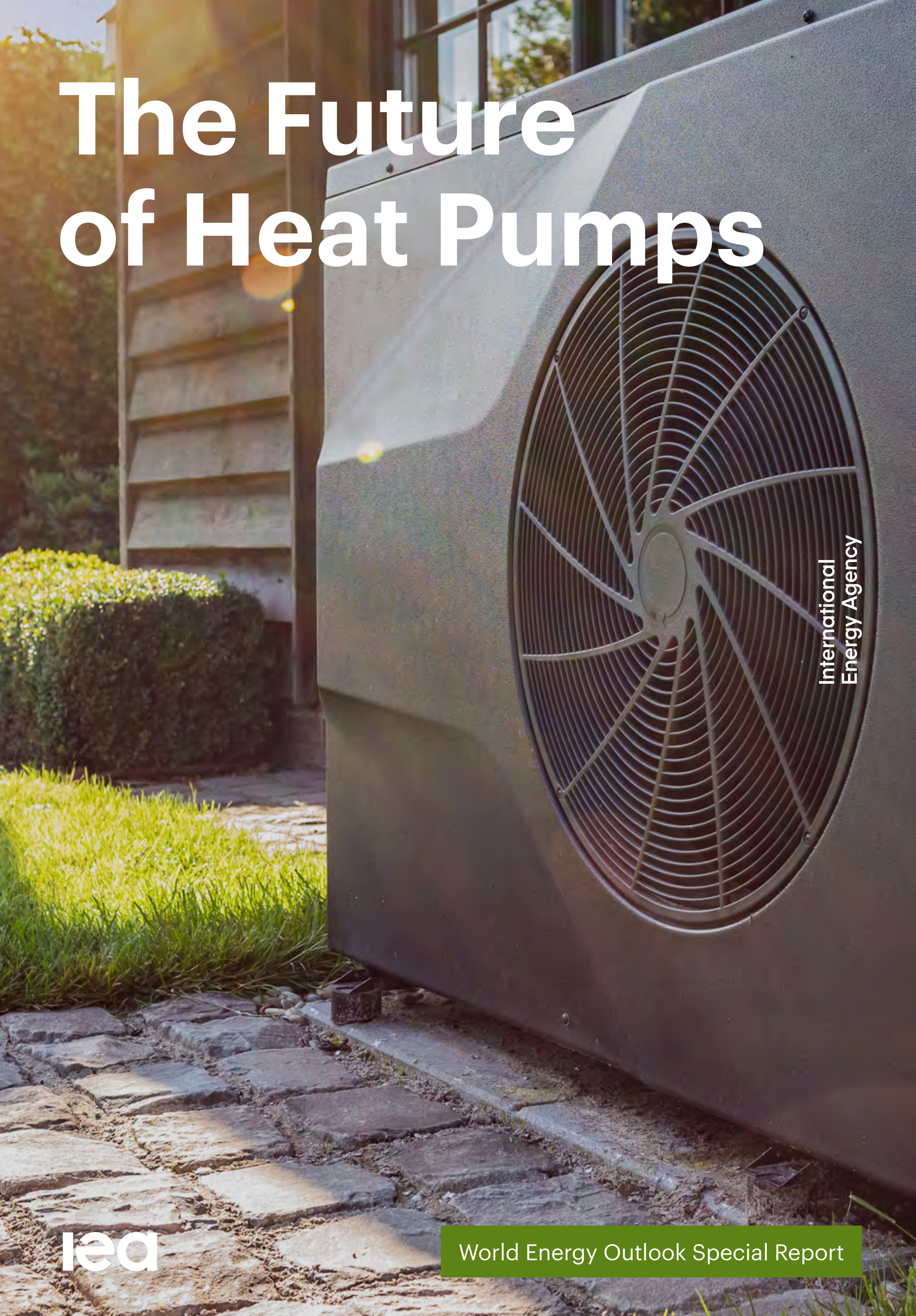
The Future of Heat Pumps



International Energy Agency

World Energy Outlook Special Report

INTERNATIONAL ENERGY AGENCY

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Today, many of the ways we heat buildings around the world – such as homes, offices, schools and factories – still rely largely on fossil fuels, particularly natural gas. It has long been clear that this leads to large amounts of greenhouse gas emissions – and the current global energy crisis is a sharp reminder of the urgency of moving to more affordable, reliable and cleaner ways of heating buildings.

In this context, heat pumps, which can efficiently provide heating to buildings and industry, are *the* key technology to make heating more secure and sustainable. They are quickly becoming more cost competitive, drawing interest from a growing number of governments, businesses and consumers across the globe. Until now, though, there has not been a comprehensive global study of the state of play of heat pumps – and their future role in our energy systems. This *World Energy Outlook* special report aims to fill that gap.

Our in-depth analysis finds that policy plans announced so far by governments globally point to a large expansion of the use of heat pumps, which will have a clear impact on the use of gas, oil and coal for heating. Heat pumps have the potential to reduce global carbon dioxide emissions by at least 500 million tonnes in 2030. For Europe, they are a vital tool to cut reliance on Russian gas, since they can lower Europe's largest source of gas demand – heating in buildings – by at least 21 billion cubic metres in 2030.

However, this special report shows there are key bottlenecks that need addressing to ramp up heat pumps' production and deployment. Government support is essential to help consumers overcome upfront costs and tap into the savings heat pumps provide. This is an urgent priority to shield low-income households from the energy crisis. There is also a lack of workers to install heat pumps, with electricians, technicians and construction workers already among the jobs that companies in Europe and the United States are struggling to fill.

The growing role of heat pumps also requires policy makers to pay careful attention to the electricity security implications. Combining heat pump deployment with energy efficiency retrofits of buildings can reduce these risks, and leveraging smart controls can turn heat pumps into a grid asset, when employed alongside appropriate planning for electricity grids.

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Executive Director
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Heat pumps are a proven way to provide secure and sustainable heating

Heat pumps, powered by low-emissions electricity, are the central technology in the global transition to secure and sustainable heating. Heat pumps currently available on the market are three-to-five times more energy efficient than natural gas boilers. They reduce households' exposure to fossil fuel price spikes, which has been made all the more urgent by the ongoing global energy crisis. Over one-sixth of global natural gas demand is for heating in buildings – in the European Union, this number is one-third. Many heat pumps can provide cooling, too, which eliminates the need for a separate air conditioner for the 2.6 billion people who will live in regions requiring heating and cooling by 2050. Heating in buildings is responsible for 4 gigatonnes (Gt) of CO_2 emissions annually – 10% of global emissions. Installing heat pumps instead of a fossil-fuel-based boilers significantly reduces greenhouse gas emissions in all major heating markets, even with the current electricity generation mix—an advantage that will increase further as electricity systems decarbonise.

Around 10% of space heating needs globally were met by heat pumps in 2021, but the pace of installation is growing rapidly. The share of heat pumps is comparable to that of fuel oil for heating and of other forms of electric heating but lower than the over 40% of heating reliant on gas heating and the 15% reliant on district heating. In some countries, heat pumps are already the largest source of heating. In Norway, 60% of buildings are equipped with heat pumps, with Sweden and Finland at over 40%, undercutting the argument that heat pumps are unsuitable for cold climates. Global sales grew by nearly 15% in 2021, double the average of the last decade. Growth in the European Union was around 35%, and is slated to accelerate further in light of the energy crisis, with sales in the first half of 2022 roughly double over the same period last year in Poland, the Netherlands, Italy and Austria. China continues to be the largest market for new sales, while North America has the largest number of homes with heat pumps today. Together, these regions, along with Japan and Korea, are also major manufacturing hubs, home to the industry's largest players.

Government energy security concerns and climate commitments would make heat pumps become the primary means of decarbonising space and water heating. This report explores a scenario in which governments around the world meet all their announced energy and climate-related commitments in full and on time. As the proven technology of choice to decarbonise heating, global capacity of heat pumps jumps from 1 000 GW in 2021 to nearly 2 600 GW by 2030 in this scenario, boosting their share of total heating needs in buildings from one-tenth to nearly one-fifth. As a result, natural gas demand falls by 80 billion cubic metres (bcm), heating oil drops by 1 million barrels per day, and coal declines by 55 million tonnes of coal equivalent. In aggregate, this means heat pumps account for nearly half of the global reductions in fossil fuel use for heating in buildings by 2030, with the remained coming from other efficiency measures. In a scenario consistent with the global climate target of 1.5 °C, heat pumps accelerate faster – their capacity nearly triples by 2030 and their share in heating reaches one-quarter.

Heat pumps can also address heating needs in industry and district heating. Large heat pumps can provide heat up to 140-160 °C today, with higher temperatures possible through innovation and improved designs. The most common industrial heat pumps today provide lower temperature heat. The paper, food and chemicals industries have the largest near-term opportunities, with nearly 30% of their combined heating needs able to be addressed by heat pumps. In Europe alone, 15 GW of heat pumps could be installed in 3 000 facilities in these three sectors, which have been hit hard by recent rises in natural gas prices.

Heat pumps contribute to cutting gas imports quickly, especially in Europe

The potential for heat pumps to cut dependence on natural gas for heating is particularly large in the European Union, where natural gas is the most used heating fuel and where gas prices have risen the most. In a scenario consistent with the EU's climate ambitions, heat pump sales rise to 7 million by 2030 – up from 2 million in 2021 – helping achieve the REPowerEU objective of ending Russian gas imports well before 2030. This deployment reduces the consumption of natural gas by 7 bcm in 2025 and 21 bcm by 2030, an amount equivalent to almost 15% of EU pipeline imports from Russia in 2021.

Retrofitting buildings in parallel reduces the strain on the power sector

The accelerated deployment of heat pumps inevitably increases global electricity demand, though energy efficiency and demand response measures can greatly reduce the impact on power systems. The share of electricity in heating for buildings and industry rises between 2021 and 2030 to 16% if climate pledges are met, boosting global electricity use by nearly one-quarter. For households that add a heat pump without improving efficiency in parallel, this can nearly triple their peak demand during winter. Improving a home's efficiency rating by two grades (e.g. from D to B in European countries) can halve heating energy demand and reduce the size of the heat pump needed, saving consumers money and reducing the growth in peak demand by one-third. Together with careful grid planning and demand-side management, this moderates the need for distribution grid upgrades caused by electrifying heat and minimises the need for additional flexible generation capacity to 2030.

The accelerated deployment of heat pumps brings a range of benefits

Over their lifetime, heat pumps can save consumers money and shield them from price shocks. The average household or business that uses a heat pump spends less on energy than those using a gas boiler. These savings offset the higher upfront costs for heat pumps in many markets today – in some, even without subsidies. The economic proposition of heat pumps improves in the context of today's energy price spikes: household savings range from USD 300 per year in the United States to USD 900 in Europe. With appropriate support for poorer households to manage the upfront costs, heat pumps can meaningfully address energy poverty, with energy bill savings in low-income households ranging between 2% and 6% of their household income after moving away from a natural gas boiler.

Switching to heat pumps cuts emissions of greenhouse gases and helps improve air quality. Accelerated deployment of heat pumps, in line with national climate targets, can reduce global CO_2 emissions by half a gigatonne already by 2030. However, unintended leaks of F-gas refrigerants – potent greenhouse gases – can decrease their positive climate impacts. With today's refrigerants, heat pumps still reduce greenhouse gas emissions by at least 20% compared with a gas boiler, even when running on emissions-intensive electricity. This reduction can be as large as 80% in countries with cleaner electricity. Global emissions of major air pollutants caused by combustion heating in buildings also drop, particularly from coal in China, while other hazards associated with heating by fuel combustion diminish.

The expansion of heat pump manufacturing and installations to meet rising demand would create more jobs. Global employment in heat pump supply nearly triples to over 1.3 million workers to 2030 in our scenario. Jobs in installation grow the most, with growth also in maintenance and manufacturing, providing numerous opportunities, especially for medium-skilled workers.

Concerted action is needed to overcome barriers to faster adoption

Accelerating the take-up of heat pumps requires overcoming a number of barriers. Chief among them are the higher upfront cost of buying and installing the devices relative to other heating options; other non-cost deterrents to consumer adoption; manufacturing constraints; and potential shortages of qualified installers. Concerted action by governments, in partnership with the heat pump industry, is needed to address these hurdles and achieve higher rates of deployment.

Despite long-term savings, high upfront costs can deter consumers. The cost of purchasing and installing an air-to-air heat pump is typically between USD 3 000 and USD 6 000. However, even the cheapest air-to-water models, including modifications to the existing radiator systems, remain two to four times more costly than natural gas boilers in most major heating markets. Financial incentives are currently available in over 30 countries around the world – covering more than 70% of today's heating demand. The subsidies in these countries make the cheapest heat pump options comparable to the cost of a new gas boiler for consumers. Additional incentives can target low-income households (as in Poland) and/or high efficiency models (as in Canada). In some countries, the design of electricity tariffs and energy taxation put heat pumps at a disadvantage relative to fossil fuel boilers. Tariffs and taxes should instead be tilted in favour of cleaner and more efficient consumer choices.

A number of non-cost barriers hold back consumer adoption of heat pumps today. These include lack of information, split incentives for building owners and tenants, and building regulations. Several governments have taken action to adjust building codes (such as in the Czech Republic), create "one-stop shops" for consumers (such as in Ireland) and encourage alternative business models to address the split incentive – notably in North America, the United Kingdom and Germany – though stronger efforts are required. Particular attention needs to be paid to addressing barriers to the installation of heat pumps in multi-family and commercial buildings, which account for a low share of sales today.

Shortages of qualified installers, already a bottleneck in many key heating markets, call for large-scale worker reskilling. Global demand for full-time installers quadruples by 2030 in our scenario. Incorporating heat pumps into existing certifications for heating technicians, plumbers and electrical engineers, who have similar skills, would help reduce training requirements. Financial incentives, such as those used across Europe, can also attract new workers to specialised training programmes.

Governments need to work with industry to lower supply-side hurdles

Leading manufacturers have recently announced plans to invest more than USD 4 billion in expanding heat pump production capacity and related efforts, mostly in Europe. New heat pump installation in the next four years would be roughly equal to the number of heat pumps installed in the last decade. Several countries, notably the United States, are responding to supply chain vulnerabilities with incentives to build up domestic manufacturing capacity. Long-term policy consistency and regulatory certainty, together with targeted action to strengthen supply chains, remain critical for manufacturers as they consider where to expand their operations. In particular, regulations on F-gases must balance the need to limit refrigerant emissions with cost, safety, energy efficiency and supply chain considerations.

Accelerating deployment of heat pumps in line with national climate targets is well within reach but requires further efforts from policy makers and industry. The market growth in heat pumps needed this decade to hit national climate targets is not as steep as the expansion we have already seen in solar PV and electric vehicles, although there would need to be a further acceleration to get on track for the IEA's Net Zero Emissions by 2050 Scenario. The additional upfront investment required is sizable, reaching USD 160 billion annually by 2030, but these incremental costs are outweighed by economy-wide savings on fuel, especially if today's high prices persist. Governments and industry have vital roles to play to address persistent market barriers and enable heat pumps to play their full part in addressing today's most pressing issues – energy security, energy affordability, and rapid reductions in emissions.

The Russian Federation's invasion of Ukraine and its subsequent decision to slash deliveries of natural gas to Europe have plunged the world into the biggest energy crisis since the 1970s. While Europe is at the epicentre, surging energy prices are hitting households and companies around the world, giving additional reason for governments to step up urgent efforts to reduce reliance on fossil fuels as the effects of the global climate crisis become ever more apparent.

This report assesses the role that heat pumps could play in addressing both energy security and climate imperatives, focusing on the concrete steps needed to accelerate their deployment over the rest of the current decade. Heat pumps can reduce the European Union's reliance on Russian fossil fuels by replacing gas- and oil-fired boilers.[1] In the longer term, they are set to play the leading role in decarbonising the provision of heat as part of efforts to achieve net zero emissions of carbon dioxide by 2050. Heat pumps can be installed in buildings and district heating networks to provide both heating and cooling, and in industry to provide low- and medium-temperature heat. As they are very energy efficient, they can lower energy bills for both households and businesses. To the extent they are powered by low-emissions electricity, their use results in far less greenhouse gas emissions than standard heating equipment today.

While heat pumps can be designed to provide both heating and cooling (known as reversible heat pumps), this report focuses on heating. Special focus is given to the implications of heat pump deployment in Europe for that region's gas demand in light of the European Union's policy objective, adopted in March 2022, of eliminating Russian imports of natural gas well before 2030.

The report is structured as follows:

- Chapter 1 starts by explaining what a heat pump is and how it works, and then describes the outlook for heating needs to 2050, highlighting the differences in the current and future energy mixes and the evolution of the building stock between regions. It goes on to describe the detailed global and regional projections of the uptake of heat pumps in buildings, industry and district heating, focusing on the period to 2030, and the implications for energy demand, emissions and investment needs.
- Chapter 2 sets out in more detail the implications of accelerating the deployment of heat pumps for energy security, electricity systems and demand flexibility, energy affordability, public health, the environment, and job creation.
- Chapter 3 assesses the principal potential hurdles to the deployment of heat pumps, including the upfront cost of installing them, other market barriers, manufacturing and other supply chain constraints, and shortages of skilled workers, as well as the main policy options for addressing them.

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[1] See IEA's 10-point plan to reduce reliance on Russia's gas imports, iea.li/gas-reliance

Outlook for deploying heat pumps

Mercury rising?

SUMMARY

- Reducing fossil fuel use in heating is essential to simultaneously address pressing energy security risks, protect households and businesses from volatile energy prices, and achieve climate objectives. Nearly half of global buildings-related energy use goes to heating, where natural gas is the dominant source today, consuming 760 bcm annually. The share is higher in the European Union, where gas heating in buildings consumes more than the power sector. Together with other fossil fuels, heating directly and indirectly emitted over 4 Gt CO_2 in 2021 – 10% of global energy-related CO_2 emissions.
- Heat pumps are the primary means of decarbonising space and water heating in buildings. Heat pumps installed in buildings have a combined capacity of more than 1 000 GW today. Capacity is set to grow to 2 600 GW by 2030 in the Announced Pledges Scenario, in which national climate and energy security targets are assumed to be met. This would boost their share of total heating needs in buildings from almost 10% in 2021 to one fifth. Many of these pumps are reversible, i.e. they can provide cooling, too. By 2050, 2.6 billion people will be living in areas with substantial cooling and heating needs.
- Heat pumps contribute almost half of global reductions in fossil fuel use for heating in buildings in 2030 in the APS. Heat pumps help decrease natural gas demand by more than 80 bcm and heating oil demand by 1 mb/d, while coal use falls to negligible levels. Heat pumps contribute around 9% of the increase in electricity demand to 2030, adding only modestly to system-wide peak loads in the winter. This could be absorbed without new generation capacity in most regions, though careful grid planning would be needed to ensure network stability, especially in distribution grids.
- The European Union sees a sharp decline in natural gas thanks to heat pumps in the APS in an effort to meet objectives in REPowerEU. Annual installations of heat pumps across the European Union reach nearly 7 million in 2030 – up from just 2 million in 2021. This rapid growth reduces gas consumption by 7 bcm in 2025 and 21 bcm in 2030, roughly equal to 15% of EU imports from Russia in 2021.
- Heat pumps also reduce fossil fuel demand in industry, which accounts for roughly a fifth of natural gas consumption today. They can be used for low-temperature process heat below 100 °C in a range of sectors today, but technologies are commercially available for processes up to 150 °C, with higher temperatures technically achievable. Nearly 40% of industrial heating demand in 2030 is at temperatures suitable for heat pumps. District heating networks can also be repurposed to use large-scale heat pumps. Several European countries have targets to decarbonise their heating networks by 2040.

1.1 Introduction

This chapter assesses the outlook for heat pump installations and their impact on the energy mix for heating in buildings and industry, drawing on the projections of the system-wide energy scenarios depicted in the latest edition of the World Energy Outlook (WEO), released in October 2022 (IEA, 2022a). Emphasis is given here to the **Announced Pledges Scenario (APS)**, which assumes that governments around the world meet all announced energy- and climate-related commitments in full and on time. This is contrasted throughout the report with the **Stated Policies Scenario (STEPS)**, which describes how the global energy system would evolve under the policies already in place today, provided they are backed by concrete implementation plans. These comparisons are intended to highlight where additional efforts are required to accelerate heat pump deployment. In some cases, the APS projections are also compared with the **Net Zero Emissions by 2050 (NZE) Scenario**, which represents a pathway to reduce energy emissions to zero on a net basis by 2050 in order to stabilise global average temperatures at 1.5 °C above pre-industrial levels. More detail about the scenarios and the projections can be found in WEO 2022.

A heat pump uses technology similar to that found in a refrigerator or an air conditioner. It extracts heat[1] from a source**,** such as the surrounding air, geothermal energy stored in the ground, or nearby sources of water or waste heat from a factory. It then amplifies and transfers the heat to where it is needed (Figure 1.1). Because most of the heat is transferred rather than generated, heat pumps are far more efficient than conventional heating technologies such as boilers or electric heaters and can be cheaper to run. The output of energy in the form of heat is normally several times greater than that required to power the heat pump, normally in the form of electricity. For example, the coefficient of performance (COP) for a typical household heat pump is around four, i.e. the energy output is four times greater than the electrical energy used to run it. This makes current models 3-5 times more energy efficient than gas boilers. Heat pumps can be combined with other heating systems, commonly gas, in hybrid configurations.

The heat pump itself consists of a compressor, which moves a refrigerant through a refrigeration cycle, and a heat exchanger, which extracts heat from the source. The heat is then passed on to a heat sink through another heat exchanger. In buildings, the heat is delivered using either forced air or hydronic systems such as radiators or under-floor heating. Heat pumps can be connected to a tank to produce sanitary hot water or provide flexibility in hydronic systems. Many of the heat pumps can also provide space cooling in summer in addition to meeting space heating needs in winter. In industry, heat pumps are used to deliver hot air, water or steam, or to directly heat materials. Large-scale heat pumps in commercial or industrial applications or in district heating networks require higher input temperatures than in residential applications, which can be sourced from the waste heat of industrial processes, data centres or wastewater.

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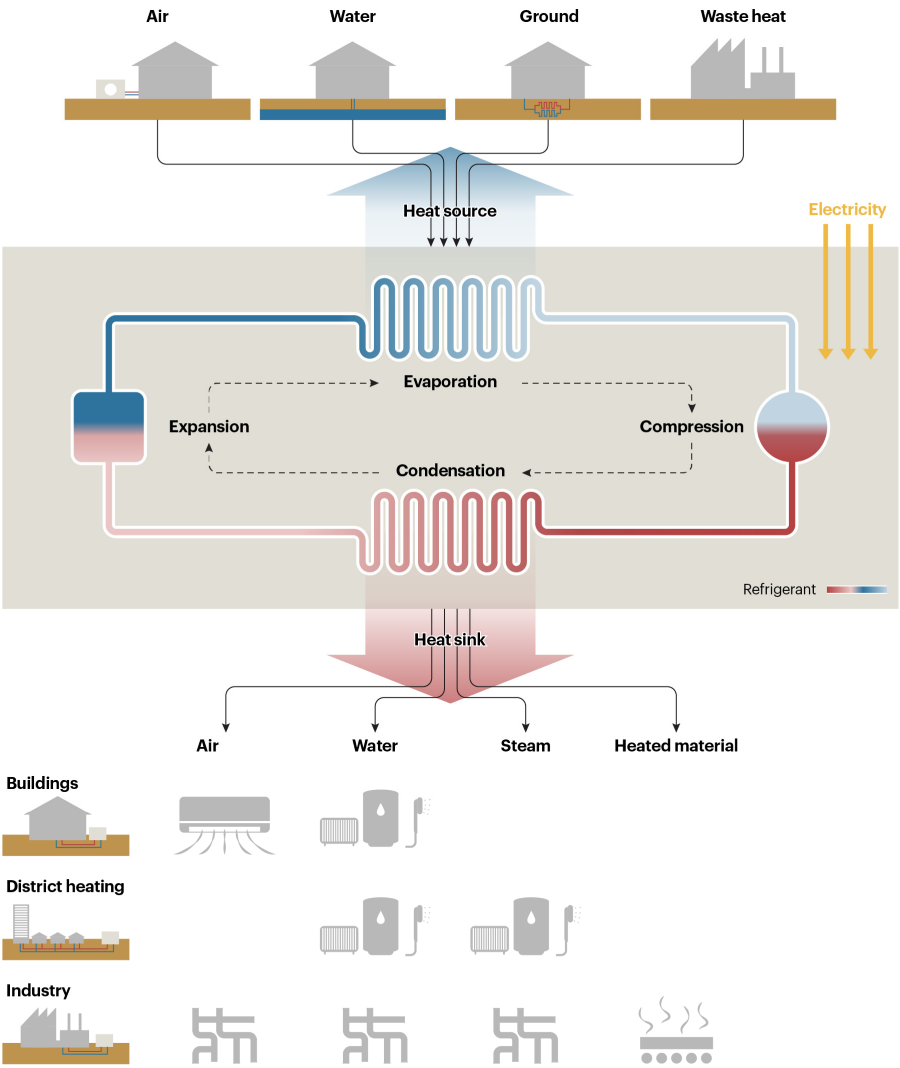
[1] Physically, heat energy is present whenever the temperature is above absolute zero (at 0 Kelvin or -273 °C).

Figure 1.1 ▷ How a heat pump works



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A typical residential heat pump needs just one unit of electricity input to provide four units of heat output; the cycle can be reversed to provide cooling services

Notes: The auxiliary energy source can also be another fuel such as natural gas, but most heat pumps today are powered by electricity.

The efficiency of a heat pump depends critically on the source of the heat. In winter, the ground and external water sources typically remain warmer than the ambient air, so ground-source and water-source heat pumps consume less electricity than air-source ones, yielding a higher COP. This is particularly the case in cold climates where defrosting the outside components of air-source heat pumps can consume additional energy. However, ground-source heat pumps are more expensive to install, as they require an underground heat exchanger – a deep vertical borehole or a large network of pipes buried at least one metre below the surface of the ground. Connecting a water-source heat pump to a nearby river, groundwater or wastewater can also be costly.

For these reasons, ground- and water-source heat pumps are generally less common than air-source pumps. Worldwide, almost 85% of all heat pumps sold for buildings worldwide are air-source, as they require the least effort to be installed. Many of these are air-to-air units, while in heating-dominated regions air-to-water (or hydronic) units are growing in prevalence. In Europe, air-source hydronic systems are more common than in other regions and account for nearly half of all units sold. Ground-source heat pumps and hybrid heat pumps that combine a heat pump with another heating source, like a gas boiler, are a small portion of global sales today, but make up a substantial share of the market in some countries. In Sweden, the leading market for ground-source heat pumps, every fourth house is equipped with such a model. The market for ground-source heat pumps is also growing steadily in the People’s Republic of China (hereafter, “China”), where they often replace coal-based heating systems, helping to reduce carbon dioxide (CO_2) emissions and improve air quality.

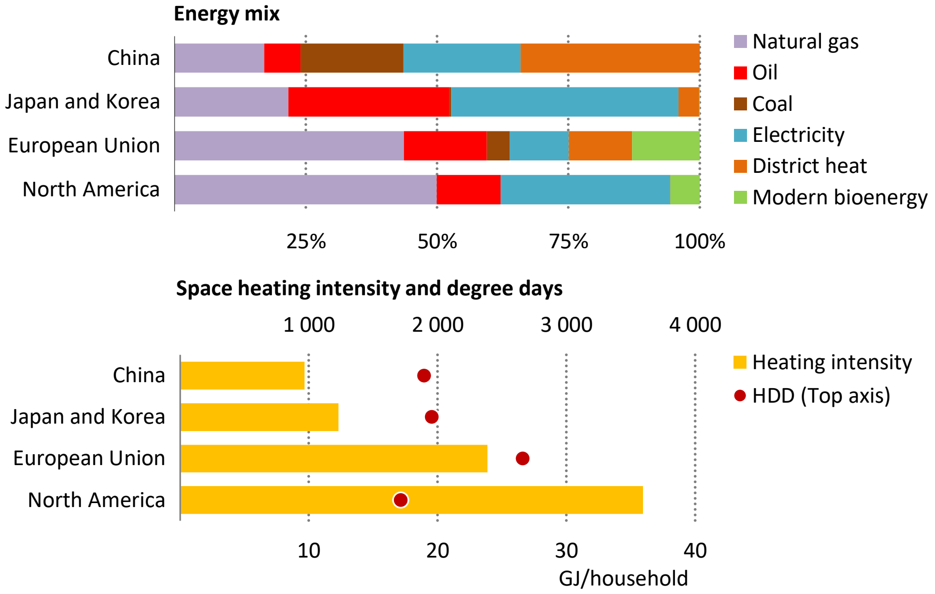
Single-family homes and apartments can use a single or multiple small units, or, in multi-family and commercial buildings, a centralised unit to provide heating and cooling to multiple units. In Asia, individual air-to-air units are common in multifamily housing, however restrictions in multifamily housing, notably in Europe, make heat pumps less common outside single-family homes. Centralised heat pumps can provide heat to entire multifamily and commercial buildings, but make up a small share of total heat pump capacity installed today. In Europe, for example, only 10% of units sold in 2021 were larger, centralised units for multifamily housing (EHPA, 2022). Commercial buildings are particularly well-suited for centralised heat pumps as they often have substantial year-round cooling needs, such as for hospitals, food refrigeration in supermarkets or large server rooms in offices, in addition to space heating needs. Commercial systems can achieve high efficiencies and minimise electricity consumption by utilising the waste heat from cooling to meet heating needs.

Heat pump technology is mature and their production and installation can, in principle, be scaled up quickly. But there are a number of hurdles to expanding their deployment, including the relatively high cost of installing them and various supply chain constraints such as shortages of skilled workers. Concerted efforts are needed to reduce market and regulatory barriers and bolster supply chains, reflected in the recent proliferation of new government policies and roadmaps to encourage the uptake of heat pumps, notably the European Union (EU) REPowerEU Plan and the United States (US) Inflation Reduction Act, both of which were adopted in 2022.

1.2 Heating needs

Heating currently represents a sizeable share of global energy consumption and a major source of CO_2 emissions. Global energy demand for space and water heating amounted to 62 exajoules (EJ) in 2021, accounting for around half of energy consumption in buildings and directly emitting 2.5 gigatonnes (Gt) of CO_2 – roughly 80% of direct buildings emissions. This moves up to 4 Gt of CO_2 when considering indirect emissions from electricity and district heating.

Figure 1.2 ▻ Household space heating in selected countries/regions, 2021

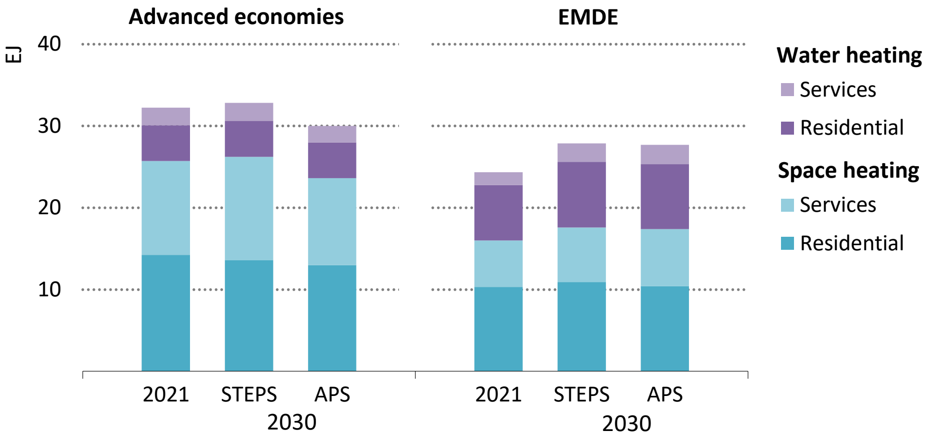


Natural gas is the leading form of energy for space heating in buildings, meeting around 45% of space heating energy demand globally

Notes: GJ = gigajoules; HDD = heating degree day. HDDs are a standardised measure of heating needs permitting comparisons across regions. They measure how cold a given location is by comparing actual temperatures with a standard base temperature. For this analysis, a base temperature of 18 °C is assumed, while the impact of humidity is also taken into account.

The level of energy demand varies substantially by household within and across countries and regions, mainly according to climate, household size, living space, the degree to which buildings are well-insulated, and the type and quality of heating equipment (Figure 1.2). Around 70% of total heating needs are for space heating and the rest for hot water. The energy mix for heating also varies. Natural gas is the leading form of energy for heating in buildings, meeting 42% of heating energy demand globally. One sixth of global natural gas demand is for heating in buildings—in the European Union this number moves up to one third. Oil follows next with 15%, then electricity at 15%, and district heating – concentrated in China, Northern and Eastern Europe, and Central Asia – at 11%. The direct use of biomass and coal make up the difference. The fuel mix for heating differs substantially across major heating regions, though gas dominates everywhere except East Asia.

Figure 1.3 ▷ Buildings space heating and water heating service demand by region and sector in the STEPS and APS, 2021 and 2030



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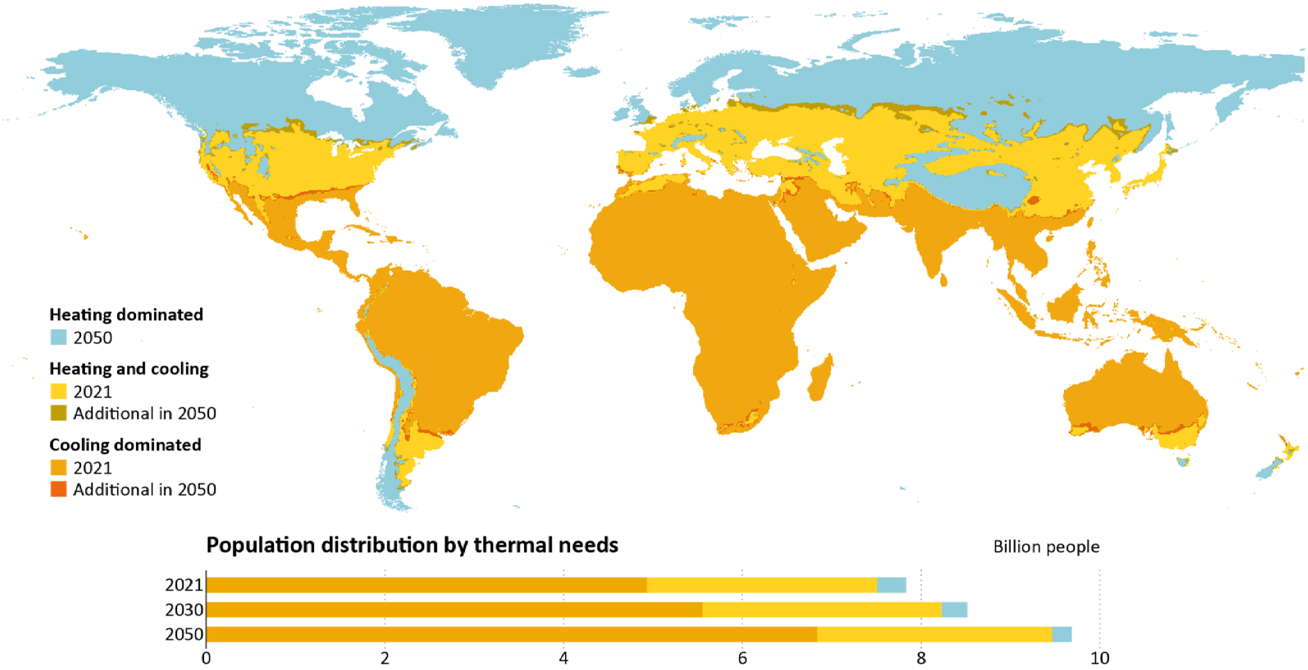
Building envelope improvements curb demand for heating services in advanced economies, while an expanding building stock boosts demand in emerging economies

Note: EMDE = emerging market and developing economies.

The majority of the world's population that needs space heating already has access, making the outlook for heating demand relatively predictable. At present, nearly 40% of the global population lives in regions that experience ambient temperatures which would require space heating at least part of the year. The number of people in these regions, mainly in the northern hemisphere, is expected to remain broadly stable over the coming decades. But rising prosperity is likely to push up overall heating needs, especially in emerging market and developing economies, as people move into new, larger dwellings and increase their use of heating services, especially hot water, though efficiency gains are likely to offset some of this growth. Increased economic activity will also push up heating needs in commercial buildings. Overall heating demand in buildings in emerging economies increases significantly between 2021 and 2030 in both the STEPS and the APS, driven mainly by hot water (Figure 1.3). By contrast, heating demand in advanced economies is broadly stable in the STEPS as efficiency improvements balance out a growing number of single-person households, while greater efforts to increase buildings efficiency, notably by improving building envelopes, reduce space heating demand modestly in the APS.

Figure 1.4 ▷ Heating and cooling needs by region in the STEPS, 2021 and 2050

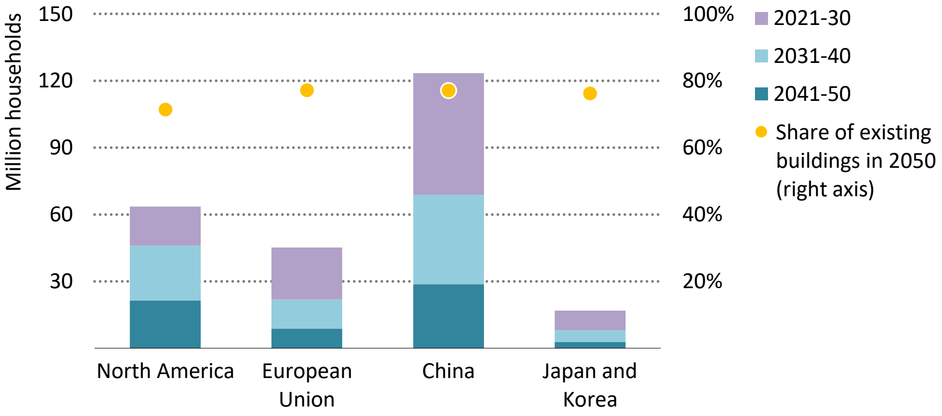


Regions where heating is needed see little growth in population to 2050, whereas it grows by a quarter in regions with cooling needs

Notes: Heating and cooling refer to areas where HDDs calculated with base temperature 18 °C HDD (18 °C) are greater or equal than 1 000 (°C days) and cooling degree days (CDDs) calculated with base temperature 10 °C CDD (10 °C) are greater or equal than 1 000 (°C days). For further information on the indicator see IEA (2020a) and for further information on HDDs and CDDs see IEA (2022b).

In the long term, overall energy use for heating in the regions that have significant space heating needs is expected to decline due to climate change (though this will be offset to some degree by increased cooling needs in those and other regions). Conversely, nearly everyone globally will face heatwaves that pose a public health risk by 2050, driving greater use of air conditioning in most regions (also see Section 5.7 on space cooling in WEO 2022). Heat pumps can provide both heating and cooling, and so could become the preferred choice for new buildings and heating retrofits in regions that require both at different times of the year. The number of people living in regions which require both heating and cooling needs is set to grow by around 3% to 2.6 billion people by 2050 in the STEPS (Figure 1.4). In most regions requiring heating, the majority of buildings built today will still be in use in 2050 (Figure 1.5). This means that reducing fossil fuel use in heating will call for efficiency retrofits and switching to low-carbon heating technologies. Strong building codes that ensure new buildings are zero-carbon-ready are also needed to decarbonise heating.

Figure 1.5 ⊳ Household additions by decade in selected countries/regions, 2021-2050



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Three-quarters of the buildings stock in 2050 is already standing today in North America and the EU, which together account for more than 40% of current global heating needs

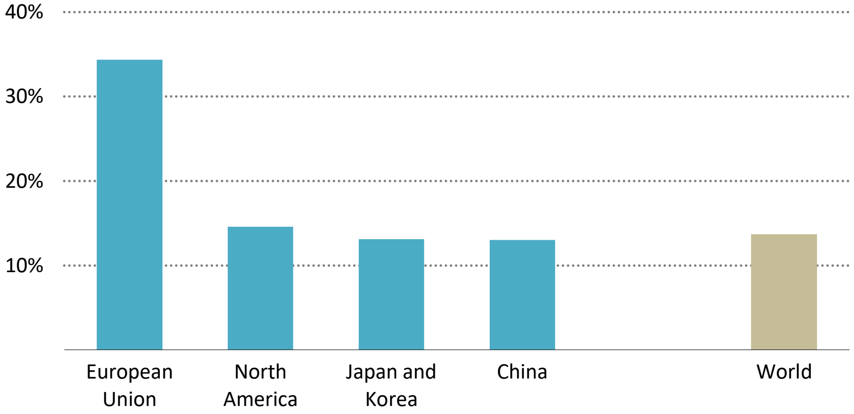
Note: Projected demolition rates in China are assumed lower than current ones.

1.3 Heat pumps in buildings

1.3.1 Global prospects

Global heat pump sales in 2021 were up 13% on 2020 levels, with growth fastest at around 35% in the European Union (Figure 1.6). Despite rising sales in recent years, heat pumps still met merely around 10% of global heating needs in buildings in 2021. Heat pumps in residential and non-residential buildings today account for more than 1 000 gigawatts (GW) of capacity,[2] nearly half of which is installed in North America. Many units are used in mild-to-warm climates, where they are used primarily for cooling yet still represent the primary heating source (for a few months of the year). However, the penetration of heat pumps today is highest in the coldest parts of Europe, meeting 60% of total buildings heating needs in Norway and over 40% in Sweden and Finland thanks to long-standing policy support (Rosenow et al., 2022).

Figure 1.6 ▷ Annual growth in sales of heat pumps in buildings in selected regions, 2021



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North America has the most heat pumps installed and China the largest market, but the European Union is the fastest-growing market today

Sources: IEA analysis based on AHRI (2022), Chinabaogao (2022), EHPA (2021), JRAIA (2022).

A large increase in heat pump policies and incentives, notably in the US Inflation Reduction Act, is set to accelerate their deployment, as shown in the STEPS.

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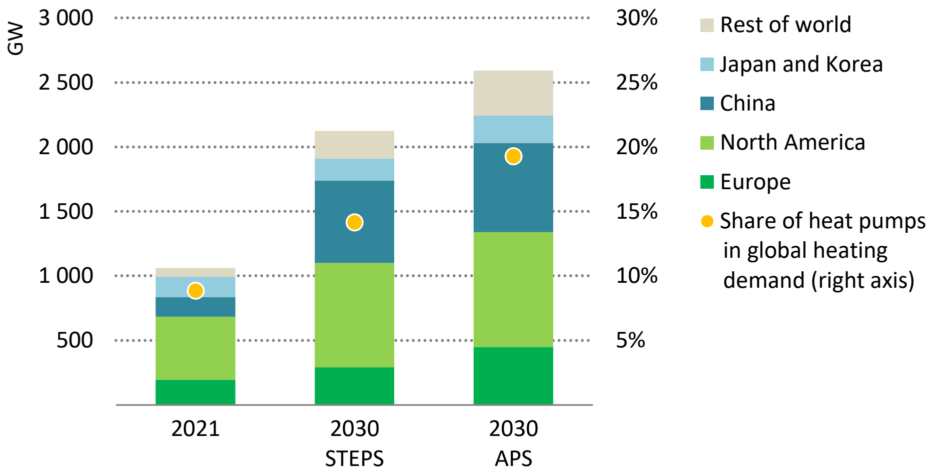
[2] Heat pumps are measured by their wattage of output capacity to facilitate cross-comparison across regions. The average capacity of the heat pump stock varies greatly across regions. Regions such as North America and Europe have larger heat pumps (5 kW to 10 kW) on average, while in Asia they are often smaller (3 kW to 5 kW). Based on this, a global average equivalent for heat pump capacity for single dwellings or rooms could be considered around 5 kW. The sizing also depends on the building stock and the climate. Centralised units in multifamily buildings have capacities of more than 20 kW, and those in large commercial buildings can have capacities beyond 100 kW.

In the STEPS, global capacity of heat pumps in buildings increases to more than 2 100 GW by 2030, meeting 14% of global buildings heating needs (Figure 1.7). Policy support for heat pumps is available in many major heating regions. Subsidies are available in regions that now cover more than 70% of global space heating demand in residential buildings.[3] Additionally, minimum energy performance standards for existing buildings and building energy codes for new buildings have been introduced in several countries, while fossil fuel boiler bans are now in force on the national level in various countries, including Denmark, France, the Netherlands and Norway as well as on the subnational level in the United States and Canada, among others.

Figure 1.7 ▻ Heat pump capacity in buildings by country/region and scenario, 2021 and 2030



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Around 20% of heating needs are met by heat pumps in 2030 in the APS, with China, North America and Europe remaining the leading markets

Increased policy support for heat pumps is needed to achieve national climate and energy security objectives. In the APS, which assumes those objectives are met, heat pump capacity grows to nearly 2 600 GW by 2030, meeting almost 20% of the sector's heating needs. For instance, to fulfil the REPowerEU objective of ending natural gas imports from the Russian Federation (hereafter, "Russia") well before 2030, the number of heat pumps in the European Union must nearly triple to reach around 45 million in the APS.

Heat pumps play a major role in reducing fossil fuel use in buildings to 2030 in the APS. Their direct use for space and water heating falls by 29% between 2021 and 2030 globally (compared with 16% in the STEPS), almost half of which is due to heat pumps (Figure 1.8).

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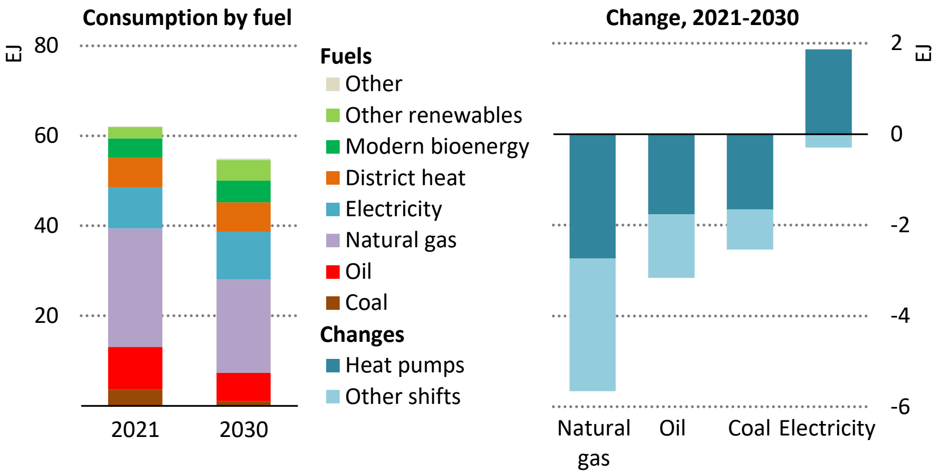
[3] These include mainly national-level policies, except for Japan and China, where subnational policies cover a substantial share of national heating demand.

The remaining reductions in fuel use come from improvements to energy efficiency of buildings, particularly building envelopes, including the adoption of automated home controls and building management systems for non-residential buildings. Gas accounts for the biggest share of the total fossil energy savings, its use dropping by over 160 billion cubic metres (bcm), or 21%, by 2030 (the fall is just 50 bcm in the STEPS), around half due to heat pumps. The European Union contributes the biggest gas savings in both scenarios. Russia's decision to cut gas flows into Europe and the consequent surge in prices are prompting governments to urgently reinforce policies encouraging a shift away from natural gas and other fossil fuels. Other major gas importers with ambitious 2030 climate targets also see large falls in gas use in buildings, in large part due to greater use of heat pumps.

Figure 1.8 ▻ Global energy consumption for space and water heating in buildings in the APS, 2021-2030



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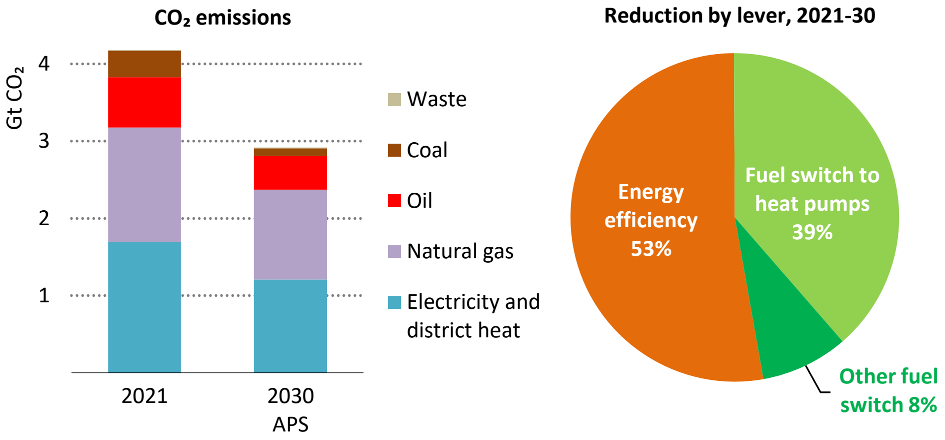
Heat pumps reduce demand for fossil fuels in space and water heating by 29% in the APS by 2030, reducing natural gas demand the most

Heat pumps also displace large amounts of oil and coal for heating in buildings in the two scenarios. Oil-based heating systems, which are currently found mainly in regions where there is no natural gas distribution, continue their rapid decline in the APS, falling from 15% of global heating demand in 2021 to around 11% in 2030 – a slightly faster fall than in the STEPS. Heat pumps are the main contributor to these declines. Coal heating in households is nearly eliminated by 2030 in the APS, led by strong targets and campaigns in China to improve air quality, with heat pumps replacing most coal use, notably in peri-urban and rural areas.

The faster deployment of heat pumps in the APS drives up global electricity demand, but this is far outweighed by the savings in fossil fuels due to their much greater efficiency. Electricity use in heat pumps doubles and climbs by over 500 terawatt-hours (TWh), contributing around 9% of the total increases in electricity demand over 2021-2030. In most regions, existing generation capacity is sufficient to meet this increase in demand, though additional investment to upgrade networks, notably distribution systems, will be needed in some countries. The increased electricity demand from heat pumps does not lead to a rise in fossil fuel demand in the power sector in that scenario, as the assumed achievement of decarbonisation targets leads to a fall of nearly one-fifth of fossil fuel use in the power sector by 2030. This decline is fastest in Group of Seven (G7) countries and the European Union. Hydrogen plays a negligible role in the space and water heating fuel mix in the APS by 2030. A key reason is that when accounting for the energy losses associated with hydrogen conversion, transport and use, hydrogen technologies for use in buildings are much less efficient than heat pumps and other available options (IEA, 2022c).

The switching away from fossil fuels to electric heat pumps contributes substantially to decarbonising heating in buildings. CO_2 emissions associated with space and water heating worldwide, including indirect emissions from power generation, decline by over 1.2 Gt, or more than a quarter, by 2030 in the APS (Figure 1.9). Heat pumps account for around 500 million tonnes (Mt), or nearly 40%, of this reduction, roughly equivalent to Canada's emissions in 2021. Advanced economies, mainly the European Union and the United States, account for nearly three quarters of the decline in heating-related emissions thanks to heat pumps. Progressive increases in renewable electricity generation increase the emissions savings from heat pumps over time.

Figure 1.9 ▹ **Global CO_2 emissions from space and water heating in buildings in the APS, 2021-2030**



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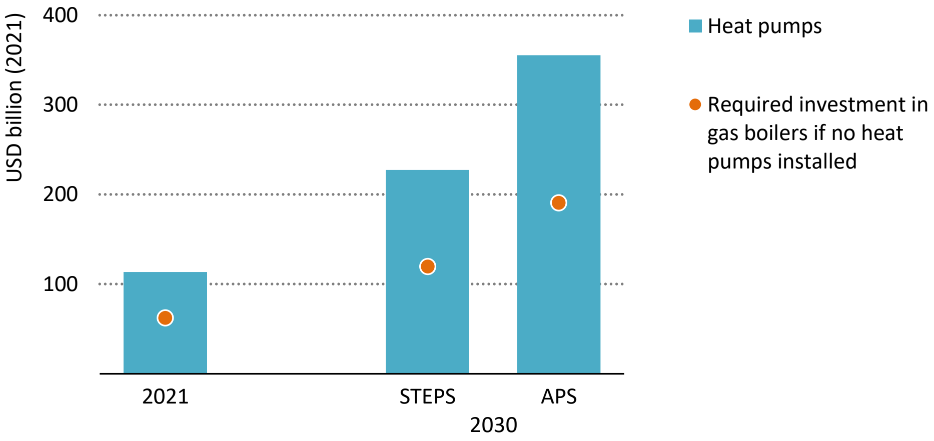
Heat pumps reduce global CO_2 emissions by 500 Mt by 2030 in the APS, around 40% of total direct and indirect emissions reductions in space and water heating in buildings

The rate of deployment of heat pumps in the APS implies a huge increase in spending on the equipment and its installation by owners of residential and commercial buildings. Global investment triples by 2030 to USD 350 billion in real 2021 dollars (Figure 1.10). This is roughly equal to that invested in solar photovoltaic (PV) and wind power globally in 2021. The premium for investing in a heat pump over buying a conventional heating option such as a condensing gas boiler is around USD 160 billion in 2030, much of which is already covered by policy incentives already available in the leading markets today (and taken into account in the STEPS). However, these incremental costs are outweighed by the economy-wide savings on fuel, especially should the global energy crisis continue (Chapter 3).

Figure 1.10 ▷ Global investments for heat pumps in buildings by scenario, 2021 and 2030



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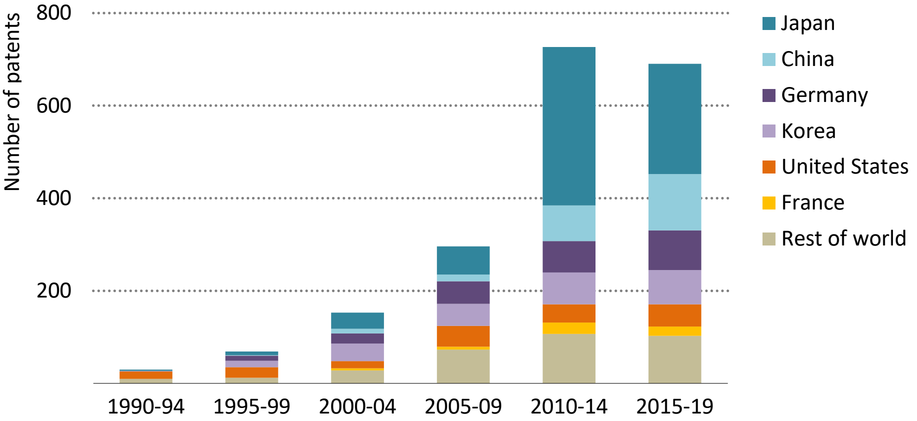
Heat pump investment triples to USD 350 billion in 2030 in the APS, USD 160 billion more than what would be needed if all new heating systems were gas boilers instead

In addition, heat pump related research, development and demonstration (RD&D) investments need to be stepped up to meet research and innovation needs (Box 1.1). Public spending on heat pump and chiller research as reported to the IEA is around USD 30 million per year, nearly four times higher than in 2010. Global investment in heat pump start-ups and scale-ups increased nearly sixfold between 2016 and 2021 (European Commission, 2022a). Patent counts for heat pumps, a measure of technology innovation, have more than doubled in 2015-19 compared with 2005-09, with China and Japan accounting for half of all inventions (Figure 1.11).

Figure 1.11 ⊳ Patent counts for heat pump technologies by country, 1990-2019



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The number of patents for heat pump technologies has risen drastically, led by China and Japan who accounted for more than half of the new patents since 2010

Box 1.1 ⊳ RD&D for the next generation of heat pumps

Over the last decades, heat pump performance has improved significantly e.g. in terms of efficiency and noise. For example, COPs have increased by more than 70% since the early 1990s for air-to-water heat pumps in Switzerland (Swiss Office of Energy, 2020). However, additional research and innovation could yield further benefits. RD&D efforts are currently focused on smart and flexible features, reduced noise, higher efficiencies, more compact design, improved ease of installation, and lower environmental footprints associated with the materials and refrigerants used. Sharing progress under key RD&D programmes run by governments and industry could help accelerate the deployment of innovative technologies worldwide, lowering costs and emissions.

The IEA's Heat Pumping Technologies Technology Collaboration Programme (HPT TCP) and the Innovation Community on Affordable Heating and Cooling of Buildings (a Mission Innovation initiative) are key forums for advancing RD&D collaboration on heat pumps. The HPT TCP is exploring potential improvements for system and resource efficiency by optimising the use of heat pumps for both heating and cooling purposes, including in commercial applications with simultaneous needs. One aspect being looked at is the dual ability of a heat pump when operated in a very low-temperature thermal grid on a district or city level to be used as a heat sink and source simultaneously. Air conditioners result in large amounts of waste heat that could be recovered to produce domestic hot water in well-designed systems.

Long-term RD&D efforts have made heat pumps a viable option even in cold climates. However, to efficiently apply the technology in very cold climates, the next generation of heat pumps will need to be more efficient over a larger temperature range. Progress is also needed in adapting heat pumps for the most difficult conditions for carrying out building retrofits, such as where insulation is tricky and where the heating system requires high temperatures. To achieve this, continuous research on component development and system design is necessary. The US Department of Energy recently launched the Residential Cold Climate Heat Pump Technology Challenge to accelerate the deployment of technologies in very cold climates (US DOE, 2022). Optimised heat pump solutions differentiated by climate needs could also bring down equipment costs.

Stepping up research on technologies that are still far from market introduction is also needed to pave the way for leapfrogging in the development of more efficient and cost-effective heating solutions. They include non-traditional compression technologies for heat pumps such as solid-state (e.g. magnetocaloric, thermoelectric and elastocaloric) and gaseous (e.g. Brayton and Stirling cycles) ones. Early results for elastocaloric-based cooling systems are particularly promising.

Note: This box was prepared in collaboration with Caroline Haglund Stignor, Monica Axell and Metkel Yebiyo of the RISE Heat Pump Centre and Stephan Renz, Chairman of the HPT TCP.

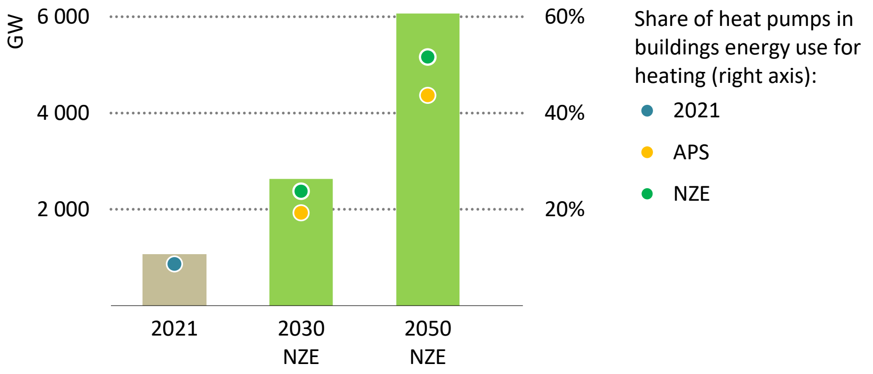
Achieving the APS level of deployment would further require strengthening policy support, including bigger financial incentives and restrictions on the installation of fossil fuel boilers in existing and new buildings (see Chapter 3). In the NZE Scenario, a key measure to support even faster deployment of heat pumps than in the APS is the prohibition of the sale of new fossil fuel boilers from 2025 (see Box 1.2).

Box 1.2 ▹ Heat pump deployment in the NZE Scenario

In the NZE Scenario, in which the world achieves the goal of net zero emissions of CO_2 by mid-century, the capacity of heat pumps installed worldwide nearly triples by 2030 and then doubles again by 2050 (Figure 1.12). This implies that at least 24% of global heating needs will be met by heat pumps in 2030, almost three times more than today's share. By 2050, this share reaches 52%.

The recent introduction of ambitious policies in several countries, notably the US Inflation Reduction Act, REPowerEU and Green Transformation (GX) in Japan, are already boosting the uptake of heat pumps and sending strong market signals to manufacturers and installers. These are almost sufficient to get the world on track for 2030, but additional policy efforts would be needed to achieve the continued acceleration in deployment required to be on track for the NZE Scenario beyond 2030, notably in emerging economies. In the NZE Scenario, deployment is boosted by bigger reductions in heat pump costs to end users through innovation and subsidies, higher carbon penalties, and a ban of new fossil fuel boiler sales by 2025.

Figure 1.12 ▻ Global heat pump capacity and coverage of heating needs in the APS and NZE Scenario, 2021-2050



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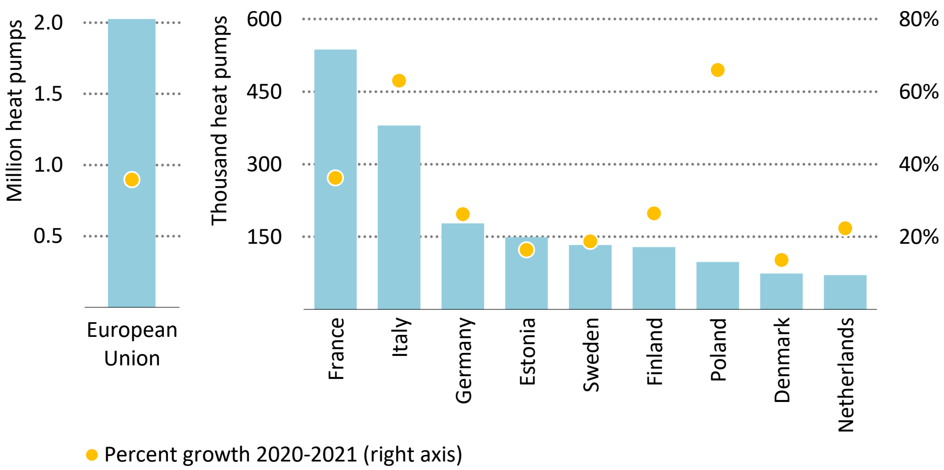
Global heat pump capacity nearly triples by 2030 in the NZE Scenario and then doubles again by 2050, with stronger policies than those already planned needed beyond 2030

1.3.2 Focus on the European Union

Russia's invasion of Ukraine and subsequent disruption to imports of Russian gas have driven Europe into a major energy crisis with far-reaching economic and social consequences. In response, the European Commission released in May 2022 the REPowerEU Plan, which aims to rapidly phase out EU imports of fossil fuels from Russia, with the import of gas ending well before 2030 – a goal that is fully achieved in the APS. REPowerEU sets out a number of measures to diversify the suppliers of gas, as well as to accelerate energy efficiency improvements and switching to clean fuels. These measures reinforce those that were already included the EU Fit for 55 package that was announced in 2021 – a set of proposals to revise and update EU legislation aimed at reducing net greenhouse gas (GHG) emissions by at least 55% by 2030 (relative to 1990).

Lowering natural gas use in buildings, in large part through the replacement of gas boilers with heat pumps, is a vital part of REPowerEU. In 2021, EU gas use in buildings amounted to 150 bcm – the largest single use of gas in the European Union, ahead of the power sector – and contributed 11% of the Union's total energy-related CO_2 emissions. Heat pump sales are already growing rapidly, jumping by 35% to around 2 million in 2021, fuelled by strong policy support in the leading markets, including France, Italy and Poland (Figure 1.13). In some cases, heat pumps are also replacing coal and oil boilers, as well as inefficient electric resistance heaters. In Poland, for example, a combination of clean energy subsidies and regional-level bans for coal boilers, motivated by air quality concerns, helped to boost sales by two-thirds in 2021 (Morawiecka and Rosenow, 2022). In Italy, a more than 60% surge in sales was driven by the Superbonus – a Covid-19 recovery measure that provides a tax credit worth up to 110% of the cost of building renovations aimed at improving energy efficiency.

Figure 1.13 ▻ Heat pump sales and growth in the European Union and selected member countries, 2021



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Heat pump sales across the European Union grew by around 35% to 2 million in 2021, fuelled by strong policy support in countries including France, Italy and Poland

Sources: IEA analysis based on EHPA (2022); PORT PC (2022).

Table 1.1 ▻ Selected European policy targets for heat pump deployment

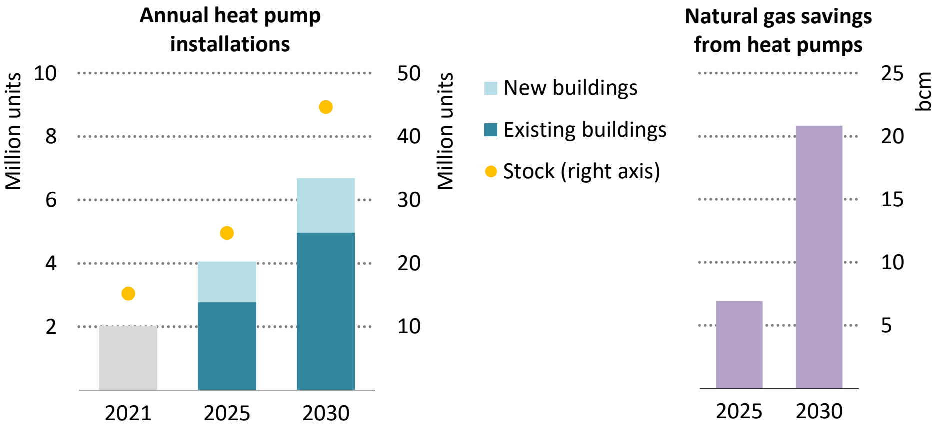
Country	Year	Target
European Union	2030	30 million additional heat pumps installed compared with 2022
Belgium	2030	Final energy consumption by heat pumps to increase fivefold over 2018
France	2023	Reach 2.7 million to 2.9 million total heat pumps installed
Germany	2024 2030	Install 500 000 heat pumps per year Reach a heat pump stock of 6 million
Hungary	2030	Final energy consumption by heat pumps to increase sixfold over 2020
Italy	2030	Final energy consumption by heat pumps to increase twofold over 2017
Poland	2030	Final energy consumption by heat pumps to increase threefold over 2020
Spain	2030	Final energy consumption by heat pumps to increase sixfold over 2020
United Kingdom	2028	600 000 annual heat pump installations

Sources: European Commission (2022b); France, Ministry of Ecological Transition (2022); Clean Energy Wire (2022); GOV.UK (2020); Government of Italy (2019); Government of Spain (2019); Toleikyte and Carlsson (2021).

A number of EU countries have recently strengthened their policy support for heat pumps, putting the Union on course for another record year of installations in 2022. Sales in Poland doubled in the first half of the year, with similar trends being reported in the Netherlands, Italy and Austria, and strong growth in Finland and Germany (Mathiesen et al., 2022). Several EU countries, as well as the United Kingdom, have announced ambitious deployment targets in recent years (Table 1.1). The REPowerEU plan aims to reinforce and build upon these current policies and market trends, targeting a doubling in the current deployment rate of individual heat pumps leading to the installation of 30 million new units between 2022 and 2030. The plan also targets an acceleration in the deployment of large-scale heat pumps by developing and modernising district and communal heating and by integrating them into new projects exploiting industrial heat.

EU heat pump sales reach 4 million units by 2025 and nearly 7 million by 2030 in the APS, which takes account of the targets described above. This results in a reduction in the consumption of gas for heating in buildings by 7 bcm in 2025 and 21 bcm by 2030, roughly equal to 15% of Russian imports today (Figure 1.14). Heat pumps contribute roughly one-third of the total reduction in gas use in buildings for heating between now and 2030, with energy efficiency retrofits making up most of the rest. An average of 2.5-3% of the existing building stock are retrofitted each year in that scenario, the majority of them involving the installation of heat pumps. New building energy codes across all EU member states also support the adoption of heat pumps.

Figure 1.14 ▷ EU heat pump installations and stock and related cumulative natural gas savings in the APS, 2021-2030



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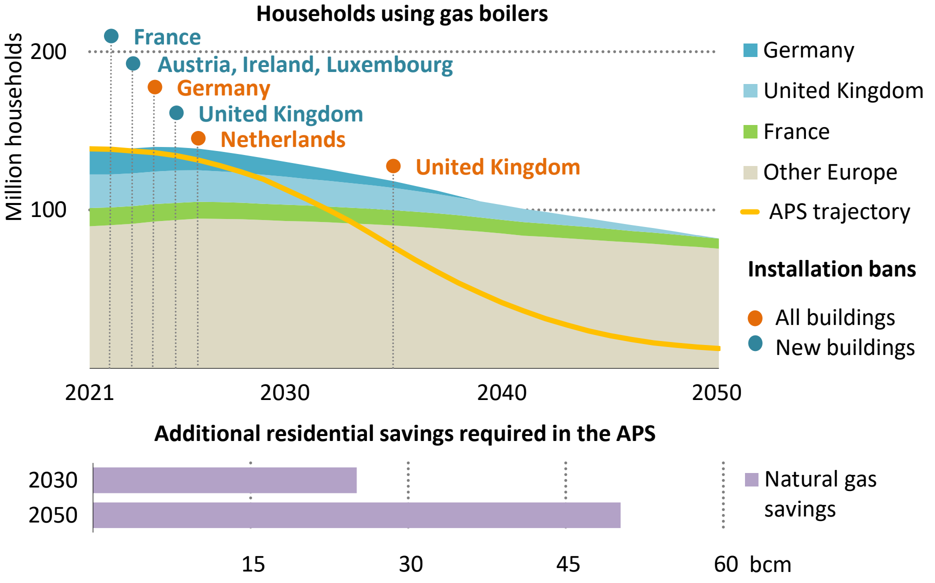
New heat pump installations cut the consumption of gas by 7 bcm in 2025 and 21 bcm by 2030 in the APS, roughly equal to 15% of Russian imports today

New policy measures are needed to ensure that the EU and national targets are met. Policies that provide incentives for comprehensive retrofits, including heat pumps, are a cornerstone of many countries' energy efficiency packages today, including measures included in the EU Renovation Wave initiative, launched in 2020, which aims to double the energy renovation rate of the housing stock. To further incentivise heat pump deployment, nine European countries have announced or implemented national bans on gas and oil boilers, while four others have announced bans for oil boilers only. Some of these bans cover installations only in new buildings while others also cover replacements in existing buildings. Current and announced fossil fuel boiler bans in the EU will require roughly 16 million households to switch to alternative heating options by 2030, 10 million of which would be gas boilers, saving 7.5 bcm of natural gas. If all of new heating systems were heat pumps, this would make up around half of heat pump shifts to 2030 in the APS. If all EU countries were to implement a ban on new fossil fuel boiler installations starting in 2025, this would require 48 million households to switch to alternative heating options by 2030. Even if only 60% of these households shifted to heat pumps, this would be equal to heat pump shifts in the APS (Figure 1.15). In addition, bans provide a clear and stable long-term vision to manufacturers.

Figure 1.15 ▻ Impact of implemented and announced gas boiler bans in Europe and remaining heating demand gap with the APS, 2021-50



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To achieve the natural gas savings in 2050 in the APS, all countries with net zero by 2050 targets need to ban new fossil fuel boiler installations in all building types by 2030

Note: Gas boiler installation bans were also introduced in Denmark for new buildings in 2013, in Norway for all buildings in 2017 and in the Netherlands for new buildings in 2018. In some cases, such as Germany, bans are not explicit, but rather rely on renewable energy share obligations which cannot be met by gas boilers.

Despite a strong manufacturing base in Europe, imports of heat pumps and components from Asia have increased over the last few years. To limit import dependency, the European Commission plans to ramp up domestic production by facilitating access to finance where needed. REPowerEU also aims to strengthen European heat pump supply chains and make them more sustainable by enhancing the regulatory framework, ensuring life-cycle sustainability and supporting innovation. It also proposes to establish a large-scale skills partnership under the EU Pact for Skills to train and reskill people to work in the heat pump industry (see Chapter 3).

1.4 Industrial heat pumps

There is considerable potential for electric heat pumps to provide process heat for industry. Because of the complexity of industrial processes, heat pumps generally need to be tailored to specific applications. In contrast to those used in buildings, industrial heat pumps typically rely on higher input temperatures, as the required output temperatures are also significantly higher. Today, industrial heat pumps are mainly used for low-temperature processes below 100 °C, notably in the paper, food and chemicals industries (Table 1.2). However, output temperatures of up to 150 °C can already be achieved if waste heat of about 100 °C is available as input. For temperatures between 150 °C and 200 °C, heat pumps need special refrigerants and compressors, for which technologies are still in an early prototype stage.

Table 1.2 ▹ Industrial heat pump technology readiness by temperature range

Temperature range	Technology readiness level (TRL)	Example process
<80 °C	🟢 TRL 11: Proof of market stability	Paper: De-inking Food: Concentration Chemical: Bio-reactions
80 °C to 100 °C	🟢 TRL 10: Commercial and competitive, but large-scale deployment not yet achieved	Paper: Bleaching Food: Pasteurisation Chemical: Boiling
100 °C to 140 °C	🟢 TRL 8-9: First-of-a-kind commercial applications in relevant environment	Paper: Drying Food: Evaporation Chemical: Concentration
140 °C to 160 °C	🟡 TRL 6-7: Pre-commercial demonstration	Paper: Pulp boiling Food: Drying Chemical: Distillation Various industries: Steam production
160 °C to 200 °C	🟢 TRL 8-9: First-of-a-kind commercial applications for small-scale MVR systems and heat transformers 🔴 TRL 4-5: Early to large prototype	Various industries: High-temperature steam production
>200 °C	🔴 TRL 4: Early prototype	Various industries: High-temperature processes

Readiness level: 🔴 TRL 1 to 5 🟡 TRL 6 to 7 🟢 TRL 8 to 11

Notes: MVR = mechanical vapour recompression. TRLs can vary for specific processes or different heat pump capacities.

Sources: Representation using the IEA extended TRLs (IEA, 2020b) based on Maruf et al. (2022).

Industrial heat pumps can be very efficient, with a COP of more than three, when the temperature lift, i.e. the difference between the input and output temperatures, is in the 30-50 °C range. For higher temperature lifts, the COP is generally lower, though a heat pump can be configured in a way that limits the loss of efficiency, such as by incorporating intermediate heat exchangers or cascaded cycles (whereby the pump operates as two single-stage cycles coupled together by a cascade heat exchanger). However, the costs of such heat pump systems are usually significantly higher.

There is growing interest in the use of steam with mechanical vapour recompression (MVR) equipment in a similar way to heat pumps (that is, using electricity to upgrade heat to a higher temperature). When operating in a closed loop, as in a common heat pump, water can act as the refrigerant in the cycle. Its physical properties allow it to deliver higher target temperatures than other refrigerant fluids without constraints due to environmental or fire hazards. In an open-cycle configuration, high temperature steam can be produced from lower pressure steam or condensate. As steam is one of the preferred heat carriers in industry, the technology is well-suited to meet industrial heating needs.

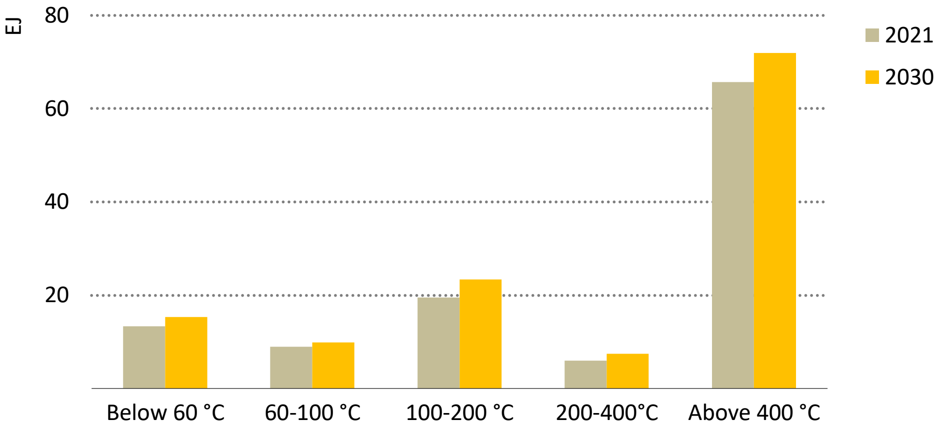
Public funding can help accelerate the development and commercialisation of solutions, which could open the way for new applications such as surface treatment of metals in the automotive industry or drying and washing in the textiles sector. The EU Innovation Fund is supporting demonstration projects, including for industrial applications, while the Horizon Europe programme is funding research and innovation projects in this field.

At temperatures above 200 °C, direct electrification of industrial processes is generally preferable over heat pumps at present (Madeddu et al., 2020). A number of such technologies are being developed or are already in use. For example, BASF, SABIC and Linde have recently started construction of a pilot-scale steam cracker that uses electricity instead of fossil fuels to provide the necessary reaction heat of around 850 °C to break the hydrocarbon feedstock into valuable base materials for the chemical industry (BASF, 2022). Nonetheless, innovation could lead to higher-temperature heat pumps becoming viable.

Hydrogen combustion is yet another option to provide low-emissions heat for industry. While the greatest potential for hydrogen is in high-temperature applications where heat pumps cannot operate and direct electrification is difficult, hydrogen could technically also replace natural gas in boilers for lower-temperature heat and steam. However, compared with heat pumps or direct electrification, hydrogen-based heat suffers from low overall efficiency due to losses incurred in the production of low-emission hydrogen via electrolysis and associated high cost (for technology cost comparisons, see Figure 1.18).

Heat pumps, among other clean energy technologies, can play an important role in decarbonising industrial heat production, particularly for low-temperature processes and quickly reducing fossil fuel demand. Process heat requirements continue to increase across all temperature ranges over this decade in the APS, while the share of heat demand from processes below 200 °C remains just below 40% (Figure 1.16).

Figure 1.16 ▷ Global industrial process heat demand by temperature in the APS, 2021 and 2030



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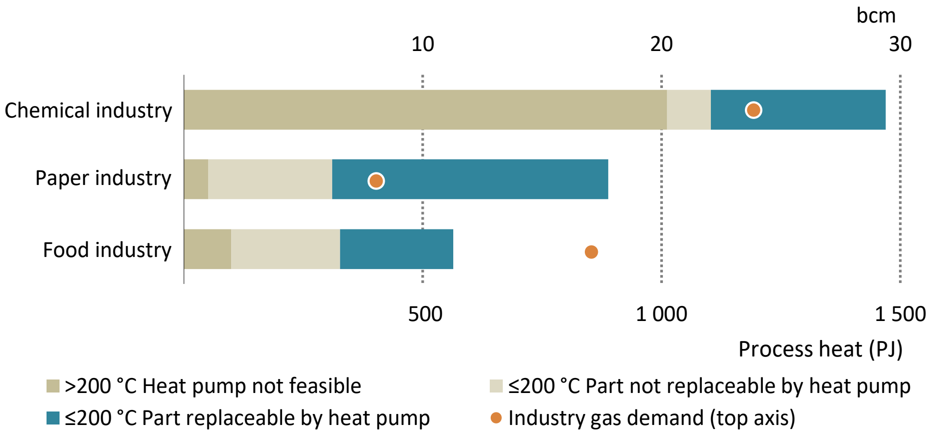
Heat pumps can play an important role in decarbonising industrial heat production, particularly for low-temperature processes

The potential for industrial heat pumps varies by sector (Marina et al., 2021). In the paper industry, around 65% of process heat needs across all temperature ranges can, in principle, be met by industrial heat pumps, but substantial system changes may be required. In the food industry, around 40% of all processes can be covered by heat pumps, mainly where temperatures of up to 150 °C are needed, due to the limited availability of high-temperature waste heat. While around two-thirds of heat demand below this threshold could be met by heat pumps based on current waste heat availability, the potential would be higher if additional heat sources from neighbouring industrial facilities were tapped or if processes were modified to run on lower temperatures, for example by employing hot water instead of steam. In the chemical industry, where most processes require very high temperatures, heat pumps can cover only around a quarter of process heat demand. However, low-temperature processes in that sector benefit from substantial amounts of waste heat from other processes on the same site. Of the combined heating needs from these three industries, around 30% could be addressed by today's heat pump technologies. Natural gas for low-temperature heating in these industries consumed 60 bcm globally in 2021. In Europe alone, heat pumps with a combined capacity of 15 GW could be implemented in almost 3 000 installations across these three industrial sectors (Figure 1.17).

The design and technical specifications of industrial heat pumps often differ substantially from residential ones. In addition to the higher output temperatures needed, warm industrial wastewater or heated air flows are typically available in industrial facilities to provide the required heat sources to generate sufficiently high temperatures. However, requirements for refrigerants[4] are different as they need to provide higher temperatures and are employed at larger quantities, leading to increased challenges in terms of environmental or fire hazards. In addition, industrial heat pumps often operate at higher pressures, requiring thicker piping, while compressors need to be able to operate at higher temperatures.

Figure 1.17 ▹ **Industrial gas and process heat demand by temperature level and heat pump replacement potential in Europe, 2019**



IEA. CC BY 4.0.

The food and paper industries are prime candidates for deploying industrial heat pumps on a large scale, helping to reduce energy use, gas demand and emissions

Notes: PJ = petajoules. Europe = European Union and the United Kingdom.

Sources: IEA analysis based on European Commission (2016) and Marina et al. (2021). Feasibility based on TRLs from Table 1.2.

Switching to a heat pump in an industrial process requires specialised planning, design, manufacturing and installation. Requirements can vary between facilities running similar processes within the same industry. Industrial heat pumps are often designed for specific processes and temperature configurations, limiting opportunities to mass produce, which pushes up design and manufacturing costs. There are also differences in costs and feasibility between installing heat pumps for new processes and retrofitting existing processes with heat pumps, which can be much more complex. New projects can benefit from co-operation with heat pump manufacturers to establish standard temperature settings for industrial heat pumps in specific processes and industrial subsectors (e.g. inlet temperatures and temperature lift ranges), which can bring down costs by streamlining equipment

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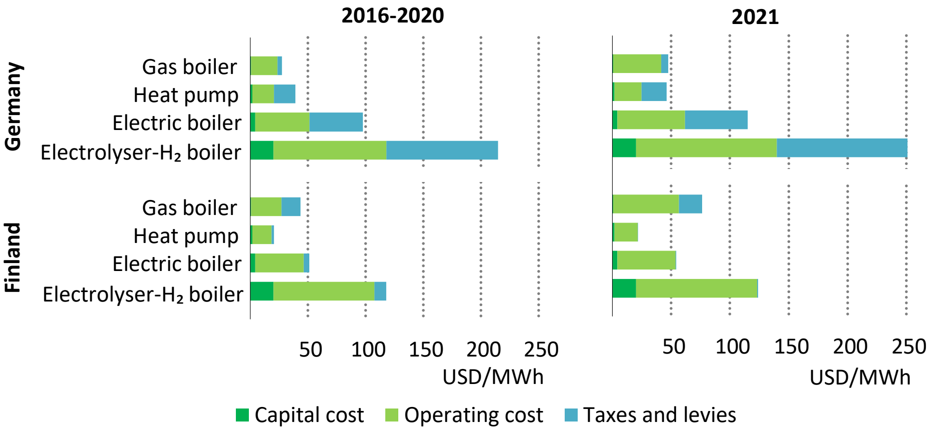
[4] While residential heat pumps mainly use hydrofluorocarbons (HFCs) such as R134a or R32 or, increasingly, hydrocarbons, such as propane, or carbon dioxide, industrial heat pumps mostly rely on hydrofluoro-olefins (HFOs), ammonia, isobutane or cyclopentane as refrigerants. Water can furthermore be used as a refrigerant for high-temperature steam processes. Refrigerants are discussed in detail in Chapter 2.

manufacturing and installation. Some industries have specific operational requirements. For example, refrigerants used in heat pumps in the food industry face stricter requirements for contact with the product and may need an additional heat cycle to guarantee food safety.

As in the buildings sector, costs remain a major barrier to the adoption of heat pumps. The cost of the equipment, installation and related process changes are often high but less decisive in industry than operating costs. In addition, current electricity market designs and tax structures often favour natural gas over electricity use in industry in many jurisdictions. However, recent strong gas price increases that have exceeded electricity price hikes have strengthened the business case for heat pumps. While in countries such as Germany, where electricity taxes and levies have been relatively high and gas boilers used to be on average more competitive than heat pumps until 2020 (Figure 1.18), rising gas prices in late 2021 made heat pumps more favourable, and continued price hikes since Russia's invasion of Ukraine are increasing that effect. Furthermore, the reform of electricity pricing in Germany in 2022 decreased taxes and levies significantly, enabling a sustained growth path for industrial heat pumps. In Finland, the energy cost environment had already been more favourable for heat pumps in recent years, thanks to a cut in the electricity tax for industry to the EU minimum level of EUR 0.50 per megawatt-hour (MWh), aiming to discourage the use of fossil fuels.

Figure 1.18 ▷ Average levelised cost of production of industrial heat in Germany and Finland



IEA. CC BY 4.0.

Recent gas price increases and tax changes have made heat pumps the cheapest solution for producing industrial heat in Germany and Finland

Notes: Capital cost is very low relative to the overall cost. The bar is sometimes not discernible in the figure. Operating cost includes energy and distribution charges and CO_2 prices for gas boilers. Electrolyser-H_2 boiler capital cost includes estimations for on-site hydrogen production; Operating cost considers electricity prices and the power-to-heat efficiency of hydrogen.

A number of countries have introduced policies to lower upfront cost and information barriers to industrial heat pumps. In Germany, for example, subsidies in the federal funding programme for energy and resource efficiency in commercial enterprises can cover up to 55% of the initial cost of the heat pump up to a ceiling of EUR 15 million per project. Other European countries have implemented similar schemes or provide support for industrial heat pumps as part of energy efficiency obligation schemes. In Brazil, the PotencializEE programme offers training for industrial energy efficiency experts to help facilities identify clean and efficient technologies such as heat pumps. Additional incentives are needed to make more waste heat available across factory boundaries. Thermal storage could further enable the usage of a larger part of waste heat. Stronger industrial efficiency targets and funding for audits, technology development and the deployment of first-of-a-kind commercial units are key to maximise the potential for heat pumps. Lastly, a range of industrial heating systems, in particular in emerging and developing economies, can be further optimised by integrating waste heat even without the use of additional energy inputs and heat pumps.

1.5 Heat pumps for district heating

Individual heat pumps may not be the preferred heating option in buildings in certain settings, such as in densely populated urban areas, or in industry due to technical, economic or other constraints. In these cases, or to exploit existing heat sources more efficiently, district heating can be a viable solution. Large heat pumps can be used to provide district heat to buildings, commercial premises and industrial sites, by expanding existing networks or by developing new ones. In the European Union, for example, 60 million people are currently supplied by district heat and 80 million more people live in cities that have an existing network (Euroheat & Power, 2022).

The decarbonisation potential of district heating is largely untapped at present, with fossil fuels still supplying around 90% of district heat globally and even higher shares in the two largest markets, China and Russia. In Europe, which accounts for 20% of global district heat production, carbon intensity is more than one-third below the global average, though renewables still account for only a quarter of heat supply and heat pumps for a mere 1%. Four European countries (Austria, Denmark, Finland and Sweden) currently have targets to decarbonise their district heating networks between 2030 and 2040 and Denmark is set to provide nearly a third of the district heat supply with heat pumps by 2030 (Euroheat & Power, 2022; Energistyrelsen, 2022).

District heating systems using heat pumps to recover the heat from wastewater have existed since the 1980s. More recent projects use or plan to use waste heat from data centres, metro tunnels, industrial facilities or electrolysers. Hammarbyverket in Stockholm, built in 1986, is the world's largest heat pump district heating system and a vital part of the city's overall heat network (HPT TCP, 2018). In 2006, a large-scale combined heating and cooling plant was also built underneath Katri Vala Park in Helsinki (Helen Ltd, 2020). It uses wastewater heat for district heating and hot water, as well as cool seawater for district cooling simultaneously. Wastewater heat recycling projects have been successfully implemented in other European countries as well as in Australia, Canada, China, Japan and the United States.

Other heat pump technologies for district heating networks are emerging. A novel large-scale heat pump to feed waste heat from a cooling plant for offices in Berlin into the city's district heating network was recently completed by Siemens Energy and Vattenfall Wärme Berlin AG and is set to start operating at the end of 2022. It has a thermal capacity of up to 8 megawatts (MW) and can supply hot water to around 30 000 households in summer and heat and hot water to 3 000 households in winter. The EU-funded HEATLEAP project aims to demonstrate the benefits of waste heat recovery from energy-intensive industries for district heating networks with large heat pumps with a COP of up to eight (HEATLEAP, 2022).

The potential for exploiting wastewater for district heating remains largely untapped (Wastewater Heat Online, 2022). Warm water from bathrooms and kitchens carries a substantial amount of thermal energy that can be captured and recycled back to households using high-temperature heat pumps and district heating networks. A recent analysis shows that almost 4 000 wastewater treatment plants in Europe are in close proximity to existing networks (European Commission, 2020). These plants combined could deliver 175 TWh of heat per year, equal to around a fifth of current district heat supplies in Europe. Using wastewater network heat mapping can further make heat sources in city sewage systems available.

Partnerships and innovative business models involving private and public entities, such as special-purpose vehicles, can effectively drive network transformation. However, district heating projects typically rely on public financial support. In France, for example, a heat fund of more than EUR 500 million per year has proved instrumental in driving the uptake of clean district heating. The German government has recently launched a EUR 3 billion funding scheme, which follows a systemic approach by supporting feasibility studies and transformation plans as well as subsidising both capital costs and operating costs of decarbonised district heating networks (BMWK, 2022). There is also a crucial role for cities and communities to engage in heat planning to identify sources suitable to replace individual fossil fuel heating with renewable and waste heat sources. District heating zone policies, such as those adopted in Estonia, can allow cities to mandate that buildings within certain areas connect to district heating networks beyond a specified heat consumption threshold.

Around 40% of the heat generated globally in district heating plants goes to the industrial sector, which affects a network's ability to reduce distribution temperatures, as industrial users often require high-temperature heat. However, using heat pumps to increase temperatures at local substations can offer solutions in some cases. China leads industrial district heat use, accounting for about 55% of the global total in 2021, up from around 35% in 2010. By contrast, Russia's share fell to less than 25%, down from more than 35% in 2010.

Box 1.3 ▻ Heat pumps for district heating in Sarajevo

The district heating system in Sarajevo, the capital and largest city in Bosnia and Herzegovina, uses natural gas or heavy fuel oil, while homes not served by district heating are primarily heated using firewood or coal. As a consequence, heating is the main contributor to the city's poor air quality, with oxides of sulphur and nitrogen and particulate matter regularly exceeding safe levels during winter months.

To reduce the city's reliance on fossil fuels, the European Bank for Reconstruction and Development (EBRD) is working with city authorities to introduce large-scale centralised water-source heat pumps. Two proposed projects are currently under discussion. A EUR 25 million project involves the construction of an 18 MW heat pump plant utilising treated wastewater at an average year-round temperature of 10 °C from a nearby wastewater treatment plant. The second project, which would cost around EUR 21 million, involves the construction of a 21 MW heat pump plant utilising city drinking water at an average year-round temperature of 12 °C. The share of heat pump-based generation in Sarajevo's district heating network will reach nearly 40% if both projects are implemented. Final investment decisions are expected to be made in the first quarter of 2023.

In addition to air quality improvements and CO_2 emissions reductions of up to 16 kilotonnes per year, the projects would also help address concerns about the cost and security of natural gas supplies triggered by the current energy crisis. In the longer term, there is even more potential for heat pump-based district heating in Sarajevo. A second phase project based on the full heating potential of the city's wastewater could provide 18 MW of additional capacity.

Implications of accelerated heat pump deployment

Fuels switching it up

SUMMARY

- The global energy crisis is driving a renewed focus on energy security. Electric heat pumps can reduce reliance on imported fossil fuels. The deployment of heat pumps in the APS reduces global gas demand in buildings by 80 bcm by 2030 compared with 2021, with the European Union accounting for 21 bcm. Oil imports for heating are also reduced significantly, especially in Japan and Korea. However, new risks emerge for ensuring critical heating services remain available in power outages.
- The accelerated deployment of electric heat pumps contributes to a rapid increase in demand for electricity, especially in buildings, in the APS, with the share of electricity in the fuel mix for heating in buildings and industry globally doubling over 2021-2030 to 16% and boosting total electricity use by 24%. Meeting this increase in demand would call for a substantial increase in investment in the power sector in upgrading customer connections, distribution grids, generating capacity and flexibility. Heat pumps equipped with smart technology play an important role in more than doubling EU demand-side flexibility between 2021 and 2030, their share of total flexibility resources jumping from 8% in 2021 to around 12% in 2030.
- On average, households with a heat pump spend less on energy than those using a gas boiler and are less vulnerable to price shocks, especially in systems that rely mainly on renewables. In 2021, households that switched from a gas boiler to a heat pump enjoyed sizeable savings on their energy bills. In low-income households, these savings can be a substantial share of income, between 2-6% in key heating markets. Electricity tariffs and fuel taxes need to be reformed to ensure they do not deter consumers from opting for a heat pump.
- Switching to heat pumps helps reduce GHG emissions and improve air quality. In the APS, it yields a 15-40% reduction in emissions of major air pollutants caused by heating in buildings over 2021-30 and reduces other hazards associated with heating by fuel combustion. With today's refrigerants, heat pumps reduce greenhouse gas emissions by at least 20% compared with a gas boiler when running on emissions-intensive electricity, and by up to 80% in countries with cleaner electricity. By switching away from F-gas refrigerants, this range shifts to 30-90%. Regulations on F-gas refrigerants, which have large global warming potentials, must balance efforts to contain their emissions with cost, safety, energy efficiency and supply chain considerations to maximise net emissions reductions.
- Global employment in heat pump supply nearly triples to over 1.3 million workers over 2021-30 in the APS, with a third of the new jobs in China, 20% in Europe and 15% in North America, where installation and manufacturing capacity is set to expand fastest. Most new jobs are in installation. This calls for a massive drive to recruit and train new workers.

2.1 Introduction

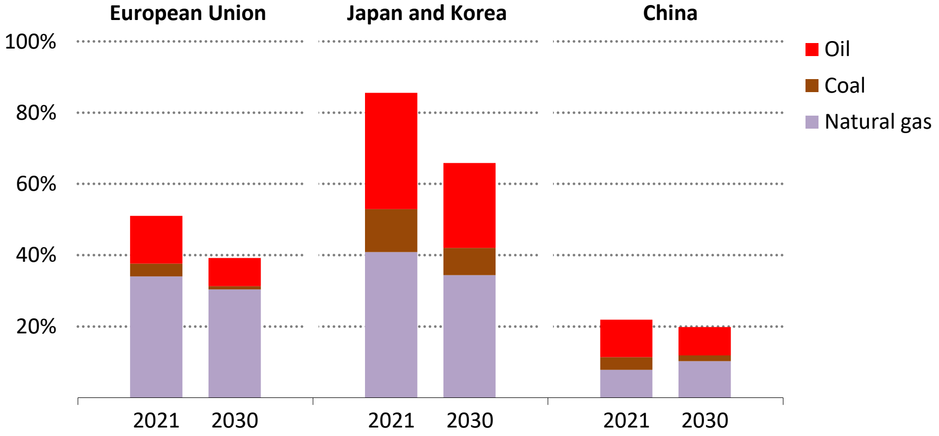
Accelerating the deployment of heat pumps would have far-reaching implications for the global energy sector, with important knock-on effects for economic activity and the environment – beyond the climate benefits. It would reduce the use of fossil fuels for heating, limiting vulnerability to supply disruptions, helping to reduce the import bills of net importing countries and freeing up fuels for export in the case of producer countries. But more heat pumps would raise demand for electricity, necessitating grid upgrades and a need for more flexibility in operating power systems to ensure security of supply, especially during the winter. The high upfront cost of installing a heat pump also affects energy affordability for poorer households. The impact of switching to heat pumps on the environment and human health, while overwhelmingly positive in most cases, is not without risk: fluorinated gases (F-gases) used in the refrigeration cycles of many models are potent greenhouse gases (GHGs). Correct handling can reduce their impact, and substitute refrigerants can replace them, though both solutions carry additional costs and challenges. And ramping up production of heat pumps would create new opportunities for economic growth and job creation, though it would require workers to be trained in their manufacture, installation, maintenance and certification. This section explores these implications in turn, highlighting the opportunities for policy makers to balance different priorities.

2.2 Energy security

The production of heat for buildings and industry is dominated today by fossil fuels, many of which are imported, leaving countries vulnerable to supply disruptions. Space and water heating in buildings alone directly accounts for one-fifth of global gas demand, and more than one-third of gas use in the European Union, making heating for buildings the largest single use of natural gas in the European Union. When the role gas plays in producing electricity and district heat is taken into account, the share of heating in buildings in the European Union is even bigger, at over 40%. Heating is also the largest end-use sector for gas in the United States and several other countries, mainly in the northern hemisphere.

Russia's invasion of Ukraine has brought fears about energy security to the fore once again, particularly in Europe, where the very real risk of gas supply shortfalls to Europe over the winter threaten to leave millions without sufficient access to heating, with obvious harmful consequences for comfort and health. Heat pumps, coupled with building energy efficiency improvements, can reduce reliance on imported fossil fuels used for heating. The European Union, Japan and Korea rely heavily on imported fuels to run boilers in buildings, as well as to generate electricity and district heat for heating buildings. In 2021, over 60% of energy use for heating in the European Union relied directly or indirectly on fuel imports, with gas making up the largest share by far. In Japan and Korea, import reliance approached 90%, with oil and gas dominating imports (Figure 2.1). China also relies on fuel imports for heating buildings, though to a lesser degree. In the APS, import reliance drops in the European Union and the other countries, largely thanks to the impact of the installation of heat pumps on gas and oil demand.

Figure 2.1 ▷ **Share of heating in buildings met by imported fossil fuels by fuel in selected regions/countries in the APS**



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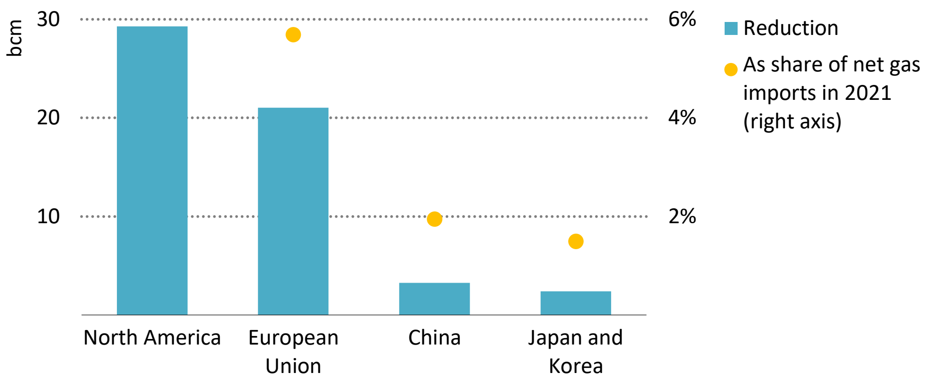
Reliance on fuel imports drops sharply in the European Union, Japan and Korea in the APS, largely thanks to the impact of heat pumps on gas and oil demand

Note: District heat and electricity refer to the indirect reliance on imported fossil fuels for heating via their use in the production of electricity and district heat used for building heating.

The IEA 10-Point plan to reduce the European Union's reliance on Russian natural gas, released in March 2022, highlights measures that could cut gas demand and alleviate potential shortages (IEA, 2022a). Curbing gas use for heating is central to this plan and to the Playing My Part initiative developed by the IEA in co-operation with the European Commission (IEA, 2022b). Immediate action to accelerate heat pump deployment and phase out the installation of gas boilers are critical measures. In the APS, ramping up the installation of heat pumps reduces gas demand in the buildings sector by 80 bcm globally by 2030 compared with today, including 21 bcm in the European Union (Figure 2.2).

Switching to heat pumps does not come without other energy security concerns. Increased use of electricity for heating increases exposure to power outages, which can pose a serious public health concern in cold climates. Moreover, power outages are more likely to occur during periods of inclement weather when the need for heating is most acute. Nonetheless, prolonged major blackouts are rare in most countries with heating needs. Backup heating solutions or emergency rendezvous points within communities that require uninterruptible heating supply, as well as the wider deployment of distributed energy resources, coupled with batteries and thermal energy storage, can help ameliorate these risks by reducing pressure on electricity distribution networks at times of peak heating demand. Hybrid heat pumps coupled with fossil fuel boilers could also reduce the impact of electricity outages, in particular in cold climates, though they would hamper full decarbonisation of buildings.

Figure 2.2 ▷ Reduction in natural gas demand in buildings associated with heat pump deployment in selected regions/countries in the APS, 2021-30



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The reductions in gas demand brought about by greater deployment of heat pumps in the APS reduce gas imports in the net importing countries, especially in the EU

2.3 Electricity systems and demand flexibility

The accelerated deployment of electric heat pumps contributes to a modest increase in demand for electricity, especially in buildings, in the APS. Electricity's share in total final energy consumption worldwide rises from 20% in 2021 to 24% by 2030. In advanced economies, it jumps from 22% to over 27%. The share of electricity in the fuel mix for heating in buildings and industry globally doubles over 2021-2030 to 16%. In major heating regions this adds little to electricity demand, roughly 1.5%-2.5% over 2021 levels by 2030, however, peak demand could grow substantially. This could call for a substantial increase in investment in the power sector. For households adding a heat pump, this can nearly triple their peak demand during the winter time. However improving a home’s efficiency rating by two grades (e.g. from D to B in Denmark) can half the heating energy demand and reduce the size of the heat pump needed, saving consumers money and reducing their peak demand by one third.

These investments would take several forms:

- Upgrading the connection to the consumer, who typically bears the cost. In many cases, installing a heat pump requires an increase in capacity, by upgrading the connection.
- Upgrading low-voltage distribution grids in areas where the widespread uptake of heat pumps, alongside other end-use technologies such as electric vehicles (EVs), significantly boosts load.
- Adding generation capacity or flexibility resources to ensure resource adequacy during the heating season. Region-specific assessments need to be done to determine the additional flexible generation capacity required to meet increased demand from heat

pumps. For example, RTE, the French transmission system operator, found that in a scenario where energy efficiency retrofit targets were hit, new capacity needs out to 2035 were unneeded. However, if only minimal buildings efficiency retrofits were to occur, RTE found that new capacity would be required.

Investment needs related to connections to buildings vary across regions. In the United States, connections are often already sized for air conditioners and can usually accommodate the addition of a heat pump. By contrast, in Italy, the typical household currently subscribes to just 3 kW of capacity with a single-phase meter with a maximum capacity of 6 kW. The installation of a heat pump could easily result in peak demand exceeding this level, requiring households to pay for an upgraded connection. The cost of upgrading customer connections needs to be taken into consideration by policy makers when deciding on financial support for installing a heat pump.

The need to upgrade distribution systems also varies widely. In France, electric resistance heating is commonplace, and so customer connections and the distribution grid were developed accordingly. However, in countries such as Germany, where heating has traditionally been provided mainly by fossil fuel boilers, distribution grids have generally not been built to accommodate widespread electric heating in residential buildings. In regions where electric heating is currently limited, the deployment of heat pumps alongside the rapid adoption of EVs could increase peak demand substantially, heightening the need to upgrade distribution grids.

Other approaches to distribution system management, including deploying distributed renewables alongside batteries, would ameliorate the need to upgrade feeder lines. In the APS, global distributed solar PV capacity more than triples between 2021 and 2030. The need to physically reinforce grids can also be reduced through load management on the demand side (Box 2.1). Digitalisation of low-voltage distribution lines can also help manage congestion and increase monitoring and remote control of grid assets, which could reduce the cost of upgrades by targeting them at points on the grid where they are needed. In particular, the replacement of older transformers with new ones incorporating voltage regulation technologies can lower costs.

Box 2.1 ▹ Using demand-side flexibility of heat pumps for grid stability

Viessmann, a German heat pump manufacturer, and the German electricity transmission system operators (TSOs), TenneT and 50Hertz, recently launched a pilot project to demonstrate the value of demand-side flexibility that can be provided by hydronic heat pumps in dealing with the variability of renewable electricity generation and ensuring grid stability. Viessmann aggregates the flexibility potential of the heat pumps of customers who have agreed to join the scheme and offers the resulting energy volume to the grid operators via the Equigy crowd balancing platform – a data exchange to enable aggregators of small loads to participate in electricity balancing markets – to reduce load at peak periods. If a TSO accepts an offer for a certain grid node, the heat output and, therefore, the electricity use of the aggregated heat pump units is lowered by turning them off or down at specific periods. In order to maintain indoor temperatures, heat is stored in a hot water buffer tank. The thermal inertia of the hydronic heating system and the building itself (especially if well-insulated) also limits the impact on temperatures of switching off the heat pump, which usually takes several hours. Customers are remunerated according to their contribution to lowering load.

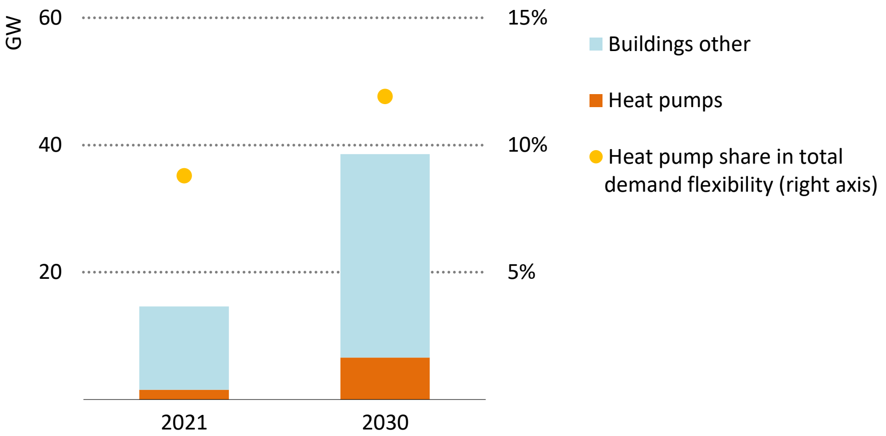
The target of the pilot project is to include 100 heat pumps. For future projects, the fleet of units would need to be much bigger for them to deliver significant grid stabilisation services. Barriers to wider adoption would need to be removed, notably complex certification standards and inadequate remuneration for demand-side flexibility from residential consumers in markets for system balancing and ancillary services.

Increased use of electricity for heating can contribute to more pronounced hourly and seasonal variations in electricity demand, especially during cold snaps, which can lead to more pronounced spikes in demand. Yet there is considerable potential for heat pumps to be used flexibly so as to mitigate their impact on overall electricity demand during peak periods in the winter. In the APS, heat pumps account for around 15% of residential electricity consumption across the European Union during the winter in 2030, and up to 70% of demand for those households using a heat pump for space and water heating. Heat pumps play an important role in more than tripling EU demand-side flexibility between 2021 and 2030, with their share of total flexibility resources jumping from 9% in 2021 to around 12% in 2030 (Figure 2.3). Buildings with solar PV will have an added incentive to shift their loads, to maximise self-consumption during the daytime.

Unlocking the potential for heat pumps to contribute to system flexibility requires the adoption of digital technologies. Automation is needed to harness heat pump flexibility, so that they can be switched on and off remotely. This flexibility requires communications and control features to be built into units. Minimum energy performance standards could require appliances to include a basic level of controllability. Most heat pumps sold today already allow to connect a control device to the unit, thus enabling demand response features. However, many manufacturers use proprietary systems, which can limit interoperability. Regulations obliging manufacturers to ensure heat pumps can receive and send data to enable not only monitoring, but also remote control of the devices, could be a first step towards the widespread adoption of smart controls. Buildings also need to be better connected and more automated to receive signals from the grid about when flexibility is needed and better manage their energy consumption (IEA, 2021b).

There is also a need for market-based incentives to encourage the owners of heat pumps to offer flexibility services to the grid, via either a lower electricity tariff or separate payments by the grid operator. Changes in market design can ensure that heat pump flexibility is adequately valued by aggregators or suppliers, and that the value is passed on to consumers in the form of lower bills (IEA, 2021a). Policy makers can promote energy provider models that enable controllability, while establishing guardrails for consumer privacy and choice.

Figure 2.3 ▻ **Demand response potential from heat pumps and other building electricity uses at times of highest flexibility needs and share in total demand-side flexibility in the European Union in the APS**



IEA. CC BY 4.0.

Heat pumps emerge as a major demand-side flexibility resource in the APS, with the thermal inertia of buildings and heating systems allowing electricity use to be cut at peak

Note: Buildings other includes refrigeration and appliances.

To maximise the potential of hydronic heat pumps to contribute to power system flexibility without affecting thermal comfort for end users, some adjustments to heating systems – including the storage of hot water or the installation of backup non-electric means of heating during periods when the heat pump is switched off – as well as improvements to thermal insulation of buildings are also needed. In well-insulated buildings, switching off a heat pump for several hours can have little impact on indoor temperatures. The benefits of more efficient building envelopes for system flexibility are demonstrated by the work of the IEA Energy in Buildings and Communities Programme (IEA, 2019). Yet most buildings, even in advanced economies, are poorly insulated, limiting the potential for heat pumps to play a role in demand-side flexibility. For example, in Japan, air-to-water heat pumps for residential buildings that optimise their use by exploiting real-time weather forecasts to generate a profile of the likely availability of rooftop solar PV generation became available for purchase in 2022. For now, harnessing flexibility from heat pumps remains a niche solution, despite a number of pilot projects (Table 2.1).

Hybrid heat pumps are another option to increase flexibility. For example, the Dutch government has proposed making hybrid heat pumps the default option in new buildings to help manage grid congestion (Netherlands Enterprise Agency, 2022).

Table 2.1 ▻ Pilot projects on exploiting the flexibility potential of heat pumps

Country	Project name	Description
Switzerland	Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid	• 0-5% peak demand reduction • 5.5% increase in self-consumption
Denmark	EcoGrid EU	• 270 households with heat pumps provided up to 167 kW peak shaving (five-minute time span)
United Kingdom	Crowdflex	• Time-of-use tariffs application reduced daily evening peak by an average of 12% for households without EV
Netherlands	Power-to-Heat for Renewable Energy Integration: Technologies, Modeling Approaches, and Flexibility Potentials	• During the flexibility events of an hour, heat pumps provided 2.5 kW flexibility capacity

2.4 Energy affordability

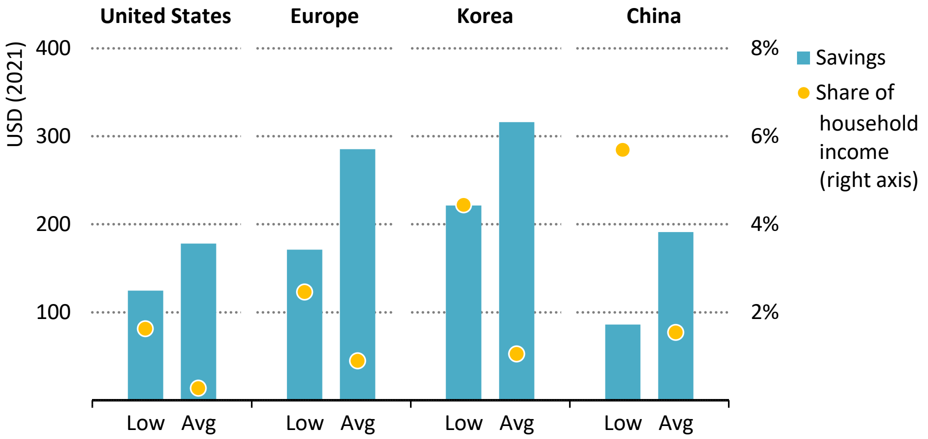
Higher energy prices are a major cause of the build-up of inflationary pressures, which are driving down household spending power and living standards in many parts of the world. Households spent on average around 7% of their income on energy in 2021, around one-half of which is for energy consumed inside the house. In heating regions, heat often represents the majority of total household utility bills. This can be even higher for poor households, which typically pay a far higher share of their income on energy, while receiving fewer energy services.

Household energy bills around the world have increased sharply – in some cases doubling. Governments around the world have responded to rising prices by introducing support measures, including caps on household energy bills (e.g. France and the United Kingdom), direct cash transfers (e.g. Germany) and long-term supply contracts securing gas demand (e.g. China and Korea). In total, governments worldwide have allocated roughly USD 550 billion to cushion consumers and businesses from high energy prices as of September 2022, with more under consideration at the time of publication.

Switching to heat pumps can help reduce household energy bills. In 2021, households that switched from a gas boiler to a heat pump enjoyed sizeable savings on their energy bills, ranging from USD 180 in the United States to almost USD 300 in Europe on average. These savings are much greater under today's price spikes, ranging from USD 300 per year in the United States to USD 900 in Europe. The savings were generally biggest in net gas-importing countries, especially in countries such as China with low residential electricity prices. As a share of total income, the savings were biggest for poor households, ranging from 2% to 6% of income (Figure 2.4).

Despite the potential cost savings on offer from switching to a heat pump, many consumers are not financially able to replace their existing heating system, especially during the current crisis, due to the large upfront installation cost. Reducing this cost will be key to scaling up the deployment of heat pumps (see Chapter 3). Poor households are least able to finance this cost and more likely to choose the cheapest replacement option when their heating system needs to be replaced, carrying the risk of locking them into expensive gas heating. In addition, gas heating costs could rise over time if investments in the gas network are increasingly recovered by a dwindling number of consumers as the clean energy transition progresses. Some governments offer targeted subsidies for energy efficiency retrofits and heat pumps for less well-off households to address these barriers. At present, a total of 12 countries, mostly in Europe, have such policies, covering roughly one-third of global heating demand.

Figure 2.4 ▷ **Energy bill savings for households switching to a heat pump from a gas boiler in selected regions/countries, 2021**



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Households switching from a gas boiler to a heat pump enjoyed big savings on their energy bills, with poor households saving most as share of their total income

Notes: Low = low-income households; Avg = average-income households. Savings are based on operating costs and exclude upfront costs. The analysis is based on average electricity and gas prices across regions/countries and an average household demand for space heating and hot water in representative cities in respective regions/countries (Detroit, Stockholm, Seoul, Beijing).

Poor households could see smaller savings and longer payback periods from switching to a heat pump than richer ones. This is because poorer households typically live in smaller units and use their heating less frequently to keep the cost down. However, poorer families also typically live in less efficient housing units, which increases the potential savings and shortens the payback period; low-income housing is typically less efficient than the average housing stock. In any case, poor households generally require upfront financial support to be able to benefit from retrofits and/or switching to heat pumps.

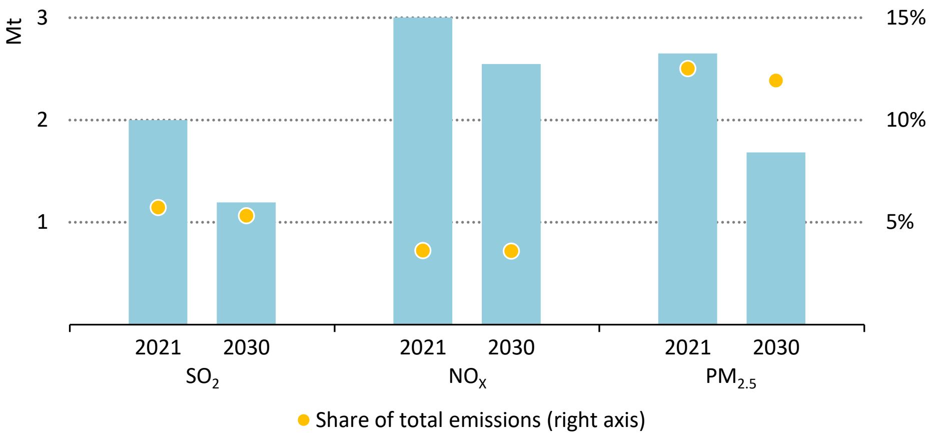
Electricity tariffs and fuel taxes need to be carefully designed to ensure they do not discourage consumers from installing a heat pump (see Chapter 3). Some electricity tariffs today are designed to promote energy efficiency by charging higher rates or adding charges for households consuming higher levels of electricity than the average, but this can penalise those who choose to switch to electric heat pumps. Some utilities offer specially metered electricity or special rates for consumers with electric heating and EVs, to avoid disincentivising these purchases. Time-of-use rates can also help reduce heat pump operating costs compared with flat tariffs, if coupled with smart controls to optimise heating. This also contributes to improving grid reliability and flexibility. Both energy taxes and carbon pricing schemes need to be designed so as not to penalise low-emissions electricity over fossil fuel use.

2.5 Public health and environment

2.5.1 Air pollution

The widespread adoption of heat pump technology could contribute to improving air quality and public health. Space and water heating in buildings based on coal, oil and biomass contributes to both household and ambient air pollution. In 2021, over 19 000 people died prematurely every day from breathing polluted air, the majority in emerging market and developing economies (IEA, 2022c).

Figure 2.5 ▷ Emissions of major air pollutants from fuel combustion for space and water heating in buildings in the APS



IEA. CC BY 4.0.

The electrification of space heating and water heating in the APS underpins a big reduction in emissions of all major air pollutants from buildings between 2021 and 2030

Sources: IIASA (2022) and IEA.

Around one-eighth of the emissions of fine particulate matter air pollution ($PM_{2.5}$) are caused by combustion activities for space and water heating in buildings, mainly the use of fuelwood and coal in heating stoves and boilers. Though a less significant contributor to overall emissions, heat services in buildings also cause emissions of nitrogen oxides (NO_x), mainly from gas boilers, and sulphur dioxide (SO_2), mainly from the use of coal in heating stoves and boilers and oil in boilers. In the APS, emissions of all major air pollutants from space and water heating in buildings fall between 2021 and 2030, by 15-40%, largely due to the deployment of heat pumps (Figure 2.5).

In addition, a large-scale switch to heat pumps can prevent other risks associated with fossil fuel combustion. For example, poorly serviced heating stoves and gas boilers can emit carbon monoxide, which is estimated to kill around 40 000 people each year, and there are also associated hazards due to explosions and fire risk (IHME, 2022).

2.5.2 F-gases

There is a potential catch in the environmental case for heat pumps. The principal attraction of heat pumps over other heating technologies is their potential for reducing GHG emissions, especially when the electricity needed to power them is generated from low-emissions energy sources. However, the more widespread use of heat pumps carries the risk of emissions of F-gases, used as refrigerants in the heat pump unit. Emissions of these gases, which are powerful GHGs, threaten to offset part of the climate benefits from switching away from fossil fuels for heating.

The main types of F-gases used today in heat pumps, refrigerators and other cooling devices are HFCs, which account for over 85% of global F-gas production (UNEP, 2017). They were widely adopted as substitutes for ozone-depleting substances that have been mostly phased out under the Montreal Protocol – a landmark multilateral environmental agreement on phasing out chemicals that damage the stratospheric ozone layer adopted in 1987. F-gases make up about 2.4% of global GHG emissions (IPCC, 2022). Emissions could grow rapidly in the coming years with the increased uptake of heat pumps and air conditioners if no further action is taken to control their use. Intergovernmental Panel on Climate Change (IPCC) scenarios compatible with a 1.5 °C rise in global temperature imply reductions in F-gas emissions of about 75% between 2021 and 2030. Due to their short atmospheric lifetimes and high global warming potential (GWP),[1] immediate action to cut F-gas emissions could have a rapid impact on global temperature increase and avoid technology lock-in.

In 2016, the Kigali Amendment to the Montreal Protocol called for a phase-down of F-gas production and consumption by 80-85%, to be reached in advanced economies by 2036 and in developing and emerging economies by 2047 to tackle the climate impacts of F-gas emissions. As of October 2022, parties representing over 80% of global GHG emissions have signed the amendment. The European Union implements its phase-down path mainly using the F-Gas Regulation, for which the European Commission has presented a revision proposal in April 2022. It proposes a ban of refrigerants with GWP over 150 for all self-contained and smaller split heat pump and air-conditioning systems.

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[1] The GWP makes it possible to compare different GHGs in terms of their climate impacts. It is defined as the heat absorbed by a given GHG expressed as a multiple of the heat that would be absorbed by the same mass of CO_2. To account for different lifetimes of gases in the atmosphere, the most common metric is the 100-year GWP, which corresponds to the heat absorbed over a 100-year period from the time of emission. Unless otherwise stated, this report uses the 100-year GWP.

Table 2.2 ▷ Common refrigerants and alternatives for residential heat pumps

Category	Refrigerant	GWP	Flammability	TFA yield
Conventional HFC	R-410a R-134a	2 088 1 430	Non-flammable (A1)	0% 7-20%
Hydrocarbon (HC)	R-290 (Propane) R-1270 (Propene) R-600 (Butane) R-691 (Pentane)	≤3	Higher flammability (A3)	0%
Lower-GWP HFC	R-32	675	Lower flammability (A2L)	0%
HFC/HFO blend	R-454B	490	Lower flammability (A2L)	30%
HFO	R-1234yf R-1234ze	4 <1	Lower flammability (A2L)	100% <10%
CO_2	R-744 (Carbon dioxide)	1	Non-flammable (A1)	0%

Notes: GWP values originate from the IPCC Fourth Assessment Report (AR4). They have expressed uncertainties of over 30%. Threshold values in policy have largely been based on that iteration. In the meantime, some values have been updated in IPCC AR5 and AR6. The TFA yield is the percentage of emitted refrigerant that decomposes to trifluoroacetic acid (TFA) in the atmosphere, an environmental and human health hazard with a very long lifetime. Higher percentages are more harmful.

Source: UBA (2021).

F-gas emissions occur during production of the gases, manufacturing of the refrigeration cycle (such as in a heat pump) and leaks during the use of the product and its decommissioning. Emissions from heat pumps can be reduced by regular maintenance and by proper decommissioning and recycling where appropriate (Daikin, 2022). However, effective systems for handling obsolete devices may not be in place globally. Current in-field best practice could reduce F-gas emissions from heat pumps worldwide by one-third, but these estimates vary widely by region and heat pump model. Additionally, alternative refrigerants could be used such as F-gases with lower GWPs as well as hydrocarbons, HFOs or CO_2, which have much lower GWPs but can be technically complex or more expensive (Table 2.2). For example, the use of propane as a refrigerant is restricted under EU building regulations due to its higher flammability. While the installation of monobloc hydronic units, where the refrigerant cycle is entirely located outdoors, gets around this problem, split systems are also an important option to make heat pumps usable in the majority of buildings. A revised International Electrotechnical Commission (IEC) norm[2] was released in May 2022 that is in the process of formal harmonisation in the European Union, but can already be adopted by manufacturers according to EU legislation. It allows for charges of flammable refrigerant sufficient for smaller split systems with indoor refrigerant cycles when the system meets additional safety requirements. For larger systems, the proposed F-gas regulation still allows HFC refrigerants with GWP below 750. To ensure safe handling of flammable refrigerant also during installation and decommissioning and to minimise accidents worldwide, the United Nations Environment Programme (UNEP) has set up a Refrigerant

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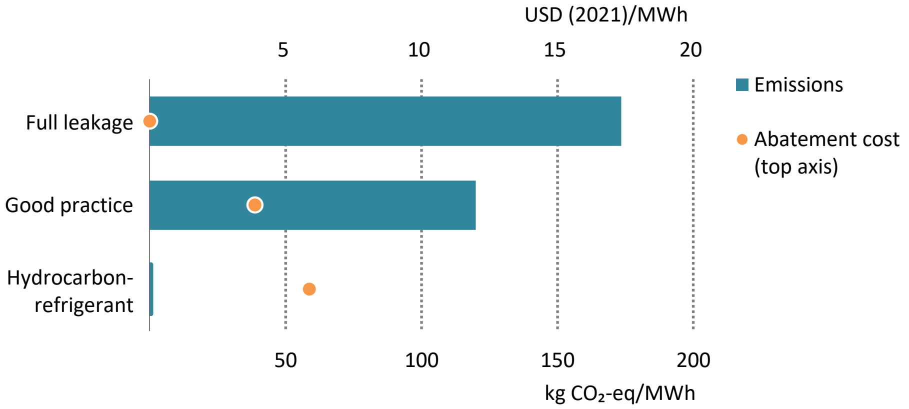
[2] IEC-60335-2-40 on particular requirements for electrical heat pumps, air conditioners and dehumidifiers (IEC, 2022).

Driving License programme that facilitates best practice knowledge exchange and training on safe handling of refrigerants between advanced economies and emerging and developing economies (UNEP, 2018).

Technological innovation is needed to reduce refrigerant loads and their associated environmental and safety risks. For example, a research project in Germany has successfully tested the prototype of a heat pump with only 10 grammes of propane refrigerant per kilowatt capacity at a COP of 4.7 whereas current systems commonly use six times that amount (Fraunhofer ISE, 2022). Some manufacturers have also developed alternative HFCs with lower GWP levels, such as HFC R-32. HFOs such as R-1234yf and R-1234ze have lower flammability, are not ozone depleting and have significantly lower GWPs but cause potential environmental and human health hazards.[3]

CO_2 refrigerants are not flammable and have very low toxicity and a GWP of one (Patenaude, 2015). However, their use requires higher operating pressures and more powerful compressors, which increases the demand for energy and materials in making and using the heat pump. Due to its physical properties, CO_2 offers increased efficiencies in specific use-cases with high temperature differentials such as water heaters or certain industrial and commercial applications.

Figure 2.6 ▷ Heat pump refrigerant GHG emissions per MWh of useful heat output and abatement cost by refrigerant option



EA. CC BY 4.0.

Specialised maintenance, recycling and the use of alternative refrigerants can substantially reduce emissions due to refrigerant leakage

Notes: kg CO_2-eq = kilogrammes of CO_2 equivalent. Baseline refrigerant mix with a GWP of 2 000.

Source: IEA analysis based on Purohit and Höglund-Isaksson (2017).

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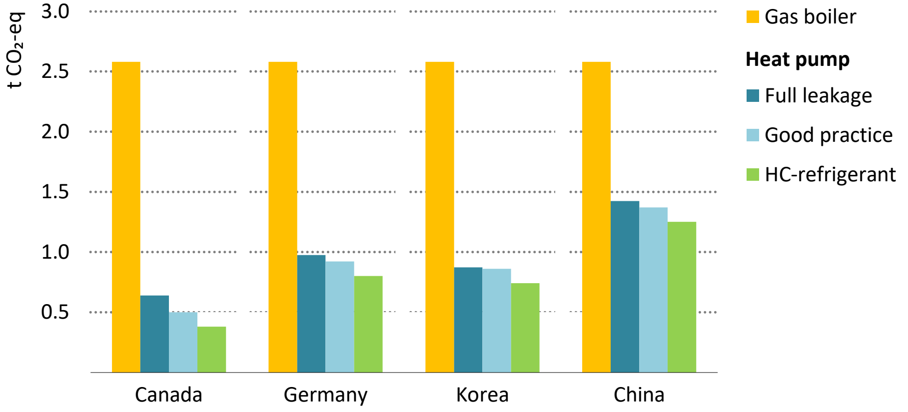
[3] HFOs are considered a per- and polyfluoroalkyl substance (PFAS) due to their transformation into TFA in the atmosphere, an environmental and human health hazard with a very long lifetime. Possible future regulation on PFAS may prohibit their use in the European Union (European Chemicals Agency, 2022).

The highest potential for cost-effective GHG emissions reductions from heat pump refrigerants lies in replacing HFCs with hydrocarbons, but adds the challenge of flammability (Figure 2.6). Between 6% and 40% of the lifetime CO_2 equivalent emissions of an average residential heat pump using the HFC R-134a are associated with refrigerant leaks, depending on the power mix, the heat pump performance and if the refrigerant is recovered at the end of life. This share will rise as electricity production is increasingly decarbonised.

With today's F-gas refrigerants and full leakage, heat pumps still reduce greenhouse gas emissions by at least 20% compared with a high-efficiency gas boiler, even when running on emissions-intensive electricity. In regions accounting for 70% of world energy consumption, the emissions savings are above 45% and reach 80% in countries with cleaner electricity mixes. These values can be improved by 10 percentage points, respectively, with alternative refrigerants. The large variation is mainly due to differences in the emissions intensity of electricity generation rather than refrigerant choice. Figure 2.7 illustrates emissions savings in four countries based on their climate conditions and emissions intensity of electricity production.

Figure 2.7 ▹ **GHG emissions per MWh of useful heat output for gas boiler and heat pump depending on refrigerant option**



IEA. CC BY 4.0.

Switching to a heat pump substantially decreases emissions regardless of climate conditions and electricity mix. Addressing F-gas emissions can reduce emissions further.

Notes: t CO_2-eq = tonnes of CO_2 equivalent; HC = hydrocarbon. Emissions savings of a heat pump are compared with a gas boiler with 90% efficiency and F-gas emissions for a baseline without professional recycling and abatement options and a refrigerant mix with GWP = 2 000. GHG emissions include greenhouse gas emissions from operating and decommissioning. Electricity production emissions factors: Canada (119 g CO_2-eq/kWh), Germany (352 g/kWh), Japan (416 g/kWh), China (549 g/kWh). Canada climate based on Ontario, Japan on Central Japan and China on Northern China.

Sources: IEA analysis based on Purohit and Höglund-Isaksson (2017); Purohit et al. (2022a); and Kowalski and Szałański (2019).

If F-gas refrigerants continue to be used in the same way, by 2030 in the NZE Scenario, the global heat pump stock will bank nearly 740 Mt CO_2 equivalent of greenhouse gas emissions – about twice the total annual greenhouse gas emissions of Australia. Even if today's best practices in maintenance and recycling were applied worldwide, only one-third of these emissions would be prevented, making it harder to limit the global temperature rise to 1.5 °C.

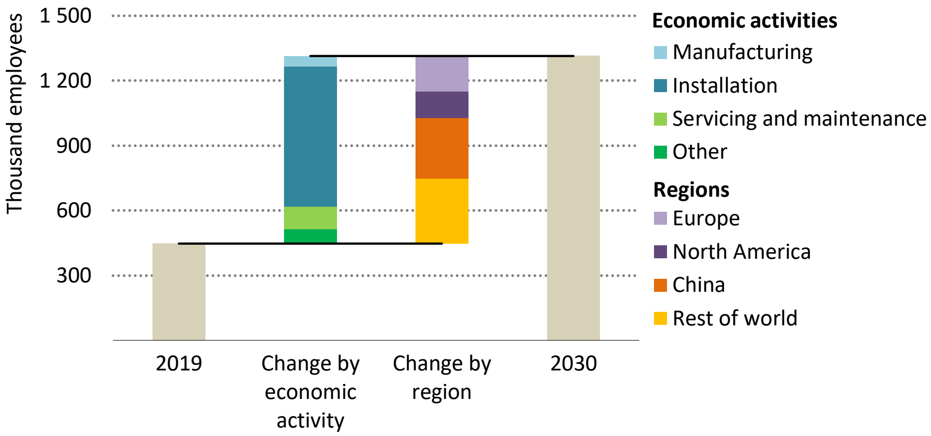
Switching to non-HFC refrigerants is technically possible, but risks impeding the deployment of heat pumps due to the technical and cost implications. Importantly, refrigerants cannot be simply swapped in existing units. While a range of heat pump manufacturers do not heavily rely on HFCs anymore, others will need to change the production process and use different components and materials. Workers in production and installation may require additional training for flammable material. A stable and ambitious regulatory framework is therefore important to give investment certainty. In the short term, an important focus for policy action should be to set up standards for leakage proofing and enforced recycling systems to avoid conventional high-GWP refrigerants to be emitted into the air from old equipment. Since F-gas leakage occurs over the duration and at the end of equipment lifetime, continued use of these refrigerants in new appliances means that F-gases will still be emitted beyond 2050 (Purohit et al., 2022b). Policy makers need to ensure that measures to accelerate the phase-out of HFCs do not hold back strengthened heat pump uptake, whose climate benefits far outweigh the negative climate effects of HFC leaks. This implies minimising HFC use for equipment for which alternatives with low GWP are available without significant losses in efficiency or other technical qualities.

2.6 Job creation

A rapid scaling-up of the deployment of heat pumps would necessitate a commensurate expansion of the workforce in manufacturing and installing them, as well as in making the various materials and components needed for their assembly. This implies a massive drive to recruit and train workers.

In 2019, around 450 000 people work directly in manufacturing, planning and installation, wholesale, servicing, and maintenance of heat pumps globally (Figure 2.8). Installation is the most labour-intensive part of the heat pumps value chain, with an estimated 210 000 workers employed. China has the most installers, since much of the building stock, particularly in the south of the country, relies on heat pumps for both cooling in the summer and heating in the winter. Air-to-water and ground-source heat pumps typically require more worker-hours per installation, boosting the numbers employed in the sector and the need to recruit new workers as the market expands. Manufacturing, servicing and maintenance together make up about half of direct heat pump jobs. As with installers, China has the biggest heat pump manufacturing labour force, numbering around 55 000, consistent with its 45% share of global heat pump manufacturing, followed by the United States, where around a quarter of heat pumps are produced.

Figure 2.8 ▹ **Change in heat pump employment by activity and region/country in the APS, 2019-2030**



IEA. CC BY 4.0.

Heat pumps create 800 000 new jobs by 2030 mainly in installation and maintenance, calling for a major recruitment and training drive

Note: Other includes wholesale and transport.

Global employment in heat pump supply nearly triples to over 1.3 million workers to 2030 in the APS. The European workforce nearly triples as manufacturers and installers respond to ambitious targets in the REPowerEU initiative and other national heat pump deployment plans. The projected growth of the heat pump workforce worldwide is accompanied by around 700 000 additional workers building more energy-efficient buildings and carrying out retrofits improving the insulation of building envelopes. Integrated heat pump systems also stimulate the creation of jobs in installing household solar PV panels and batteries.

The growth in heat pump employment in the APS is concentrated in installation. The number of heat pump installers needed climbs to 850 000 in the APS, an increase of nearly 650 000. The greatest growth in demand is in China and the rest of the Asia Pacific. The number of installers in Europe increases threefold mainly thanks to the rapid heat pump uptake in the European Union and the United Kingdom. In addition, around 170 000 more workers are needed to maintain and service the additional heat pumps that are installed worldwide by 2030. Recruiting and training all these workers represents a considerable task. There are already concerns in the industry about whether all these positions can be filled given current tight labour markets for occupations related to heating (see Chapter 3).

The number of jobs in heat pump manufacturing increases more slowly, by around 40% globally, due to improvements in labour productivity as new, more efficient factories come online. Innovative sensor controls and programming can streamline manufacturing processes and increase the efficiency of assembly lines, while modular designs and standardised components compatible with different types of heat pumps and 3D printing can reduce manufacturing times and labour inputs (RHC and EHPA, 2021). Employment in heat pump manufacturing is concentrated in China, North America and Europe, where the bulk of the manufacturing capacity is today and where major manufacturers direct the most investment into capacity expansions over the period to 2030. New manufacturing plants coming online in Europe and the United States reflect recent policy moves to onshore critical parts of supply chains (see Chapter 3). Manufacturing costs there are significantly higher than in Asia-Pacific, where most heat pumps and components are made today, due to higher labour costs, but can be lowered by automation. However, many manufacturing activities, such as welding, will remain labour-intensive.

The heat pump industry requires different types of professionals along the value chain equipped with different skill sets. Manufacturing workers need to be able to operate mechanised equipment and perform manual tasks similarly to jobs in manufacturing of other home and industrial appliances, while installation requires one or more highly skilled heating professionals who can calculate heat losses, scale the size of the heat pump and carry out plumbing and electrical tasks (see Chapter 3). Many of these skills are interchangeable with those in similar jobs in the manufacturing and heating industry, thereby offering an alternative career path to workers in the fossil fuel heating industry, such as gas boiler installers, and making it easier to recruit new workers (subject to local regulations and related mandatory qualifications).

Training will be critical to expanding the heat pump workforce around the world, particularly for installers. Installation training programmes, including those proposed by industry associations and manufacturers, need to cover rural as well as urban areas. As with the air-conditioning industry, the heat pump manufacturing and installation sector today is dominated by males. Efforts to improve gender balance could be integrated with training and recruitment programmes. Heat pump workers also generally earn a wage premium of around one-quarter over the average construction worker – though this varies considerably across countries. But training is costly, which can discourage new applicants. Decent remuneration for apprenticeships and public funding of retraining schemes are important levers for attracting workers into the sector. Labour union representation can help to promote better work conditions, safety standards and fair wages. In the United States, heat pumps as a part of the energy efficiency sector have a higher-than-average unionisation rate (US DOE, 2022).

Chapter 3

Barriers and solutions

Pumping up the market

SUMMARY

- Accelerating the take-up of heat pumps hinges on overcoming a number of barriers, chief of which are the upfront cost of installations, other non-cost deterrents to consumer adoption, manufacturing constraints and potential shortages of qualified installers. Concerted action by governments and the heat pump industry is needed to alleviate these constraints and hit the rates of deployment envisioned in the APS.
- The high upfront cost of buying and installing a heat pump relative to other heating options can deter many consumers, even though lower running costs mean that they can be cost-competitive over their lifetime—even without subsidies in some regions. The cost of installing an air-to-air heat pump is comparable to that of a gas boiler in most major heating markets today thanks to policy support, though air-to-water heat pumps can still be two to four times more expensive. Financial support is available in more than 30 countries, with many offering additional support for low-income households (as in Poland) and/or high-efficiency models (e.g. Canada). Energy tax reform and evenly applying CO_2 penalties across household heating fuels and electricity can lower running costs and make heat pumps financially attractive.
- A number of non-cost barriers, such as complicated approval processes, a lack of information, and split incentives for building owners and tenants, are major reasons for the low consumer adoption of heat pumps today in many countries. Several have taken action to ease permitting procedures (such as in the Czech Republic), create "one-stop shops" for consumers (e.g. Ireland), and encouraged alternative business models to address the split incentive problem, notably in North America, the United Kingdom and Germany, though stronger efforts are needed everywhere.
- Leading manufacturers have recently announced plans to invest more than EUR 4 billion in expanding heat pump production capacity and related efforts, mostly in Europe. However, supply chain bottlenecks, notably affecting chip sets and copper, are adding to manufacturing costs and threaten to hold back the expansion of heat pump production capacity. Several countries, notably the United States, are responding with incentives to build up domestic manufacturing capacity. Long-term policy consistency and regulatory certainty, together with targeted action to strengthen supply chains, are needed to encourage further investment.
- Shortages of qualified installers, already a problem in many key heating markets, risk undermining heat pump deployment. Demand for full-time installers quadruples to over 850 000 in 2030 in the APS. Incorporating heat pumps into existing certifications for plumbers and electrical engineers, who have similar skills, would help reduce training requirements. Financial incentives, such as those used across Europe, can also be used to attract new workers to specialised training programmes.

3.1 Introduction

Accelerating the deployment of heat pumps to the extent envisioned in the APS hinges on overcoming a number of barriers, some of which are universal while others are specific to particular countries or regions. This chapter focuses on the main hurdles for heat pumps in buildings on both the demand side – cost and other market hurdles to customer adoption of heat pumps – and the supply side – practical constraints on expanding manufacturing and the availability of sufficient numbers of trained installers. The key policy options to address these barriers are summarised in Table 3.1 and discussed in detail throughout the rest of the chapter.

Supply chain barriers upstream of the assembly and installation of heat pumps, including potential constraints on the supply of raw materials, equipment and components needed for manufacturing heat pumps, are covered in detail in the forthcoming IEA report *Energy Technology Perspectives 2023*, which is due to be released in January 2023.

Table 3.1 ▻ Overview of key barriers to accelerating the deployment of heat pumps and corresponding policy solutions

Barriers	Policy solutions
Demand side	
Cost barriers	*Upfront costs:* • Grants • Low-interest loans • Tax rebates • Green mortgages • Alternative business models • Risk mitigation schemes for medium- to large-scale projects *Operating costs:* • Rebalancing electricity and fossil fuel taxes, CO_2 tax with compensation • Electricity tariff reforms • Support for building insulation and heat distribution system upgrades • Quality and settings control after installation • User training
Non-cost hurdles to consumer adoption	• One-stop-shop platforms for consumers and comparer tools • Facilitation and support of alternative business models for heating to address split incentives • Regulation changes for optics, noise and building permissions • Revision of decision-making rules in multi-owner buildings • Minimum energy efficiency requirements for rented properties or at point-of-sale transactions • Performance labels for heating technologies • Information campaigns towards consumers • Independent and free audits to inform heating system replacement decisions

Table 3.1 ▹ Overview of key barriers to accelerating the deployment of heat pumps and corresponding policy solutions (continued…)

Barriers	Policy solutions
Supply side	
Manufacturing constraints and supply chain vulnerabilities	• Long-term certainty in policy support and regulations, as well as visibility into forthcoming regulation changes, including industry consultation • National heat pump deployment targets and roadmaps • Industrial policy including financial support to manufacturers • Securing of heat pump component supply chains
Shortages of skilled installers	• Integration of heat pumps in pre-existing certifications for heating, ventilation and air conditioning (HVAC), construction, and electrical professions • Incentives to attract HVAC professionals to gain additional certifications • Reinforcing manufacturer-run trainings and simplify installation process • Internationally standardised certification schemes with broad curricula • National heat pump deployment targets and roadmaps to build confidence and provide professionals with long-term employment prospects

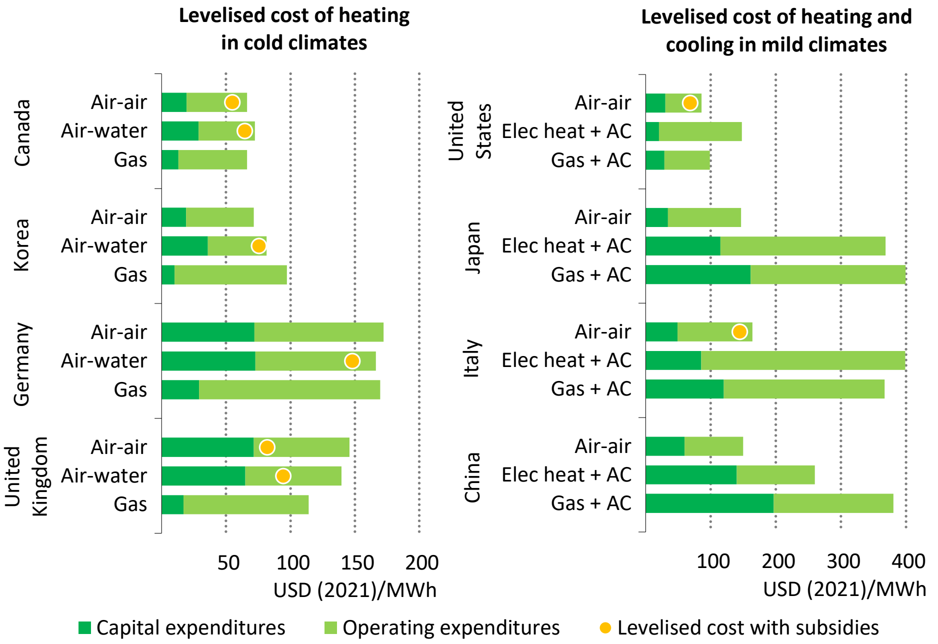
Designing and tailoring these policy strategies to context specificities requires reliable data, which are often lacking in practice. In particular, there is need for data on heat demand, industrial process needs and the sources of waste heat, using, for example, heat mapping techniques, as well as on the characteristics of building and heating system stocks, market development, installation and maintenance costs, and the real-world performance of installed systems. Governments everywhere need to step up efforts to improve data gathering to better inform both policy-making processes and investment decisions.

3.2 Cost barriers

The overall cost-competitiveness of heat pumps against other heating technologies depends on a combination of factors, including the initial purchase price, operating and maintenance costs (including the price of the electricity needed to run them), their durability, and financial incentives such as grants or tax credits. In most markets, heat pumps generally entail higher upfront costs than conventional fossil fuel heating equipment such as oil or gas boilers, even when financial incentives are taken into account, but benefit from lower running costs over their lifetime due to their much higher energy efficiency.

The ability of heat pumps to compete on cost today varies markedly across countries according to differences in all these factors. Based on average 2021 equipment prices and fuel prices projected in the APS, a new heat pump to heat an average home in a cold climate is cheaper than a natural gas condensing boiler in most of the main heating markets, often even without subsidy (Figure 3.1). In some countries such as the United Kingdom, however, subsidies for heat pumps are required to make them cost-competitive. Even where the cost of a heat pump over its lifetime is already the cheapest heating option, financial incentives, including grants and low-interest loans, may still be needed to reduce the initial cost burden, which may deter the building owner from installing a heat pump in the first place.

Figure 3.1 ▷ **Levelised cost of heating and cooling of residential heat pumps and alternatives in selected countries, 2021**



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Thanks to lower operating costs, heat pumps can be competitive with gas boilers in some leading heating markets today, even without subsidy

Notes: Air-air = air-to-air heat pump; Air-water = air-to-water heat pump; Gas = gas condensing boiler; Elec heat = electric resistance heater; AC = air conditioner. The levelised cost of heating and cooling estimates the average cost of providing 1 MWh of heating or cooling over the lifetime of the equipment, considering the capital cost of the equipment and installation; operating expenditures include the cost of fuel and regular maintenance. The analysis assumes heating and cooling degree days of one representative, cold-climate city in each representative country, then uses average energy prices in that country. For cold climates, we use Toronto, Seoul, Berlin, Edinburgh and for representative cities in mild climates we use Washington, D.C., Kyoto, Rome, Shanghai. Medium market prices for the equipment and projected fuel costs under the APS have been used. A lifetime of 17 years is assumed for gas boilers, 15 years for air-to-air and 18 years for air-to-water heat pumps. Electric resistance heaters and air conditioners are assumed to have a lifetime of 10 years.

3.2.1 Reducing upfront costs

Reducing the upfront cost of purchasing and installing heat pumps is critical to boosting their attractiveness to consumers, notably households. Equipment costs vary substantially depending on the technology type (air-to-air, air-to-water or ground-source), rated capacity, manufacturing quality and functionality, as well as across countries and regions, partly according to the maturity of the market. The latter factor also influences installation and ancillary costs, such as electrical and piping work or storage tanks, the need for which vary widely depending on the specific configuration of each installation. Differences in the cost of labour further explain upfront cost variations across countries.

In most markets, the upfront cost of a residential heat pump (including installation) is generally much higher than that of a fossil fuel boiler, though the extent of the cost gap varies widely within and across countries, even for the same technology (see Figure A.1 in Annex A). Nonetheless, in some mature markets, such as Denmark and Japan, the least expensive ductless air-to-air heat pump models have become cheaper than gas boilers for new installations in small houses, in particular thanks to reduced piping work and installation costs (Figure 3.2). In the case of ductless air-to-air systems, however, larger households with multiple heating zones require more than one unit, which generally makes them more expensive than gas boilers. Hydronic (air-to-water) heat pumps are more expensive than air-to-air heat pumps, and even the cheapest models remain more costly than gas boilers in all the main markets, with the exception of Sweden, whose early-on policies enabled the widespread adoption of heat pumps bringing installation costs down. Ground-source heat pumps are the most expensive technology type in all countries, due to the earthworks or drilling needed to install the underground heat exchanger, which can represent more than half of the total price of the system (though their far greater durability and efficiency mean that they can be competitive on a levelised cost basis). Installing a reversible heat pump, by eliminating the added cost of a separate air-conditioning unit, can effectively lower the cost for heating purposes in climates with cooling needs during part of the year.

The higher upfront cost of heat pumps compared with gas or oil boilers means that some households are simply unable to afford them, even though their lifetime cost may be much lower. To help overcome this barrier, a number of countries have introduced subsidies on heat pumps to encourage their uptake. Taking account of the minimum subsidies currently available, upfront costs for both air-to-air and air-to-water heat pumps are below those for gas boilers in some countries, including France and the United States. The cost advantage for heat pumps can be even larger for low-income households that are entitled to bigger subsidies, such as in Poland. Subsidies are also higher in some countries, such as Canada, for the most efficient models, which are generally more expensive.

Switching to a heat pump in an existing house may incur additional costs, which can also constitute a barrier to choosing that option. Older homes may have to upgrade their electrical system to accommodate a higher power load depending on the capacity of the heat pump. In addition, existing radiators may need to be replaced with larger ones, or with underfloor heating or forced-air heating systems, in order to allow heat pumps to operate at lower temperatures and benefit from greater efficiency.[1] These upgrade costs can make up as much as a third of the total cost of installing a heat pump.

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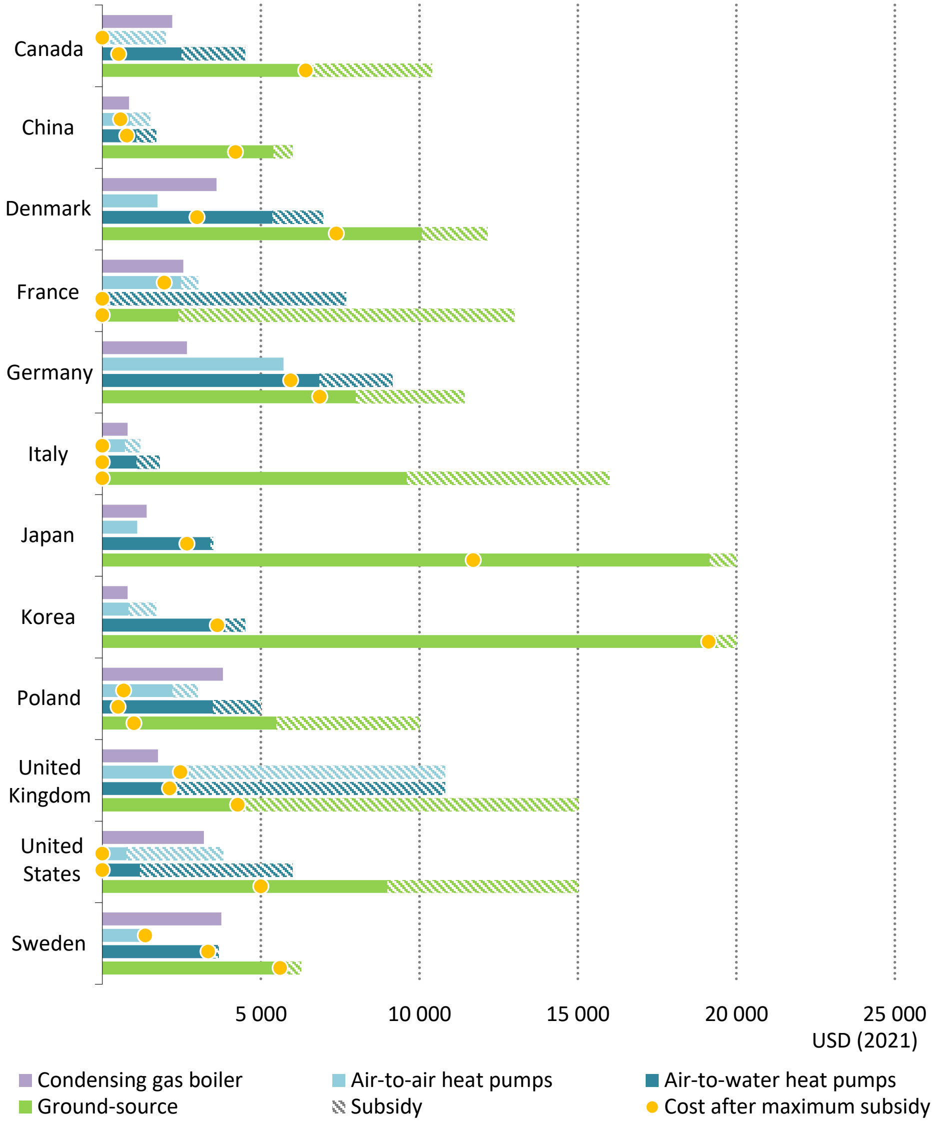
[1] Fossil fuel boilers generally operate with output temperatures at 60-80 °C. While heat pumps can produce heat above 55 °C and potentially up to 70 °C, their performance declines as their output temperature increases.

Figure 3.2 ⊳ **Equipment and installation cost of the cheapest model of main residential heating technologies in selected countries, 2022**



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Air-to-air heat pumps can be cheaper than gas boilers in some markets, but subsidies remain key to increase the competitiveness of air-to-water and ground-source units

Notes: Costs include the price of the equipment and its installation. Subsidies account for the minimum level of national financial support offered to households that qualify for it in each country. China and Japan do not offer subsidies at the national level. Some countries, such as Italy, offer subsidies that can exceed the purchase price in some cases.

Table 3.2 ▹ **Coverage of financial support mechanisms for residential heat pumps worldwide, 2022**

Type of financial support and key features	Number of countries	Share of global residential space heating
Grants	**30**	**70%**
Support eligible only for heat pumps…		
Primarily used for heat production	27	47%
Installed in older dwellings	20	28%
Running fully on electricity (hybrids excluded)	16	11%
Replacing fossil fuel heating systems	12	34%
Installed in the main residence	12	15%
Base amount set…		
As share of expenses and capped by maximum amount	16	39%
Depending on heat pump technology	10	16%
Depending on other factors	6	3%
Additional support for…		
More efficient technologies	18	29%
Lower-income households	12	34%
Heat pumps installed in houses rather than appartments	4	2%
Heat pumps installed in disadvantaged areas (e.g. no district heating)	4	2%
Heat pumps replacing a fossil fuel heating system	3	7%
Income tax rebate	**9**	**33%**
Support eligible only for heat pumps…		
Installed in older dwellings	5	12%
Installed in the main residence	3	6%
Base amount set…		
As share of purchase/installation price and capped by a maximum	7	30%
Equal to the purchase price	2	2%
Higher than the purchase/installation price depending on efficiency/energy savings	1	3%
Additional support for…		
Heat pumps replacing a fossil fuel heating system	1	<1%
VAT rebate	**5**	**12%**
VAT rate…		
Reduced for the purchase and/or installation of a heat pump	5	12%
Equal to zero for the purchase and/or installation of a heat pump	1	4%
Low-interest loans	**24**	**29%**
Loans with…		
Low interest and conditions on amount and maturity	20	18%
Zero interest and conditions on amount and maturity	7	13%

Note: Analysis based on national-level policies except for Japan and China, where only subnational schemes exist but cover a substantial share of national space heating demand.

There is a wide range and diversity of financial incentive schemes available across the main heating countries, reflecting differences in political will, national policy strategy and local factors (Table 3.2). In many countries, financial support for heat pump installations is available only if existing fossil fuel boilers are scrapped. Those countries collectively account for more than a third of global heating demand.

Grants are the most commonly used policy tool and are currently available in 30 countries, together representing 70% of global space heating demand. In some countries, grants cover most if not all the cost of purchasing and installing a heat pump for low-income households. Some countries, including France and the United Kingdom, have reduced or completely removed VAT on alternatives to gas boilers. Income tax credits are used in some countries. For instance, Italy's Superbonus scheme provides a tax credit worth up to 110% of the cost of a substantial building retrofit that can include heat pumps. However, in contrast to direct grants and subsidies, tax credits only reach consumers with a delay, often two years, but as high as five. Low- or no-interest loans, green mortgages and specific loan repayment schemes (e.g. pay-as-you consume) are widely available in many countries. In the case of medium- and large-scale ground-source heat pump projects, schemes to limit the financial risks associated with drilling are used in some countries, notably France (Georisk, 2021). It can be daunting for consumers to obtain information about their eligibility for the various types of financial support on offer and how to apply for them, so some countries have set up "one-stop shops" to facilitate this; Electric Ireland Superhomes is but one example.

Other policy approaches can also help lower the initial cost of purchasing and installing a heat pump. The right regulatory environment can enable the emergence of new business and financing models that alleviate the financial burden on consumers by reducing or eliminating the upfront cost borne by the consumer, and instead allow them to pay back these costs along with their usage, for instance through rental or heat-as-a-service models (see the next section). Where relevant, regulators should remove other upfront barriers that impede adoption, such as gas network disconnection charges.

The cost of buying and installing a heat pump is expected to decline gradually in real terms over the rest of the current decade, as markets expand and suppliers benefit from economies of scale. The largest cost components in manufacturing a heat pump are the compressor, heat exchanger and electronics, which together make up around two-thirds the cost of an air source heat pump (US DOE, 2016). There is considerable potential for reducing production costs through large-scale automation, though strong and stable policy signals are needed for manufacturers to commit to the substantial investments required to expand output capacity. Industry-wide measures could help spur faster declines, such as standardising parts and quality control testing, which could lower the cost of components, installation, and repair and maintenance. Manufacturers can also develop plug-and-play designs to make installation faster, easier and cheaper. Targeting serial installations across similar buildings in the same neighbourhood – drawing for instance on the Dutch-originated Energiesprong approach to energy efficiency retrofits to buildings – can help mutualise logistical costs

(Energiesprong, 2021). In the more mature markets, growing competition among installers is also expected to put downward pressure on costs.

Overall, total upfront costs for heat pumps could potentially decline by one-fifth in most markets during this decade, and up to 40% in some countries such as Germany (Heptonstall and Winskel, forthcoming; Agora Energiewende, 2022). However, the outlook for costs remains highly uncertain, because of the impact of other factors that could work against the trends described above, such as the tightening of regulations on the energy performance of heat pumps and the types of refrigerants permitted, as well as higher retrofit costs, as heat pumps are progressively deployed in existing buildings that require deep energy retrofits.

Box 3.1 ▹ EBRD financing for heat pumps

The European Bank for Reconstruction and Development (EBRD) supports the rapid deployment of heat pumps as a means of decarbonising heating systems. Through the Green Economy Financing Facility, the EBRD works with a network of over 170 local financial institutions and 2 300 technology providers to support businesses and homeowners wishing to invest in green technologies. It has already directly invested over EUR 80 million in a range of projects, particularly in East and South-East Europe, enabling the installation of 30 000 heat pumps. In addition, loan funds have supported the deployment of heat pumps as part of energy efficiency-focused building retrofit programmes in Poland and Romania.

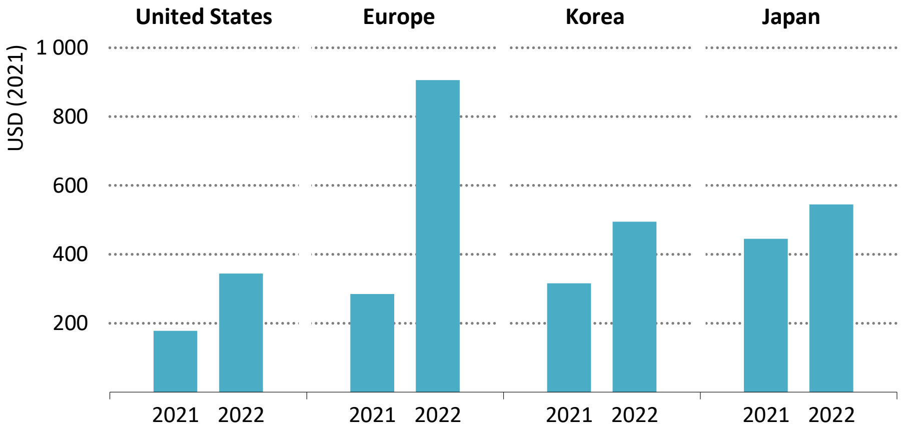
To support heat pump deployment, the EBRD relies on four main levers:

- Supporting analyses on heat pumps to optimise the scale-up of the technology in specific markets.
- Working with governments to remove barriers to heat pump deployment and assisting them in the creation of minimum performance standards.
- Supporting municipal infrastructure clients to install industrial-scale heat pumps for district heating – especially in the western Balkans – as well as building-scale heat pumps as part of both deep energy retrofits and new building projects.
- Strengthening green economy finance through the banking sector.

3.2.2 Reducing operating costs

Heat pump running costs were already lower than those of gas boilers in the main heating markets before the current energy crisis (Figure 3.3). In Europe, this advantage has grown in recent months, saving the average European household over USD 900 annually. This is because households' tariffs for electricity generally increased less than those for gas, partly due to government interventions to dampen price increases.

Figure 3.3 ▷ Energy bill savings for households switching to a heat pump from a gas boiler in selected regions/countries, 2021 and 2022



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Soaring gas prices have boosted the cost advantage of running a heat pump over a gas boiler in most countries

Note: Savings in energy bills in 2022 take account of policy interventions up to September 2022 to limit price rises, including reductions in VAT, direct subsidies, and caps on increases in electricity and gas prices. The analysis is based on average electricity and gas prices across regions/countries and an average household demand for space heating and hot water in representative cities in respective regions/countries (Detroit, Stockholm, Seoul, Niigata).

Source: IEA analysis based on Energie-Control Austria, MEKH and VaasaETT (2022).

There remains considerable scope for reforming fuel taxes in some countries, where gas still benefits from more favourable taxation than electricity. Others have taken steps to rebalance taxes. For instance, a tax reform in the Netherlands reduced tax rates on electricity, while taxes for gas use were increased, making heat pumps even cheaper to run than gas boilers. A ban on gas connections to new buildings was introduced in 2018, which has already led to an increase in demand for heat pumps (RAP, 2022a). In Denmark, where taxes made up more than half of the residential electricity price in 2021, homeowners and tenants pay a lower rate of tax of just 0.1 euro cents per kilowatt-hour of electricity if their home is heated by a heat pump (IEA, 2021).

Carbon pricing can also help level the playing field between fossil fuel and low-carbon technologies, and can significantly improve the competitiveness of heat pumps, in particular in regions with low-emissions electricity generation. Today, more than 20 countries worldwide put a price on CO_2 emissions in the buildings sector (World Bank, 2022). In Sweden, the introduction of a carbon tax in 1991 and subsequent steady increases in the tax rate have driven a large-scale switch from oil boilers to heat pumps. The Swedish carbon price reached EUR 118 per tonne of CO_2 in 2022 – one of the highest in the world. As a consequence, oil boilers have largely been phased out, with heat pumps now accounting for more than 90% of heating system sales today.

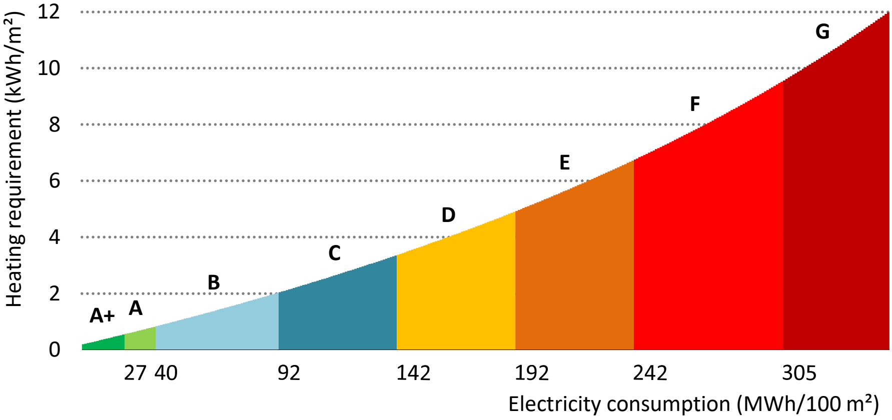
In all cases, energy taxation and carbon pricing policies need to take account of distributional impacts. Compensatory measures to protect the most vulnerable populations may be needed, which can be financed by the additional revenues generated by higher fuel and/or carbon taxes. That revenue can also be used to subsidise heat pumps and other clean energy technologies.

Electricity tariffs can also be designed in a way that reduces the running costs of heat pumps. The thermal inertia of buildings and hot water tanks offers considerable potential for heat pumps to be operated flexibly, allowing them to consume power at off-peak times of the day. This flexibility needs to be valued through time-of-use and dynamic electricity tariffs and automated operation. For example, Electric Ireland offers a night rate that is around half the price of the day rate, allowing heat pump owners to programme their devices to operate especially at night (Electric Ireland, 2022). Integrated metering, communication and active control features can enhance the demand-response potential of heat pumps and minimise operating costs. This can also help to balance the overall electricity system and reduce the impact of the large-scale deployment of heat pumps on peak demand. Flexible operation can also enable the coupling of heat pumps with rooftop solar PV, which can further reduce operating costs, though it does entail significant upfront costs.

Improved energy efficiency can also lower running costs. Well-insulated buildings and efficient heat pumps, which can be encouraged through minimum energy performance standards and labelling, are essential to reduce the capacity of heat pumps needed to warm a given amount of space and volume of water, thereby cutting the cost of operating as well as installing them. This also allows for lower flow temperatures, enabling heat pumps to operate more efficiently and cheaply. In Denmark, electricity consumption by heat pumps has been found to be up to 30 times lower in homes with the highest efficiency rating compared with the lowest efficiency rating (Figure 3.4). Improving a home’s efficiency rating by two grades (e.g. from D to B) can half the heating energy demand, saving consumers money. The IEA Energy Efficiency Market Report 2022 discusses the nexus of insulation and heat pumps in more detail (IEA, 2022a).

The running costs of a heat pump are also affected by how well it is operated and maintained. It is essential that the owner of a heat pump is informed about correct handling and the need for thorough maintenance by qualified technicians so that they operate efficiently and at optimal cost throughout their lifetime. Air-source heat pumps can become clogged with dirt over time, leading to increased electricity consumption and premature wearing of the unit, as well as noisier operation. Refrigerants also tend to leak out over time, which reduces efficiency, as well as contributing to climate change (see Chapter 2). Refrigerant leakage warning systems are currently commercially available for large heat pumps; a roll-out to residential systems could help users identify the reason for loss in performance and avoid the emission of refrigerant gas.

Figure 3.4 ▷ **Annual heat pump electricity consumption by building energy efficiency class in Denmark, 2022**



Electricity consumption by heat pumps in Denmark is up to 30 times lower in homes with the highest efficiency rating compared with the lowest efficiency rating

Notes: m^2 = square metre. The absolute values are based on the Danish building classification. Threshold values for classes depend on local climate conditions. Class A2015 is presented as A, Class A2020 is presented as A+. The electricity consumption refers to a 100 m² floor area.

Source: IEA representation based on Danish Energy Agency (2022).

3.3 Non-cost hurdles to consumer adoption

In addition to cost, there are a range of other hurdles to the adoption by consumers of heat pumps, notably restrictions relating to heat pump installation, a lack of information about the benefits of heat pumps, and split incentives between building owners and tenants. While these barriers are less concrete in nature than costs, they contribute significantly to the reticence of many consumers to opt for a heat pump over other heating systems. A failure to take action to address them could deter large numbers of consumers and hold back deployment of the technology. Many countries have developed programmes to address some of the barriers. Further efforts are needed to strengthen them and apply them more widely.

3.3.1 Restrictions on new installations

The installation of a heat pump is subject to a number of restrictions, approvals and practical constraints in most countries. Installations must usually adhere to building, fire safety, land-use and electrical codes and regulations. They may also require the approval from homeowners or buildings associations, which may be concerned about aesthetics and noise, as well as from the local authority under planning rules. Smaller households, notably in multifamily buildings, may not have the external space needed to install a heat pump (though centralised heat pump solutions exist [IEA, 2022b]), and there may be problems attaching the external compressor unit to the building facade. Obtaining approvals and designing systems to avoid practical constraints can be time-consuming and costly, leading some consumers to change their mind during the process. For water-source heat pumps utilising waste heat from sewage water in district heating or commercial applications, regulations may prohibit the rerouting of wastewater from sewage pipes past the heat exchanger.

Some countries have eased permitting procedures for heat pumps in order to encourage their deployment. In the Czech Republic, for example, outdoor residential heat pumps with a capacity of up to 20 kW are now exempt from applying for building permits. The European Commission has recently proposed to impose shorter deadlines for the permit-granting process for heat pumps across the European Union (European Commission, 2022). Many countries also do not require planning permission for small heat pumps. Some countries have relaxed approval procedures for multi-owner buildings by requiring only simple majorities for installing heat pumps and other clean technologies. For ground-source heat pumps, which may face restrictions on boring depth under drilling regulations, some governments have increased permitted depths to enable more installations. Geothermal maps that identify and classify areas according to geothermal heat availability and regulatory requirements can help streamline permitting and licensing procedures for geothermal heat pump projects (BRGM, 2022).

But many other restrictions remain in most jurisdictions. A comprehensive review of all regulations, codes and approval processes applicable to heat pumps is needed to identify redundant or onerous restrictions that do not materially improve health, safety, liveability or other outcomes. This process can be complex, involving a large number of local, national and international authorities, and so needs to be conducted by a strong, centralised body. Sharing of experiences in this domain among countries can play an important role in promoting best practice in removing red tape.

3.3.2 Lack of reliable information

Obtaining reliable information about heat pumps is crucial to the decision by a consumer to opt for that technology over other heating solutions. The process of comparing heat pump options, choosing an installer, obtaining approvals and qualifying for relevant subsidies can be very complex and time-consuming. In surveys, many consumers who have considered buying a heat pump have cited these barriers as reasons for why they eventually decided not to proceed (dena, 2022).

Energy labels are a crucial measure to help consumers identify the most energy-efficient heating solutions. In most cases, energy labelling is mandatory where minimum energy performance standards are in force for heating and cooling technologies (110 countries have adopted such standards or plan to do so). In addition to energy efficiency, labels should include smart-readiness, recyclability and noise reduction features to guide consumers.

Information and awareness campaigns can also be used to debunk misconceptions among consumers about heat pump performance. Many consumers are unaware of the significant improvements that have been made in heat pump performance, including efficiency and noise, in recent years. Initiatives to promote dialogue at the community level can also bolster consumer trust in the technology, share lessons learned and impart information to homeowners considering switching to a heat pump (RAP, 2022b). Some countries have championed the use of one-stop shops, which help consumers compare options, assess lifetime costs, choose an approved installer, obtain financing and apply for subsidies. They can be particularly helpful in assisting consumers make an informed choice in the event of a "distress purchase", when the urgency of replacing an existing heating system when it suddenly breaks down leads most consumers to simply opt for replacing their existing heating equipment without considering alternatives. Distress purchases can account for up to 60% of all heating equipment purchases in some countries (Nesta, 2021). One-stop shops can also help installers reach prospective clients. An alternative approach involves requiring energy utilities to provide comparer tools run by a third party through efficiency programmes, or requiring energy companies, manufacturers or installer networks to contribute to the cost of such initiatives. Offering free third-party energy audits, which may be seen as more trustworthy than advice provided by the utility itself, can also help consumers make informed decisions on replacing their heating system.

3.3.3 Split incentives between building owners and tenants

Split incentives between building owners and tenants are a common barrier to investments in energy efficiency in buildings, including the adoption of more efficient heating systems such as heat pumps. The owner of a building can be wary of spending more on a heat pump if they are unsure that they will be able to recoup the cost through higher rents or a higher resale value of the property at a later stage, though heat pumps can add a significant premium on the property sale price (Shen, 2021). To increase the incentive for landlords to invest in heat pumps and other clean energy technologies, some governments have passed legislation that allows homeowners to increase the gross rent by a certain percentage of the heating cost savings to split the benefit with the tenant. Minimum energy efficiency requirements for rented properties or at point-of-sale transactions can also incentivise investments in heat pumps. For example, in France, properties with an energy efficiency rating in the lowest class (G) will no longer be able to be rented as of 2023, while dwellings with ratings F and G will be subject to a rent freeze, which will only be lifted if they retrofit to reach at least an E rating.

Financing models such as energy performance and heat-as-a-service contracts that reduce or eliminate upfront investment costs can also help overcome split incentive barriers. They involve an agreement between the building owner and tenant, whereby the financial, performance or technical risks of investing in a heat pump are transferred to a specialised service company or utility, which recoups the upfront cost through a regular fee over a predetermined period, in some cases based on actual energy savings (Table 3.3). Most of the models currently available in major heating markets aim to offer an alternative to loans. In some cases, the heat pump remains the property of the service company, reducing the financial risk for the property owner.

Table 3.3 ▻ Main business models to facilitate heat pump uptake

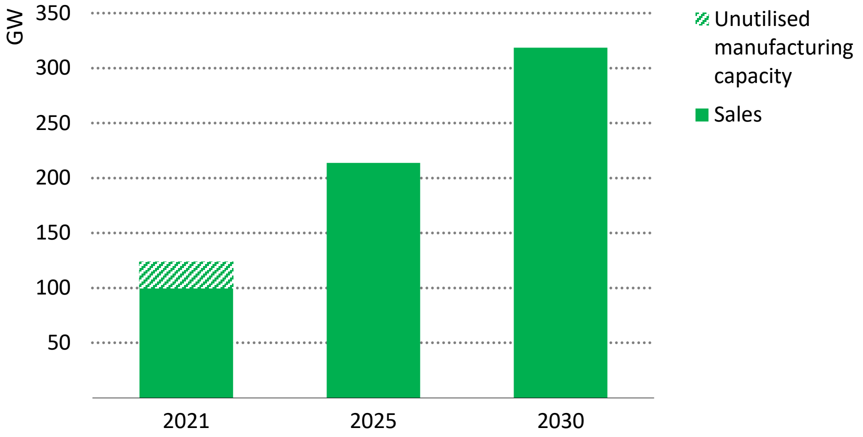
Model	Description	Examples
Energy performance contracts (EPCs)	An energy service company (ESCO) installs, owns and operates the heat pump under a long-term EPC with commercial customers based on a shared energy savings model or guarantee energy savings.	Used under the UK Renewable Heat Incentive programme
Heat-as-a-service	The heat pump, its maintenance and heat are provided by specialised ESCOs to housing associations, household owners or utilities on a long-term basis as a bundled service paid through a single subscription payment with guaranteed savings.	Being trialled in many countries, notably in Europe
Pay-for-performance	The customer pays a fixed rental fee for the heat pump equipment based on energy savings.	Used in US states such as California, Oregon and New York
On-bill financing	The cost of the heat pump installation and equipment is covered by a long-term loan repaid through the utility bill attached to the property, which can be transferred to future tenants.	Used in several Canadian provinces
Property assessed clean energy	The heat pump installation in a residential or commercial property is financed by a loan that is attached to the property and repaid as an addition to the property tax over 10-20 years, allowing for easier transfer to future tenants and more favourable interest rates.	Widely used in North America
Conventional equipment lease	The heat pump is leased to the property owner over a predetermined period, after which ownership of the pump is transferred to the user.	Available in Germany and some other countries
Clean energy intermediate lending	A large bank lends funds to a small local bank to lend out to building owners investing in heat pumps. This model enables large volumes of finance to be directed to many small-scale investment opportunities.	Widely deployed by multilateral development banks such as the EBRD, which uses the Green Technology Selector – a database of technologies that are eligible for support without additional approval – to speed up financing decisions

Sources: Catapult Energy Systems (2022); Urban (2021); EBRD (2022).

3.4 Manufacturing constraints

Accelerating the deployment of heat pumps worldwide on the scale envisioned in the APS hinges on a massive expansion of manufacturing capacity. The ability of manufacturers to meet rising demand may be constrained by various factors, including the availability of materials and components, the business and investment environment, and regulatory and legal restrictions. While not the primary focus of this report, policy makers need to be aware of these potential constraints and identify ways of assisting the private sector in addressing them. Today, most of the heat pumps sold around the world are manufactured in China, the United States, Europe, Japan and Korea. There is unutilised manufacturing capacity at existing factories at present, amounting to about 20% of total capacity in 2021, but it would not even be sufficient to meet the projected increase in sales in the APS for two years (Figure 3.5). The supply of basic materials and specialised components, including compressors, heat exchangers and refrigerants, would also need to be scaled up rapidly.

Figure 3.5 ▻ Current and projected heat pump sales in the APS and unutilised manufacturing capacity today



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Unutilised heat pump manufacturing capacity, while equal to about 20% of total capacity, would not even be sufficient to meet the growth in sales in the APS for two years

Source: IEA analysis for 2021 based on data provided by Global Research View.

Supply chain constraints are already affecting manufacturing of heat pumps and key components, especially semiconductors and chip sets in the past two years. Global shortages have already driven up costs and slowed production in the heating, ventilation and air conditioning (HVAC) industry. Higher prices of copper, steel, aluminium, silver for welding and certain plastics are also driving up costs (First Citizens Bank, 2022). Some of these materials, notably copper, are set to remain in high demand as clean energy transitions advance. Air-source heat pumps for residential applications contain around 15 to 20 kilogrammes of copper, predominantly in their pipes and valves, making up roughly 10% of the overall cost of the device (International Copper Alliance, 2022; GOV.UK, 2016). The industry is exploring using aluminium alternatives to copper for key components to reduce costs (Bloomberg News, 2021). Residential hydronic heat pumps typically contain more than twice as much aluminium and 15 times more copper and brass than their condensing gas boiler equivalents.[2]

In the medium and long term, increased recovery and recycling of materials from scrapped heat pumps, air conditioners and fossil fuel boilers through end-of-life management regulations could provide a secondary stream for the supply of copper, aluminium and iron, while avoiding impacts associated with their mining. In the European Union, heat pumps and air conditioners are currently covered by end-of-life management regulations under the Waste Electrical and Electronic Equipment Directive, which sets criteria for the collection, treatment and recovery of waste equipment (European Union, 2012).

Governments are increasingly playing a role in stimulating domestic investment in heat pump manufacturing, addressing supply chain bottlenecks and fostering innovation. Several countries have recently introduced policies aimed at onshoring the manufacture of critical clean energy technologies, including some that explicitly target heat pumps, such as the US Defense Production Act. Others target semiconductors and critical mineral manufacturing, such as the EU European Chips Act and Critical Raw Minerals Act. Some countries provide manufacturing incentives such as RD&D support for heat pumps, on top of deployment targets, bans on fossil fuel boilers and consumer incentives, all of which enhance market certainty for manufacturers as they expand their production capacities. Another measure, being planned by the UK government, involves imposing a rising quota for the number of heat pump sales in relation to a boiler manufacturer’s overall sales of heating systems (GOV.UK, 2022). Reducing regulatory uncertainty is key for manufacturers to commit to scaling up production. In the European Union, a revised version of the F-gas Regulation, currently under discussion based on the Commission’s proposal, is expected to enter into force from 2024 and will provide clarity on limitations for F-gas usage by manufacturers of heat pumps and other technologies (see Chapter 2).

Leading manufacturers have recently announced plans to invest more than EUR 4 billion in expanding heat pump production capacity and related efforts. Most announcements concern projects in Europe, though capacity is set to rise in other regions where new projects are generally less publicised (Table 3.4).

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[2] Based on PEP (2022) and personal communication with Assoclima, November 2022.

Table 3.4 ⊳ Recently announced investments in heat pump production by selected manufacturers in Europe

Company	Region/country	Investment allocation	Investment (EUR)	Date of completion
Vaillant	EU	Heat pumps and energy efficiency	130 million	2022-2023
Hoval	Liechtenstein, Slovakia	Heat pumps	60 million	2023-2024
Clivet (Midea Group)	Italy	Heat pumps	60 million	2024
Mitsubishi	Turkey, UK	Heat pumps and air conditioning	128 million	2024
Bosch	Europe	Heat pumps	300 million	2025
Daikin Europe	Belgium, Czech Republic, Germany, Poland	Heat pumps, digitalisation, R&D and service capacity	1.2 billion	2025
Stiebel Eltron	Germany	Heat pumps	600 million	2025
NIBE	Sweden	Heat pumps	460 million	2025
Viessmann	Poland	Heat pumps and other green solutions	1 billion	2025
Panasonic	Czech Republic	Heat pumps	145 million	2026

Note: Converted to EUR for Mitsubishi (USD 113 million plus GBP 15 million) and NIBE (SEK 5 billion [Swedish kronor]).

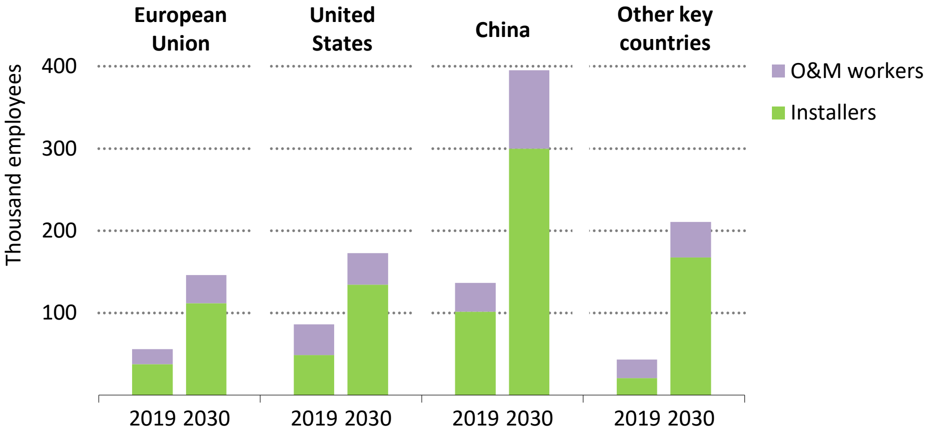
Sources: Vaillant Group (2022); Business Solutions (2021); Hoval (2022); Quanlin (2022); Mitsubishi (2022); Walker (2021); Bosch (2022); Daikin (2022); Klingauf (2022); NIBE (2022); Viessman Group (2022); Panasonic (2022).

3.5 Shortages of skilled installers

The rapid growth in deployment of heat pumps worldwide in the APS would require a big increase in the workforce at every step of the supply chain, especially installation (see Chapter 2). Today, roughly half of heat pump workers worldwide are involved in the installation process, while another quarter work in maintaining and servicing of heat pumps. Demand for installers is expected to quadruple to 2030 to over 850 000 in the APS (Figure 3.6). All the new installers would need to be adequately trained under certified programmes.

A shortage of skilled installers is already starting to create bottlenecks in the deployment of heat pumps in several countries. The skills needed to install heat pumps are similar to those of many standard occupations in construction, but require additional specialisations. These include assessing the property, calculating heat losses to design the installation, updating parts of the existing heating system and electrical wiring (Table 3.5). Some of these skills can be taught through on-the-job training, while others, notably sizing the heat pump installation, drilling, electrical work and refrigerant handling, require trained and certified personnel. Both installation and electrical skills are often included in the same qualification schemes, though in some countries such as Canada different professionals are required. Additional qualifications are required for ground-source heat pumps, including in drilling or trenching, thermal fusion of pipes and geological analysis. Skilled drilling engineers in the oil and gas sector are well-placed to take on such jobs.

Figure 3.6 ▻ Employment in heat pumps by region/country in the APS



IEA. CC BY 4.0

Demand for installers, which make up about half of the total heat pump workforce globally, increases by around 650 000 by 2030 in the APS

Notes: O&M = operations and maintenance. Other key countries = Australia, New Zealand, Canada, Japan, Korea, Eurasia and the rest of Europe.

Table 3.5 ▻ Mapping of typical skills and occupations required for heat pump installation by installation phase

Skills	Occupation	Heat pump type
Sizing and heat pump system design		
On-site assessment of existing heating infrastructure and property insulation	General construction worker, heat pump installer	All
Heat losses and heating load calculations	Heat pump installer	All
Design, choice of materials and system layout	Heat pump installer	All
Pressure drop calculations, thermal conductivity assessment	Heat pump installer	All
Installation		
Trenching and drilling	Certified drilling professional	Ground-source
Pipe joining and plumbing	Plumber, pipefitter, heat pump installer	All
Handling refrigerants	Heat pump installer with F-gas certification Heat pump installer qualified to handle flammable materials	Systems with onsite F-gas refrigerant handling Systems with on-site hydrocarbon refrigerant handling
Electrical work		
Electrical wiring	Electrician, heat pump installer	All
System configuration		
Final system setup, refrigerant gas stabilisation	Heat pump installer	All

Maintaining standards for installers remains essential to the growth of the industry. Underqualified installers can result in underperforming systems or persistent maintenance problems, including leaks and electrical issues, possibly breaching the warranty offered by the manufacturer or the terms and condition of home insurance, as well as posing reputational risks to the heat pump industry. Additionally, many installers continue to operate using outdated notions of heat pump performance, and can try to dissuade consumers from adopting heat pumps when consulting them while replacing boilers. Certification schemes designed by either regulatory or industry bodies are available in all major markets. They vary in scope and duration and are not harmonised internationally. In China, a voluntary qualification certificate is in place for companies servicing industrial and commercial refrigeration and air-conditioning equipment, including heat pumps. In Europe, installers need to obtain relevant accreditations or demonstrate a given number of years of relevant experience.

While training is needed for the safe and proper installation of heat pumps, onerous certification schemes can deter workers from procuring these qualifications. Additional training requirements, costs or a lack of demand for heat pumps in their local area can dissuade workers from applying for training and certifications and the owners of traditional heating system businesses from diversifying into heat pumps. To alleviate these hurdles, certifications for heat pumps can build on existing qualification schemes and be incorporated into the existing curriculum for electricians, plumbers, and other heating and refrigeration technicians, or in fire risk safety training. A growing number of manufacturers are also offering their own installation training programmes, which can be more targeted and shorter in duration, allowing companies to build up a workforce of certified installers more quickly. Standardising credentials and training across manufacturers and jurisdictions could help to expand the installer workforce and increase labour mobility across countries and regions. Oil and gas boiler bans and other policies that increase long-term certainty about the prospects for the heat pump industry can also encourage workers to enter the industry.

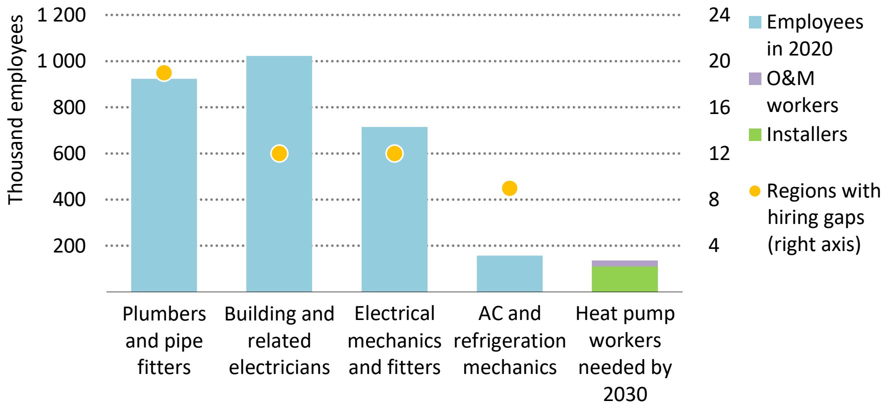
Governments can play a major role in promoting the training and recruitment of heat pump installers. They need to work with industry to update certifications, provide incentives to workers to pursue vocational education and support apprenticeships. Incentives can be provided through installers, as is the case in the United Kingdom. Government programmes focused on training heat pump installers have been introduced in several countries, including Netherlands, the United Kingdom and EU members, notably since the launch of REPowerEU (Box 3.2).

Manufacturers can also help ease installer shortages by designing more robust, standardised and easier-to-install heat pumps and by equipping installation companies with the right digital tools and applications to help them install the units correctly. Open data on building characteristics could benefit innovative business models that use digital tools to assess how easily a heat pump can be installed and to connect customers with installers.

Box 3.2 ▻ Meeting the growing demand for heat pump installers in the European Union

The REPowerEU targets for heat pumps, reflected in the APS, call for an increase in the number of trained heat pump installers from around 40 000 in 2019 to 110 000 by 2030. Certification is mandatory across all EU countries for heat pump installations that require refrigerant handling by the installer, which is the case for most systems, except self-contained systems like a monobloc. With increasing restrictions on F-Gas refrigerant usage in line with the Kigali Amendment, the required certification may pass from handling of F-Gases to handling of flammable material. However, for the majority of installations, requirements for training and certification of installers vary between countries, despite the requirement for mutually recognised certification under the Renewable Energy Directive. Given the enormous differences in the maturity of the heat pump market across countries, collaboration between them on heat pump installer training and transfer of best-practice know-how could help ensure efficient and high-quality installations and achieve the REPowerEU targets.

Figure 3.7 ▻ Number of employees in occupations related to heat pump installation with labour shortages in the European Union, 2020 and 2030



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Many EU countries face labour shortages in occupations key to heat pump installation. Workers that could be quickly upskilled to install heat pumps outnumber needs in 2030.

Note: Occupations as defined in the International Standard Classification of Occupations. "Regions with hiring gaps" includes the EU27 with Belgium divided into three autonomous regions, as well as Switzerland and Norway.

Source: IEA analysis based on ELA (2021).

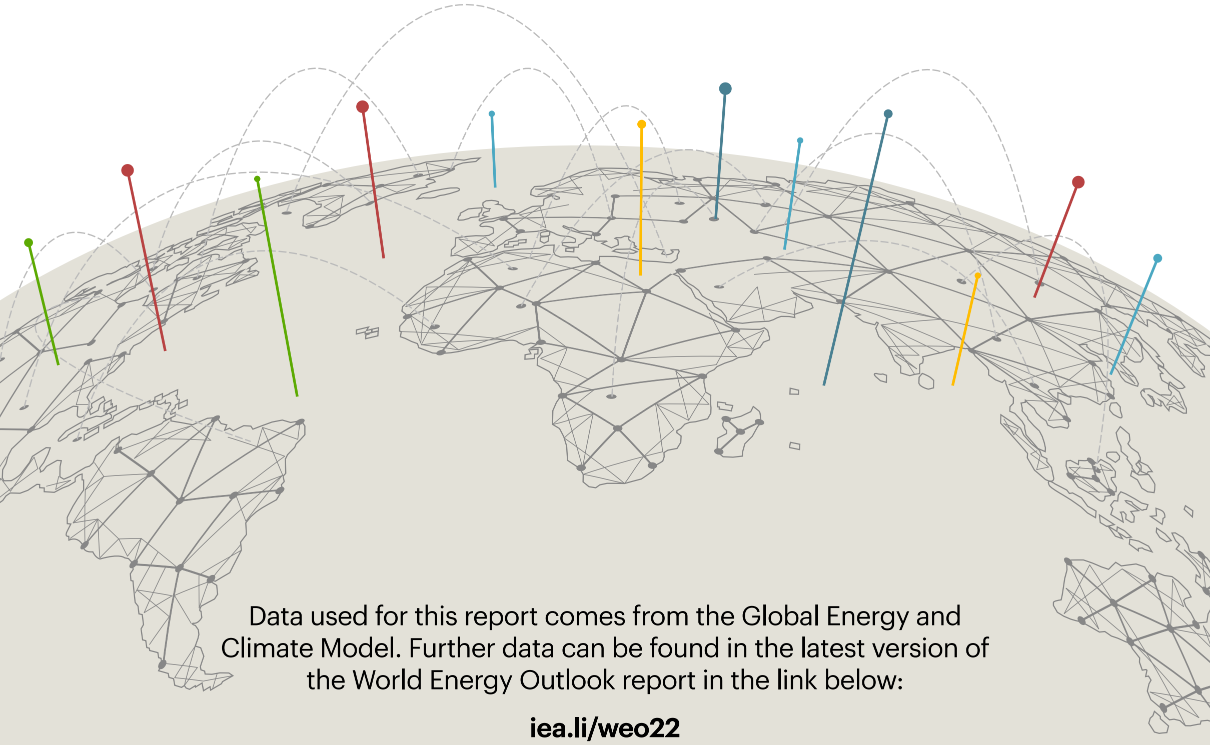
Additional training requirements will put a strain on an already tight European labour market. There is a shortage of workers in a range of occupations related to heat pump installations, such as plumbers and pipefitters, air-conditioning and refrigeration mechanics, electrical mechanics and fitters, and electricians (Figure 3.7). In a recent survey, hiring gaps for plumbers and pipefitters were reported by the most countries, with that occupation ranking second for shortages among all economic sectors (ELA, 2021). However, the number of heat pump installers and those servicing heat pumps remains far smaller than the current employment in related occupations. This places the focus squarely on incorporating heat pump-specific training into existing certification schemes and providing incentives to attract workers already in related occupations to pursue heat pump certification schemes.

Rapid upskilling and training will be crucial to meet growing demand for installers. Some measures could alleviate the risk of worsening labour shortages, including revising existing certification curriculum for plumbers, electricians and HVAC mechanics; reducing training hours and recertification to needed minimums; subsidising training costs; and introducing a comprehensive EU-wide certification scheme, which would improve the visibility of training requirements and improve labour mobility.

ANNEXES

Explore the data behind the

World Energy Outlook 2022



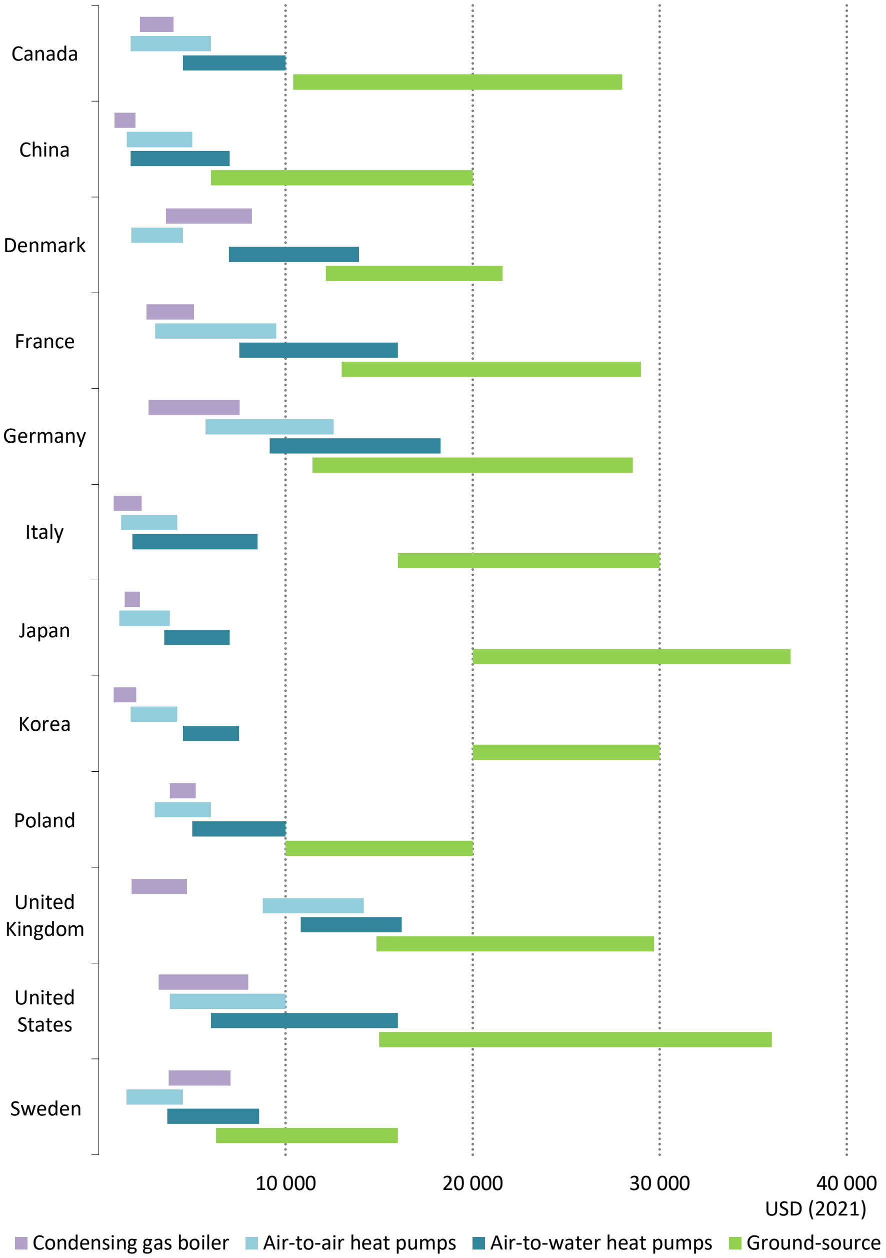
Data used for this report comes from the Global Energy and Climate Model. Further data can be found in the latest version of the World Energy Outlook report in the link below:

iea.li/weo22

Technology costs and financial support schemes

Technology costs

Figure A.1 ⊳ **Upfront cost ranges by technology in selected countries, 2022**



Financial support schemes

Table A.1 ▹ Financial support schemes for residential heat pumps in selected countries, September 2022

	Grant	Tax rebate	Loan
Australia			
Small-scale technology certificates	●		
No Interest Loans Scheme			●
Austria			
Get out of oil and gas	●		
Sauber Heizen für Alle (Clean Heating for Everyone): private individuals	●		
Belgium			
Brussels: Primes RENOLUTION (RENOLUTION Premiums)	●		
Wallonia: Prime Habitation (Housing Premium)	●		
Wallonia: Renopack			●
Flanders: My Renovation Premium	●		
Flanders: My Renovation Loan			●
National: Reduced VAT rate on heat pumps		●	
Bulgaria			
Energy Efficiency and Renewable Sources Fund			●
Tax regulation mechanism		●	
Canada			
Greener Homes initiative: Grant	●		
Greener Homes initiative: Loan			●
China			
Northern Provinces: Clean winter heating plan	●		
Croatia			
Energy renovation of family houses program	●		
Czech Republic			
Nová zelená úsporám (New green savings): Heating system replacement	●		
Nová zelená úsporám (New green savings): New water heater	●		
Kotlíkové dotace (Boiler subsidy)	●		
Private bank loans			●
Denmark			
Bygningspuljen (Building pool)	●		
Low interest rate loans			●

Table A.1 ⊳ **Financial support schemes for residential heat pumps in selected countries, September 2022** (continued)

	Grant	Tax rebate	Loan
Finland			
Replacement of oil and gas heating scheme	●		
Income tax deduction: Basic improvement work		●	
France			
Ma Prime Renov’	●		
Certificates of Energy Savings (CEE)	●		
ecoPTZ: Eco-prêt à taux zéro (zero interest loan)			●
Reduced VAT rate on heat pumps		●	
Germany			
Federal funding for efficient buildings (BEG): BEG EM (individual measures)	●		
Federal funding for efficient buildings (BEG): BEG WG (residential buildings)			●
Income tax law: Section 35c (residential buildings)		●	
Greece			
Save programme: εξοικονομώ	●		
Save programme loan: εξοικονομώ			●
Tax regulation mechanism I: Law No. 2238/1994		●	
Hungary			
Home Renovation grant	●		
Green capital requirement discount programme for residential purposes			●
Italy			
Conto Termico 2.0 (incentive scheme)	●		
Superbonus 110%		●	
Ecobonus 65%		●	
Reduced VAT rate on heat pumps		●	
Ireland			
SEAI home energy grants: Individual energy upgrade grants for Heat Pumps	●		
SEAI home energy grants: Fully funded energy upgrade	●		
An Post home energy improvement loans			●
Japan			
Heat pump subsidy programmes	●		
Korea			
KEPCO (Korea Electric Power Corp): Support for installing heat pumps	●		
Private bank loans			●

Table A.1 ⊳ Financial support schemes for residential heat pumps in selected countries, September 2022 (continued)

	Grant	Tax rebate	Loan
Latvia			
VARAM: Support for the use of renewable energy resources in households	●		
Ministry of Economy: Renovation of private houses and energy efficiency	●		
Private bank loans backed by the state			●
Lithuania			
Ministry of Environment: Use of renewable energy sources	●		
Private bank loans			●
Luxembourg			
PRIMe House 2017	●		
Reduced VAT rate on heat pumps		●	
KlimaPrêt: Zero interest rate			●
KlimaPrêt: Reduced interest rate			●
Private banks: Energy renovation loans			●
Netherlands			
ISDE: Investment grant for sustainable energy and energy savings	●		
National Heat Fund: Low interest rate loans			●
New Zealand			
Energy Efficiency Conservation Authority: Warmer Kiwi Homes programme	●		
Healthy homes standards		●	
Private banks: Green loans			●
Norway			
Enova grant	●		
Poland			
Clean Air Programme: Clean Air	●		
Clean Air Programme: Stop Smog	●		
Clean Air Programme: Thermal modernisation tax relief		●	
Moje Cieplo (My Warmth)	●		
Private bank loans			●
Portugal			
Renewable equipment loans			●
Romania			
Casa Eficienta Energetic (Energy Efficient House programme)	●		

Table A.1 ▹ **Financial support schemes for residential heat pumps in selected countries, September 2022** (continued)

	Grant	Tax rebate	Loan
Slovakia			
Zelená domácnostiam II (Green for households II programme)	●		
Slovakia’s Recovery and Resilience Plan	●		
Slovenia			
Eko Sklad (Eco Fund): Subsidies	●		
Eko Sklad (Eco Fund): Soft loan			●
Spain			
PREE 5000: Energy Rehabilitation Programme for Buildings in Municipalities of the Demographic Challenge	●		
RD 477/2021 Programme 6: Implementation of renewable thermal systems in the residential sector	●		
RD 853/2021: Refurbishment of residential buildings and social housing	●		
Sweden			
ROT-avdrag: Tax reduction		●	
United Kingdom			
Boiler Upgrade Scheme	●		
Home Energy Scotland: Interest free loan			●
Free Heat Pumps Grants Scotland	●		
Reduced VAT rate on heat pumps		●	
United States			
Residential renewable energy tax credits: Geothermal heat pumps		●	
Inflation Reduction Act: Heat pumps tax credit		●	
Inflation Reduction Act: High-Efficiency Electric Home Rebate programme	●		

Annex B

Definitions

This annex provides general information on terminology used throughout this report including: units and general conversion factors; definitions of fuels, processes and sectors; regional and country groupings; and abbreviations and acronyms.

Units

Energy	EJ	exajoule (1 joule x 10^{18})
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	bcm	billion cubic metres
Mass	kg	kilogramme
	t	tonne (1 tonne = 1 000 kg)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)
Monetary	USD million	1 US dollar x 10^6
	USD billion	1 US dollar x 10^9
	USD/t CO_2	US dollars per tonne of carbon dioxide
Power	W	watt (1 joule per second)
	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)

General conversion factors for energy

		Multiplier to convert to:		
		EJ	**bcme**	**GWh**
Convert from:	**EJ**	1	27.78	2.778 x 10^5
	bcme	0.036	1	9 999
	GWh	3.6 x 10^{-6}	1 x 10^{-4}	1

Notes: Natural gas is attributed a low heating value of 1 MJ per 44.1 kg. Conversions to and from billion cubic metres of natural gas equivalent (bcme) are given as representative multipliers but may differ from the average values obtained by converting natural gas volumes between IEA balances due to the use of country-specific energy densities. Lower heating values are used throughout.

Definitions

Buildings: The buildings sector includes energy used in residential, commercial and institutional buildings and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances, and cooking equipment.

Carbon dioxide (CO_2)**:** A gas consisting of one part carbon and two parts oxygen. It is an important greenhouse (heat-trapping) gas.

Clean energy: In *power*, clean energy includes: generation from renewable sources, nuclear and fossil fuels fitted with carbon capture, utilisation and storage (CCUS); battery storage; and electricity grids. In *efficiency*, clean energy includes energy efficiency in buildings, industry and transport, excluding aviation bunkers and domestic navigation. In *end-use applications*, clean energy includes: direct use of renewables; electric vehicles; electrification in buildings, industry and international marine transport; CCUS in industry and direct air capture. In *fuel supply*, clean energy includes low-emissions fuels.

Coal: Includes both primary coal, i.e. lignite, coking and steam coal, and derived fuels, e.g. patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas works gas, coke-oven gas, blast furnace gas and oxygen steel furnace gas. Peat is also included.

Coefficient of Performance (COP)**:** COP is a ratio used to measure the amount of useful energy (i.e. heating or cooling output) delivered relative to the energy input. The higher the COP, the more efficient the device.

Demand-side flexibility resource: Describes resources which can influence the load profile such as shifting the load curve in time without affecting total electricity demand, or load shedding such as interrupting demand for a short duration or adjusting the intensity of demand for a certain amount of time.

Electricity demand: Defined as total gross electricity generation less own use generation, plus net trade (imports less exports), less transmission and distribution losses.

Electricity generation: Defined as the total amount of electricity generated by power only or co-generation (combined heat and power) plants including generation required for own use. This is also referred to as gross generation.

Energy sector greenhouse gas (GHG) **emissions:** Energy-related and industrial process CO_2 emissions plus fugitive and vented methane and nitrous dioxide emissions from the energy and industry sectors.

Energy services: See useful energy.

F-gas: Fluorinated gases that are used in different applications including refrigeration, air conditioning and heat pumps where they are the main component of the refrigerant cycle.

Fossil fuels: Include coal, natural gas and oil.

Geothermal: Geothermal energy is heat from the subsurface of the earth. Water and/or steam carry the geothermal energy to the surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity if the temperature is adequate.

Global warming potential (GWP)**:** This metric allows comparing different greenhouse gases in terms of their effect on climate change and is used for the CO_2-equivalent calculations. The GWP of CO_2 is set to 1, so all other gases are classified relative to CO_2. To account for differing lifetimes of gases in the atmosphere, the most common metric is the 100-year GWP; sometimes also the 20-year GWP is used. A gas with a GWP_{100} of 27 has a 27-times-stronger impact on global warming than CO_2 over a 100-year time frame.

Heat (end use)**:** Can be obtained from the combustion of fossil or renewable fuels, direct geothermal or solar heat systems, exothermic chemical processes, and electricity (through resistance heating or heat pumps, which can extract it from ambient air and liquids). This category refers to the wide range of end uses, including space and water heating, and cooking in buildings, desalination and process applications in industry. It does not include cooling applications.

Heat (supply)**:** Obtained from the combustion of fuels, nuclear reactors, geothermal resources or the capture of sunlight. It may be used for heating or cooling, or converted into mechanical energy for transport or electricity generation. Commercial heat sold is reported under total final consumption with the fuel inputs allocated under power generation.

Heat pump: A heat pump extracts heat from a source, such as the surrounding air, geothermal energy stored in the ground, or nearby sources of water or waste heat from a factory. It then amplifies and transfers the heat to where it is needed.

Hydronic heat pump: Heat pump used in a hydronic heating systems that uses water to move heat from a heat pump through piping to each room via radiators or underfloor heating.

Investment: Investment is the capital expenditure in energy supply, infrastructure, end use and efficiency. Fuel supply investment includes the production, transformation and transport of oil, gas, coal and low-emissions fuels. *Power sector* investment includes new construction and refurbishment of generation, electricity networks (transmission, distribution and public electric vehicle chargers), and battery storage. *Energy efficiency* investment includes efficiency improvements in buildings, industry and transport. *Other end use* investment includes the purchase of equipment for the direct use of renewables; electric vehicles; electrification in buildings, industry and international marine transport; equipment for the use of low-emissions fuels; and CCUS in industry and direct air capture. Data and projections reflect spending over the lifetime of projects and are presented in real terms in year-2021 US dollars unless otherwise stated. Total investment reported for a year reflects the amount spent in that year.

Levelised cost of heating and cooling: The levelised cost of heating and cooling estimates the average cost of providing 1 MWh of heating or cooling over the lifetime of the equipment, considering the capital cost of the equipment and installation; operating expenditures include the cost of fuel and regular maintenance.

Low-emissions electricity: Includes renewable energy technologies, low-emissions hydrogen-based generation, low-emissions hydrogen-based fuel generation, nuclear power and fossil fuel power plants equipped with CCUS.

Low-emissions fuels: Include modern bioenergy, low-emissions hydrogen and low-emissions hydrogen-based fuels.

Natural gas: Includes gas occurring in deposits, whether liquefied or gaseous, consisting mainly of methane. It includes both non-associated gas originating from fields producing hydrocarbons only in gaseous form, and associated gas produced in association with crude oil production as well as methane recovered from coal mines (colliery gas). Natural gas liquids, manufactured gas (produced from municipal or industrial waste, or sewage) and quantities vented or flared are not included. Gas data in cubic metres are expressed on a gross calorific value basis and are measured at 15 °C and at 760 mm Hg (standard conditions). Gas data expressed in tonnes of oil equivalent, mainly for comparison reasons with other fuels, are on a net calorific basis. The difference between the net and the gross calorific value is the latent heat of vapourisation of the water vapour produced during combustion of the fuel (for gas the net calorific value is 10% lower than the gross calorific value).

Oil: Includes both conventional and unconventional oil production. Petroleum products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirits, lubricants, bitumen, paraffin, waxes and petroleum coke.

Power generation: Refers to fuel use in electricity generation plants, heat plants and co-generation plants. Both main activity producer plants and small plants that produce fuel for their own use (auto-producers) are included.

Refrigerant: Substance that transfers heat through the refrigeration cycle in a refrigeration appliance (e.g. heat pump, air conditioner, refrigerator).

Renewables: Includes bioenergy, geothermal, hydropower, solar photovoltaics (PV), concentrating solar power, and wind and marine (tide and wave) energy for electricity and heat generation.

Residential: Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking.

Services: Energy used in commercial facilities, e.g. offices, shops, hotels, restaurants, and in institutional buildings, e.g. schools, hospitals, public offices. Energy use in services includes space heating and cooling, water heating, lighting, appliances, cooking and desalination.

Solar photovoltaic (PV): Electricity produced from solar PV cells.

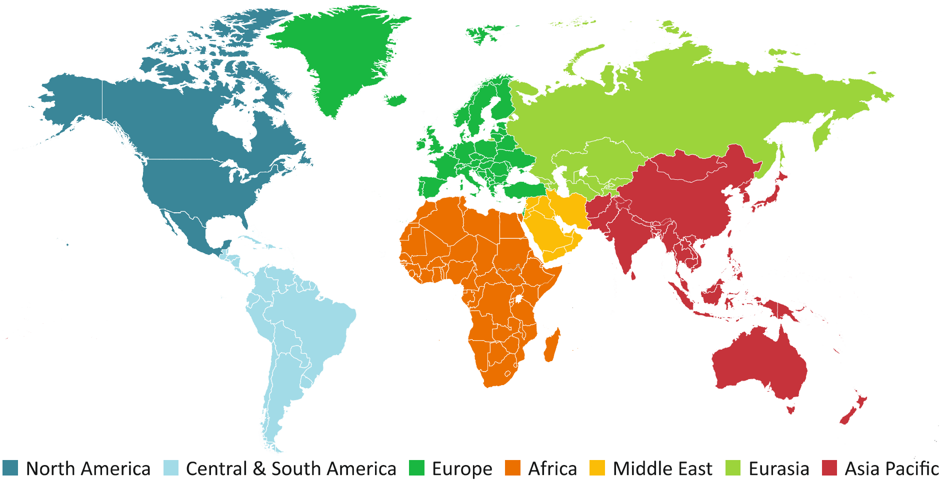
Total final consumption (TFC): Is the sum of consumption by the various end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing, mining, chemicals production, blast furnaces and coke ovens), transport, buildings (including residential and services) and other (including agriculture and other non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Useful energy: Refers to the energy that is available to end users to satisfy their needs. This is also referred to as energy services demand. As result of transformation losses at the point of use, the amount of useful energy is lower than the corresponding final energy demand for most technologies. Equipment using electricity often has higher conversion efficiency than equipment using other fuels, meaning that for a unit of energy consumed, electricity can provide more energy services.

Zero-carbon-ready buildings: A zero-carbon-ready building is highly energy efficient and uses either renewable energy directly or an energy supply that can be fully decarbonised, such as electricity or district heat.

Regional and country groupings

Figure B.1 ▷ Main country groupings



Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Advanced economies: OECD regional grouping and Bulgaria, Croatia, Cyprus,[1,2] Malta and Romania.

Africa: North Africa and sub-Saharan Africa regional groupings.

Asia-Pacific: Southeast Asia regional grouping and Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, Korea, Mongolia, Nepal, New Zealand, Pakistan, People's Republic of China (China), Sri Lanka, Chinese Taipei, and other Asia-Pacific countries and territories.[3]

Caspian: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela (Venezuela), and other Central and South American countries and territories.[4]

China: Includes the People's Republic of China and Hong Kong.

Developing Asia: Asia-Pacific regional grouping excluding Australia, Japan, Korea and New Zealand.

Emerging market and developing economies: All other countries not included in the advanced economies regional grouping.

Eurasia: Caspian regional grouping and the Russian Federation (Russia).

Europe: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel,[5] Kosovo, Montenegro, Norway, Serbia, Switzerland, Republic of Moldova, Türkiye, Ukraine, and United Kingdom.

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus,[1,2] Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

IEA (International Energy Agency)**:** OECD regional grouping excluding Chile, Colombia, Costa Rica, Iceland, Israel, Latvia and Slovenia.

Latin America: Central and South America regional grouping and Mexico.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

Non-OECD: All other countries not included in the OECD regional grouping.

Non-OPEC: All other countries not included in the OPEC regional grouping.

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia.

North America: Canada, Mexico and United States.

OECD (Organisation for Economic Co-operation and Development)**:** Australia, Austria, Belgium, Canada, Chile, Czech Republic, Colombia, Costa Rica, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom and United States.

OPEC (Organization of the Petroleum Exporting Countries)**:** Algeria, Angola, Republic of the Congo (Congo), Equatorial Guinea, Gabon, the Islamic Republic of Iran (Iran), Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates and Bolivarian Republic of Venezuela (Venezuela).

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Sub-Saharan Africa: Angola, Benin, Botswana, Cameroon, Republic of the Congo (Congo), Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Zambia, Zimbabwe, and other African countries and territories.[6]

Country notes

[1] Note by Republic of Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

[2] Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[3] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga and Vanuatu.

[4] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guiana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Saba, Saint Eustatius, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten, Turks and Caicos Islands.

[5] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

[6] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Kingdom of Eswatini, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Réunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia, and Uganda.

Abbreviations and acronyms

APS	Announced Pledges Scenario
CCUS	carbon capture, utilisation and storage
CDD	cooling degree day
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
COP	coefficient of performance
EBRD	European Bank for Reconstruction and Development
EPC	energy performance contracts

ESCO	energy service company
EU	European Union
EV	electric vehicle
F-gas	fluorinated gas
G7	Group of Seven
GHG	greenhouse gas
GWP	global warming potential
GX	Green Transformation
HDD	heating degree day
HC	hydrocarbon
HFC	hydrofluorocarbon
HFO	hydrofluoro-olefin
HPT TCP	Heat Pumping Technologies Technology Collaboration Programme
HVAC	heating, ventilation and air conditioning
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IPCC	Intergovernmental Panel on Climate Change
MVR	mechanical vapour recompression
NO_X	nitrogen oxides
NZE	Net Zero Emissions by 2050 Scenario
O&M	operations and maintenance
OECD	Organisation for Economic Co-operation and Development
PFAS	per- and polyfluoroalkyl substance
$PM_{2.5}$	fine particulate matter
PV	photovoltaic
RD&D	research, development and demonstration
SO_2	sulphur dioxide
STEPS	Stated Policies Scenario
TFA	trifluoroacetic acid
TRL	technology readiness level
TSO	transmission system operator
UNEP	United Nations Environment Programme
US	United States
WEO	World Energy Outlook

References

Chapter 1: Outlook for deploying heat pumps

Aalborg University (2013), Heat Roadmap Europe 2050: Second pre-study for the EU27, https://vbn.aau.dk/ws/portalfiles/portal/77342092/Heat_Roadmap_Europe_Pre_Study_II_May_2013.pdf

AHRI (Air-Conditioning, Heating, and Refrigeration Institute) (2022), Monthly Shipments, https://www.ahrinet.org/analytics/statistics/monthly-shipments

BASF (2022), BASF, SABIC and Linde start construction of the world's first demonstration plant for large-scale electrically heated steam cracker furnaces, https://www.basf.com/global/en/media/news-releases/2022/09/p-22-326.html

BMWK (Bundesminister für Wirtschaft und Klimaschutz) [Federal Ministry for Economic Affairs and Climate Action, Germany] (2022), Boost for green district heating: Federal funding for efficient heat networks (BEW) begins, https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2022/09/20220915-boost-for-green-district-heating-federal-funding-for-efficient-heat-networks-bew-begins.html

Chinabaogao (2022), Statistics on domestic sales, domestic sales and enterprise distribution of air source heat pump industry in my country, https://www.chinabaogao.com/data/202208/606704.html, [in Chinese].

Clean Energy Wire (2022), Stiebel Eltron to invest 600 million euros to expand heat pump production capacity, https://www.cleanenergywire.org/news/stiebel-eltron-invest-600-million-euros-expand-heat-pump-production-capacity

EHPA (European Heat Pump Association) (2021), https://www.ehpa.org/market-data

Energistyrelsen [Danish Energy Agency] (2022), Klimastatus og –fremskrivning 2022 (KF22): El og fjernvarme (ekskl. affaldsforbrænding) [Climate status and projection 2022 (KF22): Electricity and district heating (excluding waste incineration)], https://ens.dk/sites/ens.dk/files/Basisfremskrivning/kf22_sektornotat_8a_produktion_af_el_og_fjernvarme.pdf, [in Danish].

European Commission (2022a), Heat Pumps in the European Union, https://setis.ec.europa.eu/heat-pumps-european-union_en

European Commission (2022b), REPowerEU: Joint European action for more affordable, secure and sustainable energy, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2022:108:FIN

European Commission (2020), ReUseHeat: Accessible urban waste heat (Revised version) WP1 Task 1.2 Deliverable 1.4., https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5cfc2bcd3&appId=PPGMS

European Commission (2016), Mapping and analyses of the current and future (2020 2030) heating/cooling fuel deployment (fossil/renewables), https://energy.ec.europa.eu/mapping-and-analyses-current-and-future-2020-2030-heatingcooling-fuel-deployment-fossilrenewables-1_en

France, Ministry of Ecological Transition (2022), Pompes à chaleur [Heat pumps], https://www.ecologie.gouv.fr/pompes-chaleur, [in French].

GOV.UK (2020), The ten point plan for a green industrial revolution – Point 7: Greener buildings, https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution/title#point-7-greener-buildings

Government of Italy [Ministry of Infrastructure and Transport; Ministry of Economic Development; Ministry of the Environment and Land and Sea Protection] (2019), Piano Nazionale Integrato per l'Energia e il Clima [Integrated National Plan for Energy and Climate], https://www.mise.gov.it/images/stories/documenti/PNIEC_finale_17012020.pdf, [in Italian].

Government of Spain (2019), Draft of the Integrated National Energy and Climate Plan 2021-2030, https://energy.ec.europa.eu/system/files/2019-06/ec_courtesy_translation_es_necp_0.pdf

HEATLEAP (2022), HEATLEAP Project, https://heatleap-project.eu/heatleap-project/

Helen Ltd (2020), Katri Vala Heating and Cooling Plant, https://www.helen.fi/en/company/energy/energy-production/power-plants/katri-vala-heating-and-cooling-plant

HPT TCP (Technology Collaboration Programme on Heat Pumping Technologies) (2018), Heat pumps in combination with district heating increases energy efficiency at Hammarbyverket, https://heatpumpingtechnologies.org/annex47/wp-content/uploads/sites/54/2018/12/annex-47hammarbyverket.pdf

IEA (International Energy Agency) (2022a), World Energy Outlook 2022, https://www.iea.org/reports/world-energy-outlook-2022

IEA (2022b), Weather for Energy Tracker, https://www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker

IEA (2022c), Global Hydrogen Review 2022, https://www.iea.org/reports/global-hydrogen-review-2022

IEA (2020a), Is cooling the future of heating?, https://www.iea.org/commentaries/is-cooling-the-future-of-heating

IEA (2020b), Energy Technology Perspectives 2020, https://www.iea.org/reports/energy-technology-perspectives-2020

JRAIA (The Japan Refrigeration and Air Conditioning Industry Association) (2022), Voluntary statistics, https://www.jraia.or.jp/statistic/, [in Japanese].

Madeddu, S. et al. (2020), The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat), Environmental Research Letters, Vol. 15/12, https://doi.org/10.1088/1748-9326/abbd02

Marina, A. et al. (2021), An estimation of the European industrial heat pump market potential, Renewable and Sustainable Energy Reviews, Vol. 139, https://doi.org/10.1016/j.rser.2020.110545

Maruf, N. et al. (2022), Classification, potential role, and modeling of power-to-heat and thermal energy storage in energy systems: A review, Sustainable Energy Technologies and Assessments, Vol. 53(B), https://doi.org/10.1016/j.seta.2022.102553

Mathiesen, K. et al. (2022), Putin’s war accelerates the EU’s fossil fuel detox, https://www.politico.eu/article/vladimir-putin-war-ukraine-accelerates-eu-fossil-fuel-detox/

Morawiecka, M. and J. Rosenow (2022), From laggard to leader: How Poland became Europe’s fastest-growing heat pump market, https://foresightdk.com/from-laggard-to-leader-how-poland-became-europes-fastest-growing-heat-pump-market/

PORT PC (2022), Ponad dwukrotny wzrost sprzedaży powietrznych pomp ciepła w I poł. 2022 roku! [Sales of air-source heat pumps more than doubled in the first half of 2022!], https://portpc.pl/ponad-dwukrotny-wzrost-sprzedazy-powietrznych-pomp-ciepla-w-i-pol-2022-roku/, [in Polish].

Rosenow, J. et al. (2022), Heating up the global heat pump market, Nature Energy, Vol. 7, https://www.nature.com/articles/s41560-022-01104-8

Swiss Office of Energy (2020), Qualitätsüberwachung von Kleinwärmepumpen und statistische Auswertung der Prüfresultate 2019 [Quality monitoring of small heat pumps and statistical evaluation of the test results 2019], https://pubdb.bfe.admin.ch/de/publication/download/10078, [in German].

Toleikyte, A. and J. Carlsson (2021), Assessment of heating and cooling related chapters of the national energy and climate plants (NECPs), https://publications.jrc.ec.europa.eu/repository/handle/JRC124024

US DOE (United States Department of Energy) (2022), Residential Cold Climate Heat Pump Challenge, https://www.energy.gov/eere/buildings/residential-cold-climate-heat-pump-challenge

Wastewater Heat Online (2022), Case studies, https://wastewaterheat.online/case-studies

Chapter 2: Implications of accelerated heat pump deployment

Daikin (2022), Recovery, Reclamation and Destruction of Fluorocarbons, https://www.daikin.com/csr/environment/climatechange/fluorocarbon

European Chemicals Agency (2022), Registry of restriction intentions until outcome, https://echa.europa.eu/en/registry-of-restriction-intentions/-/dislist/details/0b0236e18663449b

Fraunhofer ISE (2022), Propane-based Refrigeration Circuit for Heat Pumps Achieves New Efficiency Record, https://www.ise.fraunhofer.de/en/press-media/press-releases/2022/propane-based-refrigeration-circuit-for-heat-pumps-achieves-new-efficiency-record.html

UBA (Umweltbundesamt) [German Environment Agency] (2021), Persistent degradation products of halogenated refrigerants and blowing agents in the environment: type, environmental concentrations, and fate with particular regard to new halogenated substitutes with low global warming potential, https://www.umweltbundesamt.de/publikationen/persistent-degradation-products-of-halogenated

IEA (International Energy Agency) (2022a), A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas, https://www.iea.org/reports/a-10-point-plan-to-reduce-the-european-unions-reliance-on-russian-natural-gas

IEA (2022b), Playing my part - How to save money, reduce reliance on Russian energy, support Ukraine and help the planet, https://www.iea.org/reports/playing-my-part

IEA (2022c), World Energy Outlook 2022, https://www.iea.org/reports/world-energy-outlook-2022

IEA (2021a), Unlocking the Potential of Distributed Energy Resources, https://www.iea.org/reports/unlocking-the-potential-of-distributed-energy-resources

IEA (2021b) Net Zero by 2050 - A roadmap for the Global Energy Sector, https://www.iea.org/reports/net-zero-by-2050

IEA (2019), Examples of energy flexibility in buildings, https://www.annex67.org/media/1921/examples-of-energy-flexibility-in-buildings.pdf

IEC (International Electrotechnical Commission) (2022), IEC 60335-2-40:2022, https://webstore.iec.ch/publication/62837

IHME (Institute for Health Metrics and Evaluation) (2022), Poisoning by carbon monoxide — Level 4 cause, https://www.healthdata.org/results/gbd_summaries/2019/poisoning-by-carbon-monoxide-level-4-cause

IPCC (Intergovernmental Panel on Climate Change) (2022), Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

Kowalski, P., & Szałański, P. (2019). Seasonal coefficient of performance of air-to-air heat pump and energy performance of a building in Poland, E3S Web of Conferences 116, https://doi.org/10.1051/e3sconf/201911600039

Netherlands Enterprise Agency (2022), Hybrid Heat Pumps Mandatory, https://business.gov.nl/amendment/hybrid-heat-pump-mandatory

Patenaude, A. (2015), CO2 as a Refrigerant - Basics & Considerations, RSES journal, pp. 26-30, https://www.rses.org/assets/rses_journal/0115_CO2.pdf

Purohit, P., et al. (2022a), The key role of propane in a sustainable cooling sector, Proceedings of the National Academy of Sciences, 119(34), https://doi.org/10.1073/pnas.2206131119

Purohit, P., et al. (2022b), Achieving Paris climate goals calls for increasing ambition of the Kigali Amendment, Nature Climate Change, 12, pp. 339-342, https://doi.org/10.1038/s41558-022-01310-y

Purohit, P., & Höglund-Isaksson, L. (2017), Global emissions of fluorinated greenhouse gases 2005-2050 with abatement potentials and costs, https://doi.org/10.5194/acp-17-2795-2017

RHC and EHPA (Renewable Heating and Cooling and European Heat Pump Association) (2021), Strategic Research and Innovation Agenda for Heat Pumps: Making the technology ready for mass deployment, https://www.rhc-platform.org/content/uploads/2021/06/RHC-ETIP-SRIA-HPs-2021v02-WEB.pdf

RTE (Réseau de Transport d'Électricité) [Electricity Transmission Network] (2021), Energy Pathways to 2050, https://assets.rte-france.com/prod/public/2022-01/Energy%20pathways%202050_Key%20results.pdf

US DOE (United States Department of Energy) (2022), United States Energy and Employment Report, https://www.energy.gov/policy/us-energy-employment-jobs-report-useer

UNEP (United Nations Environmental Programme) (2018), https://www.unep.org/ozonaction/refrigerant-management-0

UNEP (2017), Kigali Fact Sheet 2 - Current Use of HCFCs and HFCs, https://wedocs.unep.org/20.500.11822/2686

Chapter 3: Barriers and solutions

Agora Energiwende (2022), Durchbruch für die Wärmepumpe: Praxis Optionen für eine effiziente Wärmewende im Gebäudebestand [Breakthrough for the heat pump: Practical options for an efficient heating transition in the building stock], https://static.agora-energiewende.de/fileadmin/Projekte/2022/2022-04_DE_Scaling_up_heat_pumps/A-EW_273_Waermepumpen_WEB.pdf, [in German].

Bloomberg News (2021), Copper Is So Pricey Now That Aircons Are Switching to Aluminum, https://www.bloomberg.com/news/articles/2021-09-09/copper-is-so-pricey-now-that-aircons-are-switching-to-aluminum?leadSource=uverify%20wall

Bosch (2022), Thermotechnology: 300 million euros for the heat pump business, https://www.bosch-presse.de/pressportal/de/en/thermotechnology-300-million-euros-for-the-heat-pump-business-240185.html

Catapult Energy Systems (2022), What we do, https://es.catapult.org.uk/

BRGM (Bureau de recherches géologiques et minières) [Bureau of Geological and Mining Research, France] (2022), Greater Paris: near-surface geothermal potential mapped, https://www.brgm.fr/en/news/press-release/greater-paris-near-surface-geothermal-potential-mapped

Daikin (2022), Daikin Europe invests 300 million euro in new Polish heat pump heating factory, https://www.daikin-ce.com/en_us/press-releases/2022/daikin-europe-invests-300-million-in-new-polish-heat-pump-heatin.html

Danish Energy Agency (2022), Energimærkning af huse [Energy labeling of houses], https://sparenergi.dk/forbruger/boligen/energimaerkning-boliger/huse, [in Danish].

dena (2022), Heat pumps in energy consulting, https://www.dena.de/en/newsroom/publication-detail/pub/a-survey-of-experts-the-heat-pump-in-energy-consultations/

EBRD (European Bank for Reconstruction and Development) (2022), Green Technology Selector, https://techselector.com/ts-en/

ELA (European Labour Authority) (2021), Report on Labour Shortages and Surpluses, https://www.ela.europa.eu/en/media/725

Electric Ireland (2022), Heat Pump Price Plan, https://www.electricireland.ie/residential/electricity-and-gas/heat-pump-price-plan

Energie-Control Austria, MEKH and VaasaETT (2022), Household Energy Price Index (HEPI) (database), https://www.energypriceindex.com/price-data (accessed October 2022).

Energiesprong (2021), Serial renovation: Germany's first pilot project completed, https://energiesprong.org/serial-renovation-germanys-first-pilot-project-completed/

European Commission (2022), Proposal for a council regulation laying down a framework to accelerate the deployment of renewable energy, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=COM:2022:591:FIN

European Union (2012), Directive 2012/19/EU of the European Parliament and of the council on waste electrical and electronic equipment (WEEE - recast), https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:197:0038:0071:EN:PDF

First Citizens Bank (2022), HVAC Equipment Shortage: How Will Ongoing Supply Chain Issues Affect Techs?, https://www.firstcitizens.com/small-business/insights/skilled-trades/hvac-equipment-shortage

Georisk (2021), Where are we with geothermal risk mitigation schemes?, https://www.georisk-project.eu/where-are-we-with-geothermal-risk-mitigation-schemes/

GOV.UK (2022), A market-based mechanism for low carbon heat – Consultation, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1026607/clean-heat-market-consultation.pdf

GOV.UK (2016), Potential Cost Reductions for Air Source Heat Pumps, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf

Heptonstall, P., & Winskel, M. (forthcoming), Decarbonising home heating: An evidence review of domestic heat pump installation costs.

Hoval (2022), Hoval increases investment in heat pump production, https://www.hoval.co.uk/press/uk/hoval-increases-investment-in-heat-pump-production?e=

IEA (International Energy Agency) (2022a), Energy Efficiency 2022, https://www.iea.org/reports/energy-efficiency-2022

IEA (2022b), Solution matrix, https://heatpumpingtechnologies.org/annex50/solution-matrix/

IEA (2021), Denmark: Strategic Market Outlook, https://heatpumpingtechnologies.org/publications/denmark-strategic-market-outlook/

International Copper Alliance (2022), Home and Office: Infrastructure Reimagined Factsheet, https://copperalliance.org/wp-content/uploads/2022/02/ICA-IR-HomeOffice-202202-R4.pdf

Klingauf, J. (2022), Wärmepumpen-Boom: Deutscher Mittelständler Stiebel Eltron investiert 600 Millionen Euro [Heat pump boom: German medium-sized company Stiebel Eltron invests 600 million euros], https://stiebel-eltron.pressroom-rbt.com/2022/08/30/waermepumpen-boom-deutscher-mittelstaendler-stiebel-eltron-investiert-600-millionen-euro/, [in German].

Mitsubishi (2022), Mitsubishi Electric to expand production capacity at A/C base in Turkey, https://www.mitsubishielectric.com/news/2022/0527.html

Nesta (2021), Interim boilers for broken heating, https://www.nesta.org.uk/interim-boilers-for-broken-heating/

NIBE (2022), Interim report 2, 2022 (Q2), https://www.nibe.com/investors/pm-news-reports/2022---news-reports/2022-08-18-interim-report-2-2022-q2

Panasonic (2022), Panasonic Accelerates Investment in Air-to-water Heat Pump production its Czech factory, https://news.panasonic.com/global/press/en220902-2

PEP (2022), PEP EcoPassport (database), http://www.pep-ecopassport.org/ (accessed September 2022).

Quanlin, Q. (2022), Midea starts work on new heat pump plant in Italy, https://www.chinadaily.com.cn/a/202210/15/WS634a007ba310fd2b29e7c96a.html

RAP (Regulatory Assistance Project) (2022a), Levelling the playing field: Aligning heating energy taxes and levies in Europe with climate goals, https://www.raponline.org/wp-content/uploads/2022/07/Taxes-and-levies-final-2022-july-18.pdf

RAP (2022b), A policy toolkit for global mass heat pump deployment, https://www.raponline.org/wp-content/uploads/2022/11/RAP_Heat_Pump_Toolkit.pdf

Shen, X et al. (2021), Estimation of change in house sales prices in the United States after heat pump adoption, Nature Energy, Vol. 6, pp. 30-37, https://doi.org/10.1038/s41560-020-00706-4

Urban, R. (2021), Clean Energy Financing Programs Canada, https://www.energyhub.org/financing/#canada-wide

US DOE (United States Department of Energy) (2016), Heat Pump Supply Chains and Manufacturing Competitiveness Considerations, https://www.energy.gov/sites/prod/files/2016/04/f30/30005_Mann_040716-1105.pdf

Vaillant Group (2022), EIB supports the Vaillant Group's research and development for climate friendly heating solutions, https://www.vaillant-group.com/news-stories/eib-supports-the-vaillant-group%60s-research-and-development-for-climate-friendly-heating-systems.html

Viessmann Group (2022), Viessmann Group to invest EUR 1 billion in heat pumps & green solutions, https://www.viessmann.family/en/newsroom/company/viessmann-group-to-invest-eur-1-billion-in-heat-pumps-and-green-solutions

Walker, P. (2021), Mitsubishi invests £15 million in Livingston heat pump factory, https://www.insider.co.uk/news/mitsubishi-invests-15-million-livingston-25369217

World Bank (2022), Carbon Pricing Dashboard, https://carbonpricingdashboard.worldbank.org/

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The Future of Heat Pumps

World Energy Outlook Special Report

Heat pumps, powered by low-emissions electricity, are the central technology in the global transition to secure and sustainable heating. The Future of Heat Pumps, a special report in the IEA’s World Energy Outlook series, provides an outlook for heat pumps, identifying key opportunities to accelerate their deployment. It also highlights the major barriers and policy solutions, and explores the implications of an accelerated uptake of heat pumps for energy security, consumers’ energy bills, employment and efforts to tackle climate change.

Around 10% of space heating needs globally were met by heat pumps in 2021, but the pace of installation is growing rapidly with sales at record levels. Government policy support is needed, though, to help consumers overcome heat pumps’ higher upfront costs relative to alternatives. Financial incentives for heat pumps are already available in over 30 countries, which together cover more than 70% of heating demand today. The IEA estimates heat pumps globally have the potential to reduce global carbon dioxide (CO2) emissions by at least 500 million tonnes in 2030 – equal to the annual CO2 emissions of all cars in Europe today.