Fraunhofer ISE

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Agora Energiewende

Heat pumps are the key to climate neutrality in buildings.

Insights from Germany.

JULY 2023, BERLIN

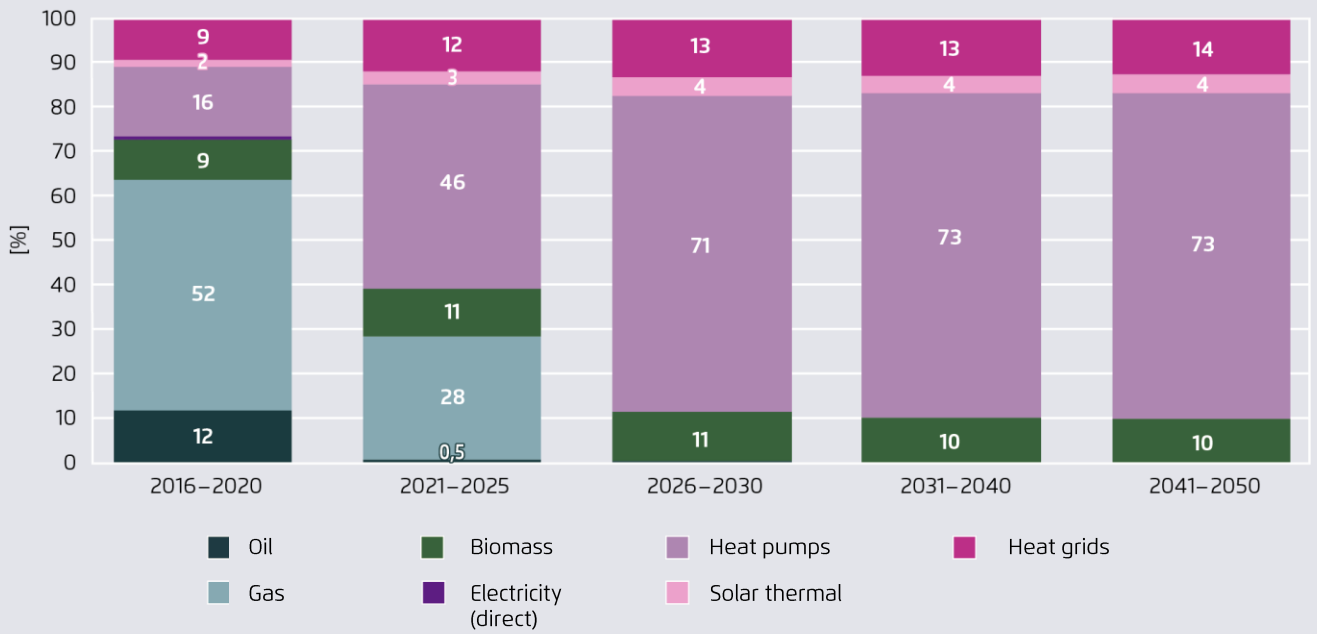
Highlight results

1	Germany aims to reach climate neutrality by 2045. This requires substantial efforts across all sectors. In order to fully decarbonize the buildings sector, scenarios show that about 6 million heat pumps must be installed by 2030. This requires a balanced yet ambitious policy mix.
2	Setting clear targets creates planning certainty for German and European heat pump manufacturers and enables them to invest in new production capacities and business models. This also helps securing European supply chains for this strategic transformation technology.
3	Heat pumps are well suited for existing buildings. They can meet the required heating demand, even in cold winters, and do so at lower operating costs than gas boilers (2022 price ranges). Hybrid heat pumps are usually not a sensible alternative.
4	Additional policy measures to address bottlenecks in installation are needed. This includes strengthening and expanding training programs and disseminating relevant information to key actors, from installers to house owners and energy utilities.

Status quo: The market for heating technologies is dominated by oil and gas boilers

In order to achieve climate neutrality by 2045, around 500,000 heat pumps must be installed annually by 2024.

Market shares of space heating technologies in Germany



Prognos, Öko-Institut, Wuppertal-Institut (2021): Klimaneutrales Deutschland 2045

There are **three key levers** for decarbonizing the buildings sector in Germany:

- → Large-scale roll-out of heat pumps
- → Raising rate & depth of building renovations
- → Climate-friendly heat grids.

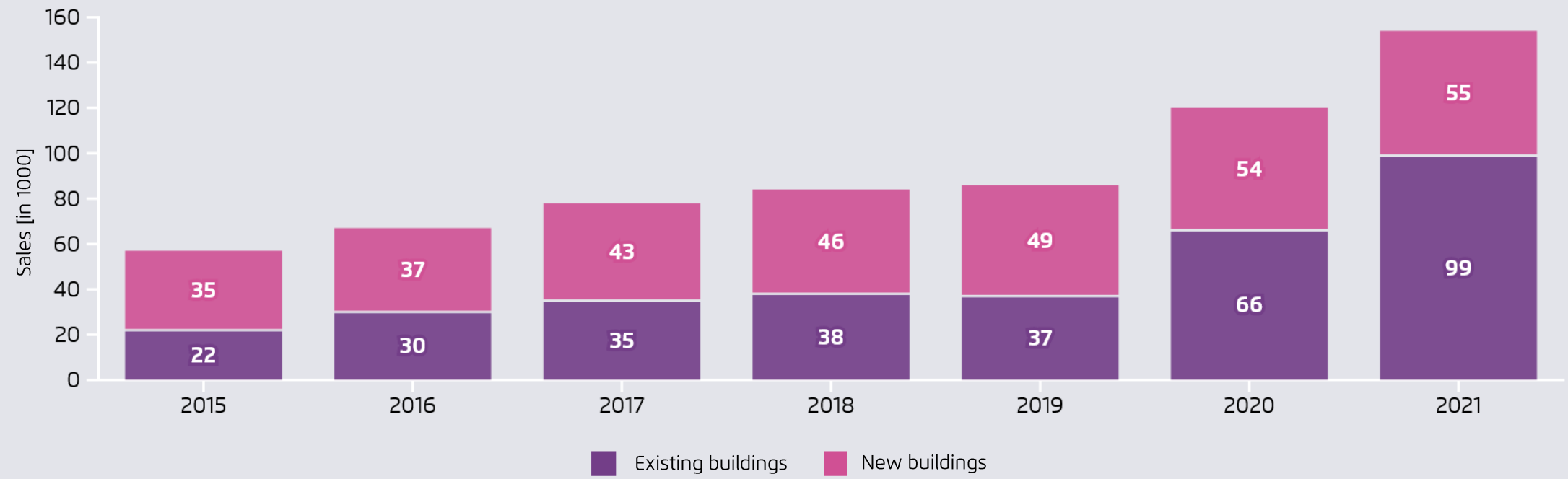
The number of heat pumps needed to reach the 2030 climate target for buildings in the "Big 5" climate neutrality scenarios* is between 3.2 and 6.5 million. The Agora scenario foresees over **6 million** heat pumps in 2030.

At least 500,000 heat pumps need to be installed each year from 2024 onwards. For comparison: in 2022, market sales of heat pumps were around 236,000 units.

*) *„Big 5“: Agora KND2045, Ariadne, Dena KN100, BMWK Langfristszenarien, BDI Klimapfade 2.0*

Accelerating heat pump adoption in existing buildings is key: the past years‘s trends is moving in the right direction.

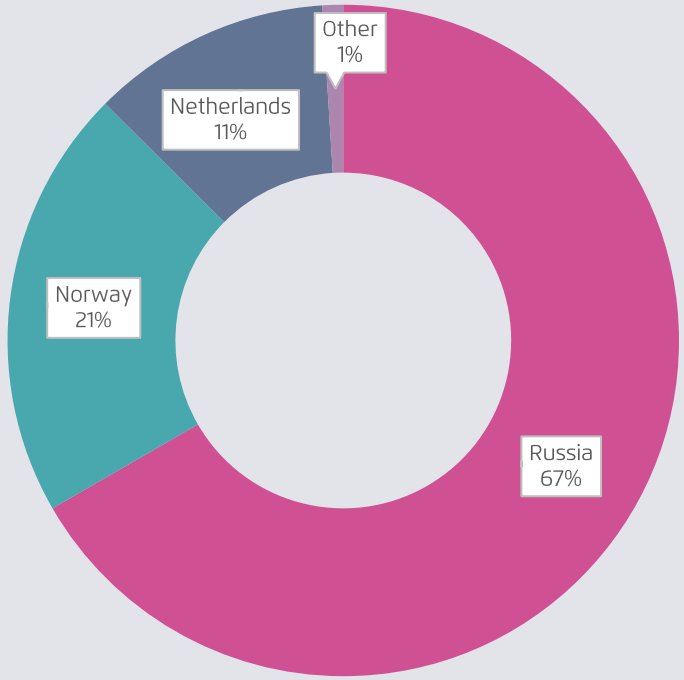
Market sales of heat pumps in new and existing buildings in Germany



Agora Energiewende (2022) based on BWP and Destatis (2022)

Besides climate protection, heat pumps make a significant contribution to energy security.

Countries of origin of gas imports to Germany in 2020

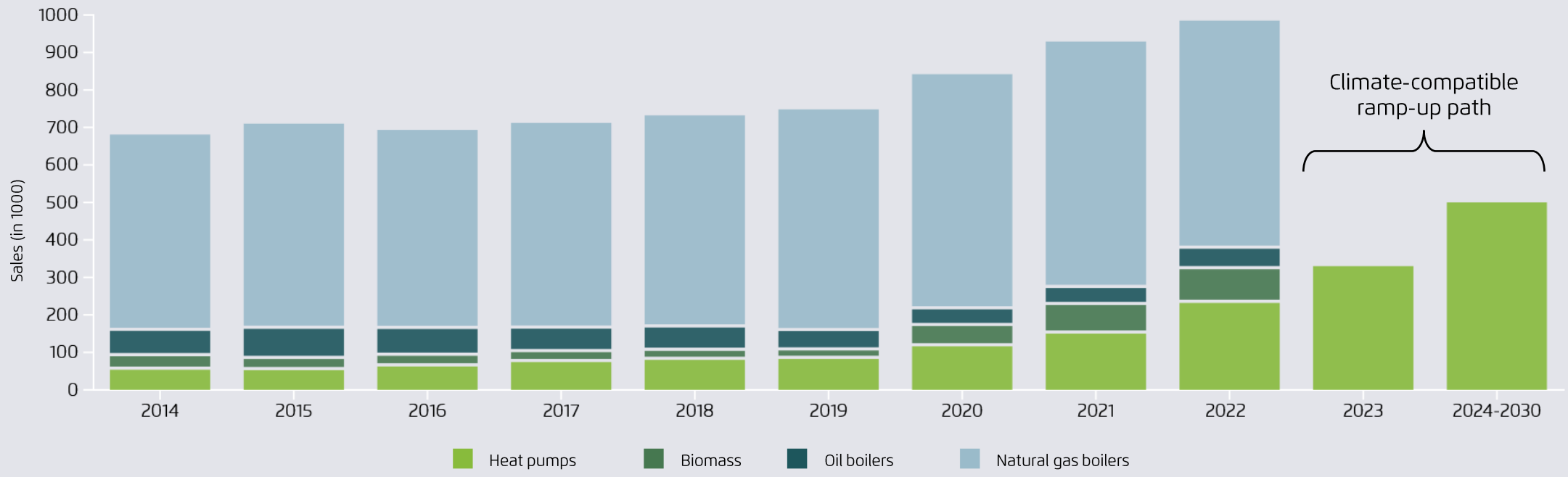


Agora Energiewende, based on data by the Bundesnetzagentur (Monitoringbericht 2021)

- Since most heat pumps are powered by electricity, which is increasingly renewable and locally generated, heat pumps also make an important contribution to more energy independence.
- In 2020, around 2/3 of the gas imports to Germany came from Russia. These imports have been gradually replaced by other origins, but high prices and security of supply remain an issue.
- Gas consumption for heating buildings was around 360 TWh, which makes buildings one of the main consumers of natural gas and thus a key field for policy action.

New oil and gas boilers jeopardise the medium to long-term climate targets and make phase-out regulations necessary.

Sales of decentralized heating technologies in Germany since 2014



Agora Energiewende (2023), based on BWP (2022, 2023) und BDH (2022)

Phase-out regulations in Germany and Europe

The governing parties in Germany pledged to implement an ambitious phase-out regulation for fossil fuel-based boilers, but it was weakened significantly in June 2023.

When the social-democratic (SPD), green (Die Grünen) and liberal (FDP) party agreed to form a coalition in 2021, they pledged to implement a regulation that would successively phase out fossil fuel-based boilers and thus make a significant contribution towards climate mitigation.

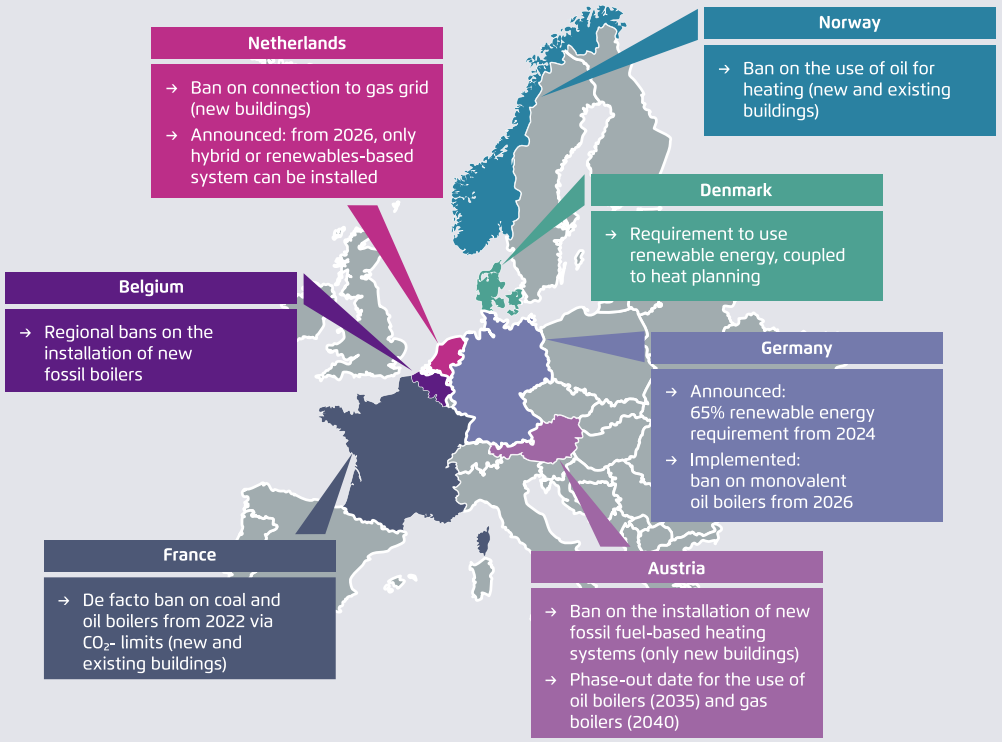
Initial proposal: All new heating systems must be based on at least 65% renewables. This is a de facto ban of new stand-alone oil and gas boilers.

Revised proposal: Only new heating systems in new buildings (in certain areas) must be based on at least 65% renewables. This 65% rule will apply to existing buildings only once a municipal heat plan is in place (due in 2026/2028). Notable exceptions for hydrogen and biomass are in place. Uncertainties remain.

The revised 65%-rule means that climate targets for the buildings sector will almost certainly be missed. Homeowners' investment decisions are subject to substantial cost risks, esp. concerning future CO2 and hydrogen prices. Further, market actors (such as heat pump manufacturers, trades, energy suppliers and the housing industry) lack the reliable framework conditions needed to make investments for the transition.

Several European countries have announced or implemented phase-out regulations.

Overview of phase-out regulations in other countries



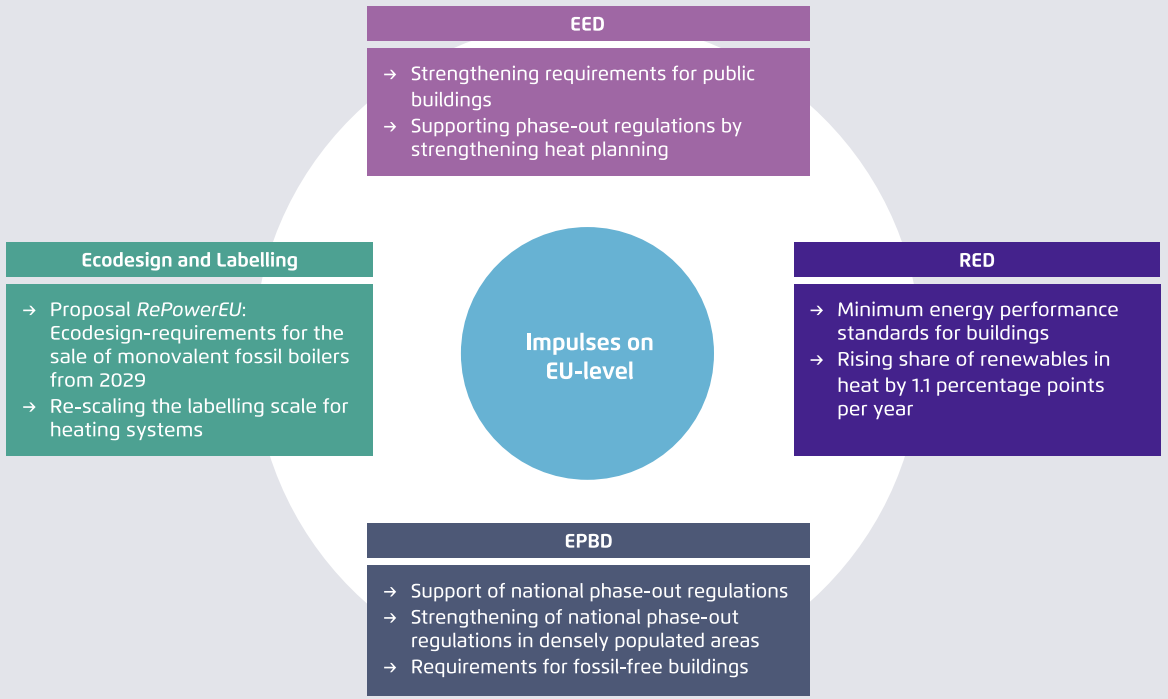
Agora Energiewende based on Öko-Institut (2021)*

- → Many neighbouring countries have already planned or implemented similar regulations restricting the use of fossil fuels for heating.
- → Countries have chosen varying policy designs.
- → Examples: bans on the installation or use of fossil fuel-based boilers, asset-related CO_2 limits or obligations for renewable heat.

* Öko-Institut 2021: Phase-out regulations for fossil fuel boilers at EU and national level

On the EU level, there are several laws or policy initiatives that mandate or facilitate the phase-out of oil and gas boilers.

Impulses for the market transformation at EU level



Agora Energiewende based on Öko-Institut (2021)

- → The **RePowerEU Plan** published in May 2022 provides important impetus for the transformation of the market for heating technologies at EU level.
- → A de facto phase-out of monovalent fossil boilers via the **Ecodesign** regulations for heating systems has been announced and is foreseen to apply from 2029.
- → The implementation of national regulations is explicitly supported by the EU, e.g. in the **EPBD**: the member states may go beyond the EU's minimum standards in their own regulations.
- → With a swift and ambitious implementation of a phase-out regulation, countries can take on a **pioneering role**.

Heat pumps also operate efficiently in existing buildings

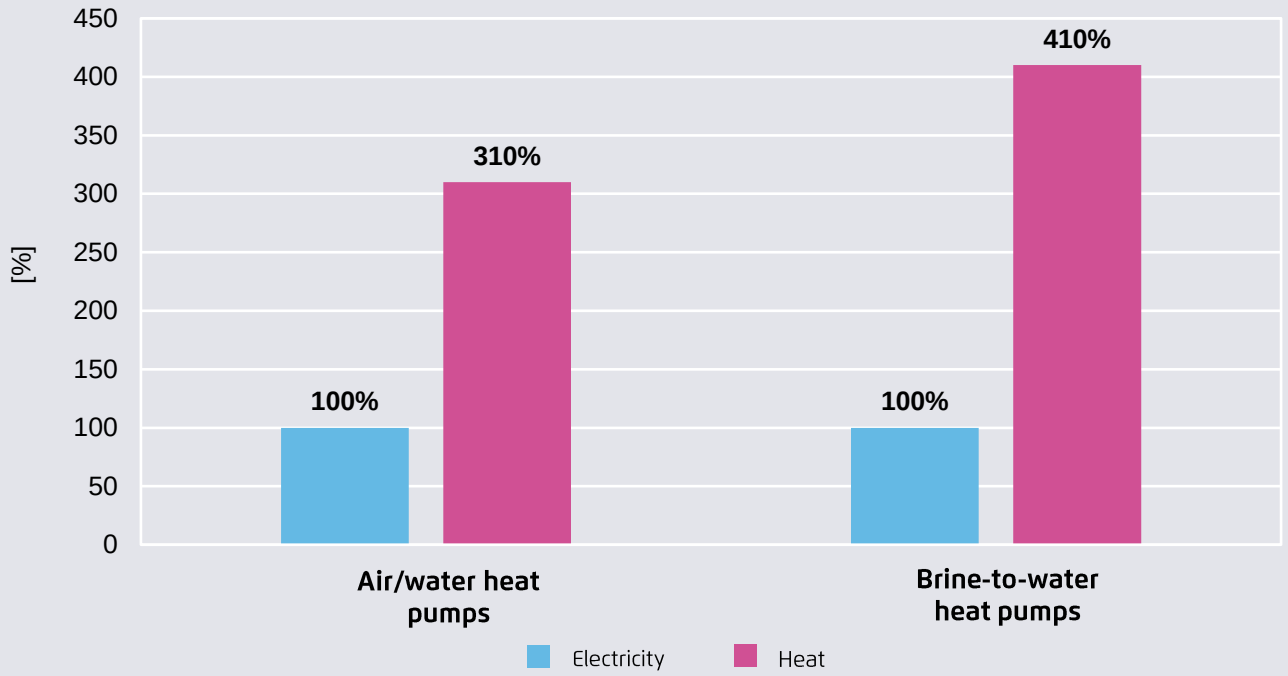
Heat pumps are highly suitable for the existing buildings stock.

Heat pumps not only operate efficiently in new buildings, but also in existing ones.

- From a technical point of view, there are hardly any reasons that speak against the use of heat pumps in the existing buildings stock.
- The heat pump market offers a large number of products that can already meet almost all conceivable requirements.
- The market analysis of the technical status of heat pumps shows that from the customer's point of view there is no reason to wait for further developments and to delay the installation of a heat pump.

Heat pumps achieve good efficiency results in the existing buildings stock. Ground source heat pumps are most efficient.

Average efficiency of heat pump systems in old buildings



Agora Energiewende, based on Fraunhofer ISE (2022)*

- Results from field tests show: Heat pumps also achieve good efficiency values in existing buildings.
- In most cases, heat pumps can work successfully and efficiently, even with "normal" radiators.
- They are able to provide the necessary heat even in very cold winters.
- The average annual efficiency of air-to-water heat pumps from the latest monitoring project of Fraunhofer ISE is 3.1. For brine-to-water (ground source) heat pumps it is 4.1.

* Fraunhofer ISE 2022: "WPsmart im Bestand"

System temperatures in the existing buildings stock: usually no problem for heat pumps.

- **Half of all buildings are suitable** for the use of heat pumps even without renovation measures. Another 20-30% of buildings need only small renovation measures to enable the efficient operation of heat pumps.
- In many older buildings, at least the windows have been replaced since initial construction. Often, therefore, heating systems can already be operated at lower system temperatures: the prevalent **radiators are sufficient** for this.
- With today's heat pump technology, **maximum flow temperatures of up to 75°C** are possible. This makes it technically possible to heat buildings with heat pumps that still require high system temperatures.
- If no or only a few renovation measures have been implemented in a building so far, it generally makes sense to improve the building insulation to lower overall energy consumption and thus expenditures. However, heat pumps can also be installed *before* thermal insulation measures. With inverter technology, a heat pump can run efficiently over a wide performance range. After a renovation, the heat pump simply no longer runs at full capacity on the coldest days.

New buildings segments for heat pumps: The terraced house in a confined area

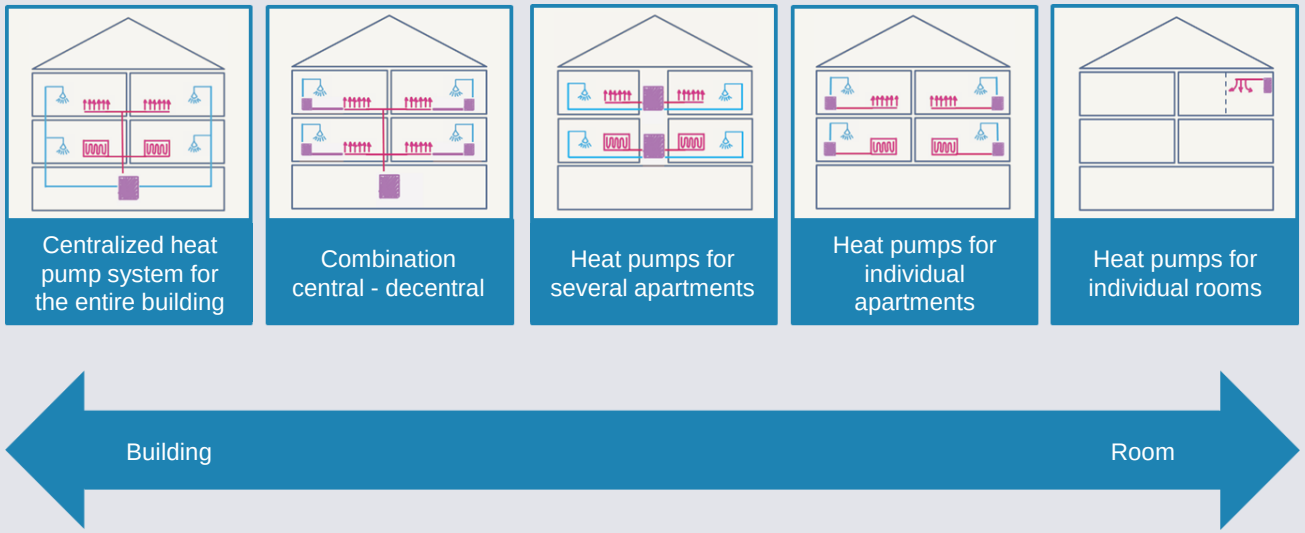
Challenge: Location of the heat pump

- → Geothermal probes must maintain sufficient distance from other boreholes.
- → For air-source heat pumps, excessive noise emissions should be avoided. There are various options for the installation location of air heat pumps (in front of or behind the building, on a flat roof, evaporator instead of a chimney on a gable roof, ...).
- → **Example solution 1:** Central air-to-water heat pump with 7 to 10 kW, erected directly in front of the house with a sound insulation bonnet; optionally combined with a PV thermal solar system.
- → **Example solution 2:** System with several geothermal boreholes and connected (cold) local heating grid for approx. 10 terraced houses, each connected to the network with a brine heat pump (6-8 kW)

Quantity estimate: approx. 5 million terraced houses, with very different construction methods and densities.

New buildings segments for heat pumps: Apartment buildings

Classification of options for apartment buildings



Agora Energiewende, based on Fraunhofer ISE (2022)*

- The use of heat pumps in apartment buildings is possible and has already been demonstrated in various projects in Germany and Europe.
- The diversity of apartment buildings and their characteristics make it possible to apply different technical solutions concerning the installation of heat pumps.
- In the future, it is important to achieve more standardisation.
- A general classification of heat pump solutions for apartment buildings allows an overview of the possibilities.

* Fraunhofer ISE 2022: "Annex 50" (https://heatpumpingtechnologies.org/annex50)

New buildings segments for heat pumps: Apartment buildings with central heating systems in inner-cities

- **Solution 1:** Central air heat pump with approx. 80-90 kW, installed on the flat roof or corresponding brine heat pump with ground probe in the courtyard or wastewater heat exchangers.
- It can be assumed that building owners will stick with central heating. The air-source heat pump is installed on the roof. Domestic hot water is heated either centrally with ultrafiltration or decentrally using instantaneous water heaters or domestic hot water heat pumps.
- **Solution 2:** Conversion to apartment heating. Advantages: the operating cost billing is simplified, pipe losses are reduced and more efficient decentralised domestic hot water heating is enabled. The decentralized heat pump can be installed within a few days during a vacancy.

Examples: IEA Technology Collaboration Programme
(https://heatpumpingtechnologies.org)

Quantity estimate: 600,000 buildings.
Of the approx. 3 million apartment buildings with up to 12 residential units, about 60% are equipped with central heating, 20% with apartment heating (usually gas boilers). It is estimated that one third of the MFH are located in inner-city developments.

New buildings segments for heat pumps: Large apartment buildings with gas boilers for each floor

- **Solution 1:** Central heat source, e.g. 3x50 kW air-water heat pumps on the roof, connection of the apartments by means of cold heat grid and brine heat pumps (approx. 5-7 kW).
- Alternatively, a commercial waste heat source or a nearby body of water could be considered as a heat source. A local heat grid supplies the apartments with approx. 10-40°C water. In the apartments, space heating and hot water are produced by brine heat pumps (approx. 5-7 kW).
- **Solution 2:** Independent air-to-water heat pumps per apartment or floor
- The outside air can be used by placing the air-to-water heat pump as a monobloc in a utility room (per floor or apartment). The supply and exhaust air of the fan is provided via a ventilation grille.

Examples: IEA Technology Collaboration Programme, Annex 50
(https://heatpumpingtechnologies.org/annex50/)

Quantity estimate: 600,000 buildings.
Of the approx. 3 million multi-family houses with up to 12 residential units, about 60% are equipped with central heating, 20% with apartment heating (usually gas boilers).

New buildings segments for heat pumps: Apartment buildings with night storage heating

- There is a choice between converting to a water- or air-based heating distribution system. With water-based systems, underfloor heating can be installed; however, the conversion is complex. Especially for one-room flats, room-by-room installation with air-to-air heat pumps is possible.
- **Solution 1:** Central or apartment-by-apartment conversion to a ventilation system and air-based heat pumps
- **Solution 2:** Water-based heat pump as central source, combined with air-guided apartment systems
- **Solution 3:** Conversion to a water-based piping system, underfloor heating and heat pump

Examples:
- https://www.ehpa.org/fileadmin/user_upload/Renovation_Booklet_Vol_1_2020_online4.pdf
- https://collectivehousing.daikin.eu/en-GB/high-rise

Quantity estimate: Approximately 1 million buildings have night storage heaters. Although these systems are mainly installed in detached and semi-detached houses, the procedure is described here for the more complex case of apartment buildings.

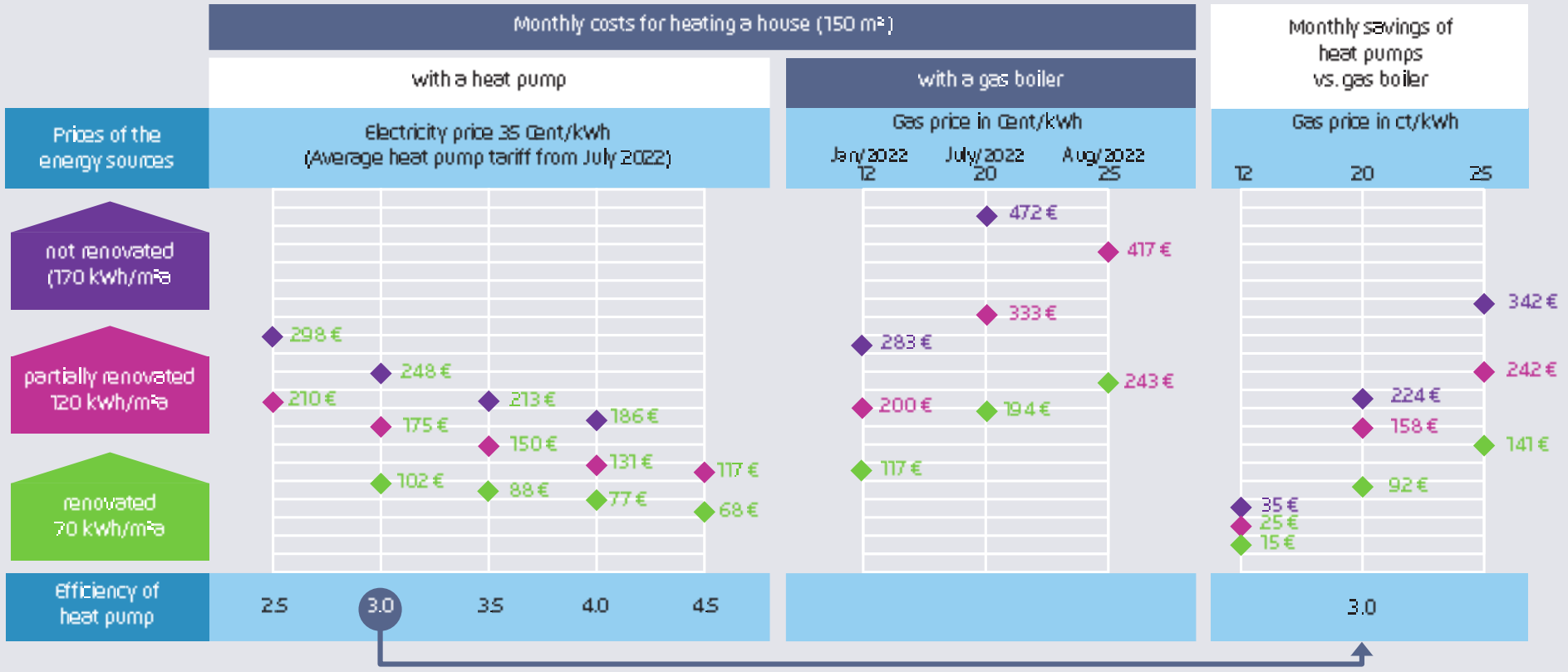
A consumer perspective: Costs and technology choices

The investment costs for heat pumps are high, but there is considerable potential for cost reductions in production and installation.

The investment cost of a heat pump (excluding subsidies) is currently two to three times higher than that of a gas boiler. These high costs are caused by two main factors: production and installation costs.

- **Installation costs** have risen significantly due to a shortage of tradespeople.
- Potential for cost reduction: mainly by shortening installation times. According to statements from manufacturers, halving current installation time (about 3 days with 2 installers) is possible. The way to achieve this: higher component integration and more pre-assembly as well as supporting digital methods.
- Examples from other countries (e.g. novel training models of the British company Octopus) show: new business models can enable significant cost reductions
- **Production costs:** Representatives of the heat pump industry see a realistic cost reduction potential of 40% by 2030.
- Strongly increasing unit numbers enable new production processes as well as economies of scale through increasing modularisation, integration and automation.

The operating costs for heat pumps are lower than those for gas boilers. Policy should ensure that the gas-to-electricity price ratio makes heat pumps the more economical choice.



Fraunhofer ISE (2022)

What are hybrid heat pumps?

So-called hybrid heat pumps are often discussed as an option for use in existing buildings.

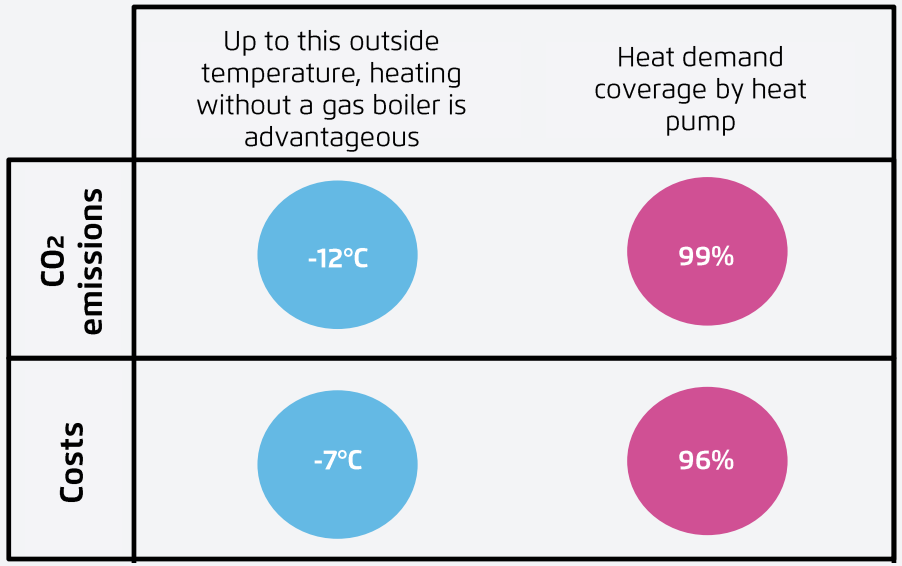
- In contrast to "monovalent" systems (heat pump only) and "monoenergetic" systems (heat pump plus heating rod), a "hybrid system" is a system that uses different energy sources.
- A hybrid system can consist of one unit or several components. Hybrid heat pumps usually consist of a heat pump and a fossil fuel boiler. The two components of a hybrid heat pump should have a common control system.
- The term hybrid heat pump is sometimes also used to describe the combination of a heat pump and a solar system (both thermal and photovoltaic).

The typical hybrid heat pump (heat pump plus gas or oil boiler) is usually of two types:

- A combination of a heat pump (as the primary heat generator) and a small peak boiler.
- A combination of a fossil fuel boiler (as the primary heat generator) and a small heat pump (add-on solution).

Environmental and economic assessment of hybrid heat pumps: Hybrid heat pumps are no advantageous alternative.

- From an **ecological point of view**, heat pumps are able to take over the entire heat supply in unrefurbished old buildings. Above an outside temperature of -12°C it is always more advantageous to heat without a gas boiler.
- From an **economic point of view**, at current energy prices (June 2022), it is cheaper to heat with the heat pump alone up to an outside temperature of -7°C. In this case, the heat pump takes over 96% of heat demand.
- For comparison: The average temperature in Germany in January was 1.7 °C between 1991 and 2020.

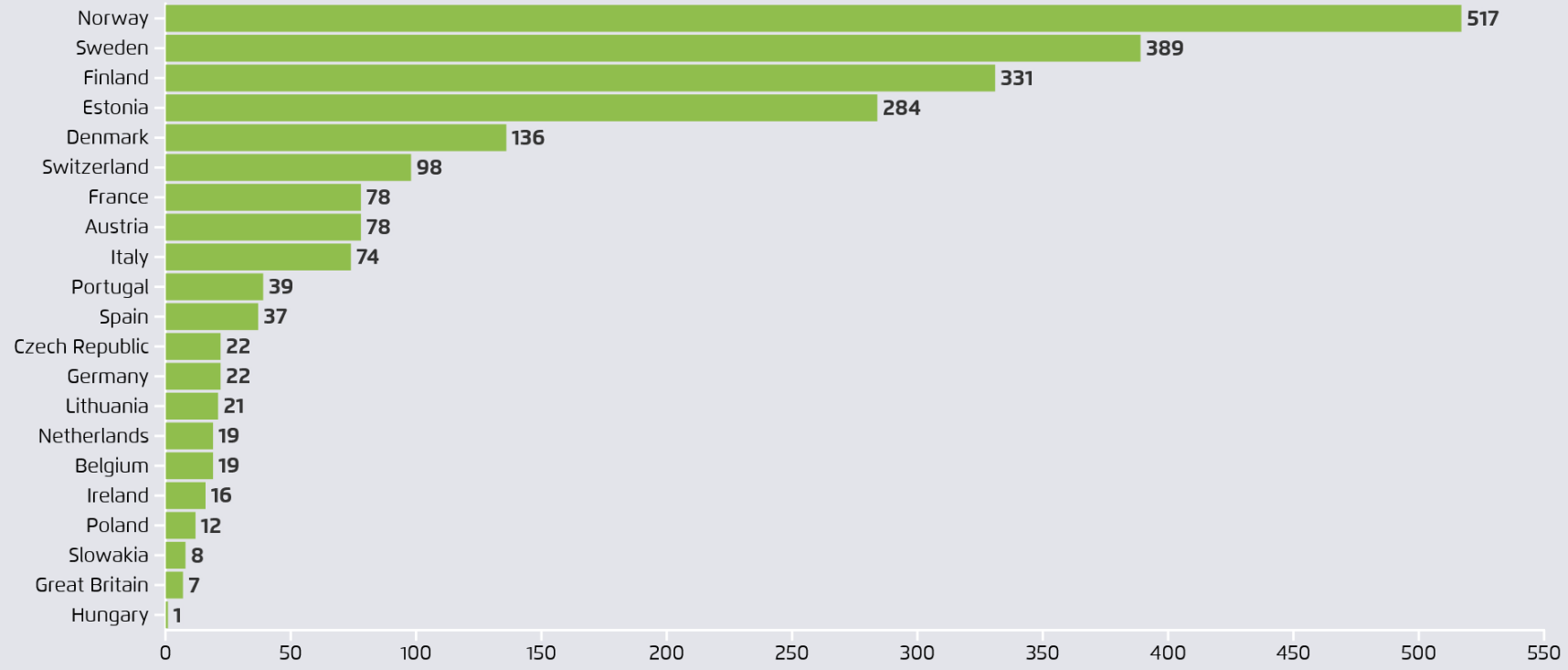


Assumptions:
COP of heat pump A2/W35 3.7
Efficiency of gas boiler: 90%
Radiator, heating curve 0.9 (55°C at -15°C)
Emission factor electricity: 366 g/kWh
Emission factor natural gas + solar: 181 g/kWh
Costs electricity: 35 ct/kWh
Costs natural gas: 15 ct/kWh

Best practices market ramp-up

Several countries show: High penetration of heat pumps is possible – even in cold climates.

Number of installed heat pumps per 1000 households (2021)



Agora Energiewende, based on Orsted und stats.ehpa.org (2021)

Frontrunner Sweden: Tenders helped heat pumps to break through early on and contributed to quality assurance.

Historical development

- Between 1989 and 1995, three tenders were held, supported by various Swedish authorities.
- Today there are about 2 million heat pumps installed in Sweden.
- The market share of heat pumps is over 90%.
- For comparison: in Germany the market share was about 15% in 2021 and 24% in 2022.
- Besides the stimulation of demand: development of heat pump technologies for specific segments as well as quality assurance.

Thee tenders between 1989 and 1995

First tender (1989)

Swedish heat pump association and state agencies: guarantee for 100 units sold, subsidy of SEK 250,000 (EUR 25,000)

Second tender (1991)

Support for four companies in replacement programmes: direct electric heating with heat pumps, SEK 100,000 each

Third tender (1993-1995)

Development of heat pumps with 30% cost reduction and 30% efficiency increase compared to the heat pump technologies at the time

Frontrunner Sweden: Comprehensive support through informing households and promoting research programmes

Extensive activities to **provide information** on heat pumps:

- → In the course of the tenders: supported by good staffing in competent authorities.
- → Information campaigns in the 2000s

Research programmes:

- → First research and development projects funded as early as the 1970s (by Swedish Building and Technology Research Authorities).
- → Testing of heat pumps: extensive activities of the State Metrology Institute since the 1970s
- → Since the 1990s, the Swedish Energy Agency has supported further research and development projects.

Frontrunner Sweden: Training initiative for a well-staffed and competent installation market

Installation process

- Lack of know-how in the installation market was already recognised as a challenge for market development in Sweden in the 1970s.
- Several Swedish heat pump manufacturers focused on forming and training their own installation teams. Professional competence was ensured through training and certification.
- Based on the activities of individual manufacturers, a competent installation market for heat pump installation developed in Sweden.

Frontrunner Sweden: Most of the measures are transferable to Germany. Other countries can benefit from the pioneering work.

Price structure electricity vs. fossil fuels

→ Key driving factor in Sweden; important prerequisite for a successful market ramp-up

Supporting measures

→ Funding programs have a lower priority in Sweden and may have even led to price increases. Here, new support instruments (e.g., tenders) may be helpful.

Tenders

→ In Sweden, the cooperation between industry associations and government agencies has been very successful. In addition to generating demand, the tenders were particularly important for quality assurance.

Information and capacity building

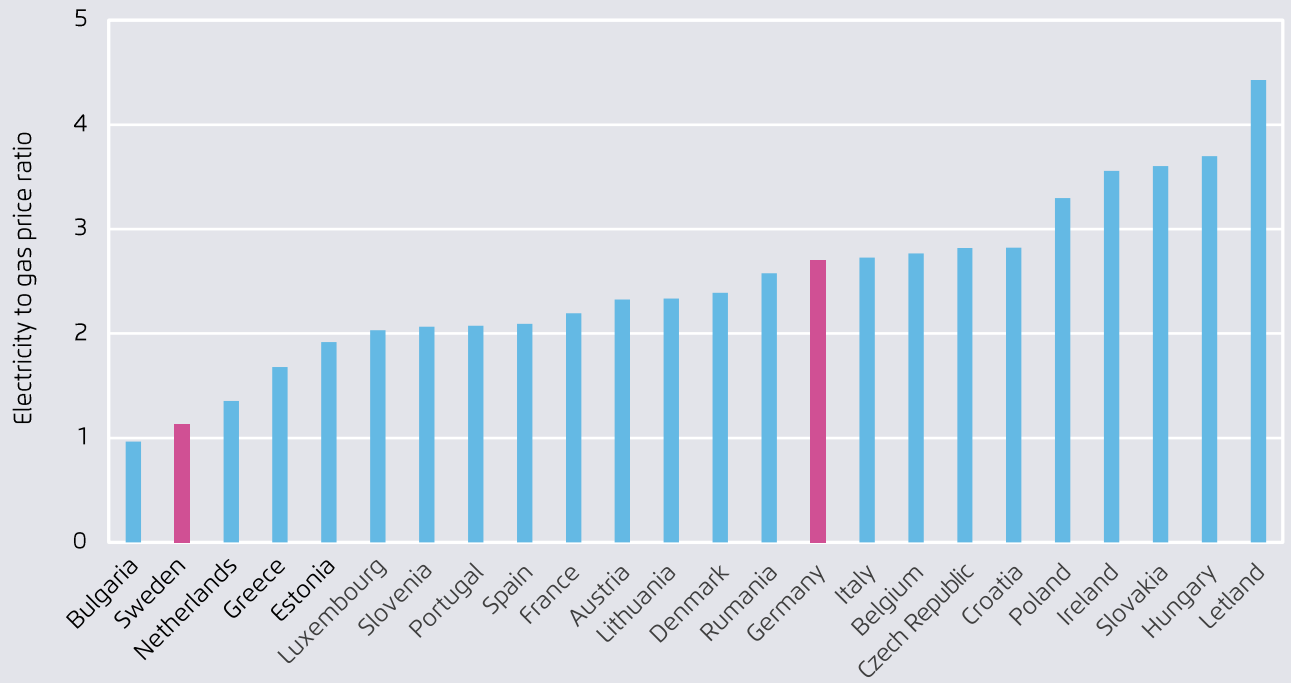
→ Sweden has been a pioneer in this field for several decades. Building on this experience, German market actors can build up competencies much more quickly

Gas infrastructure

→ The fact that there is only a limited developed gas grid in Sweden has facilitated the transition from fossil to renewables-based heat. In Germany, competition from natural gas is stronger due to large-scale grids.

The electricity to gas price ratio in Germany is unfavourable for heat pumps. But, first measures have targeted this, more are planned.

Electricity to gas price ratio
(Q2 2022)



Agora Energiewende based on Eurostat-Daten (2022)

- In Sweden, the favourable relationship between electricity prices and fossil fuel prices makes heat pumps the most economical technology. One reason for this is the CO_2 price: Sweden has one of the **highest CO_2 prices** in the world, at around 120 EUR per t CO_2.
- In Germany the price ratio is less favourable. This is mainly due to the fact that **electricity is comparatively expensive** due to surcharges and taxes. The abolition of the EEG levy improves the price ratio. Additional measures are planned.
- *Note: the figure is based on Eurostat data for household electricity; heat pump tariffs are not taken into account.*

Need for policy action

Reliable framework conditions are the key for the market ramp-up of heat pumps – in Germany and around the world.

- The market ramp-up of heat pumps requires a strong regulatory impulse. Such an instrument, e.g. an ambitious phase-out provision (such as the initial version of the 65%-rule in DE) is key to align the heating market with the climate targets and to break the dependence on fossil fuel imports.
- In view of the usual useful lifetimes of heating systems, it is necessary to establish a clear regulatory framework immediately. With lifetimes of 20-30 years, most of the heating systems installed today jeopardize the 2045 climate neutrality goal.
- The heat pump manufacturing and installation market will also benefit from a clear, swift and ambitious implementation because it will create reliable framework conditions for market actors. After all, the market transformation requires substantial investments.
- At the same time, phase-out provisions have an important signaling effect for other actors: Companies in the energy sector need to develop new business and service models (e.g. in the area of heat pump contracting or district heating expansion) and adapt the electricity distribution grids to accommodate a rising number of heat pumps.

Additional policy instruments are needed to support the transition, including:

- **lowering the electricity price for heat pumps**. In Germany, abolishing the renewable energies act (EEG) surcharge was an important step towards lowering the operating costs of heat pumps. But further steps should follow, such as the German government's proposed exemption of heat pump electricity from the cogeneration law (KWKG) surcharge and offshore grid surcharge; or lowering the electricity tax to the EU minimum rate.
- **examining the legal possibility of obliging electricity suppliers to offer heat pump tariffs nationwide**. Time-variable tariffs could reward the flexibility contribution of heat pumps to the energy system;
- **strengthening training programs**: such as promoting the establishment of regional or municipal competence centers for heat pumps. In addition: financing the working time that installers spend on training courses. Background: For a heat pump training course, installers are not available to their companies for around 2 working days; which means a loss of revenue for the companies.
- **dismantling current regulatory barriers:** such as clarifying the legal question of minimum distances to neighbouring properties, standardizing the treatment of brine heat pumps under the mining law, simplifying approval processes, adapting the drinking water ordinance.

The transformation of the heating market requires fundamental adjustments from all actors involved, from manufacturers to the housing industry.

Manufacturing

- Rapidly expand production capacities for heat pumps, convert existing production lines for fossil fuel boilers to heat pumps.
- Increase the degree of industrialisation of production to reduce labour input
- Develop robust heat pump standard solutions (plug-and-play) that are easy to install and tolerant of installation or design errors (trade-off between robustness, efficiency and cost)
- Faster market diffusion of niche solutions (e.g. for floor heating)

Installation

- Trades: Aligning the product portfolio with the sale, installation and maintenance of heat pumps.
- Training of employees for the design/ planning, installation and maintenance of heat pumps; development of new qualification concepts.
- Potentially, involve new actors (e.g. energy suppliers) in the sale and installation of heat pumps (new sales channels).
- Development of new products, services and markets, e.g. for second-hand boilers, the installation of boilers for the transition time or new contracting offers specifically tailored to heat pumps.

Energy utilities and housing companies

- Adaptation of the electricity distribution networks to the additional loads.
- Upgrading the electricity grids so that the flexibility of the heat pumps can be used for the electricity system.
- Establishing heat pumps as a standard solution in the housing stock of large housing companies

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