by 2045 will have to provide sustainable heat in Germany to meet the climate protection targets.

Heat pumps using near-surface geothermal energy (ground-source heat pumps) are the most advantageous option for heating and cooling buildings in a sustainable, future-proof way that is independent of imported raw materials. Due to the seasonally constant and high temperature of the ground, geothermal heat pumps ensure economical operation, for both new and existing buildings, without fine dust or noise emissions.

Geothermal heat pumps are available on the market today from many manufacturers. The systems are extremely efficient, cover a broad performance spectrum and offer proven solutions for the climate-friendly provision of heating and cooling.

> **"Geothermal heat pumps have the potential to provide up to 75 per cent of Germany's space heating and hot water needs."**

The cumulative useful heating demand for space and hot water in Germany is currently between 780 and 800 terawatt hours per year (TWh/a). Geothermal heat pumps have the potential to meet up to 75 percent of this heating demand, corresponding to around 600 TWh/a. Additionally, the same systems can meet a large part of the growing cooling demand.

To achieve the climate policy goals, this largely untapped potential must be pursued across the board. 12 million heat pumps will need to be installed by 2045 to meet climate protection targets. If the number of new installations continues the growth path of recent years, there will be a shortfall of just under 5 million heat pumps in 2030 and over 7 million in 2045. This continuation or making only minor adjustments will lead to a missed opportunity for a successful "Wärmewende". Due to the significantly higher efficiency of ground source heat pumps compared to air-source heat pumps, a shift in the field inventory of ground-source heat pumps from 20% to 50% by 2030 means that 5 million heat pumps could save 375,000 tons of CO_2 per year. A further increase to 15 million heat pumps would reduce electricity demand by 7.5 TWh/a.

However, there are obstacles to a broad roll-out of geothermal heat pumps in the market: the inadequate political and regulatory frameworks and the unwillingness of the housing industry, private and public property owners, and the energy supply companies to invest. In addition to promoting the use of geothermal heat pumps, the integration of seasonal (underground) heat storage, including a corresponding legal framework, the expansion of (cooling and) heating networks at the neighbourhood level, and innovative operator models (e.g. citizen energy communities) would be helpful instruments. One bottleneck is the foreseeable insufficient availability of skilled workers in the well construction and drilling industry and in the ventilation, heating and air-conditioning trades. In order to increase the installation of heat pumps, installers would need to transfer skills from fossil fuel combustion technology and apply them to the field of electricity based renewable heating.

This roadmap summarises the current state of the art on the subject of geothermal heat pumps in Germany. It examines the technical advantages and societal potential, and identifies the regulatory and economic barriers to widespread use in Germany. From this, the authors develop recommendations for action to achieve the climate targets.

Recommended actions:

1. **Approval process:** The federal states in Germany should reduce and ideally standardize their restrictions. Geothermal wells up to a depth of 400 m should generally be exempt from the obligation to obtain a mining permit. In particular, the apparent contradiction between water protection and geothermal energy is not state of the art. Permits must be granted according to transparent criteria, reliably and without delay. The operation of geothermal heat pumps must not be hindered by temporary permits. The permit requirement for geothermal heat pumps with a heating capacity of up to 30 kilowatts should be replaced by a standard notification requirement.

2. **Skilled workers:** Training in the heating, ventilation, and air conditioning trades needs focus on the content of the "Wärmewende", and the chambers need to provide nearly 400,000 tradespeople with appropriate training without delay. The drilling industry also needs more capacity; there is a short-term shortage of 2,500 drilling rigs and over 6,000 skilled workers. This requires more inter-company training, easier lateral entry and further development of the content of the training curricula.

3. **Administration and management:** Licensing authorities need to be able to act in a goal- and implementation-oriented manner, for example by adjusting staffing plans in advance and filling these positions consistently. Further training opportunities for administrative staff must be provided.

4. **Promote renewable energy instead of fossil fuels:** The installation of fossil fuel heating systems must be banned as soon as possible. Existing systems must be replaced well before 2045. The federal and state governments must develop appropriate incentive programs now. At the same time, legislation must be drafted to exempt electrical energy for heat pumps from taxes and levies.

5. **Data:** The scope of the existing databases has to be further developed by the respective state geological services. In line with the certification scope of the DVGW worksheet W 120-2, the state services must provide data on the subsurface to a depth of 200 m in the short term and to a depth of 400 m in the medium term.

6. **Social acceptance:** Property owners are generally not aware of the advantages of geothermal heat pumps. Often, the higher initial investment costs obscure the view of the low long-term running costs, that make the systems economically efficient. Education and targeted information campaigns are needed. With a modernisation program for public buildings, municipalities, federal states and the federal government could lead the way and set an example to be followed. Private and public housing companies with large portfolios need to be motivated to implement their investment needs quickly.

Introduction

Germany faces major social and energy policy challenges if it is to meet its climate protection targets by 2045. The debate about phasing out fossil fuels is also being driven by global political events in Russia and Eastern Europe. At the same time, however, dependence on fossil fuels remains at 67% of the final energy consumption. The heating sector accounts for the largest share of final energy demand in Germany with 56% or around 1,400 TWh/a (2019). Not least because of cheap fossil fuel imports, this sector has not been a focus of the "Energiewende".

Heat consumption in Germany for space heating (641 TWh/a in 2020) and domestic hot water (131 TWh/a in 2020) has been around 780-800 TWh/a for many years (figure 1) and is mainly used in densely populated regions (figure 2).

Climate protection. The particularly heat-intensive building sector has the task, on the basis in the Federal Climate Protection Act (KSG 2021), to gradually reduce its CO_2 emissions by 43% from 2020 to 2030[2], and then to zero by 2045. While a reduction in energy demand for space heating is possible primarily through the renovation of existing buildings, the complete avoidance of greenhouse gas emissions can only be achieved by moving away from the two fossil fuels natural gas and oil. Of over 900,000 heat generators sold in 2021, around 70% still used gas and around 5% used oil[3]. At the same time, renewable energies accounted for only 16.5% of final energy consumption for heating and cooling in Germany.[4]

The housing industry plays a key role in the "Wärmewende" by converting the energy supply of existing properties and new housing quarters. Heating systems based on renewable energies are becoming a key technology in the conversion process. Ground-source geothermal heat pumps are one of the most efficient options and must make a significant contribution in the future to the "Wärme- and Energiewende". The required temperature for heating is between 30°C and 70°C and heat pumps can usually cover the demand well. With an average service life of 20 years for newly installed heat generators, today's investments determine the CO_2 emissions until 2040.

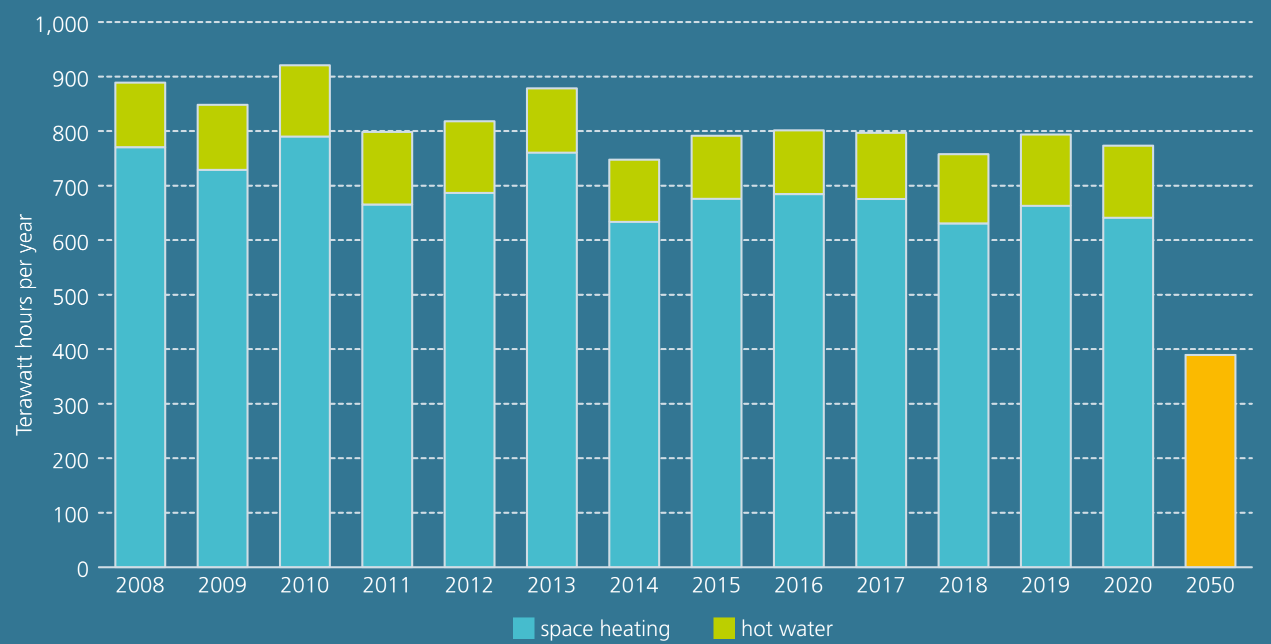


Figure 1: Heat demand (space heating and hot water) in Germany Absolute long-term demand in TWh/a, forecast 2050 (own presentation).[1]

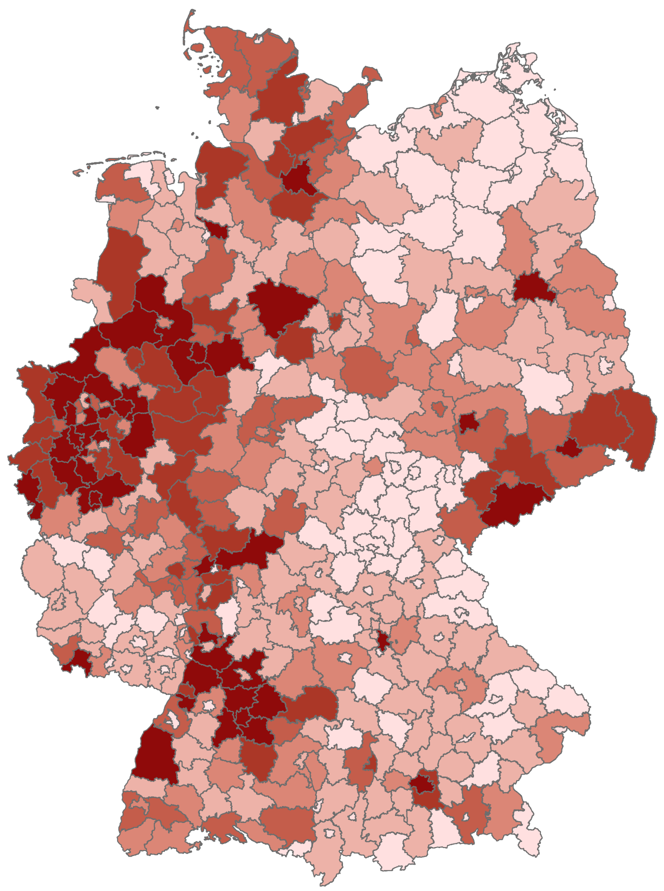
Existing plants must be replaced well before 2045. The federal and state governments must develop appropriate incentive programs now. In parallel, the legislature should relieve electrical energy for heat pumps from taxes and levies.

Figure 2: Regional distribution of demand for heating for private households (PHH) and trade, commerce, services (TCS); Excluding industrial process heat (reference year 2014; graphic: Fraunhofer IFAM)

Heat demand of the PHH and TCS sectors (TWh/a)

< 1.0
> 1.0 – 1.5
> 1.5 – 2.0
> 2.0 – 2.5
> 2.5 – 3.0
> 3.0

0 50 100 km



1 BMWI: Zahlen und Fakten: Energiedaten, 2021; Prognose 2050: Fraunhofer IEE: Energiewende Barometer, 2018

2 Erstes Gesetz zur Änderung des Klimaschutzgesetzes vom 18.08.2021 (BGBl. I S. 3905)

3 BDH: Marktentwicklung Wärmeerzeuger Deutschland 2012-2021

4 BMWK: Erneuerbare Energien 2021 Daten der Arbeitsgruppe Erneuerbare Energien – Statistik (AGEE-Stat), 2022

Geothermal systems

The present paper addresses the expansion potentials of ground-source geothermal energy systems for heating buildings and neighbourhoods with heat pumps. For this purpose, the subsurface of the ground is tapped as a heat source down to depths of up to 400m and then combined with heat pumps to create an efficient and sustainable holistic system. For larger systems, the subsurface is often also used as a seasonal heat storage. The majority of current geothermal heat pump systems reach drilling depths of between 100m and 200m. Various technical options can be used to generate heat and cold (see Figure 3, variants 1 to 3). Depending on drilling depth, near-surface geothermal energy is available at temperatures of about 5°C up to about 15°C.

Closed systems are vertical geothermal probes or horizontal geothermal heat collectors which use U-shaped synthetic pipes, mostly made of PE, in boreholes or trenches. In the heat-transferring pipes a liquid circulates which transports the heat extracted from the ground to the surface. Heat pumps extract the heat from the fluid and raise it by means of a compressor to the desired temperature. The fluid is then returned underground to be reheated.

Open systems, on the other hand, pump groundwater from wells to the surface. After the heat has been extracted by a heat pump, the cooled water is returned to the aquifer via a second well. The decision in favour of closed geothermal

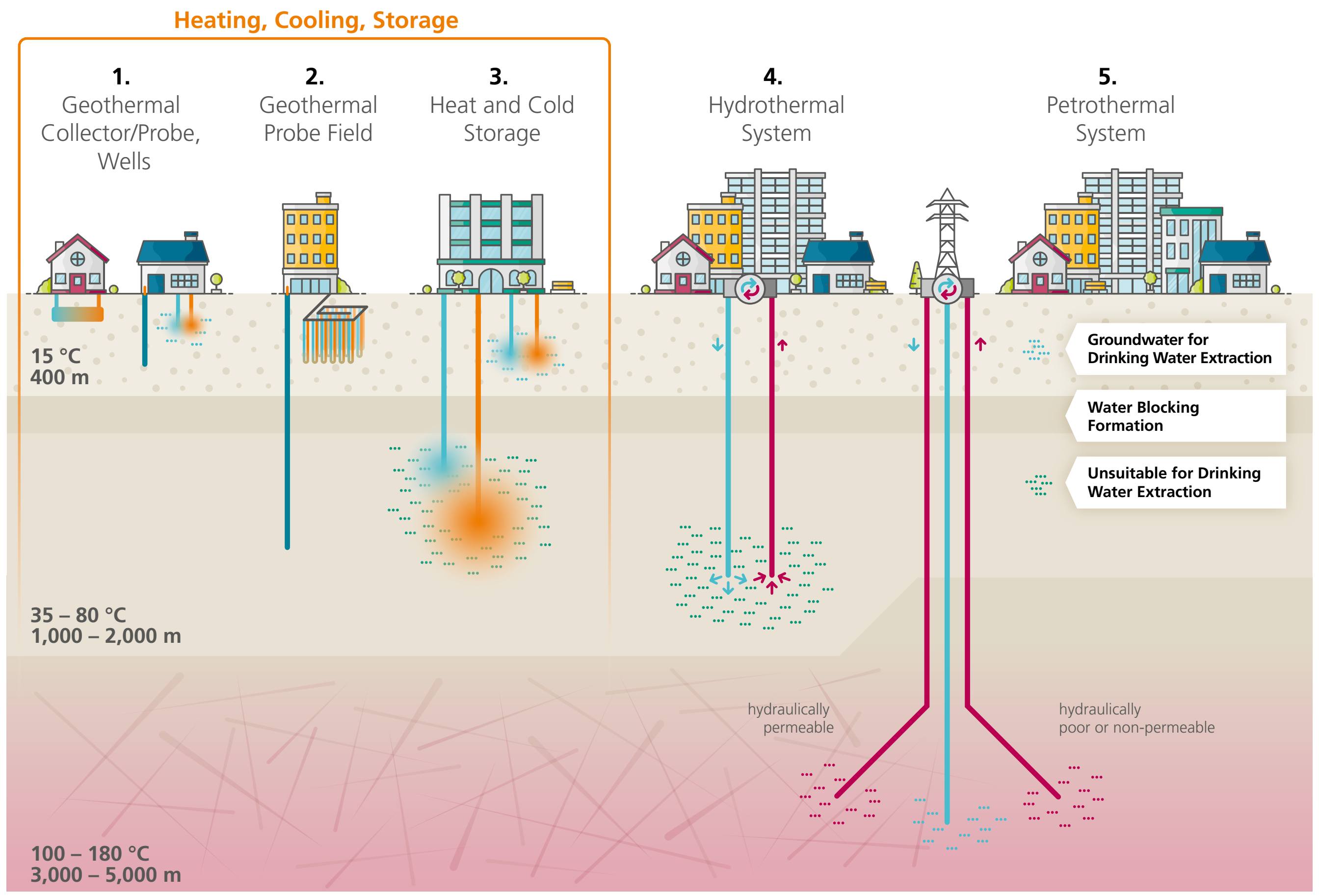


Figure 3: Geothermal systems: Geothermal probes / geothermal collectors/groundwater wells for the extraction and storage of heat and cold from near-surface geological formations up to 400 m (variants 1 to 3) for individual properties and neighborhood supply (subject of this paper). Deep geothermal hydrothermal and petrothermal systems (variants 4 and 5) reach down to a depth of 5,000 m and are used for large-scale applications.

wells or for open, well-based solutions depends on the local geological and hydrogeological subsurface. While geothermal probes can be used in almost any geological formation, wells require a sufficient groundwater-bearing layer.

Advantages and unique selling propositions

Scalability. Geothermal heat pumps can be used to both heat and cool residential and non-residential buildings. The range extends from individual, small residential houses to larger individual buildings (e.g. larger office buildings, hospitals, apartment buildings, multi-story residential buildings, public properties) to the supply of entire city quarters.

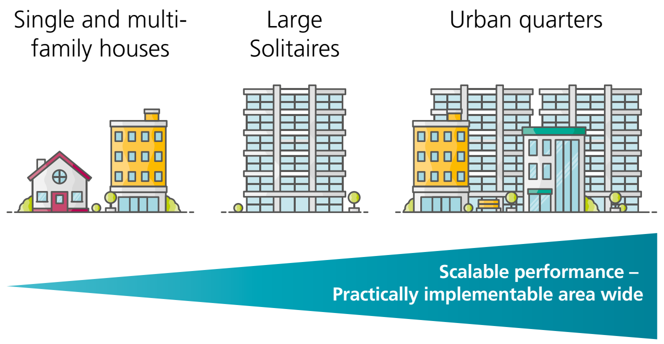


Figure 4: Application options for geothermal heat pumps

Larger power requirements go hand in hand with larger heat source systems. While one or two geothermal probes are usually sufficient, larger infrastructures use geothermal probe fields with up to several hundred geothermal probes.

Heating and cooling with one system. Geothermal heat pumps use heat from underground and raise it to a higher temperature for heating buildings and water. The same system can also cool buildings economically and efficiently, either directly via the temperatures prevailing underground (natural/passive cooling) or by using the heat pump as a chiller (active cooling). A separate system for building cooling is not necessary. In addition, the building cooling system provides an artificial regeneration of the subsoil and leads to a reduction in the number of bore meters drilled or to an increase of the flow temperature during the heating period (and thus to more efficiency).

Reliability and availability. Ground coupled heat pump systems have been tried and tested in many European countries for decades; in Germany alone, almost 435,000 systems have proven their efficiency. All system components, i.e. geothermal heat pumps, probes and collectors as well as groundwater wells are available on the market from a large number of suppliers, and a significant expansion in the context of the "Energiewende" could therefore begin immediately.

Environmental impact. Geothermal heat pumps do not cause emissions during operation. There are no harmful environmental effects due to exhaust fumes, particulate matter or noise emissions. As long as electricity is generated from fossil fuel sources, CO_2 emissions are generated at the power plant site for the operation of the electric heat pump. Through the increased use of renewable electricity in line with the German government's climate targets, emissions will drop to zero in 2045 or faster if the operators have the appropriate incentives to immediately use only electricity from sustainable sources.

Land consumption. The heat source is created underground and usually does not require a structure on the surface. There is no detrimental effect on the urban or rural landscape. Geothermal probes and large geothermal probe fields can be built over, so that the land use is negligible in terms of urban development.

Economic efficiency. The economic operation of geothermal heat pumps in comparison to fossil gas heating systems results primarily from the ratio of the electricity price to the gas price. The development shows that already today heat pumps with an annual performance factor (APF) of 3.5 already achieve significant monetary savings in operation (Figure 5). The geopolitical developments and distortions on the German and European gas market significantly reinforcing this trend.

Sector coupling. Heat pumps form the interface between the energy sectors, electricity and heat. Heat pumps are already technically capable of generating electrical energy beyond the current demand through the use of buffer storage tanks. Heat supply on the basis of geothermal heat pumps is, compared to the transformation path of electric energy to hydrogen, methanation, and finally condensing boiler heating, particularly efficient. Figure 6 illustrates

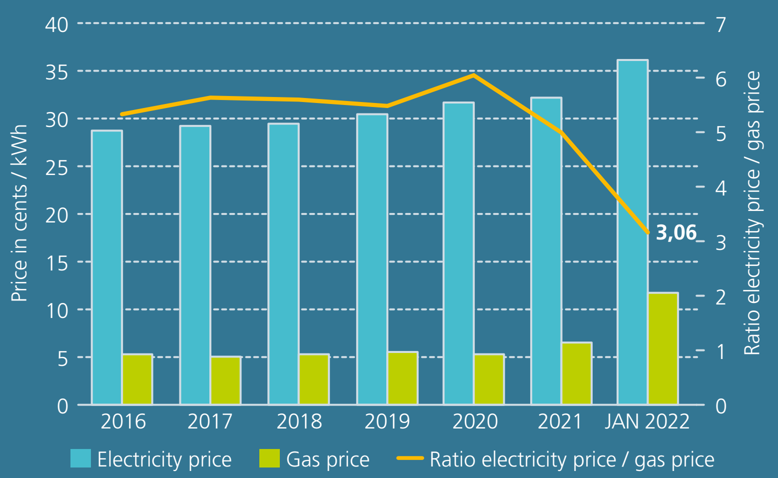


Figure 5: Ratio of gross gas and gross electricity prices for end customers in Germany including levies and surcharges (own illustration based on BDEW Electricity Price Analysis January 2022 and BDEW Gas Price Analysis January 2022)

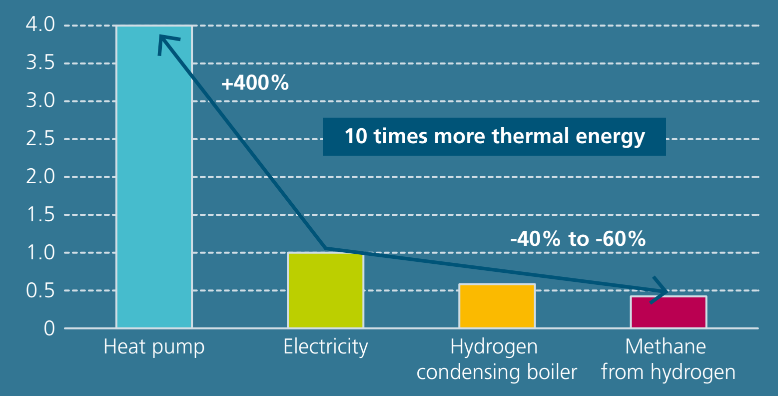


Figure 6: Usable thermal energy from electrical energy; a comparison between geothermal heat pumps and hydrogen from electrolysis or subsequent methanation (Source: own representation, assumptions on efficiencies: electrolysis: 65%, methanation: 80%, compression: 85%, heating: 90%).[7]

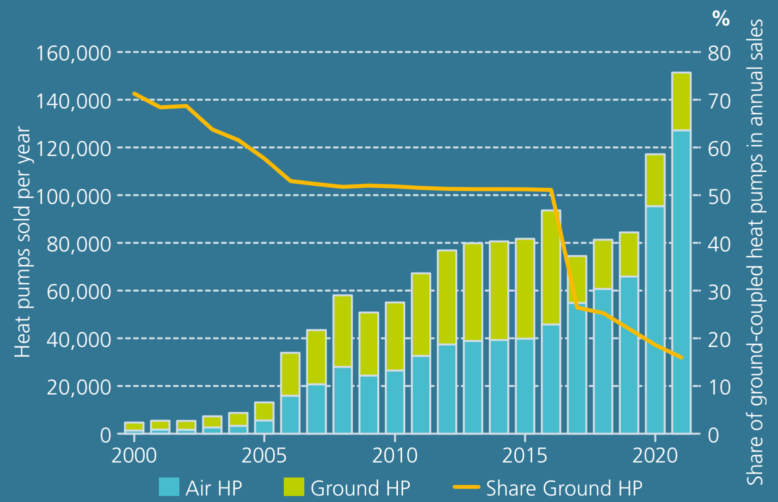


Figure 7: Annual heat pump sales in Germany (own representation)[10]

that, in a direct system comparison, for a kilowatt hour of electrical energy up to ten times more thermal energy can be generated. In an energy system based largely on renewable, volatile electricity, heat pump systems will also make a significant contribution to the system if they are able to respond flexibly to the fluctuating supply of regenerable electricity and convert it into heat with foresight.[5,6]

Independence. Geothermal energy is a domestic and renewable resource. The operation of geothermal heat pumps does not require energy imports, as the electrical energy required can be produced domestically, ideally from renewable sources.

Efficiency advantages. Geothermal heat pumps have higher capital costs than air-source heat pumps due to necessary drilling. However, this is offset by lower operating costs, which are based on the comparatively seasonally constant and high ground temperatures. This results in a significantly higher efficiency of geothermal heat pumps compared to air-source heat pumps (see info box[8,9]).

5 Wärmepumpen in Bestandsgebäuden: Ergebnisse aus dem Forschungsprojekt »WPsmart im Bestand« (Abschlussbericht), Fraunhofer ISE, Freiburg 2020
6 Beuker, S., H. Doderer, A. Funke, C. Koch, H. Kondziella, J. Hartung, S. Maeding, H. Medert, G. Meyer-Braune, M. Rath, N. Rogler: Synthesebericht Flexibilität, Markt und Regulierung, 2021
7 Sarah Milanzi, Carla Spiller, Benjamin Grosse, Lisa Hermann, Johannes Kochems, Joachim Müller-Kirchenbauer: Working Paper Energie und Ressourcen Technischer Stand und Flexibilität des Power-to-Gas-Verfahrens, Berlin, 2018; Dr. Vladimir von Schnurbein: Die Speicherung überschüssigen EE-Stroms durch Synthetisches Methan (SNG)
8 Wärmepumpen in Bestandsgebäuden: Ergebnisse aus dem Forschungsprojekt »WPsmart im Bestand« (Abschlussbericht), Fraunhofer ISE, Freiburg 2020
9 The studies conclude, that the SEER on average of air-source heat pumps in existing buildings is ~3.1, while that of ground-source heat pumps is ~4.1. In the further course of this study, comparative considerations under the assumption of an air heat pump SEER =3 and a geothermal heat pump SEER =4.

This higher efficiency leads to the following advantages:

- The lower electricity demand per kilowatt hour of heat generated increases the economic efficiency and the environmental friendliness (lower CO_2 emissions) of plant operation.
- Due to the higher source temperatures, higher heating flow temperatures are possible: this results in supply options also for existing buildings.
- Lower load peaks on cold days have a positive effect on the operation of the power grid.

Market development

Ground-source heat pumps are a well-established and market-ready technology for heating and cooling in residential and non-residential buildings. After an initial boom in the early 1980s, heat pumps have established themselves on the German heating market since the turn of the millennium. Since 2006, more than 50,000 systems have been sold annually. As Figure 7 shows, sales figures increased from around 80,000 heat pumps per year in the mid-2010s to over 150,000 heat pumps in 2021.

Most recently, there has been a clear shift from geothermal heat pumps to air-source heat pumps. The percentage share of ground-source heat pumps was more than 50% in 2016, the sales figures for air-source heat pumps have increased to such an extent in recent years that the share of ground-source heat pumps fell to below 20%.

In total, the market data at the end of 2021 showed there are around 435,000 geothermal heat pump systems in Germany, providing around 10 TWh of heat per year. Just over 10% of these systems use groundwater directly as a heat source, while 90% use the dominant technology of geothermal probes or collectors.[11] In total, however, these systems account for only 1.3% of the German energy demand for space heating and domestic hot water. In contrast, the stock of air-source heat pumps comprises around 770,000 systems (16.5 TWh of heat per year)[12].

10 Sales figures from surveys by the BDH and BWP
11 Jensen & Pester, 2019, geben den Anteil für Niedersachen z.B. mit 80% an. Regional kann es durchaus unterschiedliche Ausprägungen geben
12 The stock data is based on our own calculations. Updating of the Data according to Born et al.: Analyse des deutschen Wärmepumpenmarktes, 2017.

Efficiency of heat pumps

The efficiency of a heat pump is expressed by the Seasonal Energy Efficiency Rating (SEER). The SEER describes the ratio of usable thermal energy to electrical energy consumed. The higher the coefficient of performance, the more efficient the heat pump. The Fraunhofer ISE has conducted extensive field studies of heat pumps, with the result that the SEER of geothermal heat pumps is on average one than that of air-source heat pumps.

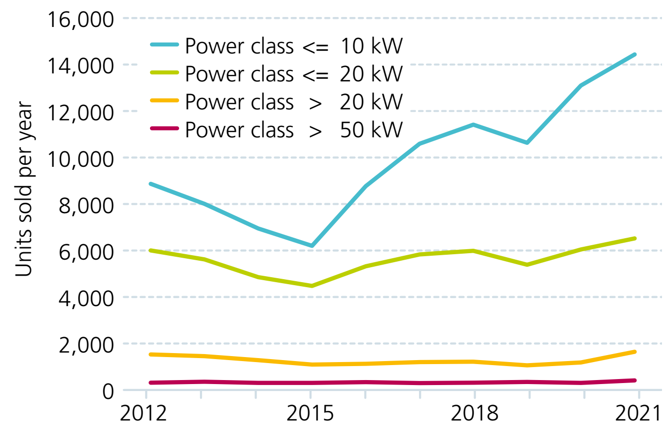


Figure 8: Performance classes of the sales of geothermal heat pumps (own representation)[13]

Furthermore, a trend can be observed that mainly ground-source heat pumps of a relatively small output capacity are installed (outputs of less than 20 kW, Figure 8).

This is primarily due to the fact that heat pumps are predominantly installed in smaller residential buildings, and increasingly in new buildings. In 2020, over 50% of newly constructed buildings had a heat pump installed (over 50,000 systems).[14] In the same year, almost 70,000 heat pumps were installed in existing buildings.[15]

What is needed, therefore, is a market turnaround that will:
- significantly increase the quantity of geothermal heat pumps sold and installed in the short and medium term, and
- increasingly target existing buildings and larger urban structures in order to make a measurable contribution to the "Energiewende".

13 Sales figures from surveys by the BDH and BWP
14 Sales figures from surveys by the BDH and BWP
15 Statistisches Bundesamt (Baufertigstellungen)

Potential for geothermal heat pumps in Germany

The geological offices of the federal states usually provide map-based data for the geothermal development of the subsurface. The maps vary in the level of quality and detail. The presented contents range from general licensing restrictions or limitations over geothermal yields of small plants with standardized boundary conditions to depth-resolved thermal conductivities. This data is an important basis for the planning and dimensioning of geothermal heat pumps.

However, these maps do not represent the geothermal potential, i.e., the actual usable heat energy of the subsurface combined with the local heat demand of the existing buildings.

The potential for providing useful heat by means of geothermal heat pumps for existing buildings is complex and depends on five basic influencing variables:

1. **Thermohydraulic properties of the subsurface:** The thermal conductivity of the rock, the thermal capacity of the subsurface, the formation temperature, connectivity i.e. groundwater-driven heat transport..
2. **Thermal properties of the existing buildings:** Physical properties of the buildings/insulation standard, building function, location of the buildings, heating distribution system.
3. **Property of the building site:** Open areas that can be used specifically for the drilling of the subsurface.
4. **Technical heat source development:** Number of geothermal probes, depth of boreholes, spacing between probes.
5. **Regulatory framework:** Nature conservation, water protection and building law exclusion and restricted areas for heat source development, geological barriers.

A detailed, integrated potential analysis considering the characteristics of the building, general conditions of the property, legal conditions and local geothermal potential has been carried out so far for the state of North Rhine-Westphalia (NRW). The LANUV technical report 40/4 "Potential Study Renewable Energies NRW Part 4 – Geothermal Energy" presents the state-wide and parcel-specific analysis for near-surface geothermal utilization options.[16] This potential study serves as a reference for the determination of the Germany-wide potential and for the potential and for the consideration of the current state of the art in the development of geothermal energy.

The following example uses North Rhine-Westphalia (NRW) as a case study to examine the system for determining the potential for geothermal heat pump systems. This potential is then scaled up to apply to the whole of Germany. The existing urban data from NRW was used for the determination of the theoretical coverage of near-surface geothermal energy for municipal heat supply:

- All plots of land in NRW
- Buildings: All building floor plans of the real estate cadastre with use identification and building height data.

As a result, the building footprints were geometrically planned out of the developed ownership units in order to assign geothermally usable and drillable property areas ("undeveloped areas of built-up property units" as a result). Over 9 million buildings with together a building footprint of more than 1,000 km² were investigated. Unheated buildings (garages, silos, halls, etc.) were excluded.

In order to determine the potential for the property-specific geothermal coverage share, an extensive survey was carried out, which considered the aforementioned influencing parameters of a property and the heat demand of the building stock as well as the coupling of these parameters under consideration of regulatory boundary conditions.

Factors limiting the potential were the complete exclusion of restricted areas (water and spring protection areas) and a drilling depth limit of 40m in geologically critical areas, a basic maximum length of geothermal probes of 100m, the exclusion of well systems and the fact that the only supply options were considered in which the property unit and building formed a single unit.

16 Landesamt für Natur, Umwelt und Verbraucherschutz NRW LANUV-Fachbericht 40 (2015): Potenzialstudie Erneuerbare Energien NRW Teil 4 – Geothermie, 78 S.; Autoren: Bracke, R.; Rocholl, W.; Schmidt, B.; Bussmann, B.; Eicker, T.; Kelz, B.

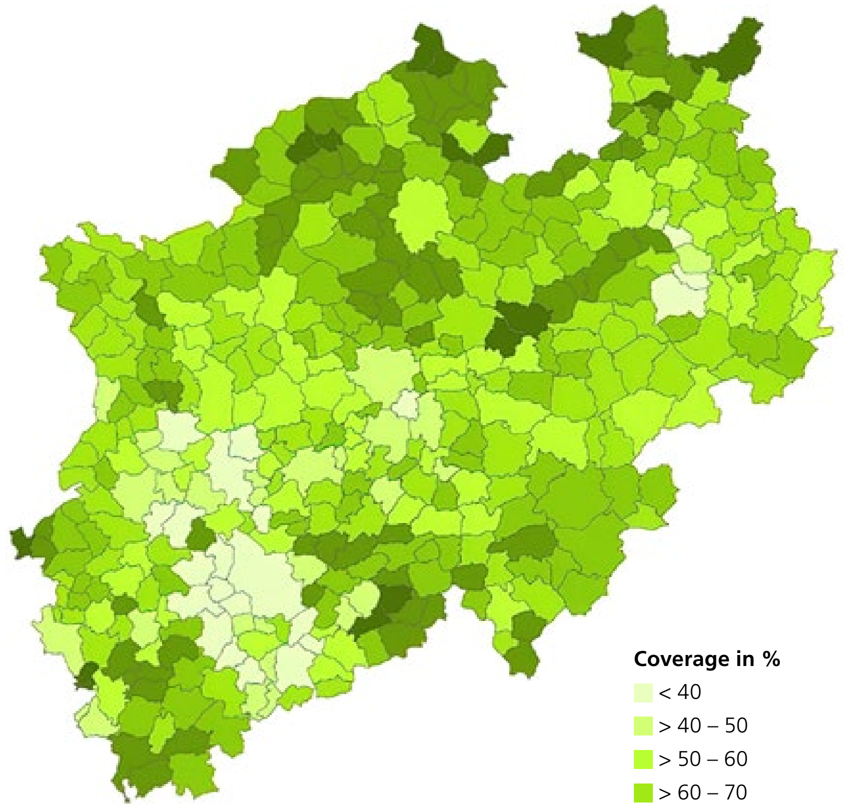


Figure 9: Coverage potentials for ground-source heat pump systems with differences for urban and rural areas using the example of NRW[17]

The building data was compared with the site-specific extraction capacities for geothermal probes (geothermal potential) on the basis of the data sets of the NRW geological service. The site-specific, proportionally developed property was finally offset against the building-specific requirements and the geothermal potential.

Under the assumptions made made, the result is a conservative useful heat demand of 271.1 TWh/a for all heated buildings in NRW. This compares with an actually usable geothermal potential of 141.5 TWh/a from geothermal probes up to 100 m deep (base scenario) in the proportionate open spaces of all developed properties in the federal state.

The survey showed that different building and population densities (large cities vs. rural areas) lead to very different coverage potentials. Large cities (e.g., Cologne, Düsseldorf) have a high heat demand, while at the same time the high building density and the lack of space on the building sites of many inner-city properties limits the necessary number of borehole heat exchangers. This leads to a lower coverage potential. In some rural communities, on the other hand, coverage potentials of over 95% are achieved (with a low heat demand and large land area).

In total, the percentage coverage for the whole of NRW is around 52% (excluding water protection zones I to III). This means that in the basic scenario more than half of all buildings could be covered by near-surface geothermal energy.[18]

On the basis of the restrictions, simplifications and assumptions made in the LANUV Technical Report 40/4, basic assumptions can be developed and different expansion

Coverage ratio of near-surface geothermal energy (%)

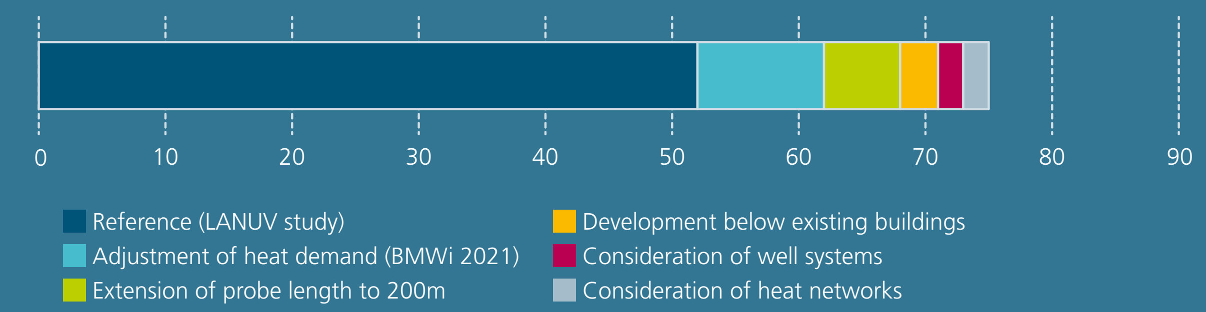


Figure 10: Variant analysis of the coverage ratio (own representation)

17 Landesamt für Natur, Umwelt und Verbraucherschutz NRW LANUV-Fachbericht 40 (2015): Potenzialstudie Erneuerbare Energien NRW Teil 4 – Geothermie, 78 S.; Autoren: Bracke, R.; Rocholl, W.; Schmidt, B.; Bussmann, B.; Eicker, T.; Kelz, B.

18 Ibid

options can be calculated which reflect the state of the art and the resulting additional potentials for increasing the share of geothermal energy.

The calculation of the coverage share of geothermal heat pumps in the report is based on a deliberately conservative assumption of the heat demand of all existing buildings in NRW. This basic assumption can be updated by demand figures of the BMWi from 2021 for the whole of Germany. Based on the number of inhabitants in the individual federal states the total demand was broken down from NRW, whose coverage share for geothermal heat pumps is 65%. This coverage share serves as a base scenario for the further calculations and estimates of this roadmap.

One important expansion option to increase geothermal potential is the extension of the depth of boreholes for geothermal probes from 100 m to 200 m. This can be done, if necessary, in combination with seasonal heat storage systems, and could double the capacity of a geothermal probe. New drilling techniques and inner-city borehole designs make it possible to drill new boreholes in confined spaces, e.g. by drilling at an angle under existing buildings ("Geo-Star" principle). The construction of well facilities in hydro-geologically suitable regions or the expansion of local heating networks, in combination with near-surface geothermal energy systems and heat storage facilities, can be important technology drivers for increasing the coverage share. Figure 10 shows the calculated effects of the various options for the expansion of coverage shares.

Expansion scenarios	Description	Expansion path	Coverage share
Reference scenario	LANUV NRW Technical Report 40, Part 4	Reference	52%
Adaptation of the heat demand to current figures of the BMWi	The reference for the reduction of heat demand for this technical report was calculated very conservatively. Using the population distribution of the federal states, the data of the BMWi was transferred to NRW.	Base scenario	62% (own calculation)
Increase of the average length of geothermal probes	An extension of the probe length from 100 m to 200 m results in an increase of the probe field configuration and efficiency of the heat source by 80% to 110%.	Increase of the share of geothermal energy through supplementary technical development measures	Increase of the coverage share to 68% (own calculations)
Drilling techniques to enlarge the volume of usable subsurface	The amount of usable subsurface in areas with little available ground can be increased through inclined boreholes under existing buildings.		Increase of the coverage share to 71% (own calculations)
Consideration of well systems	Additional consideration of well systems as a heat source that can be used in hydrogeologically favourable regions.		Increase of the coverage share to 73% (estimation)
New construction of (low temperature) heat networks	Additional consideration of (low-temperature) heat networks with geothermal source plants. Buildings and heat source systems do not have to be located on the same plot of land.		Increase in the coverage share to 75% (estimation)

Table 1: Overview of technical options for increasing the coverage potential of ground-source heat pumps using Near-Surface Geothermal Energy. (Own representation)

Potential for geothermal heat pumps in Germany

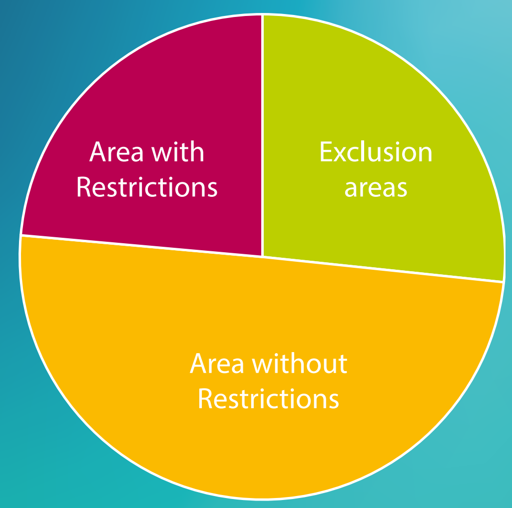
The potentials identified can be transferred to the whole of Germany as a rough approximation, although there are differences between the geological conditions of individual federal states and the potential for near-surface geothermal use, as well as the building density and the proportion of restriction areas. However, the over 50% of the state area in NRW represents a conservative approach that can be rolled out on average across the entire Federal Republic of Germany (see info box).

Depending on the additional technical development measures, this results in a basic technical and feasible **coverage rate for the whole of Germany of up to 75%.**

For Germany as a whole, this results in a potential of up to 600 TWh per year to cover the useful heat demand (heating and hot water) using geothermal heat pumps. In order to make use of this potential, it is irrelevant whether decentralized heat sources supply individual buildings and units, or whether larger central plants are used to supply local heating networks.

Restriction areas in NRW

According to the North Rhine-Westphalia Geothermal Potential Study, a good half of the state's land is subject to permit conditions. These areas are distributed evenly between exclusion areas (protection zones of water and medicinal spring protection areas and building areas) and restriction areas (drilling depth limits in hydrogeologically critical areas). Only just under 50% of the land is available for unrestricted use (in the sense of the study).



(own representation)

Development of the heat pump market

A large number of studies by various research institutes in recent years have described scenarios of how the stock of heat generators will have to change by 2030 or 2045 / 2050 in order to achieve Germany's climate policy goals. What all publications have in common is that heat pumps play a central role.

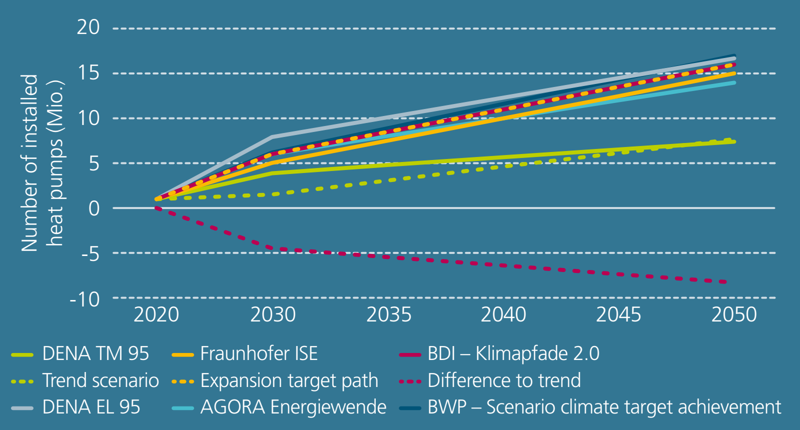


Figure 11: Scenarios for the heat pump stock up to 2050 (own representation)[19]

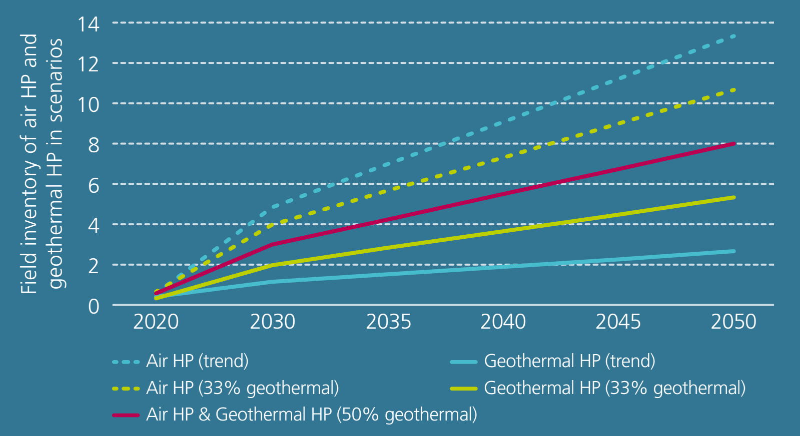


Figure 12: Share of ground-source heat pumps in the future field stock. Scenario Trend: New construction is divided as in the reference year 2021 – 85% air-source heat pumps & 15% geothermal heat pumps; Scenario 33% geothermal heat: geothermal heat pumps have a share of 1/3 of the plant stock; Scenario 50% geothermal: equal distribution of the between air HP and geothermal HP (own representation)

The various scenarios, as shown in Figure 11, postulate a target path expansion in heat pumps of 6 million in 2030 and 16 million by 2050. The most recent publication by Greenpeace (2022) even concludes that by 2035 12 million installed heat pumps will be needed. Comparing these targets with the forecast scenario based on averages between 2016 and 2021, it becomes clear that in just eight years there will be a shortfall of almost 5 million heat pumps and more than 7 million in 2045. The continuation of the current path or making only minor adjustments will therefore not achieve the goal. A successful "Wärmewende" cannot be reached on the current path.

In the studies, heat pumps are partly considered as one system and not differentiated according to the various heat sources (earth, water and air). Agora, Dena and Fraunhofer ISE make contradictory statements in this regard.

Share of ground-source heat pumps of the field inventory (2050)

- 7% to 8% (Fraunhofer ISE)
- 33% to 50% (Dena) (depending on building size and existing / new buildings)
- Over 50% (Agora)[20]

In this context, the consistent expansion of geothermal heat pumps using the potentials described above and the ratio between ground-source and air-source heat pumps will have a direct effect on the entire German energy system.

19 Agora Energiewende: „Klimaneutrales Deutschland" (2021); BDI: „Klimapfade für Deutschland" (2021); dena: „Gebäudestudie – Szenarien für eine marktwirtschaftliche Klima- und Ressourcenschutzpolitik 2050 im Gebäudesektor" (2017); Greenpeace: Heizen ohne Öl und Gas bis 2035 (2022); Fraunhofer ISE: Wege zu einem klimaneutralem Energiesystem 2050 (2020); BWP: Branchenstudie 20211

20 Agora – Wärmewende 2030, 2017

On the basis of various scenarios (Figure 12) regarding the shares of air-source and ground-source heat pumps, and assuming that the necessary expansion targets are met, the following developments can be achieved:

- **Scenario Trend** – Additional capacity is analogous to the capacity and ratios of previous years.
- **Scenario 33% geotherm** – 1/3 of the additional capacity is accounted for by the geothermal heat pumps, 2/3 to air-source heat pumps.
- **Scenario 50% geothermal** – Additional capacity is equally distributed between ground source and air-source heat pumps.

Electricity demand

The electricity demand of air-source heat pumps is higher than that of ground-source heat pumps of the same thermal capacity due to their lower Seasonal Energy Efficiency Rating (SEER). A high proportion of geothermal heat pumps therefore results in lower electricity consumption.

Share of ground-source heat pumps of total stock	5 Mio. HP	10 Mio. HP	15 Mio. HP
20% ground-source heat pumps	31.67	63.33	95.00
33% ground-source heat pumps	30.25	60.50	90.75
50% ground-source heat pumps	29.17	58.33	87.50

Table 2: Electricity demand of heat pumps (TWh/a) – assumption 10 kW output, 20,000 kWh heat, SEER air HP:3, ground HP: 4

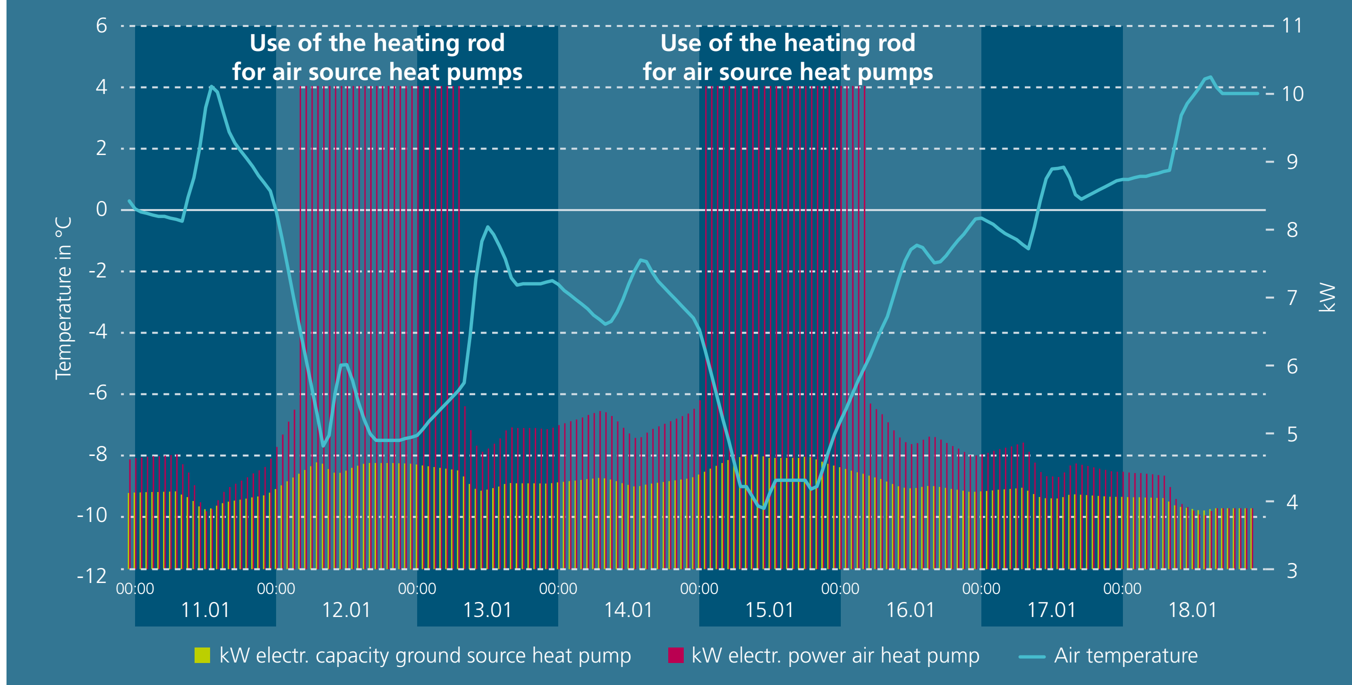


Figure 13: Electrical peak loads for air-source heat pumps due to the use of heating rods (own representation)[21]

21 Own calculations, climate data: Deutscher Wetterdienst TRY (test reference year, location Ruhr area), bivalence point of the air-source heat pump -5°C, Power of the heating element 10kW, power of the heat pumps 20kW

A shift in the coverage share of ground-source heat pumps in the field inventory from 20% to 50% would result in an inventory of 15 million heat pumps, and an annual electricity demand drop by 7.5 TWh. This corresponds to 1.35%[22] of the total gross electricity consumption in Germany in 2020. In addition, geothermal heat pumps reduce the load peaks during cold outdoor temperatures when the efficiency of the air-source heat pump is at its lowest or when electric heating elements have to take over the supply.

CO_2-emissions

The CO_2 emissions associated with the heat pump result from the electrical power required to operate it.

As can be seen from Figures 14 and 15, air-source heat pumps require 33% more electrical energy and therefore generate higher CO_2 emissions.

As a result, by shifting the field inventory from 20% ground-source heat pumps to 50% in 2030, 375,000 tonnes of CO_2 can be saved annually with 5 million heat pumps. While the savings potential decreases over time due to the improved CO_2 emission factor of electricity supply, the potential within the next decade is enormous.

Expansion of low-temperature heating networks

For densely populated urban areas, the heat supply will have to be tied to a heating grid in the future, since local conditions practically rule out renewable alternatives.

For this purpose, geothermal heat pumps can be used to reliably supply renewable heat throughout the entire year via central heat source systems.

Particularly for low-temperature networks of the 4th generation or for bidirectional heating and cooling networks of the 5th generation, cf. Figure 16, near-surface geothermal energy is an excellent source.

Heat conversion in (partially refurbished) old buildings

For a successful "Wärmewende", more and more existing buildings need to be equipped with renewable heating systems. Geothermal heat pumps can also meet the comparatively high flow temperatures of the existing heating systems with radiators efficiently and economically. The goal of building renovation, the reduction of the heating requirement, and geothermal heat pumps complement each other considerably.

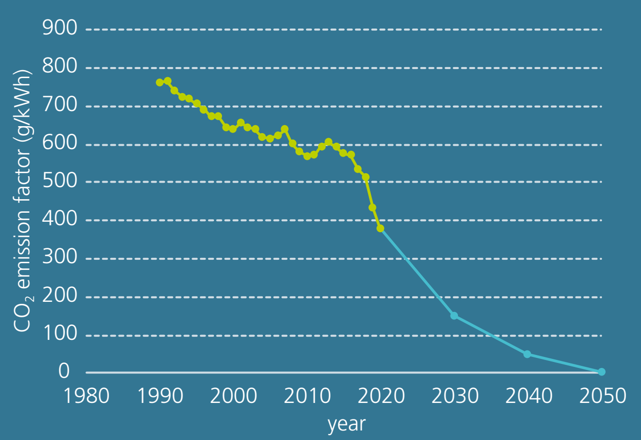


Figure 14: CO_2-emissions of the German electricity supply mix (own representation)[23]

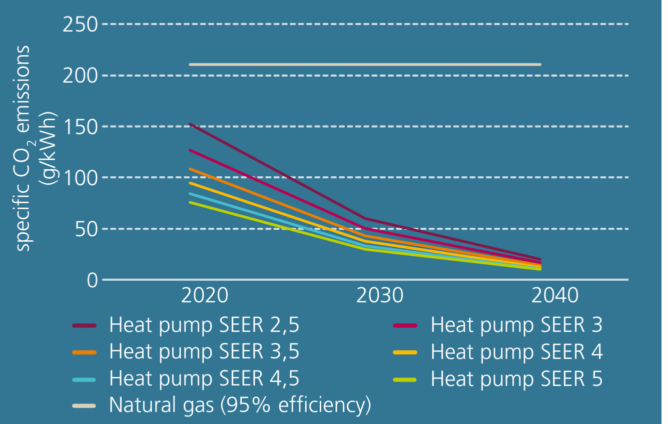


Figure 15: CO_2-emissions of heat pumps as a function of the heat pump efficiency SEER (own representation)[24]

22 UBA (Umweltbundesamt) auf Basis AG Energiebilanzen, Tabelle Bruttostromerzeugung in Deutschland, Stand 12/2021

23 UBA; Prognose ab 2020, Fraunhofer ISE, Wege zu einem klimaneutralem Energiesystem, 2020

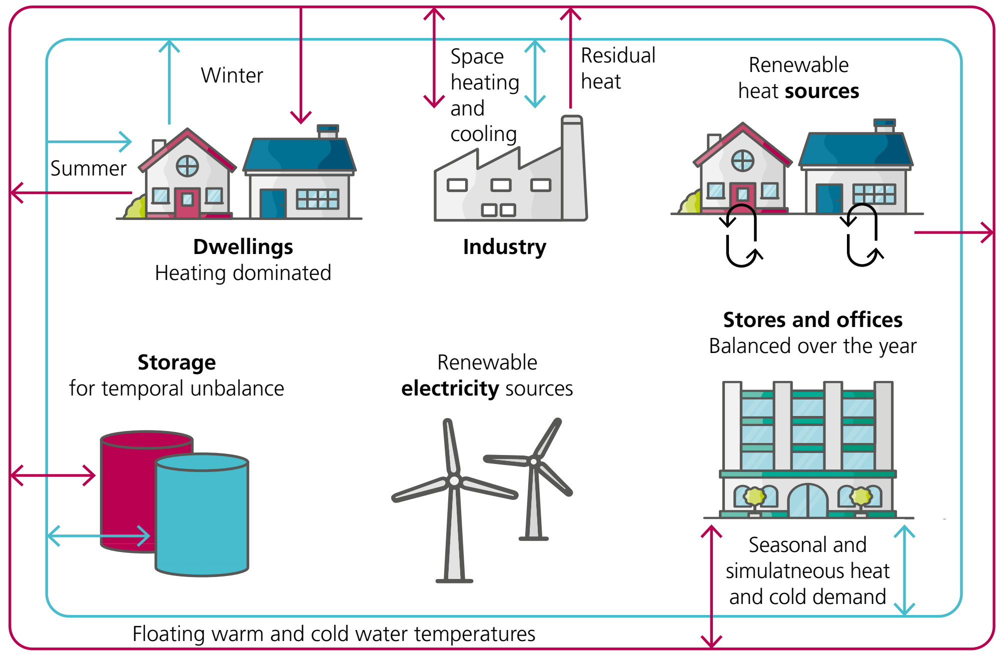


Figure 16: 5th generation heating and cooling network[24]

Cooling

In the current discussion on the "Wärmewende", the current and increasing future cooling requirements for the air-conditioning of residential and non-residential buildings is only marginally discussed. Ground-source heat pumps can provide large parts of this cooling energy extremely efficiently.

In 2005, only about 20 TWh/a of electrical energy was used in Germany for air-conditioning, mainly for room air-conditioning units with electric compressors.[25] Against the backdrop of global warming and the increasing number of extreme weather periods, demand will rise in the future. The prognoses for this range widely, with assumptions from around 60 TWh/a[26] for the year 2030 reaching up to 85% of the heat demand in the year 2050.[27] This would correspond to 340 TWh in Germany.

Assuming that in the year 2030 approx. 25% of the building cooling was achieved via the passive cooling function of geothermal heat pumps (Energy Efficiency Ratio (EER) > 25) instead of using conventional air conditioners (EER ~ 3), this would result in an additional total of 13.2 TWh/a of electricity would be saved and almost 2 million tons less CO_2 would be emitted.

A successful "Wärmewende" requires a determined and rapid change of course. Only with a significant contribution to and rapid expansion of ground-source heat pumps can this be achieved. The contribution to CO_2 savings with simultaneously lower demands on the future power grid are the most important arguments.

Particularly for existing buildings, geothermal heat pumps are the most efficient and scalable system for new heating networks and for combined heating and cooling.

24 Boesten et al. (2019) ergänzt von Vera Eizenhöfer

25 UBA – Klimaschutz durch Reduzierung des Energiebedarfs für Gebäudekühlung, 2011

26 Ibid

27 EMPA (CH): Benchmarking cooling and heating energy demands considering climate change, population growth and cooling device uptake, 2021

Barriers and needs for action

As shown, the necessary target of the expansion to 50% geothermal, with 3 million geothermal heat pumps by 2030 and 8 million systems by 2050, will not be achieved under current market conditions. In order to boost the energy and heat transition, the following measures are necessary in the short and medium term:

Skilled workers and competence development

The capacities and education or training of specialists for all necessary process and work steps in the planning, dimensioning, construction, installation and approval of geothermal heat pump systems are indispensable.

HVAC trade

There are currently just under 400,000 employees in HVAC (heating, ventilation, and air conditioning) sector in Germany.[28] Like many other areas of trade, the sector is acutely affected by a shortage of skilled workers. While in 2020 the sector was already short of 10,000 skilled workers, the gap will rise to a good 30,000 by 2030. Additionally, the requirements of the "Energie- and Wärmewende", such as the installation and maintenance of geothermal heat pump systems, will increase this shortage by a further 20,000 skilled workers.[29] Looking at all skilled trades across society, the HVAC trade is one of those most affected by the shortage of skilled workers.[30]

- In order to fundamentally overcome this shortage, it is essential to implement a (possibly cross-sectoral) skilled workers campaign for trades.

The dual training program to become a plant mechanic for ventilation, heating and air conditioning technology in Germany is still focused on fossil heating systems. Training content for sustainable, electricity-based heat supply options, such as geothermal heat pumps, is significantly underrepresented.[31]

- There needs to be greater integration of sustainable heat supply options into the dual training. HVAC mechanics must be made fit for the "Energiewende".
- Offers for further training and qualification of the 400,000 skilled tradespeople in the HVAC trade must be expanded and strengthened. The training courses should be based on VDI Guideline 4645.
- Further education must be anchored in federal law in order to motivate the skilled tradesmen sufficiently.

The Drilling Industry

The accelerated expansion of geothermal heat pump systems requires the drilling companies to expand their capacities to work; an increase in the number of installed systems leads directly to an increase in the amount of drilling needed. Thus 200,000 additional geothermal heat pumps per year require more than 40 million additional meters of drilling per year, i.e. at least 2500 additional drilling rigs with at least 6250 skilled operators must be available.[32]

Already today, the drilling companies operating on the market are working to full capacity, with waiting times for clients average several months. At the same time only 36 apprentices have successfully completed the examination to become a well driller in the year 2020.[33] In addition to the general lack of demand among young people for apprenticeships, structural deficits make it difficult to increase the number of graduates. The only inter-company training centre is located in Bad Zwischenahn (Lower Saxony), and is time-consuming for trainees to attend.

28 Zentralverband Sanitär Heizung Klima, 2022
29 Prognos im Auftrag des VdZ – Spitzenverband der Gebäudetechnik: Fachkräftebedarf für die Energiewende in Gebäuden, 2018
30 Kompetenzzentrum Fachkräftesicherung (KOFA), Fachkräfteengpässe in Unternehmen – Fachkräftemangel und Nachwuchsqualifizierung im Handwerk, 2021
31 Kultusministerkonferenz: Rahmenlehrplan für den Ausbildungsberuf Anlagenmechaniker für Sanitär-, Heizungs- und Klimatechnik und Anlagenmechanikerin für Sanitär-, Heizungs- und Klimatechnik, 2016
32 Own calculation assuming that each drilling rig requires an average of 2.5 skilled workers, who can drill a total of 15,000 meters of annually
33 Bibb DAZUBI: Datenblatt Brunnenbauer/-in, 10/2021

The training of skilled workers in the ventilation, heating and air-conditioning trade needs a focus on the heat transition. In the drilling trade, there is a need for more intercompany training, easier lateral entry and further development of the content of training curricula.

Alternatively, it is possible to undertake advanced training as a "specialist for geothermal purposes and the installation of closed heat transfer systems" as a career change on the job at drilling companies. The entry requirements, which differ partially in each federal state, are unnecessarily hindering. Adjusting the entry requirements is possible without a loss of quality.

- There must be an expansion, decentralization and strengthening of the inter-company training centres. In the long term, further training centres must be established in the south, west and east of Germany.
- Facilitation and nationwide standardization of lateral entry must take place immediately in order to attract and develop skilled workers in the short term.
  - Reduction of the minimum age to 18 years
  - A maximum of 2 year's work experience as a prerequisite for access, or direct access for relevant training occupations.

Analogous to the HVAC trade, the training regulations for well drilling do not sufficiently reflect the knowledge required for the construction of boreholes for geothermal applications. Adapting regulations to the requirements of the "Energiewende" is therefore urgently needed.

- Adaptation of the curriculum for well builders with regard to renewable energies; geothermal aspects have to become the focus of the curricula.[34]

Furthermore, as part of quality assurance, drilling companies must have certification in accordance with DVGW W120[35].

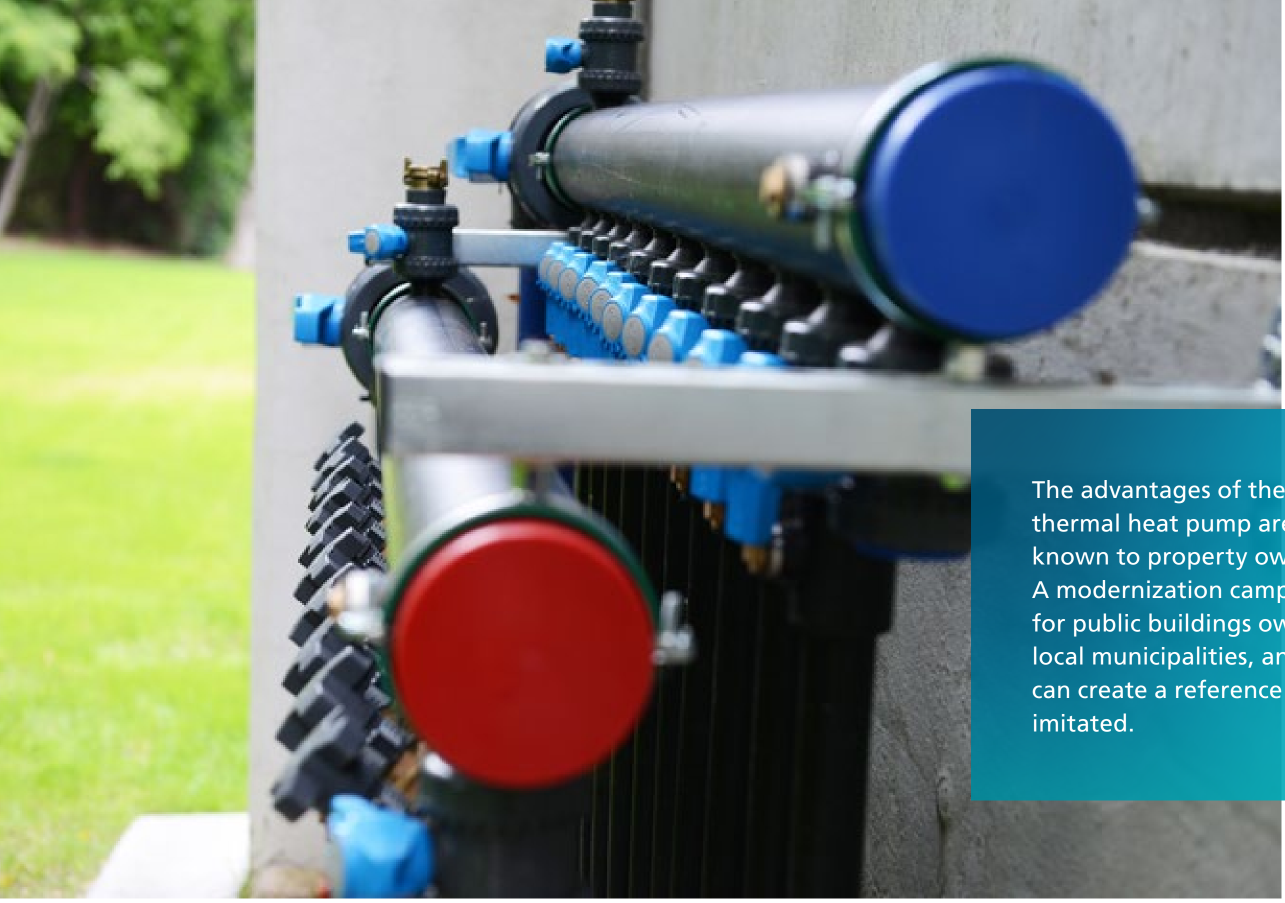
This sensible quality assurance measure makes it more difficult to access the German market for foreign companies within the EU.

- Strengthening the EU internal market for foreign drilling companies. Therefore, preparation of a uniform positive list of foreign qualifications and certifications that are equivalent to DVGW W120 certification should be made.

Furthermore, in order to strengthen the two trades (heat pump installation and borehole drilling) the following must be implemented:

- The introduction of monetary support for the training e.g. through the introduction of a training bonus.
- Targeted approach and motivation of immigrants.

34 Kultusministerkonferenz: Rahmenlehrpläne für die Berufsausbildung in der Bauwirtschaft, 1999
35 DVGW-Arbeitsblatt W-120



The advantages of the geothermal heat pump are not yet known to property owners. A modernization campaign for public buildings owned by local municipalities, and states can create a reference to be imitated.

Approval authorities

The construction of a geothermal well, a geothermal probe or a well system requires a permit from the responsible approval authority. Already today the approval process can lead to delays of up to 6 months.

- A forward-looking adjustment of the staffing plans in the licensing approval authorities must be made. The designated positions must be filled in full.
- In order to guarantee the technical quality on the part of the licensing authorities, there is a need to define the competence requirements for the job holders and suitable further training courses.

Planning area

Geothermal heat pump systems with larger capacities or combined heating and cooling loads must be dimensioned by professionally qualified planning and engineering offices. In order to familiarize the market players with the specific features, differences and planning principles, appropriate further training courses must be created to a sufficient level. Up to now, there have been individual offers, but which are not sufficient in their quantity.

- Creation and establishment of training programs for planning offices that will enable them to dimension and plan ground heat pump systems in the future.

Economic aspects

The decision for the use of geothermal heat pump systems instead of fossil fuel heat generators is always economic. Compared to gas condensing, the investment costs, especially for the development of the heat source, are higher, while the operating costs are lower. Current price developments for natural gas and electricity are beneficial for the heat pump. To compensate for the higher investment costs, heat pumps are subsidized in Germany by the so-called Federal Subsidy for Efficient Buildings (BEG – Bundesförderung für effiziente Gebäude). The scope of the current subsidy (35% to 50% subsidy of the total investment costs) is generally considered to be sufficient. In order to avoid delaying planned investments, it is advisable to reliably fix the subsidy for a longer period of time.

The operating costs of the heat pump will be reduced by the change of German legislation abolition of the so-called EEG surcharge as of 01.07.2022. Thus, an old demand of the interest federations is now fulfilled.[36]

In order to permanently force the conversion to an electricity-based heating system, the purchase price of heat pump electricity should be further reduced.

- Immediate adjustment of the existing subsidy system. No further subsidies for fossil gas condensing boilers. Clear focus on renewable heating systems.

36 BMWK: Gesetz zur Absenkung der Kostenbelastung durch die EEG-Umlage und zur Weitergabe dieser Absenkung an die Letztverbraucher, 2022

- Establishment of a funding framework that is reliable in the long term. Reliability promotes investment decisions today and accelerates the heat transition.
- Reduce the electrical energy price for heat pumps. A reduction or exemption in value-added tax reliably ensures economic efficiency and promotes the conversion of heating systems.

Regulatory framework

The “Wärmewende” in Germany must be supported by regulatory measures. Appropriate restrictive measures against fossil-fuel heating systems will inevitably promote renewable alternatives. The success of the “Wärmewende” and the further expansion of ground-source heat pump systems therefore requires:

- A ban on the installation of fossil heating systems. Positive experiences have already been made in Denmark and the Netherlands.[37] The announcement that, from 2024, 65% of new heating systems are to use renewable energy sources is a step in the right direction.[38] It is important to implement a complete ban well before 2045.
- In addition, a roadmap is needed for the mandatory replacement of existing fossil-fuel heating systems. This must be announced at an early stage, and if necessary also supported monetarily.
- The CO_2 price introduced in Germany (also in view against the current backdrop of the turmoil on the energy market) should be systematically pursued as a regulatory control instrument.

Awareness raising and reference projects

Reference projects make the great opportunities known offered by ground-source heat pump systems to the general public. In order to achieve this goal:

- It is necessary to implement an extensive information campaign for consumers and suppliers (e.g. through consumer advice centres or energy consultants).
- A public buildings modernization campaign is needed. Public buildings at all administrative levels can serve as reference objects for the German real estate stock. This is in line with the various initiatives of the federal and state governments for a climate-neutral administration by 2030.[39]
- A “Geothermal heat pumps for the housing industry” initiative should be implemented. Existing buildings are still only hesitantly being converted to renewable heating systems. Geothermal heat pumps offer a wider range of options. With the German housing associations, a large real estate portfolio can be addressed. An initiative is necessary as a start-up aid.

Comprehensive data bases and implementation-oriented approval processes

For the planning and dimensioning of ground-source heat pump systems, individual German states provide comprehensive, map-based data. Approval for the installation of heat pump systems is currently limited by the alleged conflict with the water resources law, which seeks to protect groundwater as a resource. There is a lack of comprehensible and nationally uniform interpretations of the legal framework, which sufficiently acknowledge climate protection concerns. In order to achieve an extensive expansion for the “Wärmewende”, it is necessary to expand the existing database and to design approval process, including the designation of restriction areas, in a transparent, uniform and goal-oriented manner:

- Climate protection must be just as prominently represented as water protection. Water protection and geothermal plants are not mutually exclusive. Real danger to groundwater from the operation of geothermal probes is very low.
- Federal states must rethink and revise their general restrictions, with the guiding principles being implementation orientation, technical innovations and further developments.
- There should be a standardized approval process for all federal states in order to ensure reliability, planning certainty and transparent requirements for the companies and builders involved. The aim must be to establish uniform, legally secure guidelines for the approval authorities in order to avoid divergent decisions in individual cases and to enable prompt approval procedures.
- The licensing requirement for geothermal heat pumps with a heating capacity of up to 30 kilowatts in geologically and hydro-geologically uncritical areas (standard case) should be replaced by a notification requirement.

37 Agentur für Erneuerbare Energien und Fraunhofer IEE: Kommunale Wärmewende

38 Ergebnis des Koalitionsausschusses vom 23. März 2022: Maßnahmenpaket des Bundes zum Umgang mit den hohen Energiekosten

39 U.a. BMUV, MUKE BW, KNLV NRW

The federal states are to review their general and far-reaching restrictions that inhibit the use of geothermal heat pumps. Permits must be issued based on transparent criteria, reliable and prompt. In particular, the supposed contradiction of water protection and geothermal energy does not correspond to the state of the art.

- The long-term operation of geothermal heat pumps must not be made more difficult. Long-term or unlimited approval must be the rule.
- Existing restrictions, e.g. those imposed by the “Site Selection legislation” (StandAG) or the obligations arising from the so-called “Ordinance on Installations for the Handling of Substances (AwSV)”, must be critically examined with regard to their inhibiting effect.
- The scope of the existing data must be further developed. Analogous to the certification of the DVGW Code of Practice W 120-2, this data must be made available up to a depth of 200 m in the short term and up to 400 m in the medium term.

Municipal heat planning

The big potential of the geothermal heat pump requires an intersection of the respective heat potential and the respective heat requirements, including the planning of development concepts. Municipal heat plans are the instrument for determining a development path in a targeted manner.

- Implementation and legal anchoring of municipal heat planning throughout Germany.
- Designation of priority areas for the use of geothermal heat pumps. This should be coupled with the obligation to notify instead of the obligation to obtain a permit (see above).
- Integration of thermal management plans for the subsurface to enable optimized heat utilization.

“We will advocate for comprehensive municipal heating planning and the expansion of heating networks. We aim to achieve a very high share of renewable energies in heating and want to generate 50 percent of heat by 2030 in a climate-neutral way.”

Coalition agreement – “Dare more progress” 2021-2025

Research and development

In order to develop further site-specific or occasion-related alternatives and to increase to the potential of 600 TWh/a of regenerative heat, the application options of geothermal heat pumps in other areas must be investigated, demonstrated, and evaluated. E.g. low-temperature heat sources that are only partially geothermal in origin, conventional development technologies with greater depth (-> medium-depth geothermal), solar thermal seasonal heat storage and heat grid systems with integrated heat storage and multiple heat sources.

In order for these options to be pursued successfully, the following topics must be further investigated and addressed by research programs:

- Investigation and potential assessment of other geothermal heat sources, e.g. sewers or surface waters (lakes, rivers, canals).
- Investigation and demonstration of medium-depth geothermal pumping systems (400m-800m depth).
- Creation of legal control approaches to the management of subsurface heat storage and grid-connected heat supply.
- Demonstration sites “Geothermal heat pumps in existing neighbourhoods” with and for the housing industry.
- Smart regulation and control of complex low-temperature networks with multiple heat sources and integrated heat storage systems.

Roadmaps

Roadmaps

Sector	Roadmap for …	Indicator	2025	2030	2040+
Politics	Expansion targets (number of installed geothermal heat pumps)	Quantity		3 million	6 million
	Share of geothermal heat pumps to the total number of heat pumps	Share		50%	50%
	Administration	Approval: simplify and standardize	Drillings up to 400m depth without mining law approval is feasible; simplified and implementation-oriented permit should be established; municipal heat planning anchored in law; water legal permits issued for an unlimited period.	Municipal heat planning established nationwide; in the standard case, the approval of a geothermal heat pump is replaced by a notification	
	Market Incentives	Electricity purchase price for heat pump systems	Charges and taxes of the electricity purchase price for heat pump systems are to be reduced; large systems are to be subject to the BEW subsidy		
	Regulation	CO_2 pricing; ban fossil heat generators; minimization of restrictions	The expansion of CO_2 pricing as a guiding measure; the prohibition of fossil heat generators in new construction; revise wide-ranging, undifferentiated restrictions	Complete revision of wide-ranging, undifferentiated restrictions; prohibition of new installation of fossil heat generators in existing buildings	Complete phase-out of fossil heat generation
Market	Housing economy/ Real estate economy	Project implementation	Numerous showcases in existing quarters		
	Building-Stock	Demonstrator "Geothermal heat pumps in existing quarters"	5% of stock converted to geothermal pumps	20% of stock converted to geothermal heat pumps	40% stock converted to geothermal heat pump
	Heat and Cooling grids	Expansion of low-ex local heating grids based on geothermal heat	Further develop business and operator models, establish management and usage of public spaces		

Sector	Roadmap for …	Indicator	2025	2030	2040+
Capacity & acceptance	Technology	Building up drilling capacities	List of foreign drilling companies who can access the EU internal market	> 1,000 additional drilling rigs	> 2,000 additional drilling rigs
	Professionals	Specialists for drilling companies	Facilitated lateral entry, retraining, training premium	> 2,500 persons; additional inter-company training centres decentralized in Germany	> 6,000 persons
		Professionals for authorities	Filling positions, establishing further education programs	Expansion of positions	
		Specialists for installation companies	Campaign for further education, training grant		
		Specialists for planning offices	Campaign for BSE specialist and planners		
	Education program	Curricula for manual, technical and academic professions	Adaption of training and training programs to the requirements of the "Wärmewende"		
	Acceptance	Information campaign for consumers and suppliers	Comprehensive information campaign on the advantages and application options of geothermal heat pumps in new and existing buildings		
		Modernization campaign of "Public Buildings"	Geothermal heat pumps are becoming the standard case in the renovation of public administration: climate neutral administration		
Innovation & technology	Potential maps and estimates	Potential assessment of further geothermal low-temperature sources	Model regions	Nationwide coverage	
	Research activities	Research program medium-deep geothermal energy	Investigation and demonstration of medium depth geothermal heat pump systems (~ 400 to 800 m deep)	Medium-depth geothermal energy as standard in inner-city areas established	
		Storage and grids	Regulation and control of complex low-temperature networks with multiple heat sources and integrated heat storage		

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