ISSN 1831-9424

European Commission

CLEAN ENERGY TECHNOLOGY OBSERVATORY

HEAT PUMPS IN THE EUROPEAN UNION

2022

STATUS REPORT ON TECHNOLOGY DEVELOPMENT, TRENDS, VALUE CHAINS AND MARKETS

Joint Research Centre

EUR 31268 EN

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JRC130874

EUR 31268 EN

PDF ISBN 978-92-76-58572-5 ISSN 1831-9424 doi:10.2760/372872 KJ-NA-31-268-EN-N

Luxembourg: Publications Office of the European Union, 2022

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How to cite this report: Lyons, L., Georgakaki, A., Kuokkanen, A., Letout, S., Mountraki, A., Ince, E., Shtjefni, D., Joanny, G., Eulaerts, O.D. and M. Grabowska, *Clean Energy Technology Observatory: Heat Pumps in the European Union – 2022 Status Report on Technology Development, Trends, Value Chains and Markets*, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/372872, JRC130874.

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Abstract

There were almost 17 million heat pumps installed in Europe by the end of 2021. REPowerEU envisages a doubling of the pace of deployment, to install hydronic heat pumps in an additional 10 million buildings in the next five years, and 30 million by 2030.

The average annual sales growth in Europe between 2019 and 2021 would achieve that target. However, there are a number of barriers that might slow the rate of growth, such as availability of installers, and volatility in metals prices and semiconductors supply.

The EU is a recognised technology leader, especially in ground-source heat pumps and larger heat pumps for the commercial and district heating and cooling segments. This is also reflected in patenting trends, scientific publications, and public RD&I funding.

The EU heat pumps sector is well positioned to benefit from increasing deployment, and from market trends such as the reduction of environmental impacts through regulations on ecodesign and F-gases. However, in 2020, the EU trade balance turned from a surplus to a deficit for the first time. By 2021, the deficit had grown to EUR 390 million, from a surplus of EUR 202 million five years previously.

Rapid deployment will require increased EU manufacturing of heat pumps and components. Significant investments are already being made, totalling at least EUR 3.3 billion to 2025. Trends in turnover and employment are positive as well, with 318 800 direct and indirect jobs in 2020.

Acknowledgements

Eric Lecomte (ENER) provided invaluable direction, substantive contributions to the analysis and co-ordination of stakeholder consultation. Important feedback and comments were provided by Johan Carlsson, Evangelos Tzimas and Delia D'Agostino (JRC); Piero de Bonis (RTD); Serban Scrieciu and Jacek Truszczynski (GROW); Arno Kaschl, Stefano Nicola Granata and Piero Carlo Dos Reis (CLIMA); Niels Ladefoged and Philippe Riviere (ENER); and Pau Rey Garcia (CINEA). Stakeholders consulted include Philippe Dumas (European Geothermal Energy Council), Thomas Nowak (European Heat Pump Association, EHPA), Thomas Trevisan (ATMOsphere (shecco)), Veerle Beelaerts and Federica Sabbati (European Heating Industry), Tim Sollberger (European Partnership for Energy and the Environment, EPEE), Claire Grossmann (Air conditioning and Refrigeration European Association, AREA), and Luigi Tischer (Ariston). Nigel Taylor (JRC), Giulia Serra (ENER) and Andreas Schmitz (JRC) provided project management of this report in the context of the Clean Energy Technology Observatory and the Competitiveness Progress Report.

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Executive Summary

This report is an output of the Clean Energy Technology Observatory, which is being implemented by the European Commission's Joint Research Centre on behalf of its DG Research and Innovation, in co-ordination with DG Energy. The scope is heat pumps for building applications, including large buildings and district heat networks.

In the buildings context, heat pumps are used for heating, hot water, and in some cases also for cooling. The most common types use electricity and the refrigeration cycle to concentrate and move heat. Heat pumps are much more energy efficient than boilers; enable the greater use of renewable energy sources, ambient energy and waste heat; and can increase the flexibility of the entire energy system.

Focusing on those heat pumps that are used mainly for heating, there were 180 million units operational worldwide in 2020. That number needs to rise to 600 million by 2030 to be on track to meet a goal of net-zero emissions by 2050.

In Europe, there were around 16.8 million heating and hot water heat pumps installed by the end of 2021. Sales bounced back from the pandemic year of 2020 to grow by around 34% in 2021, to 2.18 million.

REPowerEU envisages a doubling of the yearly pace of deployment, to install hydronic heat pump systems (those most likely to replace gas boilers) in an additional 10 million buildings in the next five years, and 30 million by 2030. If maintained, the average annual sales growth in Europe between 2019 and 2021 of all types of heat pump used for heating (20% per year) would achieve that target. However, there are a number of barriers that might slow the rate of growth, in particular a shortage of skilled installers and macroeconomic factors.

Such rapid deployment to 2030, and even more so to 2050, will require increased EU manufacturing of heat pumps and also some components. Significant investments in new and extended factories, as well as repurposing of existing production lines, are already in train, totalling at least EUR 3.3 billion to 2025. Long-term market predictability based on a stable policy framework will be key to maintaining this trend.

From the user perspective, the up-front investment in purchasing a heat pump is an important hurdle. However, the lifetime cost of a heating technology is dominated by the operating cost, which has been falling over time and is expected to continue to do so as the market grows and technologies develop. Moreover, heat pump owners can benefit from a premium on their property value.

The overall trend for public RD&I investment into heat pumps is increasing. Although amounts are small compared to some other energy technologies, the EU spends a significant amount on public research into heat pumps relative to some other countries around the world.

The EU is a recognised technology leader in heat pumps, especially in ground-source heat pumps and larger heat pumps for the commercial and district heating and cooling segments. This is also reflected in private investments, patenting trends and scientific publications.

Trends in turnover and employment are positive as well, with 318 800 direct and indirect jobs in 2020. The EU heat pumps sector is well established and highly innovative. It is well positioned to benefit from increasing deployment, and from market trends such as the reduction of environmental impacts through regulations on ecodesign and F-gases (hydrofluorocarbon refrigerant supply is dominated by China).

In 2020, the EU trade balance turned from a surplus to a deficit for the first time, mainly as a result of growth in imports, in particular from China. By 2021, the deficit had grown to EUR 390 million, from a surplus of EUR 202 million five years previously. EU suppliers need to ramp up production to maintain their market share vis-à-vis third countries, in a context of increased domestic demand.

Finally, heat pumps have few specific materials vulnerabilities. They are however vulnerable to broader trends such as volatility in metals prices and semiconductors supply.

1 Introduction

This report is an output of the Clean Energy Technology Observatory (CETO), which is being implemented by the European Commission's Joint Research Centre on behalf of its DG Research and Innovation, in co-ordination with DG Energy. CETO's objective is to provide an evidence-based analysis feeding the policymaking process and hence increase the effectiveness of research, development and innovation (RD&I) policies for clean energy technologies and solutions. It monitors EU RD&I activities on the clean energy technologies needed to deliver the European Green Deal, and assesses the competitiveness of the EU clean energy sector and its positioning in the global energy market. This report on heat pumps is one of a series of annual reports on technologies released as part of CETO.

The methodology is based on four pillars:

- Technology development, for which the focus is technology readiness level (TRL);
- Data compilation and monitoring, using a set of indicators capturing the entire value chain;
- Market scenarios of long-term deployment trends worldwide;
- Peer review and expert judgement.

The main data sources include:

- Patents statistics, for patents filed on heat pumps and sub-technologies;
- Scientific publishing statistics from the TIM (Tools for Information Monitoring) software of the JRC;[1]
- Existing scientific overviews and compilations.

In buildings, heat pumps are used for space heating, hot water, and in some cases also for space cooling (Figure 1). The most common types use electricity and the refrigeration cycle to concentrate and move heat. This report therefore focuses primarily on electric heat pumps but there are also thermally driven heat pumps and hybrid systems commercially available, as well as other technologies at research stage. Heat pumps are much more energy efficient than boilers; enable the greater use of renewable energy sources, ambient energy and waste heat; and can increase the flexibility of the entire energy system.

Figure 1. Interior view of a home with heat pump

Source: EHI, 2021a.

[1] https://knowledge4policy.ec.europa.eu/text-mining/topic/tim_analytics_en.

Heat pumps are typically reversible (bivalent), i.e. they can be used for both heating and cooling, either alternately or simultaneously. This report focuses on heat pumps used at least partly for space heating or hot water. Units that are used only for cooling are excluded where possible. Note however, that the projected growth in demand for air conditioning worldwide (2 billion units installed so far) represents an opportunity for concomitant innovation and economies of scale in reversible heat pumps providing both heating and cooling.

The scope also excludes heat pumps used in industrial processes (Box 1) and devices that use similar concepts for different purposes or in other settings. Heat pumps or heat pump concepts are also used in fridges (1.7 billion in operation worldwide), clothes dryers, for climate control in vehicles (and battery management in electric vehicles), and to heat swimming pools.

Box 1. Heat pumps for industrial applications

Industrial heat pumps are mostly bespoke installations and still small in number relative to the market potential. However, demand is increasing, for example in food and materials drying, distilling, dairy production and paper. Existing technologies achieve temperatures up to 140-160°C. Prototypes are being tested at 180°C and ongoing research aims at achieving 200-250°C. Industrial heat pumps are at TRLs 7-9 (see section 2.1.2).

This sub-sector of the heat pumps market would benefit from more standardised components, in particular compressors and heat exchangers, a boost in manufacturing capacity, as well as communications to raise awareness of the feasibility and opportunities. Improved market data would also help, and future CETO reports could play a role in that regard.

The scope does include heat pumps used in district heating and cooling (DHC) networks – whether in a centralised way or located in individual dwellings as part of 5th Generation DHC.[2] The scope also includes commercial and apartment buildings, for which dedicated heat pumps are available, often from the same manufacturers as in the residential segment.

[2] See for example https://5gdhc.eu/5gdhc-in-short and www.eon.se/en_US/foeretag/ectogrid.

2 State of the art and future developments and trends

2.1 Technology Readiness Level

2.1.1 Brief technology description and of sub-technologies overview

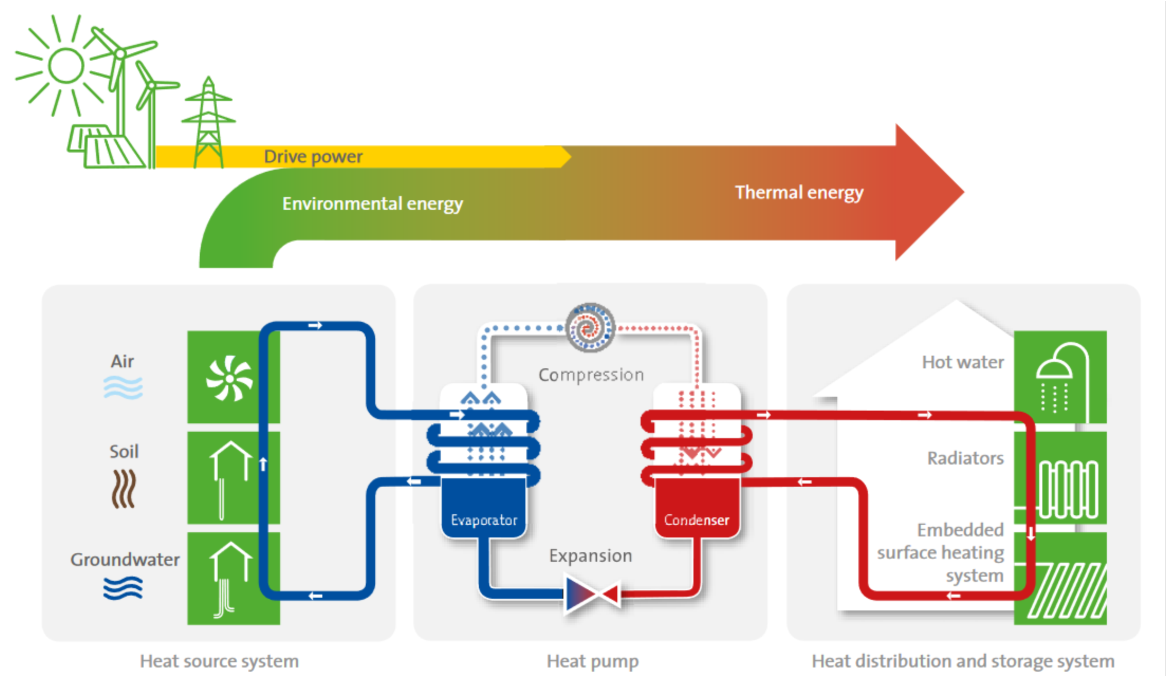
Heat pump systems can be classified by ambient heat source (air, ground or water)[3] and whether they distribute heat using a) warm air (including via fan coils or air ducts) or b) hot water piped to radiators or underfloor heating (hydronic heat pumps). Heat pumps are generally used for thermal comfort but can also be designed primarily for the production of domestic (sanitary) hot water.

Electrically driven compressor heat pumps are by far the dominant technology in terms of sales but other types are also commercially available, such as thermally driven heat pumps that use gas instead of electricity, and hybrid heat pump systems that combine more than one technology. Adsorption heat pumps use solid sorption to capture ambient heat, while absorption heat pumps use a liquid.

A compression heat pump system is generally comprised of a) a heat source system, which could be an air fan in the case of an air-source heat pump or a heat collector for ground- or water-source heat pumps, b) a heat pump unit containing two heat exchangers (evaporator and condenser), a compressor, an expansion valve and a controller c) a heat distribution (and in some cases storage) system. Most residential heat pumps now use a rotary or scroll compressor instead of a piston, depending on the heat pump capacity and operating range.

The fan or heat collector sources low-temperature heat from the environment, which is then extracted by the evaporator using a refrigerant. The gaseous refrigerant is then compressed, raising its temperature, and this higher temperature heat is transferred via the condenser to air or water in the heat distribution system to provide space heating or hot water (Figure 2). Reversing valves change the flow of the refrigerant; thermostatic and electronic expansion valves regulate the flow.

Figure 2. Working principle of a compression heat pump



Source: EHI, 2021a.

Air-air heat pumps are often used in commercial buildings such as offices or hospitals. In residential settings, air-air heat pumps often have one outdoor unit and one indoor unit and can be referred to as split units. Ground-source heat pumps are also often used in larger buildings because of economies of scale and their suitability for providing cooling and hot water as well as heating.

[3] Air-source heat pumps are also known as aerothermal heat pumps; ground-source heat pumps are also known as geothermal heat pumps. Water-source heat pumps are also known as hydrothermal or brine-water heat pumps.

Exhaust air heat pumps use heat recovery to transfer heat (at around 22°C) from a ventilation system to warm air or hot water. They use ducting rather than radiators or underfloor heating. Exhaust air heat pumps can be particularly suitable for very low energy buildings because the air flows are not large.

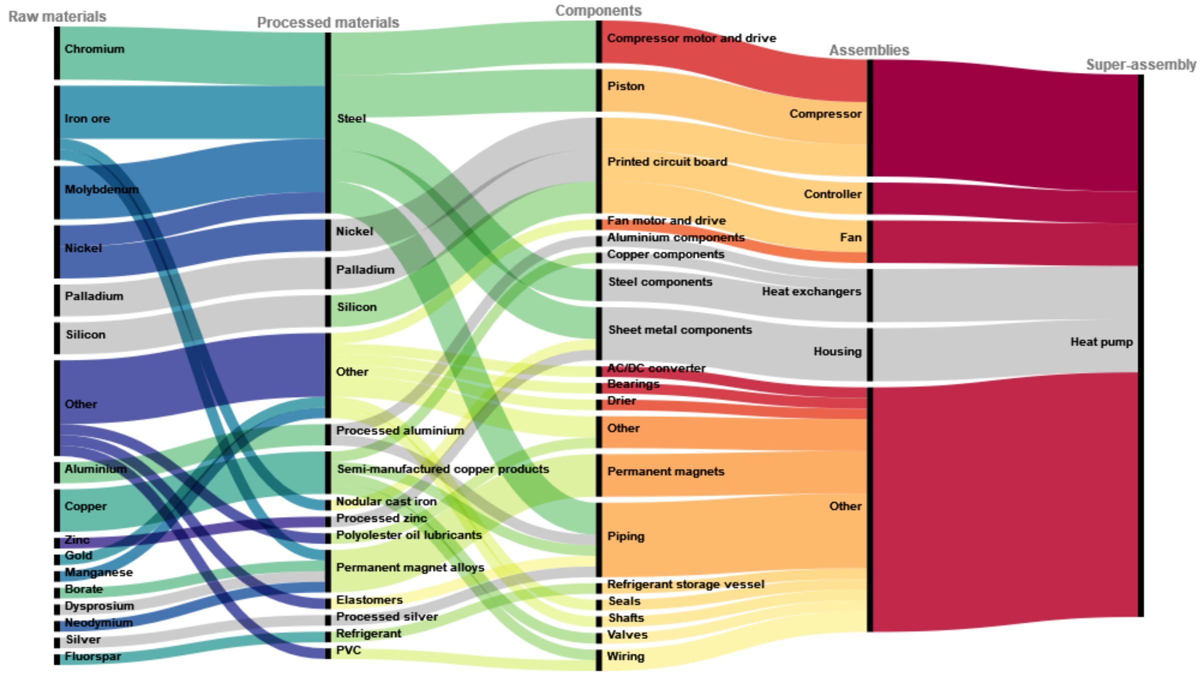
Heat pumps can have another technology acting as a back-up in case of failure, to meet peaks, or to take advantage of variable energy prices. The most common back-up technology is an electric heater, and these heaters are typically used less than 5% of the time (Fraunhofer in Nowak, 2022).

A so-called hybrid system is a heat pump combined with another technology, such as a gas boiler or solar thermal system, as a supplementary heater. Smart controls are used to operate and optimise such systems. Photovoltaic-thermal (PV-T) collectors consist of a thermal absorber below a solar PV module and deliver both electricity and heat that can be used as a flexible energy source for heat pumps (REN21, 2022).

Finally, heat pumps can also be integrated with rooftop PV, thermal storage (e.g. building thermal mass or water buffer tank) and smart controls. Such systems can take into account solar production to maximise self-consumption and respond to grid load signals (e.g. dynamic electricity prices) for demand-side flexibility. Further flexibility can be provided through cluster control within a district or flexible operation of large heat pumps in DHC.

In terms of materials, compressors and housing are made from reinforced steel. Heat exchangers are made from low-alloyed steel (for a plate heat exchanger), copper or aluminium. Piping can be made of steel, copper or aluminium depending on the refrigerant used, and welded using silver. Electrical cables and expansion valves use copper. Pipework is insulated with an elastomer (ethylene, propylene or vinyl-chloride monomers) and cables are insulated with polyvinylchloride (PVC) (Figure 3).

Figure 3. Heat pumps materials, components and assemblies



Source: Based on JRC CT EII project (forthcoming).

Note: This chart is for illustrative purposes and the supply chain varies depending on heat pump type and model.

Refrigerants for compression heat pumps can be synthetically produced fluorinated gases (F-gases) such as R410A, which has a 100-year Global Warming Potential (GWP) of 2 088, R134a (GWP 1 300) or more recently R32 (GWP 675) as well as some hydrofluoroolefin options; or naturally occurring refrigerants such as ammonia (GWP 0.1), water, methanol, carbon dioxide (GWP 1) or propane (GWP 0.02).[4]

R410A accounts for the large majority of air-water and water-source heat pump sales in Europe currently, while most air-air heat pumps on sale use R32. Until now, compression heat pumps have generally used F-

[4] See also EC Report https://ec.europa.eu/clima/document/download/344eede6-497a-46b6-8151-91174d0f7eb9_en?filename=c_2020_6637_en.pdf.

gases, but a shift to natural refrigerants where possible is under way, as a result of industry implementing the F-Gas Regulation (European Commission, 2022a).

Semiconductors are used in heat pumps in several ways. The controller most obviously, but also in compressors, pumps and fans. Direct current (DC) inverters, DC pumps and DC fans all rely on printed circuit boards (PCBs) and semiconductors.

Inverters are now common. Mostly frequency controlled, variable speed inverters allow the fan and compressor to run at different speeds depending on the demand, which is more efficient than adapting the heat supply by cycling.

2.1.2 Technology Readiness Levels for the main sub-technologies and concepts

The Horizon Europe TRLs are:

Research

1 Basic principles, ideas observed and reported

2 Technology concept or application has been formulated

3 Concept validation, experimental proof of concept

Development

4 Technology validated in lab

5 Technology validated in a relevant environment

6 Prototype demonstrated in a relevant environment

Deployment

7 Prototype demonstrated in operational environment (pre-commercial scale)

8 Actual system fully qualified and tested

9 Product ready for the market

Heat pump technologies are mature, with a TRL of 9 for all the main sub-technologies (air-air, air-water, ground-source, water-source) (Hofmeister and Guddat, 2017). Most types of thermally driven heat pumps are also at TRL 8-9.

Although heat pumps can be installed in almost all buildings, they work best in those with high energy performance and therefore low feed-in temperature requirements (less than 55°C). The smaller the difference between the energy source and the desired temperature in the building, the higher the efficiency (and the smaller the heat pump size). Making heat pumps cost-effective even in less well insulated buildings, partly by reducing the up-front investment cost and partly by improving the efficiency and extending the operating range, is therefore an important area for RD&I.

Specific areas of innovation include hybrid systems; integration with other systems such as ventilation, hot water, air conditioning, storage and solar thermal; hardware solutions to improve efficiency; reductions in size of components, and indoor and outdoor units; reductions of noise from compressors and outdoor fans, e.g. through insulation, encapsulation or new designs (EHI, 2021b); industrial, multi-family building and DHC applications; new business models such as heat-as-a-service; electrochemical compressors; 3D-extruded components; and generation of cold at temperatures below freezing by water-based absorption and adsorption processes.

Advanced inverter designs can be driven at higher speed, and active variable heat exchangers can optimise performance when switching from heating to cooling functions. Heat pump units that are optimised to provide both heating and cooling is an important market trend.

Another important topic is overcoming performance degradation and discontinuous heating at very low ambient temperatures. Recent heat pump models can be used in areas with extended periods of sub-freezing temperatures, down to around -20°C. Design innovations for low ambient temperatures include higher capacity and pressure, and improved materials.

Research is also needed in order to ensure safe end-of-life disposal of refrigerants and to continue development of alternative technologies or refrigerants that comply with the F-Gas Regulation (ICF and Cleantech Group, 2020).[5]

Digital technologies can help optimise performance, for example based on energy prices or weather. Ziehl-Abegg is one company that offers cloud-based fan monitoring and predictive maintenance (ICF and Cleantech Group, 2020). Smart controls are also important for sector coupling, demand response and hybrid systems. For example in 2022, German network operator TenneT and heat pump manufacturer Viessmann launched a project to link heat pump use to the availability of wind and solar power, using controllable thermostats and on-site thermal storage tanks (REN21, 2022). Inverter manufacturer SMA Solar Technology offers an energy manager that maximises the use of self-produced PV electricity with Stiebel-Eltron and Vaillant heat pumps.[6] A final example is that new market actors like Octopus, Tiko and OVO are using heat pumps to provide grid flexibility.

The prioritisation of research needs varies somewhat by heat pump type. For example, air-air heat pumps achieve high efficiency but can have some disadvantages in terms of comfort and noise relative to other types, for a given cost profile. Ground-source heat pumps have high up-front costs and so would benefit from new business models or improvements in technical solutions such as shared boreholes and ground loops.[7]

More innovative types of heat pump are also being developed but will need time to be commercialised. For example:

- Magnetocaloric heat pumps produce temperature change by variation of magnetic field. They can achieve high efficiency but need more RD&I overall to become competitive.[8]
- Thermo-acoustic heat pumps work by compressing and expanding helium. They use helium as a medium.[9]
- Membrane heat pumps are at prototype stage, characterised by a TRL of 5-6.
- Transcritical thermal compression heat pumps for the residential sector are at TRL 4 (Eurac et al., 2021).

At EU level, the framework for technology development is set by the implementation plans of the Strategic Energy Technology Plan (SET-Plan) working group on energy efficiency in buildings and the Strategic Research and Innovation Agenda of the European Technology and Innovation Platform on Renewable Heating and Cooling (RHC Platform). The SET-Plan working group has specific targets for heat pumps to:

- Reduce costs for small and large heat pumps by 50% (compared to the 2015 market price);
- Develop prefabricated, fully integrated "plug and play" hybrid/multisource heat pump systems and integrated compact heating/cooling plants based on modular heat pumps.[10]

The RHC Platform updated its Strategic Research and Innovation Agenda in 2021. It contains a comprehensive list of research priorities and topics for the heat pumps sector, grouped under: Demand from the end user perspective; Design; Manufacturing; Installation; Maintenance and operation; and Replacement and upgrading (RHC Platform, 2021).

Several Member States are also members of the International Energy Agency (IEA) Technology Collaboration Programme on Heat Pumping Technologies.[11] Its research areas (Annexes) in 2021 were (IEA HPT, 2022):

- Heat pumps in multi-family buildings for space heating and domestic hot water;
- Long-term performance measurement of GSHP systems serving commercial, institutional and multi-family buildings;
- Advanced cooling/refrigeration technologies development;
- Heat pump systems with low GWP refrigerants;
- Comfort and climate box;

[5] See for example www.ise.fraunhofer.de/en/research-projects/lc-150.html.
[6] See www.shk-profi.de/news/shk_SMA_Solar_kooperiert_mit_Stiebel_Eltron_und_Vaillant_1628380.html.
[7] See for example https://theconversation.com/no-space-for-a-heat-pump-heres-how-your-whole-street-could-get-off-gas-heating-180005.
[8] RES4BUILD (https://res4build.eu/) is one Horizon 2020 project looking to improve the performance of magnetocaloric heat pumps.
[9] See for example www.blueheartenergy.com or www.equium.fr.
[10] See https://setis.ec.europa.eu/implementing-actions/energy-efficiency-buildings_en.
[11] Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands and Sweden.

— Internet of Things for heat pumps;

— Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids;

— High-temperature heat pumps;

— Design and integration of heat pumps for nZEB (finalised);

— Acoustic signature of heat pumps (finalised).

2.2 Stock and sales at world and EU levels

2.2.1 Latest available data

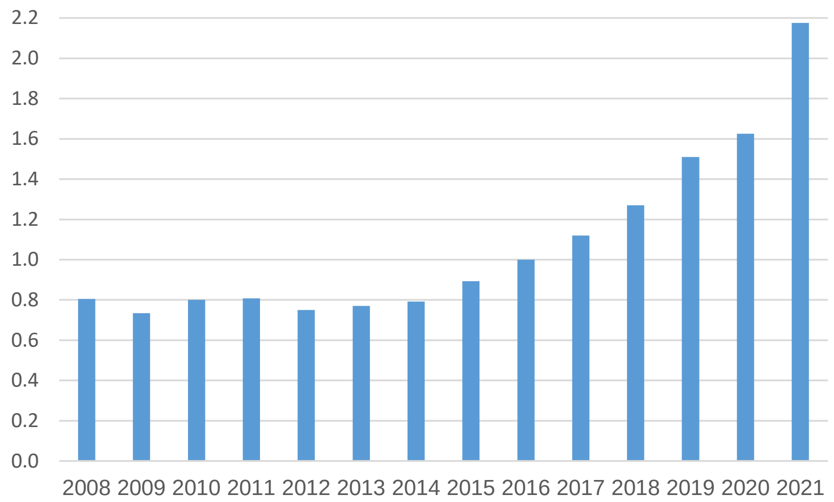
There were 180 million heat pumps in heating mode operational in 2020 worldwide. China has the largest installed stock, at 57.7 million units (IEA, 2021).

The world heat pump market (focusing on heat pumps that are mainly used for heating) grew at an average rate of 10% per year between 2014 and 2020, although sales fell 3% in 2020 due to the pandemic (REN21, 2022). Notably, sales of air-water heat pumps in China grew by 12.6% in 2021 to around 2.19 million units (JARN, 2022a).

In Europe, there were around 16.8 million heat pumps mainly used for heating and hot water[12] installed by the end of 2021 (based on EHPA data).[13] By comparison, there are still 61 million non-condensing gas boilers and oil boilers installed in the EU (EHI, 2021a).[14]

EHPA estimates that 21.5% of all heating devices sold in Europe in 2021 were heat pumps. Sales have been growing fast (Figure 4): focusing on heat pumps used mainly for heating, 1.62 million units were sold in Europe in 2020 (EHPA, 2022a).

Figure 4. Heat pump sales in Europe, 2008-2021 (millions)



Source: Based on EHPA data.

[12] The use of air-air heat pumps predominantly for heating is assumed for countries in cold climates (Estonia, Denmark, Finland, Lithuania, Norway). The number of units reported results from total sales adjusted by a correction factor (around 10%) aiming to exclude cooling-only units. In the case of Sweden, where air-air sales data is no longer collected by the national association, the number of air-air units was estimated by EHPA. Air-air units sold in the average climate zone have not been counted, due to a lack of reliable information on their use for heating or cooling. For countries in the warm climate zone (France, Italy, Portugal and Spain) only a share of the total sales number has been included. A study of the Italian market comes to the conclusion that in 9.5% of all dwellings, reversible air-air heat pumps were the only heat generator installed. This value is used for Italy with a similar assumption being taken for Portugal, Spain and southern France. Reversible heat pumps connected to hydronic systems are always counted, as their primary use as heating system can be assumed. Multi-split systems are counted, as they are specifically designed for heating and cooling. 90% of the reported sales numbers are included in order to allow for deviations from declared use (i.e. used for cooling only).

[13] EHPA data focus on heat pumps used for heating, and cover 21 European countries: 18 Member States, the UK, Norway and Switzerland. Bulgaria, Cyprus, Greece, Croatia, Latvia, Luxembourg, Malta, Romania and Slovenia are not included.

[14] EHI data covers Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the UK. Data for Germany and Italy include hybrid systems.

Sales grew by around 34% in 2021, to 2.18 million (based on Nowak, 2022). Some preliminary data suggests heat pump sales continue to grow rapidly in 2022. For example, an increase of 90% in Finland by volume in the first quarter compared to the same period of 2021 has been reported (JARN, 2022b). However, condensing gas boilers are still the most sold heating technology (Eurogas and GIE, 2022).

The stock of heat pumps is not evenly spread by Member State, with colder Member States having greater shares of heat pumps. Ground-source heat pumps in particular are concentrated in key markets, with Sweden (about 560 000 units) and Germany (410 000) accounting for more than half the total (EGEC, 2022).

Existing buildings need to be assessed for energy performance but in many cases heat pumps can be deployed even without renovation, either standalone or as part of hybrid systems (Nowak, 2022). In Finland, 70-80% of new dwellings are equipped with heat pumps (Schwartzkopff, 2022) but renovation already accounts for 93% of heat pump sales. Italy (85%) and Spain (75%) also show high shares of existing buildings in total sales (EHPA, 2021a). In Sweden, more than half of single-family homes have a heat pump installed (REN21, 2022).

Box 2. The share of hybrids in heat pump sales

Sales of hybrid heat pump systems are growing in some European countries (notably Italy and the Netherlands, two countries that are relatively reliant on gas) as a result of supportive policy. This trend is expected to accelerate in those countries but there is debate among stakeholders about how much of a role hybrid systems should play overall.

Hybrid heat pumps have the advantage that they can be deployed in buildings that are less well insulated, but there is also a possibility that they could have a negative effect on emissions if they use a gas boiler as the back-up (as most do) and delay deeper renovations to some extent. This is linked to a broader debate about the merits of staged renovation versus deep renovation. One-stop shops are one way to address this, by helping to ensure coherence between energy efficiency (e.g. insulation) and decarbonisation measures (e.g. heat pumps).

Looking at the broader market that includes reversible heat pumps used as air conditioners, the EU has 42 million "heat pumps" in operation, of which 38 million are air-source (EurObserv'ER, 2021).[15] The country with the most air-source heat pumps in total is Italy (about 18 million), followed by France (9 million) and Spain (5 million) – three countries where the devices are mainly used for cooling.

Under that broader definition, more than 3.6 million air-air heat pumps, nearly 580 000 air-water heat pumps and 100 000 ground-source heat pumps were sold in the EU in 2020, representing growth compared to 2019 of 1%, 15% and 19% respectively. France, Italy and Germany saw the most sales in 2021, with Germany seeing 28% growth in that year to reach total sales of 154 000 units (REN21, 2022).

The biggest markets for air-air heat pumps are still Italy, Spain and France. The market for air-water heat pumps, which are mainly used for heating, grew particularly fast in Poland (108% growth), Denmark (51%), Germany (44%), Belgium (36%) and Sweden (34%), driven by strong policy incentives in those countries. In Hungary, the air-water heat pump market exploded from virtually non-existent to more than 5 000 units sold in 2020 (JRC, 2021). For ground-source heat pumps, Germany became the largest market in 2021 in terms of units sold (27 000), with a 32% increase compared to 2020 (EGEC, 2022). Sales growth was even stronger in France (73%), Austria (59%) and Belgium (35%).

Heat pumps for the production of domestic (sanitary) hot water are used mainly in China (1.27 million units sold in 2021) and Japan (585 000 units). In the EU, France dominates sales, with 110 320 heat pump water heaters sold in 2020, out of a total of around 185 000 (EHPA, 2021a). The hot water heat pumps segment grew particularly fast over the past decade, often in combination with a fossil fuel boiler or PV system (EHPA, 2021b). France is also the largest market in the EU for PV-T systems used as the heat source for heat pumps (REN21, 2022).

Electric heat pumps represent more than 95% of sales in Europe by type. Sales of exhaust air heat pumps were 26 000 in 2020, hybrid heat pump sales were 11 000 and DHC heat pumps were 6 000 (EHPA, 2021a). The stock of thermally driven heat pumps in Europe is in the tens of thousands, installed in the light commercial sector in particular.

[15] Only heat pumps that meet the efficiency criteria (seasonal performance factor) defined by Directive 2009/28/EC are counted.

In energy terms, heat pumps met around 7% of world heating demand in residential buildings in 2020 (REN21, 2022), which needs to rise to 20% by 2030 to meet 2050 net-zero goals (IEA in ATMOsphere, 2022). In the EU, the share is around 10%, which is a five-fold increase since 2009. In 2020, heat pumps with a thermal capacity of 14.24 GW were sold and installed, producing around 27.11 TWh of useful energy (EHPA, 2021a). That brought total installed capacity to 128.7 GW, producing 252.6 TWh of useful energy.

Heat pumps in single-family dwellings are around 3-23 kW thermal capacity, with an average of 10-11 kW (VHK and BRG, 2019). Heat pumps for multi-family buildings have capacities of more than 20 kW and account for less than 10% of all heat pumps sold (EHPA, 2021a). Light commercial heat pumps can have capacities up to several 100 kW, while those for use in DHC range from 300 kW to 160 MW (Lyons et al., 2021).

2.2.2 Projections

The number of heat pumps installed worldwide needs to rise to 600 million heat pumps by 2030 to be on track to meet a goal of net-zero emissions by 2050 (IEA in ATMOsphere, 2022). Around 55% of all heating systems worldwide must be equipped with heat pumps by 2050 (IEA HPT, 2022). That implies a tenfold increase in the number of installed heat pumps. The US market is driven mainly by policy incentives, while the Asia-Pacific market is driven by policy but also by rapid growth in construction. The European market is also driven by a mix of policy and market drivers (see next section).

European market penetration lags other regions but has recently shown strong growth and there is a lot of potential remaining, especially in the largest markets, i.e. France, Italy and Germany. In their National Energy and Climate Plans (NECPs), all Member States expect to see an increase in final energy consumption (FEC) by heat pumps over the period 2020–2030. The highest increase can be seen in Spain (1 046%), followed by Hungary (467%), Belgium (234%) and Poland (195%). The highest FEC in 2030 is in Italy (5.7 Mtoe), followed by France (4.5 Mtoe) (Toleikyte and Carlsson, 2021).[16]

The stock of heat pumps is expected to double in Europe within about five years. A JRC comparison of projections finds 15-43% of EU heating demand met by heat pumps by 2030 and 25-60% by 2050 (Nijs et al., 2021) (Box 3).

Box 3. How to reduce fossil fuel use in buildings?

The EU climate target of reducing greenhouse gas emissions by 55% by 2030 and the building envelope renovation ambition in the Renovation Wave imply a transformation of the buildings sector. The envelope renovation rate, currently standing at 1.3% of the stock per year, needs to increase to 2.5% and include a switch to low-carbon heating systems such as heat pumps. This means that by 2030, more than 15 million dwellings (about half) using oil or coal and around 25 million dwellings (one quarter) using gas should replace their boilers with low-carbon heating alternatives. Dwellings using fossil fuels, in particular, would benefit from renovations that combine energy efficiency improvements with a fuel switch.

The required investment in building renovation amounts to around EUR 159 billion per year over the period 2022-2030, of which about EUR 100 billion goes to envelope renovations and the rest to heating systems. Thus, the market for building envelope renovations can double (driven by the increasing renovation rate and depth), and the market for heating system replacement could triple (driven by higher equipment costs and the extra effort needed to retrofit existing systems).

Source: Nijs et al., 2021.

In May 2022, the European Commission presented the REPowerEU Plan (European Commission, 2022b), a plan to make Europe independent from Russian fossil fuels before 2030. Moreover, REPowerEU acknowledges the need to match faster deployment with the scale-up of European manufacturing, greater resilience and enhanced competitiveness.

REPowerEU envisages a doubling of the planned yearly pace of deployment, in order to install hydronic heat pump systems (those most likely to replace gas boilers) in 10 million buildings in the next five years, and 30 million by 2030. That would save 35 billion cubic meters of gas consumption per year. If maintained, the average annual sales growth of all heat pump types in Europe between 2019 and 2021 (20% per year, based on EHPA data) and an average lifetime of 17 years would achieve that target. However, there are a number of barriers (see next section) that might slow the rate of growth in future.

[16] Data for Germany, Latvia and Lithuania not included.

REPowerEU also contains an increased role for heat pumps in DHC. The share of large heat pumps in DHC could rise to between 25% (Paardekooper et al. in Jesper et al., 2021) and 40% Ember (2022) by 2050.

Electric heat pumps are by far the dominant technology today. Nevertheless, manufacturers of thermally driven (gas) heat pumps project that such technologies could, for example, account for one third of the UK market in 2030 (Delta-EE, 2021). Hybrid systems are also expected to show strong sales growth in some countries.

2.3 Drivers and barriers, including policies

Rapid deployment to 2030 and especially to 2050 would make it more likely that EU manufacturing of heat pumps, and even some components, will increase. Long-term market predictability, based on a stable policy framework, is key for manufacturers to make such economic decisions. EU manufacturers are committed to meeting the REPowerEU targets and believe the necessary growth rates are feasible.

Drivers of the increase in deployment in Europe include:

- Policies aimed at climate protection, electrification, energy savings, ecodesign, circular economy, sustainable products, as well as reduction of fossil fuel imports dependency (see below);
- Higher gas and oil prices and changes in tax policies (making electricity less expensive relative to fossil fuels, for example through carbon pricing or reducing value-added tax);
- Technology improvements and hybrid systems, allowing roll-out to a larger share of existing buildings;
- Increased demand for comfort in line with rising living standards (in particular, increased demand for cooling, exacerbated by more frequent heatwaves due to climate change);[17]
- Trends in population, GDP, the amount of space to be heated or cooled (number of dwellings, square metres per dwelling, etc.), behaviour (e.g. increased working from home sparking interest in home heating upgrades), etc.;
- Building energy management systems and digitalisation in general, as well as system integration, which provides new business opportunities in grid balancing, optimisation and efficient energy use (Lyons, 2019).

Heat pumps are increasingly supported by policy. At EU level, the sector is being strengthened by the revised Energy Performance of Buildings Directive (EPBD), the Renewable Energy Directive (RED), the Energy Efficiency Directive, the EU Strategy for Energy System Integration, revised ecodesign requirements and energy labelling, the proposed extension of the Emissions Trading Scheme to the buildings sector, the proposed revision of the Energy Taxation Directive, Next Generation EU and its Renovation Wave, and most recently REPowerEU.

The EPBD directs Member States to develop national long-term energy renovation strategies (LTRS) for their housing stocks and other buildings over the period to 2050. These LTRS should lead to an 80% to 95% reduction in CO_2 emissions from buildings compared to 1990 levels. Member States must also set minimum energy performance requirements for all new buildings and buildings undergoing renovations. In most cases, these requirements extend to the level of individual building elements or heating technologies.

In response to the COVID-19 crisis, the European Commission reaffirmed the importance of the European Green Deal when it proposed the Next Generation EU plan to relaunch the European economy. The plan includes a Renovation Wave strategy (COM(2020)662 final) to increase the building renovation rate and increase the share of renewable heating and cooling in buildings. Apart from its impact on greenhouse gas emissions, building renovation is a strong recovery and job creation lever that will benefit all Member States.

There have been energy efficiency requirements on local space heaters under the Ecodesign Directive since 2018. Energy labelling has also provided information to consumers on the energy performance (and other environmental parameters) of local space heaters. These rules have led to substantial energy savings for consumers. These rules are being reviewed to take account of technological progress in the sector, ease comparison across different product types, and use an A to G scale. A revised Lot 10 is expected to kick in

[17] Over time, the need for heating in buildings in the EU has decreased over time, with the need for cooling increasing: see https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20220531-1.

from 2025 with possibly new test methods from 2027. Lots 1 and 2 will have new energy efficiency thresholds and test methods by 2025, and lot 21 probably by 2030 (EHPA, 2022b).

Heat pump technology is identified by the Strategy for Energy System Integration as a key technology to decarbonise space heating and domestic hot water production, as well as cooling for buildings and industry. The heat pump sector is already the biggest contributor to the increase in renewable energy production for heating and cooling across the EU.

There is EU support for RD&I into heat pumps, mainly through Horizon Europe, that aims to improve performance (better efficiency, wider ambient temperature range, higher temperature output, lower noise, etc.) reduce cost, reduce materials use, enhance recyclability, and substitute for certain raw materials. The Innovation Fund, Interreg and LIFE are among other important sources of funding for development and support to deployment.

At national level, a variety of policies aimed at phasing out fossil boilers are being implemented, for example in Austria, France, Germany and the Netherlands. Existing grant schemes for heat pumps are being strengthened, and VAT is being reduced.[18] All National Energy and Climate Plans (NECPs) address heat pumps though they do not all provide trajectories. Ireland, for example, has a target of 600 000 heat pumps installed over the period 2021-2030. Germany has set a target of 6 million heat pumps to be installed by 2030 – six times the stock in 2020 (REN21, 2022). In order to meet such targets, almost all Member States now have proposed or implemented measures to support heat pump deployment. Under their Recovery and Resilience Plans: the Czech Republic will spend EUR 500 million on boosting renewable energy production, including support for households to acquire heat pumps; Austria will support households with EUR 159 million to replace oil and gas heating with more sustainable heating including heat pumps; and France will invest EUR 5.8 billion in a renovation programme to increase the energy efficiency of buildings, which should make them more suitable for heat pumps.

The tax treatment of electricity relative to gas is also being re-examined, at both national and EU levels. On average, electricity prices in the EU are double gas prices, and in some Member States electricity prices are 5.5 times higher than gas (REN21, 2022). Notably, in 2021 a revision of the Energy Taxation Directive was proposed that would help level the playing field between electricity and gas. In addition, since April 2022, Member States can apply reduced VAT rates to energy efficient, low emission heating systems, including heat pumps. In Finland, electricity tax reform aims to reduce the electricity tax for heat pumps from 22.53 EUR/MWh to 7.03 EUR/MWh (Tilia et al., 2021).

Potential barriers to deployment of heat pumps include:

The main barriers to deployment are up-front cost (see section 2.4 as well as the discussion of tax treatment above); availability of sufficient products to meet demand in the short term, related for example to the pandemic and the general shortage of semiconductors (see also section 4.3); and a lack of skilled workforce. Macroeconomic factors could also hinder deployment growth, e.g. import and export tariffs on raw materials or components, or rising interest rates affecting financing (in particular for ground-source heat pumps).

Regarding the workforce, there is a general shortage of planners, architects, engineers and qualified heating and cooling installers, to provide information on solutions, carry out the installation effectively (including in some cases handling of flammable refrigerants) and ensure optimal operation thereafter. This barrier is common across heating and cooling technologies but more acute in heat pumps. Bottlenecks at the installation stage are already being experienced in several Member States.

Some issues that have been cited as potential barriers in the past may no longer be. First, improvements in heat pump technology, and an expected increase in retrofit rate under the Renovation Wave, mean that the slow pace of renovation in Europe is less of a barrier than in the past. Second, the proposed amended F-Gas Regulation (4 April 2022) is careful to address concerns over the timing of the switch from F-gases to natural refrigerants (Box 4).

Box 4. F-gases and heat pumps

Driven by EU regulation, there has recently been a move away from F-gases with high GWPs, to natural refrigerants and F-gases with lower GWPs. F-gases made up 2.3% of total EU greenhouse gas emissions in 2019 (EEA, 2021).

[18] Trinomics et al. (2021) provides a roadmap and meta-study of policy support for heating and cooling decarbonisation.

Under the F-Gas Regulation, the main measure to avoid the use of such gases in equipment such as heat pumps is a quota system that progressively limits the amount (in CO_2-equivalents) of hydrofluorocarbons (HFCs) that can be put on the EU market each year. A proposal to future-proof the Regulation increases the ambition of the quota system (around 98% reduction by 2050 compared to 2015) and adds three relevant prohibitions:

F-gases with GWP >=150 cannot be used in self-contained systems ("monoblocs") from 2025 onwards;

F-gases with GWP>=150 cannot be used in small split systems from 2027 onwards;

F-gases with GWP>=750 cannot be used in larger (i.e. capacity > 12kW) split systems from 2027 onwards.

Both the deployment of heat pumps and the phase-down of F-gases reduce greenhouse gas emissions. Industry associations EHPA, EPEE, AREA and APPLiA argue that a more rapid phase-down than in the current F-Gas Regulation would limit the growth potential of heat pumps (see for example EHPA, 2022b). However, the Commission proposal for a revision is designed to allow for the heat pump growth needed under REPowerEU, while preventing direct emissions from refrigerants from increasing. The prohibition dates were proposed to allow sufficient time for manufacturing to adapt, although industry associations contend that the transition to more flammable substances presents significant additional complexities in terms of compliance and changes to building codes.

The cost to end users need not necessarily increase as a result of the phase-down, as energy savings would also be achieved. The recent review of the international product standard IEC 60335-2-40 will allow for the safe use of very climate-friendly refrigerants in all smaller heat pumps and greatly facilitate this refrigerant transition. In the unlikely event of the emergence of a major HFC market disruption (which has not occurred in the first seven years 2015-2022 of the quota system), the proposed Regulation includes the possibility for the Commission to exempt a relevant sector or adjust the quota allocation mechanisms. The efforts to reduce the climate impact of refrigerants are therefore fully coherent with the increased roll-out of heat pumps.

A more ambitious HFC phase-down also helps the EU to reduce its reliance on imported refrigerants since HFCs are mainly imported (both legally and illegally). China is the leading producer of HFCs worldwide, and has nearly 60% of the production of fluorspar (calcium fluoride). In the EU, Bulgaria and Spain combined account for about 5% (Cheng and Lauly, 2022).

A shift to natural refrigerants can thus represent a market opportunity and area for innovation. Natural refrigerants may also have an advantage in terms of price trend and price stability, and they are not patented. There is already some evidence of production lines being reconverted, and new ones started, to focus on natural refrigerants (ATMOsphere, 2022).

A third potential barrier whose importance should not be overstated is grid capacity. That can be at the level of the transmission grid and also locally in distribution, when an entire apartment building or neighbourhood switches to heat pumps. Utilities say that a roll-out of 50 million heat pumps by 2030 will not jeopardise grid stability if grids are upgraded and demand-side flexibility is exploited (aeléc et al., 2021). Additional grid investments will be needed in line with rising electricity consumption across the economy, including from electric vehicles and process electrification. However, heat pumps can provide demand response and they can be combined with thermal storage and smart controls in a "comfort and climate box" (IEA HPT, 2022). Therefore, once grid capacity continues to accommodate deployment, heat pumps can actively contribute to grid stability. There may also be significant savings at macroeconomic level if high gas prices persist (DIW, 2022).

2.4 Technology cost – Present and potential future trends

The average manufacturer selling price for heat pumps in Europe in 2016 was EUR 3 600 per unit (VHK and BRG, 2019). Prices have risen since then and vary considerably by type, manufacturer and Member State. Taking the Netherlands as an example, hybrid heat pump systems cost between EUR 5 500 and EUR 8 000 while a standard electric heat pump costs between EUR 8 000 and EUR 15 000.[19] Installing underfloor heating or insulation at the same time takes the cost to around EUR 25 000.[20]

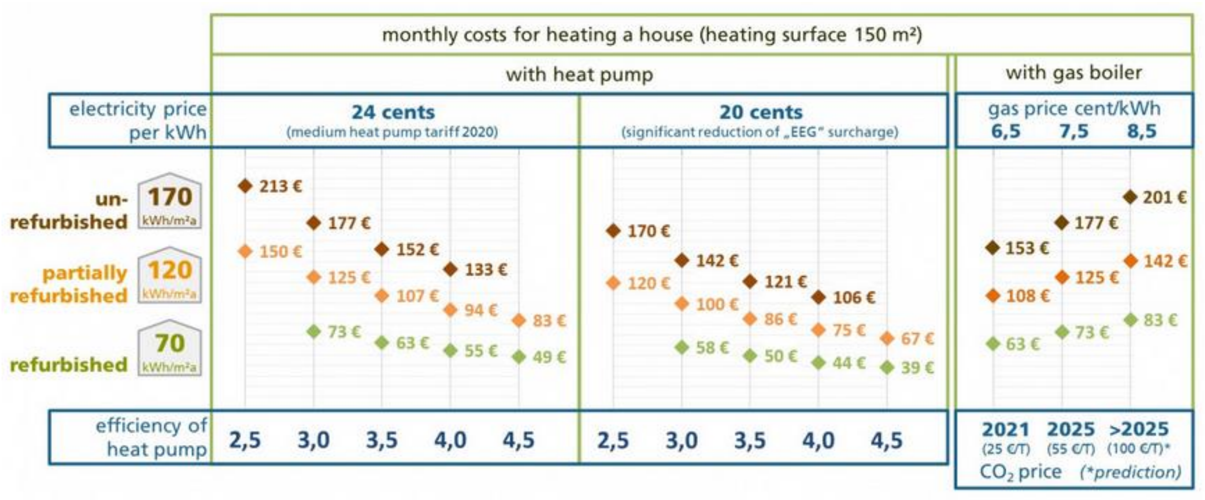
[19] www.feenstra.com/zorgelooswonen/de-10-meest-gestelde-vragen-over-de-warmtepomp/?utm_source=nieuwsbrief&utm_medium=email&utm_campaign=nbweek0922_V1_B2C&utm_content=awareness.

[20] https://group.vattenfall.com/press-and-media/newsroom/2021/vattenfalls-new-heat-pump-provides-homeowners-an-alternative-to-gas.

Ground-source heat pumps tend to be more expensive in terms of CAPEX than air-water heat pumps, due to the need for underground piping, with air-air heat pumps more affordable on that metric. On the other hand, ground-source heat pumps tend to be more efficient in operation.

Although the up-front investment is an important hurdle, the lifetime cost of a heating technology is dominated by the operating cost. The operating cost of a heat pump depends on electricity prices, the energy performance of the building, the size of the area to be heated, and the efficiency of the heat pump unit itself. Figure 5 shows indicative numbers, for Germany this time.

Figure 5. Monthly operating costs of an electric heat pump in Germany



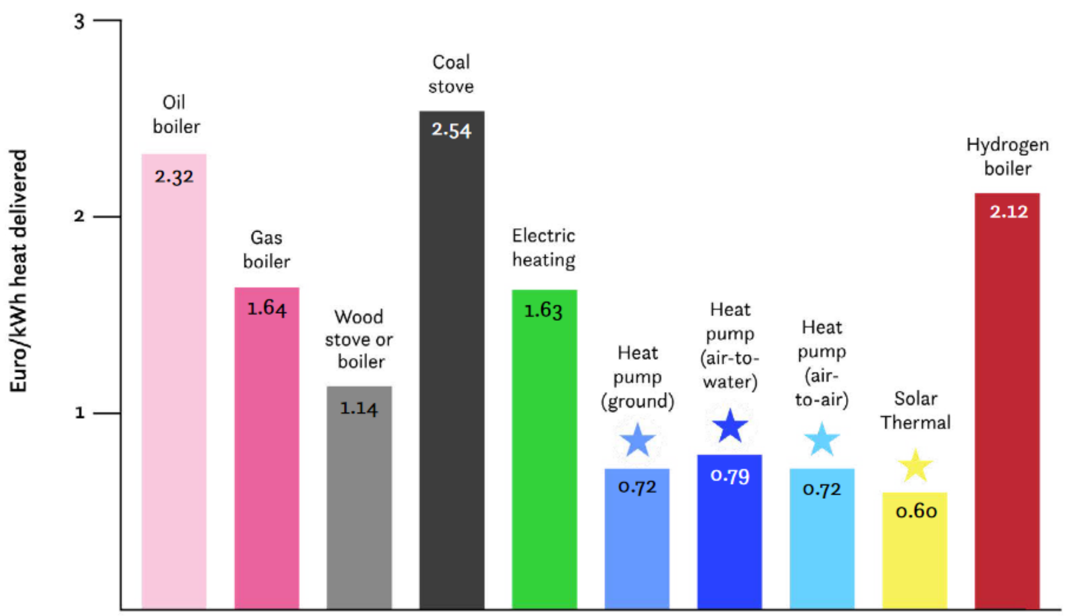
Source: Miara, 2021.

Note: EEG = German Renewable Energy Act.

In energy terms, the levelised cost of heat for domestic heat pumps in 2018 was EUR 84-145/MWh (Enerdata et al., 2020). This cost has been falling over time and is expected to continue to do so as the market grows and technologies develop.

The average energy bill for heating can be cut in half by 2050 when buildings are renovated and heat pumps become the dominant heating technology. The total cost of ownership is likely to converge towards that of condensing gas boilers by 2028 (ECF et al., 2022), with the decreasing trend continuing thereafter (Figure 6).

Figure 6. Total cost of ownership by heating technology, 2030-2040 (EUR/kWh heat delivered)



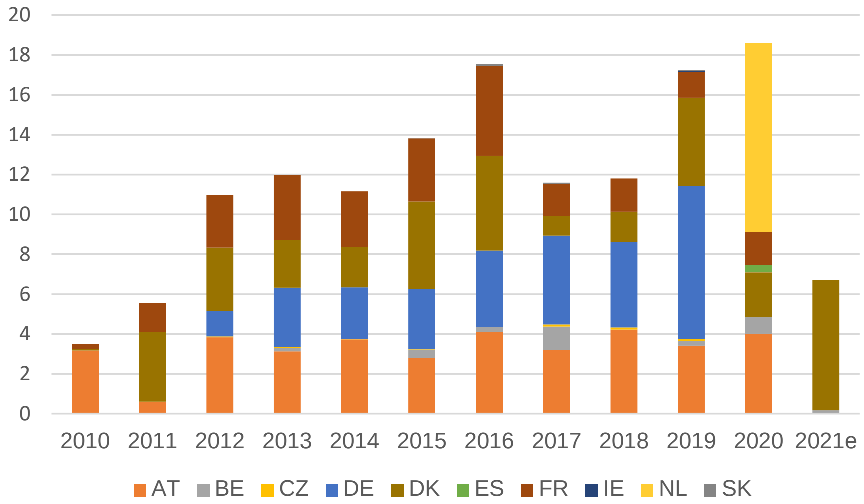
Source: Mixed scenario with hydrogen produced domestically, from ECF et al. (2022).

It is also important to note that heat pump owners can benefit from a premium on their property value. In the United States, this has been found to be 4.3-7.1% on the sale price for an air-source heat pump (Shen et al., 2021). That is substantially more than either the cost of switching or the longer-term economic savings.

2.5 Public research, development and innovation funding

Public RD&I investment into heat pumps in the EU started to be reported to the IEA in 2010, with eight Member States submitting data since then (Figure 7). The overall trend is towards a gradual increase in funding, although the data reported for 2021 are incomplete.

Figure 7. Public research investment into heat pumps in EU, 2010-2020 (EUR million)



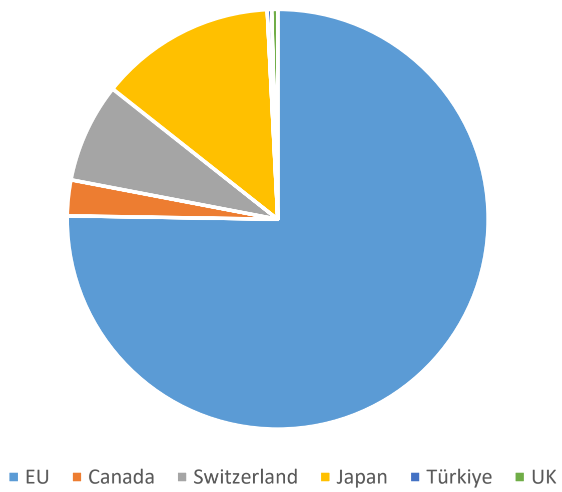
Source: JRC based on IEA (2022) and BMWi (2019).

Notes for all charts in this section: Data are for the IEA code 144 (heat pumps and chillers, excluding simple cycle air-conditioning only units or room air conditioner units) (IEA, 2011). e = estimated. IEA time series are incomplete and limited to IEA member countries (Bulgaria, Croatia, Cyprus, Latvia, Malta, Romania and Slovenia are not IEA members).

Germany reported data for the first time in 2019 (EUR 6.8 million), so the time series above has been completed based on statistics at national level. In addition, Germany's Federal Ministry of Economic Affairs and Energy (BMWi) is funding a project (REALLABOR GWP) on heat pumps in DHC networks with EUR 21 million, starting in 2021 (IEA HPT, 2021). Yet Germany has not reported any data for 2020 or 2021. Meanwhile, the Netherlands reported data this year for the first time, with EUR 9.5 million spent in 2020.

Although public RD&I funding for heat pumps is small compared to some other clean energy technologies, the EU spends a significant amount on public research into heat pumps relative to several major countries worldwide (Figure 8).

Figure 8. Public research investment into heat pumps, 2020 (EUR million)



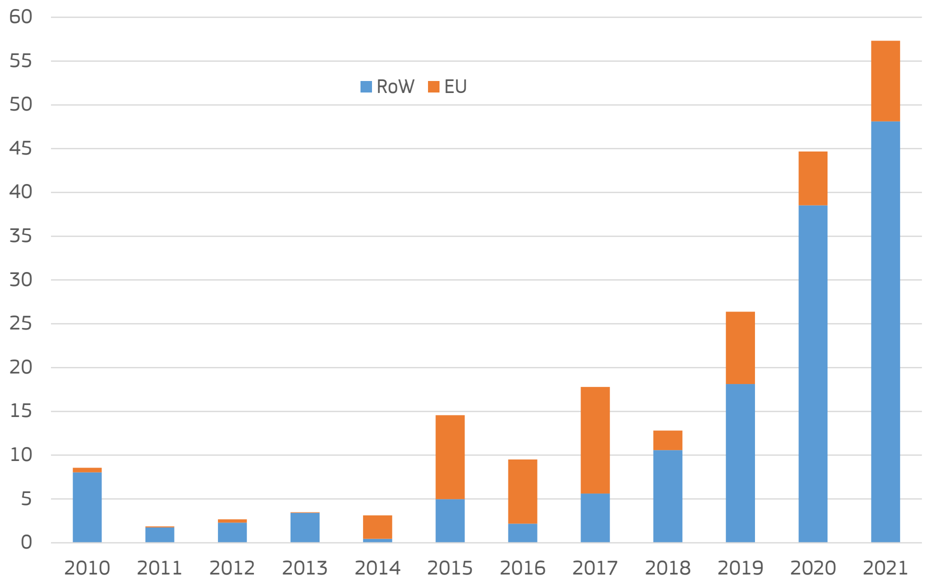
Source: JRC based on IEA (2022).

As well as national research programmes, funding obtained through EU programmes is included in the data above. For more detail, see section 2.9.

2.6 Private research and development funding

This section describes trends in investment going to start-ups and scale-ups, as a proxy for private RD&I funding. Such investment in heat pumps steadily increased between 2016 and 2021 to reach EUR 57.3 million worldwide (+28% compared to 2020) (Figure 9).

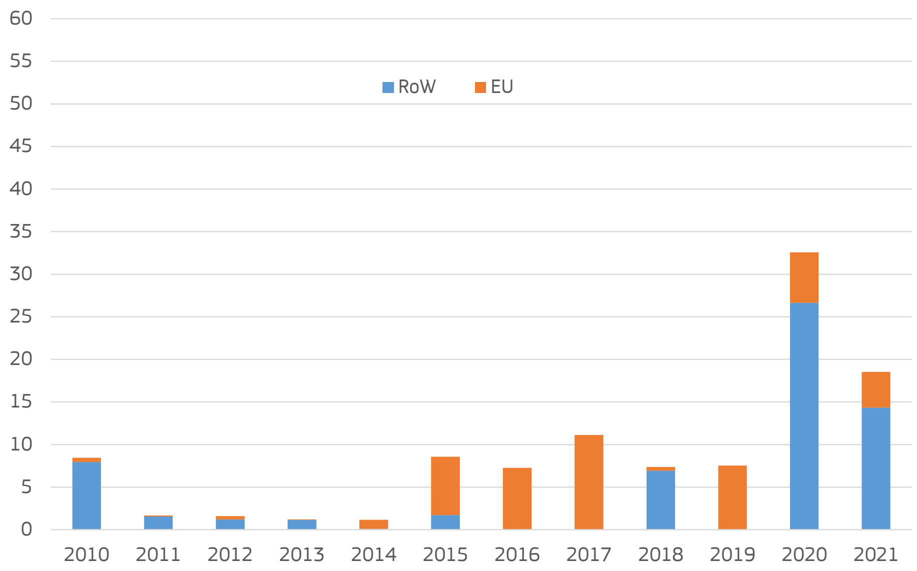
Figure 9. Investment in heat pump start-ups and scale-ups in the EU and worldwide, 2010-2021 (EUR millions)



Source: JRC based on Pitchbook.

The EU is particularly strong at attracting later-stage (scale-up) investment. The EU only accounted for 10% of early-stage investments over the 2016-21 period, compared to 43% of later-stage investment, amounting to EUR 36.5 million (Figure 10).[21]

Figure 10. Later-stage (scale-up) investments in the EU and world, 2010-2021 (EUR millions)



Source: JRC based on Pitchbook.

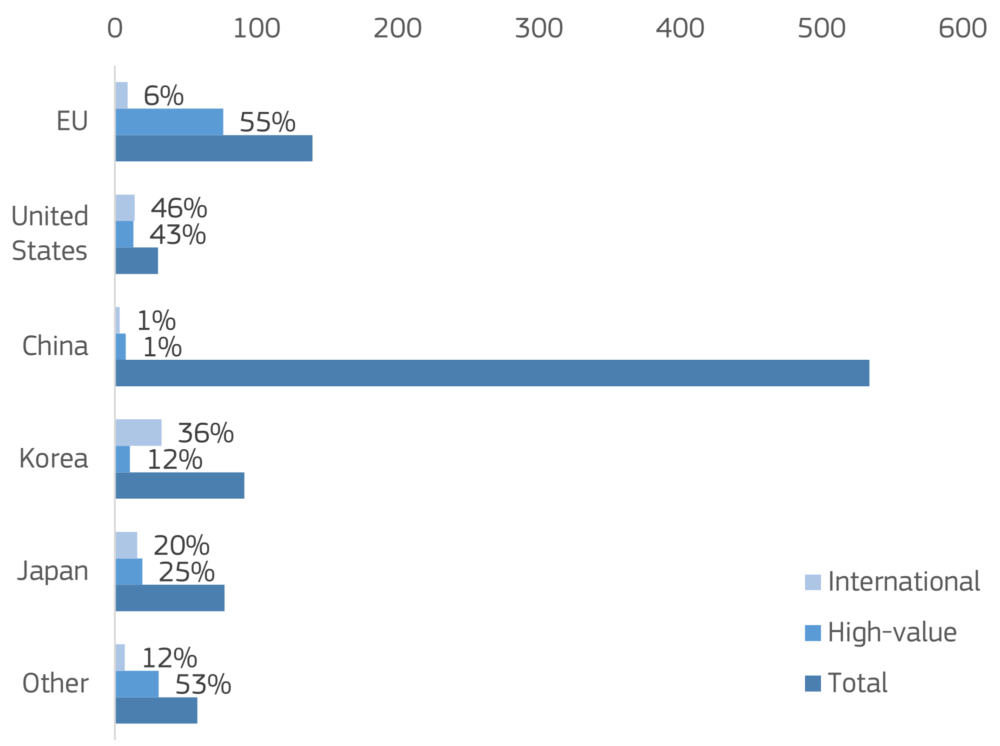
[21] Types of early-stage private investment include grants, pre/accelerator/incubator, angel, seed and early-stage venture capital investments; types of later-stage private investment include later-stage venture capital (including undisclosed series), small mergers and acquisitions (non-control) and growth private equity.

At both early and later stages, the United States is ahead of individual Member States. The next leading countries are Norway for the early stage and Ireland for the later stage. Ireland, the Netherlands and Austria are also attracting early-stage investments. Sweden, France, Germany, the Czech Republic, the Netherlands and Belgium are among the top ten countries attracting later-stage investments. Examples of companies in the heat pump value chain that have received venture capital or private equity growth investments include Edergen and TECCONTROL.

2.7 Patenting trends

The highest number of inventions originate from the Asia-Pacific region, 86% of the total. China alone accounts for 58% of all inventions, while Europe and North America only account for 9% and 4% respectively. However, only 1% of Chinese inventions are high-value patents (Figure 11). More than half of EU inventions are high value, making the EU the world leader in cutting-edge heat pump technology.[22]

Figure 11. Number of inventions and share of high-value and international activity, 2017-2019



Source: JRC based on EPO Patstat.

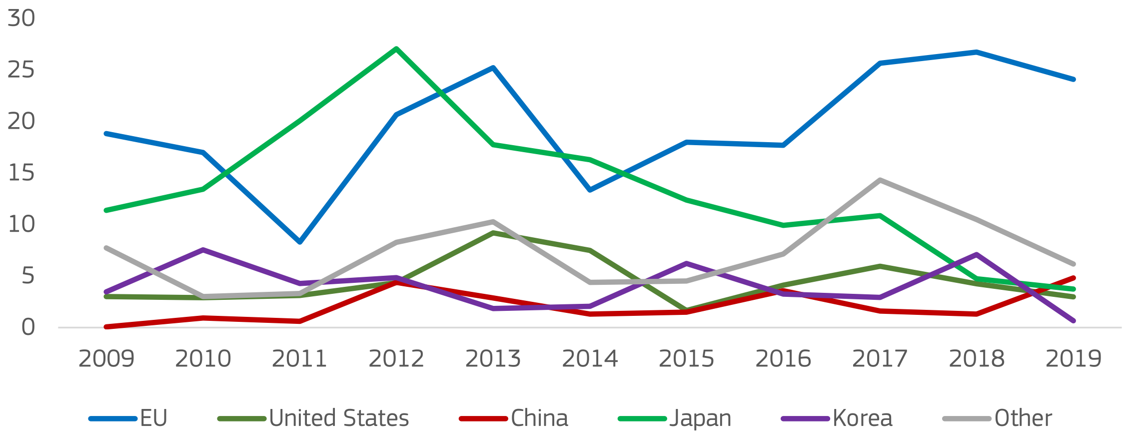
Notes: CPC codes for all charts in this section: Y02B (climate change mitigation technologies related to buildings) 10/40 (geothermal heat-pumps), 30/12 (hot water central heating systems using heat pumps), 30/13 (hot air central heating systems using heat pumps), and 30/52 (heat recovery pumps).

In the EU and China, high-value patenting activity is stable or growing, while in several other major economies it is decreasing (Japan) or stagnating (Korea, United States) (Figure 12). As a result, the EU share of all high-value patents was 48% during the period 2017-2019, a significant increase compared to 42% in the period

[22] Patent families (inventions) include all documents relevant to a distinct invention (e.g. applications to multiple authorities). Statistics are produced based on applicants, considering applications to all offices and routes. When more than one applicant or technology code is associated with an application, fractional counting is used to proportion effort between applicants or technological areas, thus preventing double-counting. An invention is considered high value when it contains patent applications to more than one office. Patent applications protected in a country different to the residence of the applicant are considered as international. High-value considers EU countries separately, while for international inventions European countries are considered collectively. The CPC classification is not used with the same degree of consistency across IPOs in Asia. The figures for the total number of inventions for Asian countries should be used with caution. This does not affect statistics for high-value and international inventions.

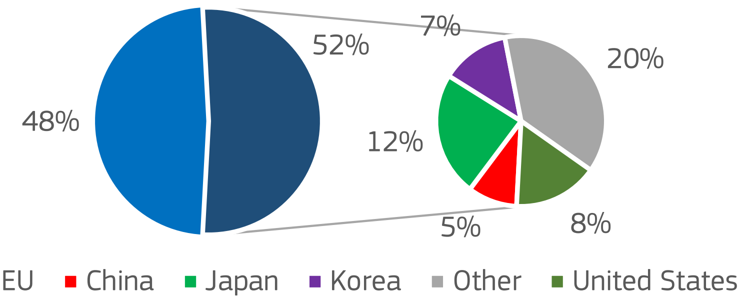
2015-2017 (Figure 13). Germany, France, Italy and Sweden were among the top ten countries worldwide (Figure 14).[23]

Figure 12. High-value inventions for mainly heating heat pumps by region, 2009-2019



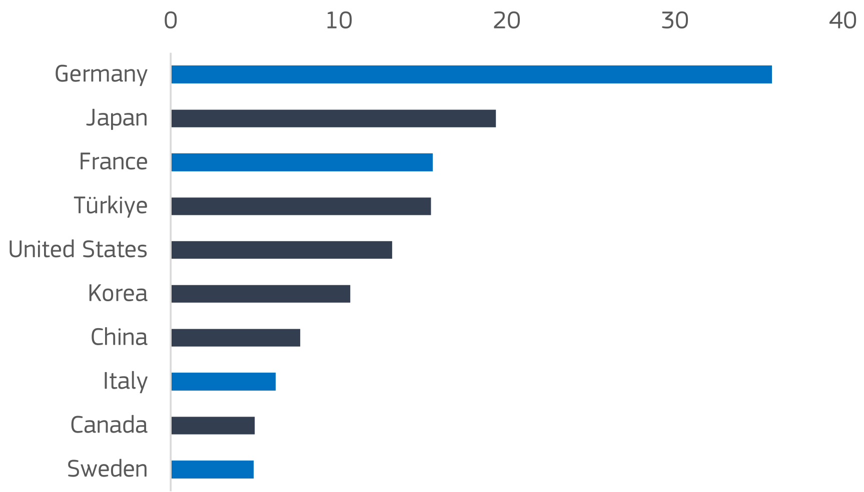
Source: JRC based on EPO Patstat.

Figure 13. Share of high-value inventions for mainly-heating heat pumps by region, 2015-2017 (left) and 2017-2019 (right)



Source: JRC, 2022.

Figure 14. Top ten countries for high-value inventions, 2017-2019

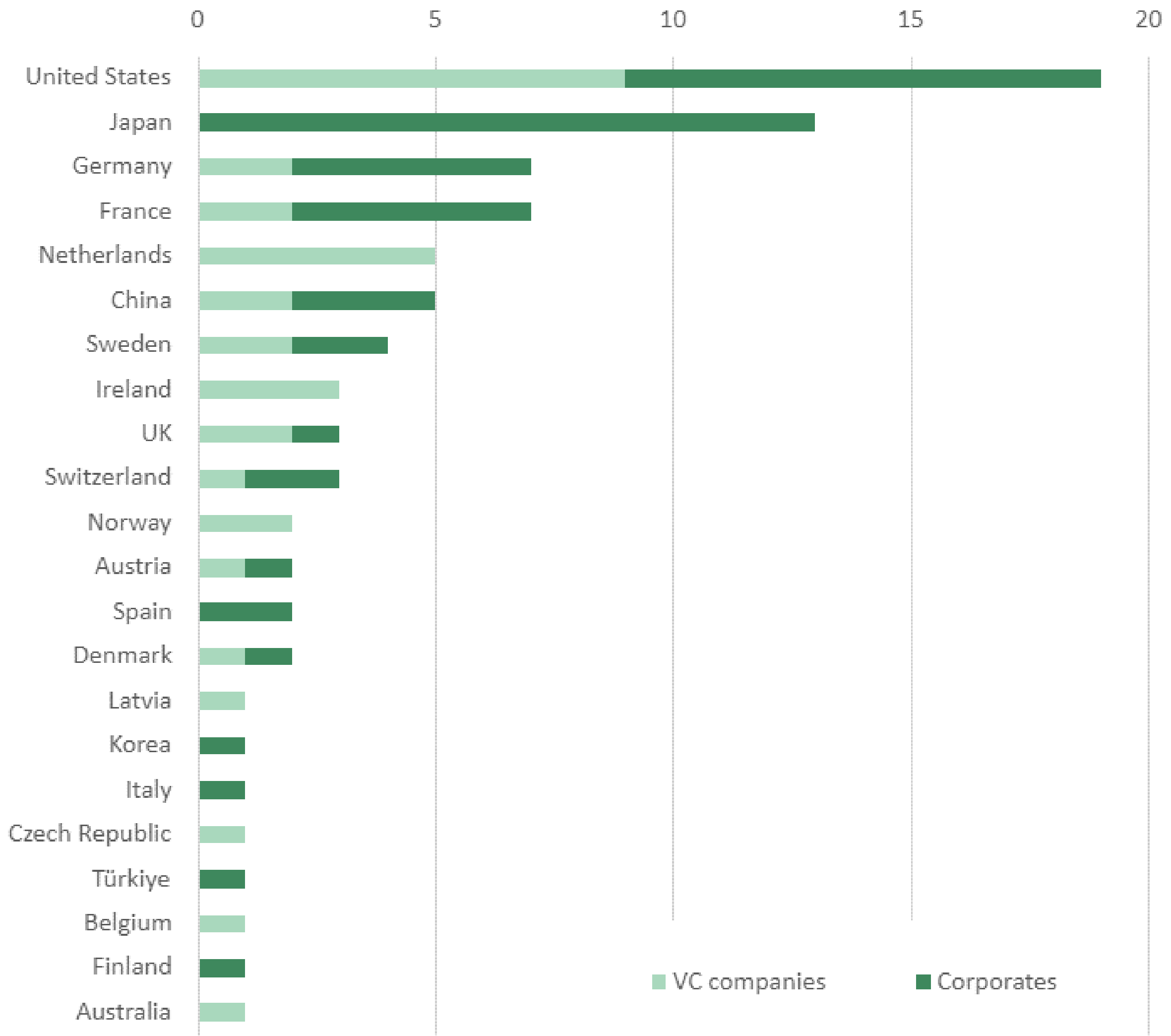


Source: JRC based on EPO Patstat.

[23] Relevant patents may be reported under a variety of CPC codes other than those considered here. The scope in this case is heat pumps mainly used for heating (SWD(2021)307).

The EU as a whole is host to 43% of all innovating companies, with the biggest pool of both start-ups and innovating corporates. The United States has a strong base of venture capital-funded companies, while all innovators in Japan are larger corporations (Figure 15).

Figure 15. Number of innovating companies by country, 2016-2021



Source: JRC based on various sources.

About 40% of EU innovating companies are start-ups and the rest are more established corporates.[24] The Netherlands has more start-ups than any other Member State.

2.8 Bibliometric trends/Level of scientific publications

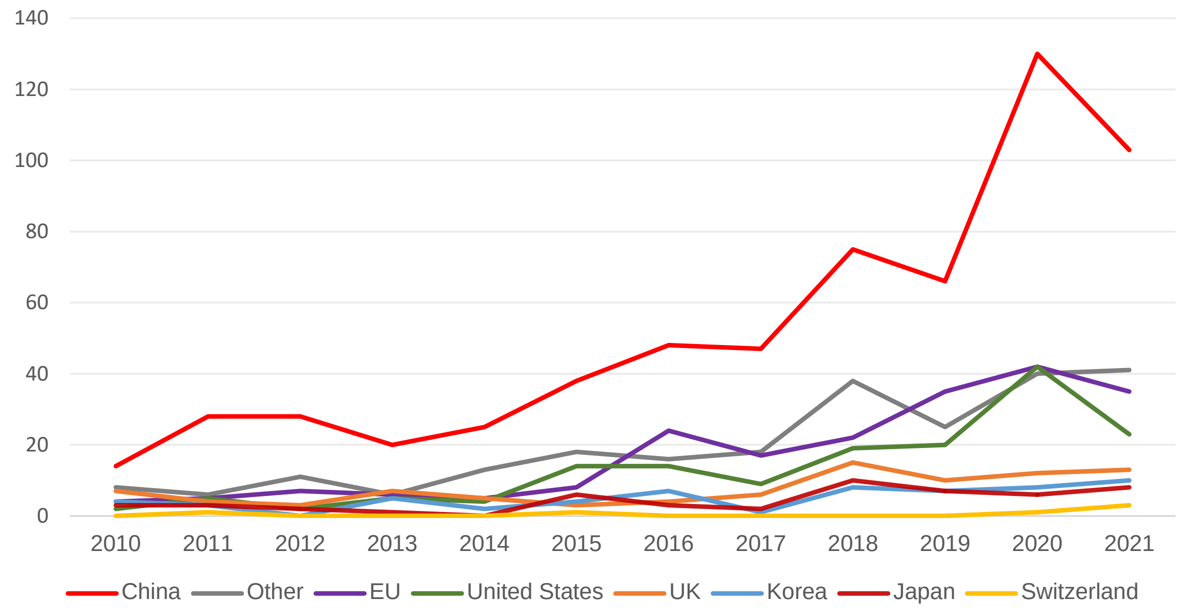
This section builds on JRC TIM data for:

- Overall publications by world region and Member State;
- Citation impact (h-index) by world region and Member State;
- Collaboration among world regions.

The overall trend is positive on all three indicators. In terms of sheer number of peer-reviewed articles, China is in the lead, closely followed by the EU when it comes to ground-source heat pumps (Figures 16 and 17).

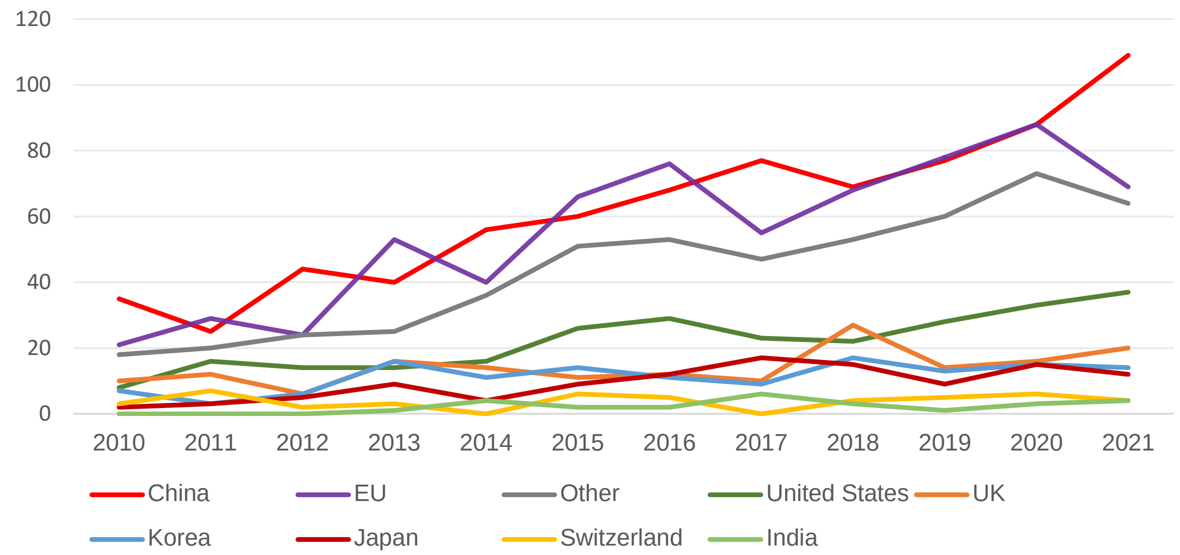
[24] By start-ups, we mean pre-venture companies and venture capital companies. Pre-venture companies have received angel or seed funding, or are less than two years old and have not received funding. Venture capital companies are companies that have, at some point, been part of the portfolio of a venture capital firm.

Figure 16. Number of peer-reviewed articles on air-source heat pumps by world region, 2010-2021



Source: JRC TIM based on Scopus database.

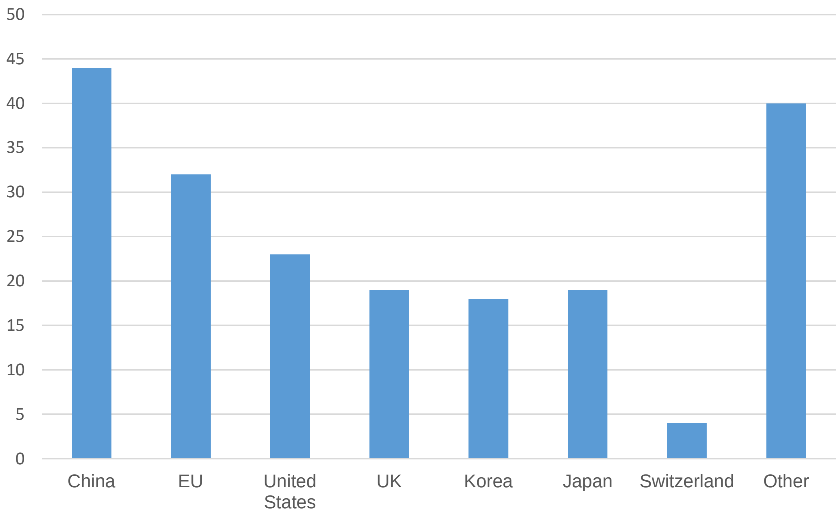
Figure 17. Number of peer-reviewed articles on ground-source heat pumps by world region, 2010-2021



Source: JRC TIM based on Scopus database.

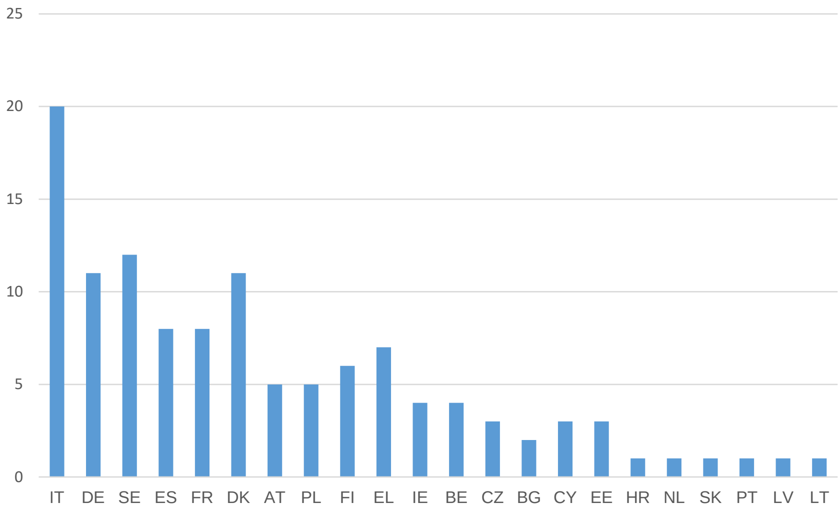
The h-index of a country is the largest number h such that at least h articles in that country for that topic were cited at least h times each. Under this measure of impact, China lead in air- and water-source heat pumps over the period 2010-2022, with the EU leading in ground-source heat pumps. Within the EU, Italy is a leader in all types of heat pump (Figures 18-23).

Figure 18. h-index for air-source heat pumps by world region, 2010-2022



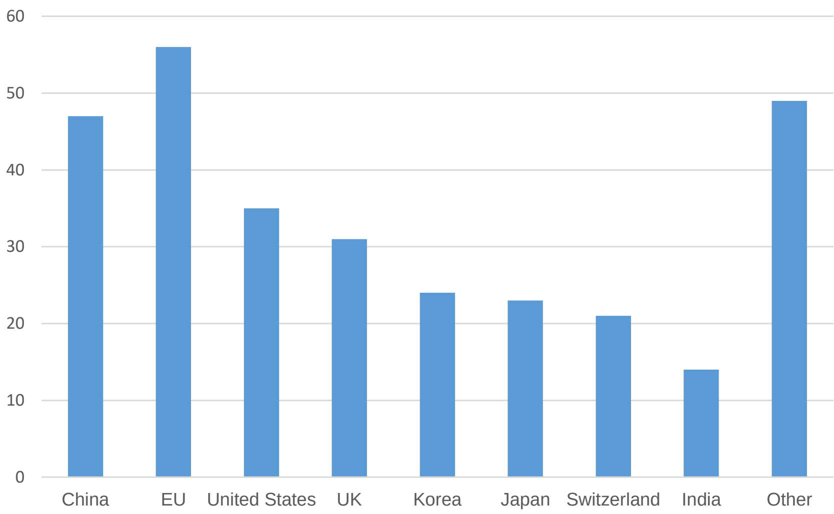
Source: JRC TIM based on Scopus database.

Figure 19. h-index for air-source heat pumps for selected Member States, 2010-2022



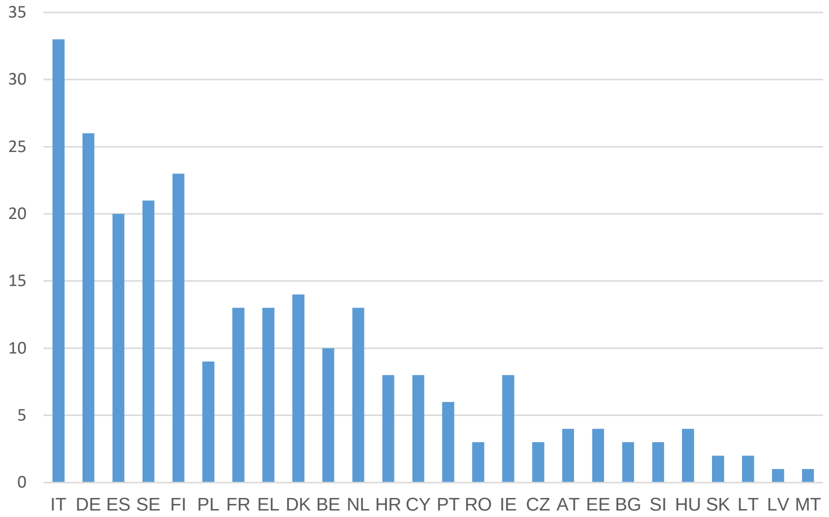
Source: JRC TIM based on Scopus database.

Figure 20. h-index for ground-source heat pumps by world region, 2010-2022



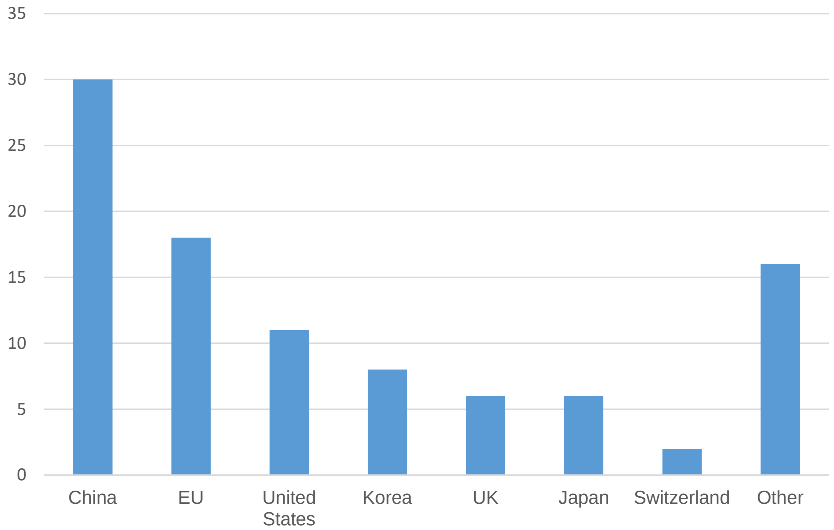
Source: JRC TIM based on Scopus database.

Figure 21. h-index for ground-source heat pumps for selected Member-States, 2021-2022



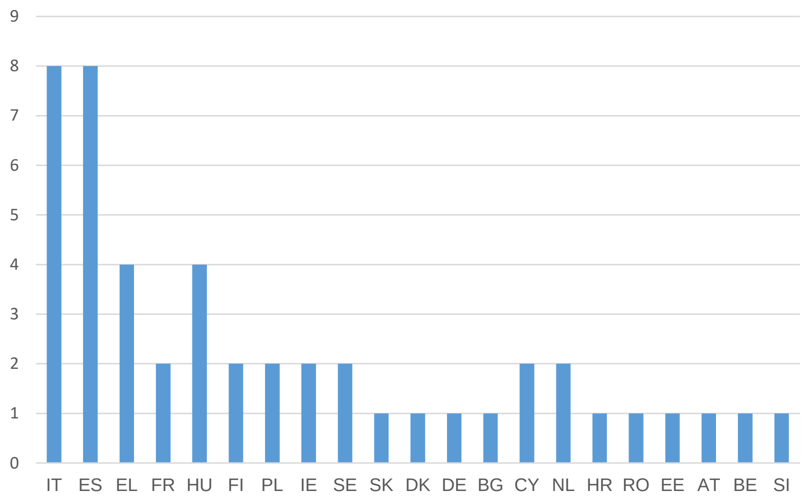
Source: JRC TIM based on Scopus database.

Figure 22. h-index for water-source heat pumps by world region, 2010-2022



Source: JRC TIM based on Scopus database.

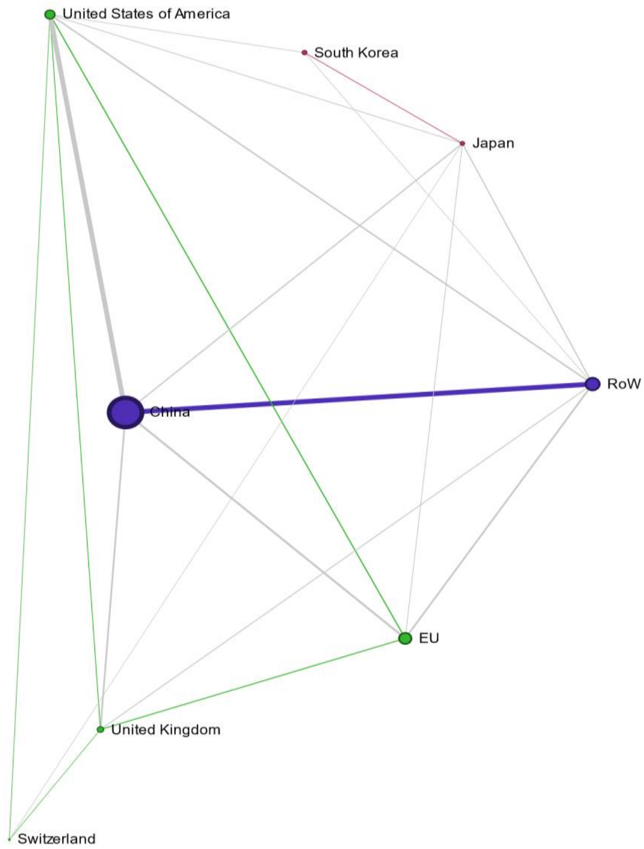
Figure 23. h-index for water-source heat pumps for selected Member States, 2010-2022



Source: JRC TIM based on Scopus database.

The EU has research links with the United States and the UK on air-source heat pumps, whereas China tends to collaborate with countries in the rest of the world (Figure 24). In ground-source heat pumps, the collaboration is among China, the EU and the rest of the world (Figure 25), whereas in water-source heat pumps, there is collaboration between China and the United States, and between Europe and the rest of the world (Figure 26).

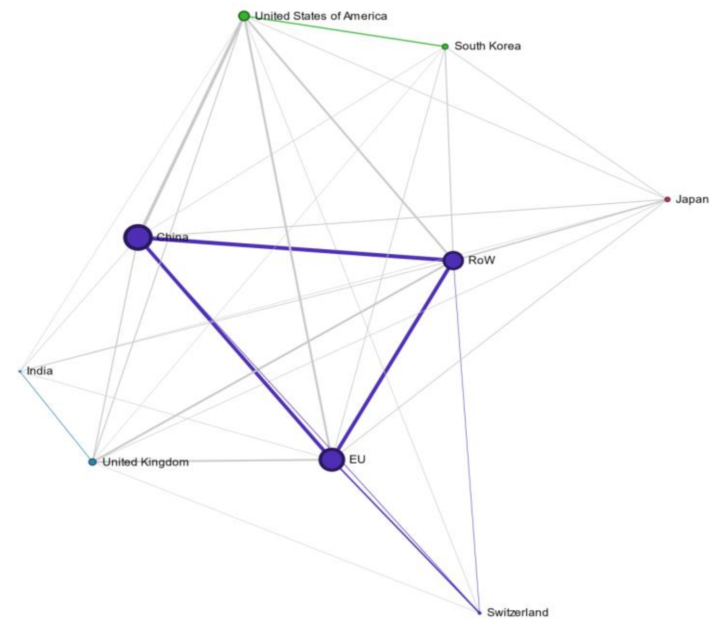
Figure 24. Collaboration among world regions for air-source heat pumps, 2010-2022



Source: JRC TIM based on Scopus database.

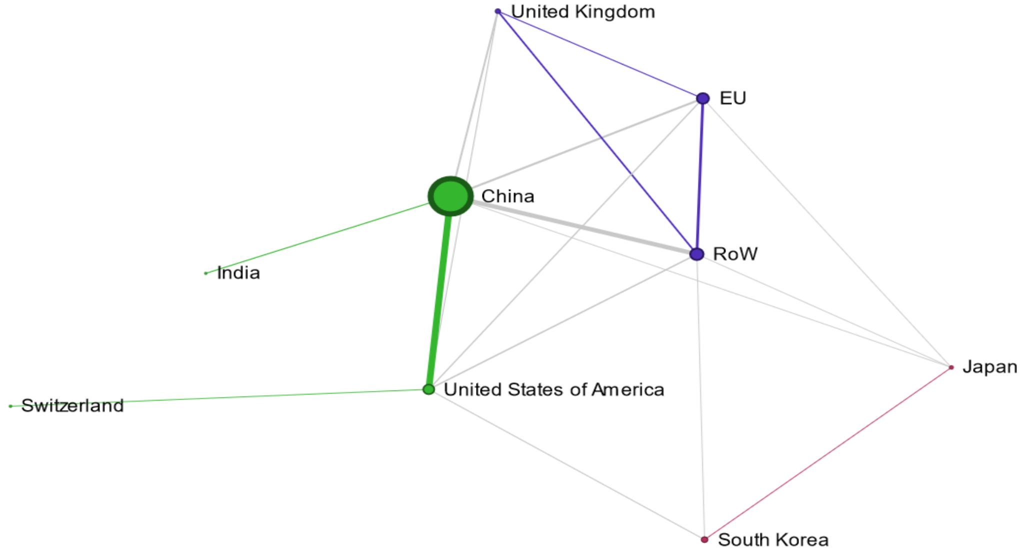
Note for Figures 24-26: Size of the node = number of documents for a location. Line thickness = number of documents in common. Colours = Communities of nodes that appear together more often.

Figure 25. Collaboration among world regions for ground-source heat pumps, 2010-2022



Source: JRC TIM based on Scopus database.

Figure 26. Collaboration among world regions for water-source heat pumps, 2010-2022



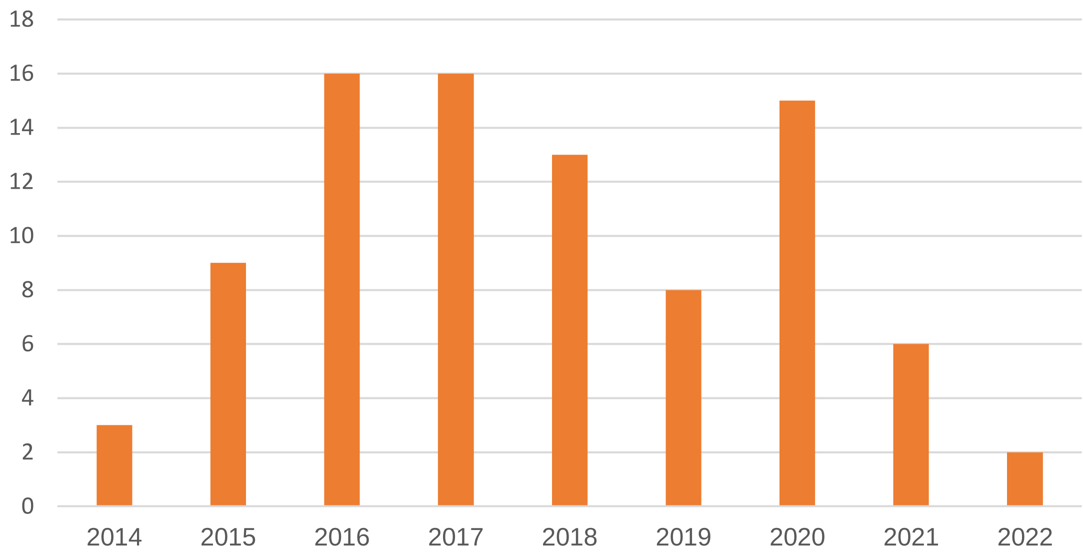
Source: JRC TIM based on Scopus database.

2.9 Impact and trends of EU-supported research, development and Innovation

EU funding instruments provide support from low-TRL breakthrough technology and materials development, to the development of components and systems, to their demonstration in laboratories and in the field, and finally to deployment, including skills development. Projects that started in the period 2014-2022 were supported with a total of EUR 277 million, mainly for the integration of heat pumps in buildings (54%) and in district heating and cooling (DHC) networks (29%), and for the development of heat pumps and related materials (17%). Projects often treat heat pumps as sources of electricity demand or as part of larger systems rather than focusing on the heat pump technology itself. There are also several projects that focus on industrial applications.

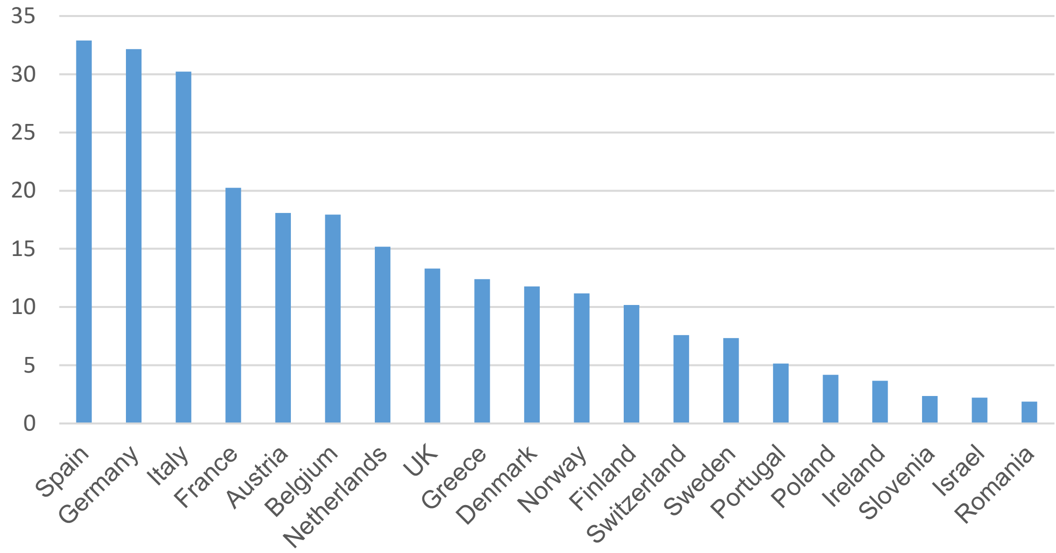
The EU instruments supporting heat-pump related materials, technologies and buildings applications include: European Research Council (ERC), Horizon 2020 (including the Energy Efficiency in Buildings partnership and the SME instrument) (Figures 27 and 28), and the Marie Skłodowska-Curie Actions.

Figure 27. Number of heat pump projects under Horizon 2020, 2014-2022



Source: JRC TIM.

Figure 28. Top 20 countries by total EU contribution to heat pump projects under Horizon 2020, 2014-2022 (EUR millions)



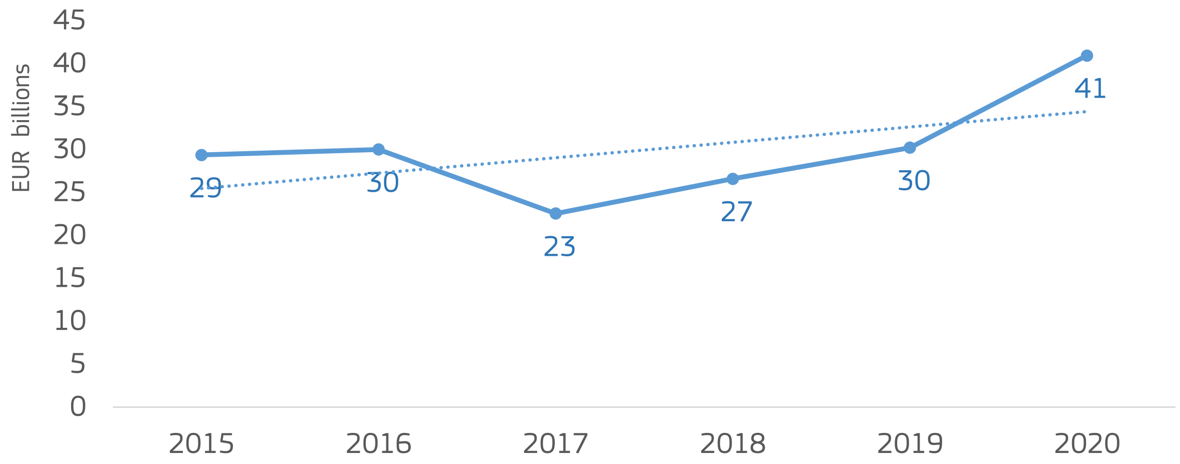
Source: JRC TIM.

3 Value-chain analysis

3.1 Turnover

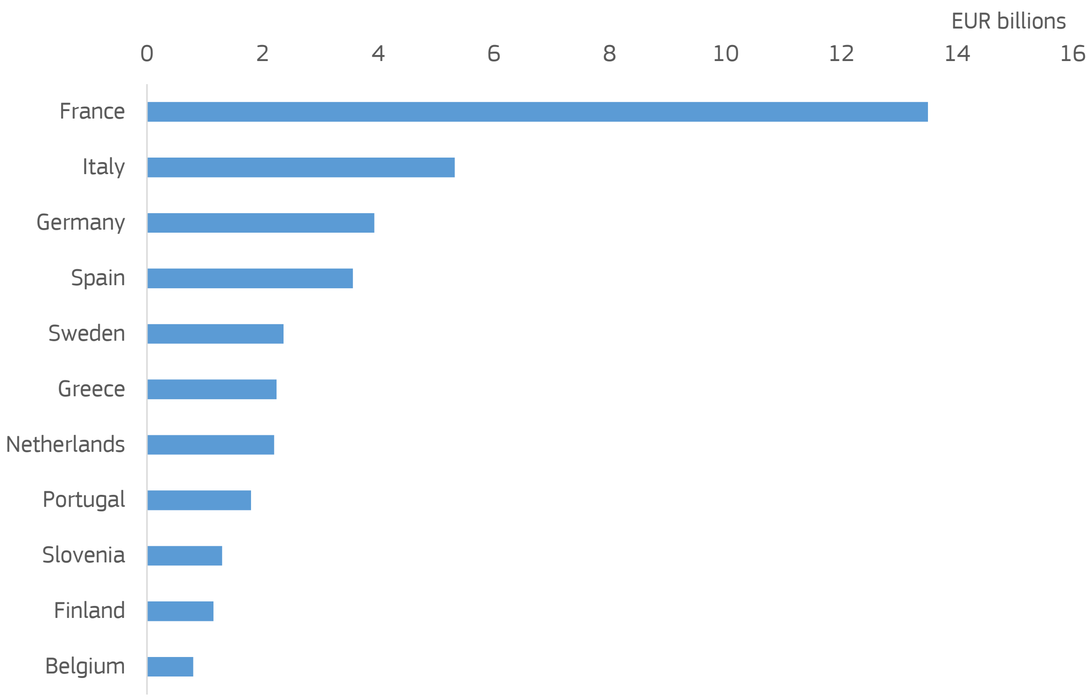
The broad EU "heat pump" sector (including mainly-heating heat pumps but also air conditioners) generated about EUR 41 billion in turnover in 2020. The market grew significantly in 2020 despite the pandemic. In 2017, turnover was just EUR 23 billion (Figure 29). In 2020, turnover in France was higher than any other Member State (Figure 30).

Figure 29. Heat pumps turnover in the EU, 2015-2020 (EUR billions)



Source: JRC based on EurObserv'ER.

Figure 30. Top ten Member States by heat pumps turnover, 2020



Source: JRC based on EurObserv'ER.

Worldwide and restricted to heat pumps that mainly provide heating, the market size exceeded USD 53 billion in 2020 and is expected to grow at a CAGR of more than 6% between 2021 and 2028 (GMI Insights, 2021). That is significantly slower than in Europe alone.

Focusing on heat pumps used for heating and hot water, EHPA estimates turnover in Europe at EUR 17 billion. Air-water heat pumps are the largest category.

3.2 Gross value added

Of the EUR 41 billion of turnover in 2020, more than EUR 16 billion was gross value added (EurObserv'ER, 2022). In general, the components accounting for significant portions of the total value of an air-source electric heat pump are the compressor (~25%), controller (~25%), heat exchangers (~15%), housing (~13%), valves (~10%), fan (~5%), pipework (~2%) and refrigerant (~2%) (Eunomia, 2020).

3.3 Environmental and socio-economic sustainability

The aim of this section is to provide a collection of key sustainability performance data or references, using a checklist approach.

Table 1. Environmental, economic and social sustainability indicators for heat pumps

Indicator	***Input***
Environmental	
LCA standards, Product Environmental Footprint Category Rules or best practice, Life-Cycle Inventory databases	Several LCA studies exist. There are values for the bill of materials in SimaPro. In addition, the Institute of International Refrigeration has published guidelines for Life Cycle Climate Performance (IIR, 2016).
Greenhouse gas emissions	In all Member States, ground-source heat pumps have lower emissions than gas boilers. For air-water boilers, the same is true everywhere except Poland and Estonia. The ongoing decarbonisation of electricity means that heat pumps will outperform boilers by 2030 even in those two countries, thus offsetting the additional emissions through savings later in the heat pump lifespan (Cool Products, 2021). See also section 3.6.
Energy balance	See section 3.6
Ecosystem and biodiversity impact	Approximately equivalent to other technologies such as boilers.
Water use	*Representative m^3/MWh for current technologies* No direct water use.
Air quality	Electric heat pumps reduce NOx emissions relative to alternative technologies, improving indoor and outdoor air quality and entailing health benefits (ECF et al., 2022).
Land use	Not significant.
Soil health	Not significant.
Hazardous materials	Natural refrigerants can have unfavourable toxicity characteristics. Heat pumps and in particular F-gas refrigerants may be significantly affected by future REACH proposals on PFASs (per- and polyfluoroalkyl substances). They are also subject to restrictions on hazardous substances due to the RoHS Directive.
Economic	
Cost of energy	See section 2.3 on technology costs.
Critical raw materials	See section 4.3.
Resource efficiency and recycling	Heat pump lifetime is between 14 and 20 years (Greening and Azapagic, 2012; Grant, 2022). Metals can be recycled. Refrigerant can be reused, assuming losses of 20% (Greening and Azapagic, 2012). The circularity of heat pumps could be improved with better reparability and modular design (SWD(2021)307). Heat pumps are within the scope of the 2012 WEEE Directive, which required Member States to achieve a recovery rate for heat pumps of 85% by August 2018, and a reuse/recycle rate of 80% (VHK and BRG, 2019).
Industry viability and expansion potential	Yes, see markets section.
Trade impacts	Yes, see markets section.
Market demand	Yes, see markets section.
Technology lock-in/innovation lock-out	There is a large number of providers and a large number of potential new entrants from related sectors and segments. There is no dominant proprietary technology or technology provider.
Tech-specific permitting requirements	None. Certification of installers required under RED.
Sustainability certification schemes	In Germany, there is a proposal to reissue a Blue Angel eco-label for domestic heat pumps (Becker et al., 2022).

Social	
Health	No known issues.
Public acceptance	Barriers to take-up may include noise, visual impact and space requirement. Immediate neighbours might object on those grounds too. Therefore, these are important areas for research (see relevant section). Space limitations are also being addressed through rooftop placement, boreholes for ground-source heat pumps, and better component integration within the heat pump housing (EHI, 2021b). On the other hand, heat pumps offer a premium on property value, and households might become more likely to install a heat pump once they see one installed nearby, similarly to the emergence of clusters of rooftop solar installations.
Education opportunities and needs	See discussion on installers elsewhere in the report.
Employment and conditions	For employment data see section 3.5.
Contribution to GDP	See section 3.1 on turnover.
Rural development impact	Heat pumps are well suited to rural areas, where district heating may not be feasible, and where there is a large share of one-off housing for which certain constraints may be less pressing, e.g. noise, space for external units, land for geothermal drilling. No need for fuels delivery by truck or for gas distribution infrastructure.
Industrial transition impact	Heat pumps installed in existing buildings replace incumbent technologies, notably boilers. There are some companies that manufacture both heat pumps and boilers, as well as some dedicated heat pump manufacturers.
Affordable energy access (Sustainable Development Goal 7)	Lower-income households benefit most from adoption, through lower energy bills (ECF et al., 2022). However, up-front costs are an important barrier.
Safety and (cyber)security	Some natural refrigerants, e.g. propane, are mildly flammable. Low systemic risk for cybersecurity as a decentralised technology but smart controls may represent a risk vector.
Energy security	Heat pump deployment reduces dependence on fossil fuels, mainly gas imports. See REPowerEU and ECF et al. (2022).
Food security	Not relevant, except insofar as electrification may alleviate demand for some forms of biomass.

3.4 Role of EU companies

The EU heat pumps sector is established, innovative and well positioned to benefit from increasing deployment. Heat pump manufacturers commonly also manufacture other heating equipment such as gas boilers. The EU heat pumps sector is represented through a number of trade associations both at national and EU levels.

Some consolidation has recently taken place in the sector. In 2016, Midea (China) acquired a majority holding in the Italian Clivet group, with manufacturing of domestic hot water heat pumps being relocated from Asia to Italy in 2017. In 2018, Stiebel Eltron (Germany) took over Danfoss Varmepumpar (Sweden). In 2019, Hisense (Chinese joint venture with Johnson Control Hitachi) acquired Gorenje (Slovenia). In 2020, Nibe (Sweden) acquired Waterkotte (Germany).

There are around 170 heat pump factories in Europe. A selection of EU-based heat pump manufacturers (assemblers rather than component manufacturers) are listed below by country, with 18 countries represented. Germany and Italy lead in terms of companies with manufacturing sites.

Table 2. Heat pumps manufacturing sites by country and company

Country	Company
Austria (count: 8)	Heliotherm
	Groupe Atlantic
	IDM Energiesysteme
	Neura/Pico Energy
	Ochsner
	Stiebel Eltron
	Vaillant
	Viessmann
Belgium (7)	Daikin
	Groupe Atlantic

	Ingersoll Rand International
	Mayekawa
	Openmotics
	Studiebureau R Boydens
	Techlink VZW (formerly Fedelec)
Bulgaria (1)	Tesy
Czech Republic (7)	Acond
	Bosch
	Daikin
	MasterTherm
	Nibe
	Panasonic
	TnG-Air.cz
Denmark (1)	Nilan
Finland (4)	Calefa
	HögforsGST
	Kaukora
	Oilon
France (15)	Airwell
	Groupe Atlantic
	BDR Thermea
	BoostHeat
	CIAT (Carrier)
	ECL Nexus
	ENGIE
	H Labbe
	LG
	Nibe
	Saunier Duval
	Vaillant
	Valeo Systems Thermiques
	Viessmann
	Vivreco Heat Pumps
Germany (24)	August Brötje
	BDR Thermea
	Bosch Thermotechnik
	Daikin
	Diehl AKO Stiftung & Co. KG
	ELECTRA Air conditioning Industries
	ELCO
	Emerson Commercial and Residential Solutions
	Fujitsu General (Euro)
	GEA Refrigeration Technologies
	Glen Dimplex
	Heliotherm
	Kermi
	Michl Technik
	Miele
	Mitsubishi Electric
	Nibe
	Panasonic
	Stiebel Eltron
	tecalor

	Vaillant
	Viessmann
	weishaupt
	WOLF
Greece (1)	Inventor A.G. Electric Appliances
Hungary (2)	Hajdu
	Thermowatt
Ireland (4)	BAXI Potterton Myson
	Firebird
	Grant
	Joule (Aero)
Italy (23)	Aermec
	Advantix
	Argoclima
	Ariston
	BAXI
	BDR Thermea
	CAREL
	Daikin
	enerblue
	Ferroli
	Haier
	Hidros
	Innova
	Midea
	Mitsubishi Electric
	Mitsubishi Heavy Industries
	Olimpia Splendid
	Parker Hannifin Manufacturing
	Riello
	Robur
	Swegon Group
	Tecnocasa Climatizzazione (EU AISIN Toyota gas heat pumps)
	Templari
Netherlands (11)	BDR Thermea
	Cooll Sustainable Energy Solutions
	Daikin
	Denso Europe
	ELCO
	Kiwa
	Mitsubishi Electric
	Remeha
	Samsung
	Triple Aqua Licensing
	Yanmar Europe
Poland (6)	Daikin
	Galmet
	HSK Lazar
	Klima-Therm
	Kospel
	THERMAGEN
Portugal (2)	Bosch Termotecnologia
	Energie

Slovakia (3)	Groupe Atlantic
	Hoval
	Stiebel Eltron
Slovenia (3)	Hisense
	KRONOTERM
	Termo Shop
Spain (13)	BAXI Climatización
	BDR Thermea
	Bosch Siemens
	CIC EnergiGUNE
	Clausius
	Daikin
	De Dietrich
	Ecoforest
	Eurofred
	Frigicoll
	Hitachi
	Panasonic
	Salvador Escoda
Sweden (9)	Alfa Laval
	Bosch
	Enertech Group
	Eon Sverige
	Nibe
	Qvantum Industries
	Sens Geoenergy Storage
	Stiebel Eltron
	Thermia

Source: Various, including CEN KEYMARK (2022), (JRC (2021), Eunomia (2020).

There are also heat pump companies based in Norway (e.g. Heaten), Switzerland (e.g. Siemens, CTA), the UK (e.g. Mitsubishi Electric and Kensa Heat Pumps) and Türkiye (Arcelik). United States companies in the heat pump value chain include Carrier (with a subsidiary in France), Honeywell, Johnson Controls (with subsidiaries in Denmark and France), Lennox, Rheem, Trane Technologies and Ingersoll Rand (with a subsidiary in Belgium). Leading Chinese manufacturers of air-source heat pumps are Midea, Gree and Haier (ChinaIOL.com, 2022). Other major players are Daikin (Japan, with subsidiaries in Belgium, Czech Republic and Poland), LG (Korea), Mitsubishi Electric (Japan, with subsidiaries in Germany, Italy, the Netherlands and the UK) and Panasonic (with subsidiaries in Czech Republic, Germany and Spain).

Compressor design and manufacturing is a specialised activity, so it has become dominated by a small number of global suppliers, including Mitsubishi Electric (Thailand) but also several European players such as Danfoss (Denmark and France), Bitzer and GEA (Germany), Tecumseh (France) and Emerson Copeland (Belgium and Northern Ireland). Some of the larger Asian electronics manufacturers, such as Hitachi and Daikin in Japan, manufacture their own compressors.

Fans are mainly manufactured by Ziehl-Abegg (Germany) and ebm-papst. The pumps market is dominated by Wilo (Germany) and Grundfos (Denmark).

Manufacturing of other mechanical components, such as heat exchangers, housing and controllers, is less specialised (they are also used in other products) and distributed among a wider range of companies worldwide. However, European companies Alfa Laval (Sweden) and SWEP are leading in many components. Absorption heat pumps, however, are one type that is vertically integrated, i.e. manufactured and assembled in Europe.

Raw material or component suppliers include ABB, ArcelorMittal, Aviva Metals, Fuji Electric Co., General Electric, Hitachi, MetalTek, Mitsubishi, Panasonic, Schneider Electric and Siemens. Manufacturers of elastomers include BASF (Germany), Dow (United States) and JSR (Japan). CAREL (Italy) is a leading manufacturer of electronic controllers (including sensors, electronic expansion valves, touchscreen displays and apps). Semiconductors have very complex value chains of their own.

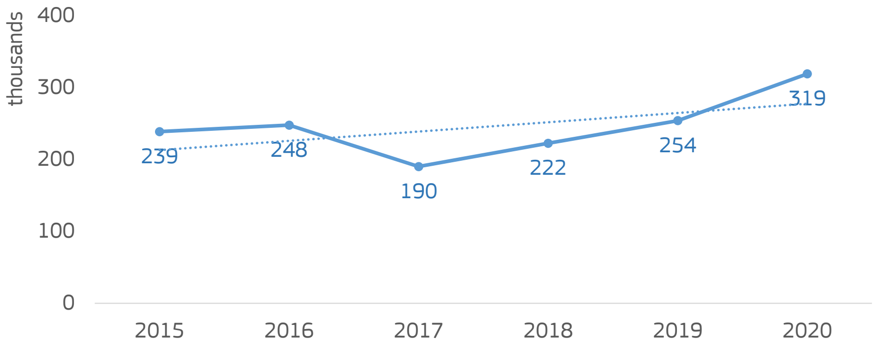
Refrigerant supply is dominated by China (e.g. Dongyue and Sinochem), with the United States (Chemours (with a subsidiary in Switzerland), DowDuPont and Honeywell) in second place. Other major international players are Asahi Glass and Daikin (Japan); SRF (India); and Koura (Mexico). EU suppliers are Arkema (France) and the Linde Group (Germany).

EU companies active in the DHC segment include Johnson Controls, Mayekawa, Ochsner, Oilon, Siemens Energy, Thermowatt, Vattenfall, MAN Energy Systems and a number of dedicated DHC companies.[25] Testing or research centres include CETIAT and Paris Mines (France), KIWA and TNO (Netherlands), Austrian Institute of Technology (Austria), Fraunhofer, TUV and TU Aachen (Germany), Polimi (Italy) and KTI Stockholm (Sweden). Engineering consultants in the sector include Ramboll, Arup, Fichtner Consulting, ETSuS (Germany), Viegand & Maagøe, VHK and WIP Renewable Energies.

3.5 Employment in the value chain including in research, development and innovation (by segment)

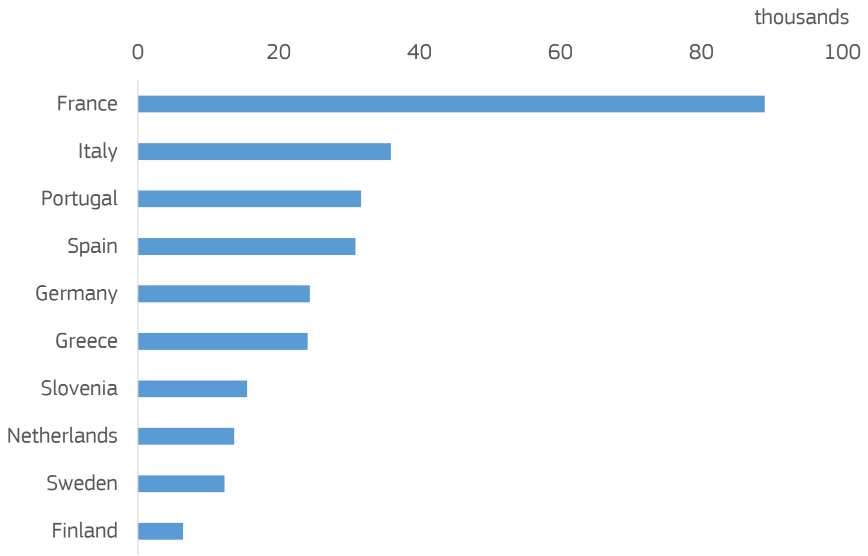
The European heating sector as a whole accounts for about 1.8 million direct and indirect jobs (EHI, 2021a). In 2020, the broad EU heat pump value chain (i.e. including all air-air heat pumps), employed 318 800 people directly and indirectly – an increase of 26% from 2019 (JRC, 2021, based on EurObserv'ER) (Figure 31). Similarly to turnover, France was the country with the most people employed in 2020 (Figure 32).

Figure 31. Direct and indirect jobs in heat pumps in the EU, 2015-2020



Source: JRC based on EurObserv'ER.

Figure 32. Direct and indirect jobs in heat pumps in the top ten EU countries, 2020

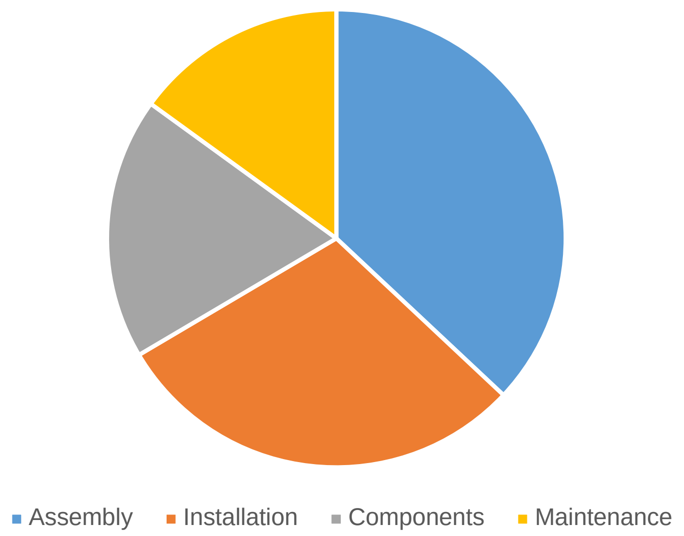


Source: JRC based on EurObserv'ER.

[25] For examples of projects, see (EHPA, 2019) or www.pv-magazine.com/2022/03/29/large-scale-high-temperature-heat-pump-for-district-heating/.

Focusing on heat pumps used for heating, employment is around 117 000 (EHPA, 2022c). The projected growth under REPowerEU would employ many more. The heat pumps sector employs people in RD&I, manufacturing, installing (including drilling), and maintenance (including periodic checks) (Figure 33).

Figure 33. Employment in the heat pump sector by stage of the value chain, 2020



Source: Based on EHPA, 2021a.

All heat pumps, whether imported or domestically produced, need to be installed on site. It takes more than twice as long to install a heat pump as it does to install a boiler, especially when that heat pump is replacing an existing boiler (EHI, 2021a). Ground- or water-source heat pumps take far longer to install than air-source heat pumps because they require drilling or digging.

Currently, there is a lack of trained heat pump installers in the EU. The RED requires installers to have a specific certification in order to install heat pumps. Also, the F-Gas Regulation requires anyone who installs, services, repairs or decommissions heat pumps with HFCs to do leak checks or to reclaim HFCs to be certified. Therefore, installers of heat pumps and other experts need to be trained specifically in relation to refrigerants and dimensioning of the system, in order to handle heat pumps safely, ensure their optimal performance and prevent emissions. The Commission proposal for a new F-Gas Regulation also includes certification based on obligatory training in climate-friendly refrigerants, but the obligation will not apply retrospectively to existing installers.

There are about 1.5 million installers of all kinds of heating appliances, most of them small companies (EHI, 2022). EHI estimates that the number of installers needs to increase by 50% to meet the 2030 REPowerEU target, and that 50% of existing installers will need reskilling. Instead, the number of installers is stagnant in several European countries.

Action is therefore required, at sectoral, national and EU levels. In particular, training is needed for switching to flammable refrigerants. Training courses are currently provided by heat pump manufacturers themselves (Viessmann, for example, has launched a training scheme on flammable refrigerants), by trade associations and by research centres.[26] Training for heat pump installers is also supported by the HP4ALL project under Horizon 2020.[27] Further support at EU level could come from the Technical Support Instrument or the Pact for Skills.

3.6 Energy intensity and labour productivity

As for boilers, the use phase (in this case electricity) dominates the life-cycle emissions of heat pumps, followed by refrigerants (approximately 14%). The carbon intensity of electricity used in Ecodesign preparatory studies is 384 g/kWh (VHK and BRG, 2019).

[26] See for example www.waermepumpe.de/fuer-handwerker/training, https://ecoforest.com/academy/en, www.viessmann.family/en/career/academy, www.daikin.nl/nl_nl/daikin-academy.html, www.cetiat.fr/en, www.eurac.edu/en/institutes-centers/institute-for-renewable-energy/pages/heat-pumps-lab, https://www.qualit-enr.org/qualifications/qualipac/.
[27] https://hp4all.eu/.

Box 5. Heat pump efficiency

The efficiency of a heat pump, expressed in Coefficient of Performance (COP), is the ratio of useful heat output to the electricity input for operation. Likewise in cooling mode, the efficiency is described by the energy efficiency ratio (EER), which is the ratio of cooling provided relative to the amount of electrical input required to generate it.

While the COP is usually based on lab measurements in standard conditions, the seasonal COP (sCOP) gives a realistic indication of energy efficiency over an entire year and is calculated for a given climatic zone (e.g. northern Europe, central Europe and southern Europe). In addition, the Seasonal Performance Factor (SPF) is measured for a given heat pump over one year and depends on the building in scope.

COP is typically between 3 and 5, with ground-source heat pumps tending to be the most efficient. The COP of large heat pumps used in DHC is usually between 1.7 and 3.8 (Tilia et al., 2021). Performance deterioration can occur in the absence of maintenance (EHI, 2021b).

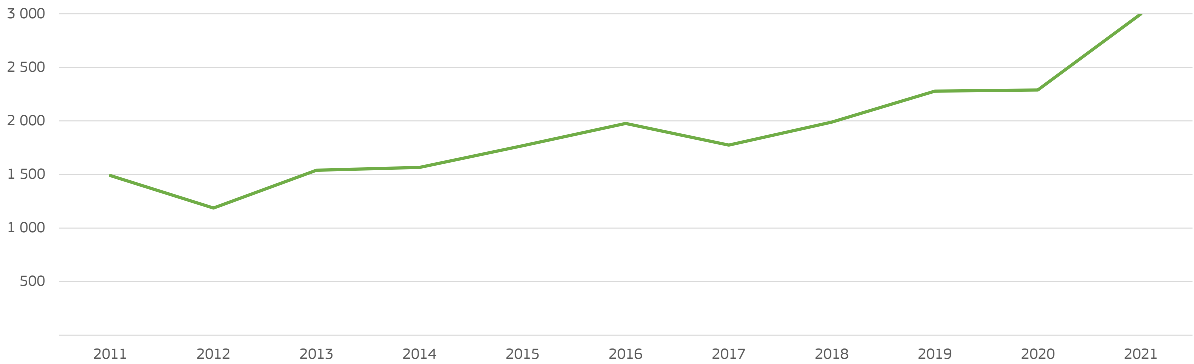
Under the proposed EU Taxonomy, heat pumps must meet energy efficiency requirements laid down in implementing regulations under the Ecodesign Directive. The refrigerant threshold for sustainable finance under the proposal is 675 GWP (EU TEG on Sustainable Finance, 2020).

Based on the broader definition of the heat pump market, labour productivity is EUR 128 607 per person.

3.7 EU production data (annual production values)

EU manufacturing capacity is increasing and productivity is improving. The value of EU production of heat pumps mainly used for heating (i.e. air-water and ground-source) was around EUR 3 billion in 2021 (JRC based on PRODCOM code 28251380) (Figure 34). Note that this uses a narrower definition than that used for turnover in section 3.1. The impact of the pandemic was felt in 2020, with growth flat overall in that year. Production in Italy dropped by as much as 60% in 2020 compared to the previous year.

Figure 34. Production value in the EU (EUR millions), 2011-2021



Source: JRC based on PRODCOM.

Note: 2021 data is an estimate.

Sweden was the top producer (EUR 749 million), notably hosting the manufacturer Nibe. Germany also remains a top producer, with an increase of 22% to EUR 641 million. In countries with smaller annual production values, the picture was more mixed. In Finland for example, production increased eightfold in 2021 to a level (EUR 16 million) last seen ten years previously. Denmark, however, saw a decrease from EUR 90 million to EUR 31 million.

Producers are investing in Europe to satisfy increasing market demand. This includes:

— Saunier Duval (France) investing EUR 10 million to increase its production capacity from 35 000 heat pumps in 2020 to 130 000 units by 2023;

— Vaillant (Germany and France) doubling its production capacity, including EUR 120 million investment in Slovakia;

— Daikin investing in new lines to produce 20 000 units by 2021 (EurObserv'ER, 2021), with further expansion planned – notably in Poland, where a new EUR 300 million factory is to open in 2024, employing 1 000 people by 2025 (Daikin, 2022);

- Stiebel Eltron aiming to double its heat pump production capacity by 2026, investing EUR 120 million and creating 400 new jobs (Farrell, 2022);
- Bosch planning to invest EUR 355 million in heat pumps by mid-2025;
- Viessmann announcing investment of EUR 1 billion over the next three years in heat pumps and other solutions, including a EUR 200 million investment in propane-based heat pump manufacturing in Poland (Hayes, 2022);
- Panasonic announcing investment of EUR 145 million at its factory in the Czech Republic to increase capacity to 500 000 air-water units by March 2026;
- Hoval investing EUR 40 million in Slovakia.

Further investments are planned by heat pump and component manufacturers in France, Italy and elsewhere. In total, Nowak (2022) estimates at least EUR 3.3 billion in planned investment to 2025. Smaller manufacturers are also increasing their capacity at very fast rates but may struggle to achieve the same economies of scale.

4 EU position and global competitiveness

4.1 Global and EU market leaders (Market share)

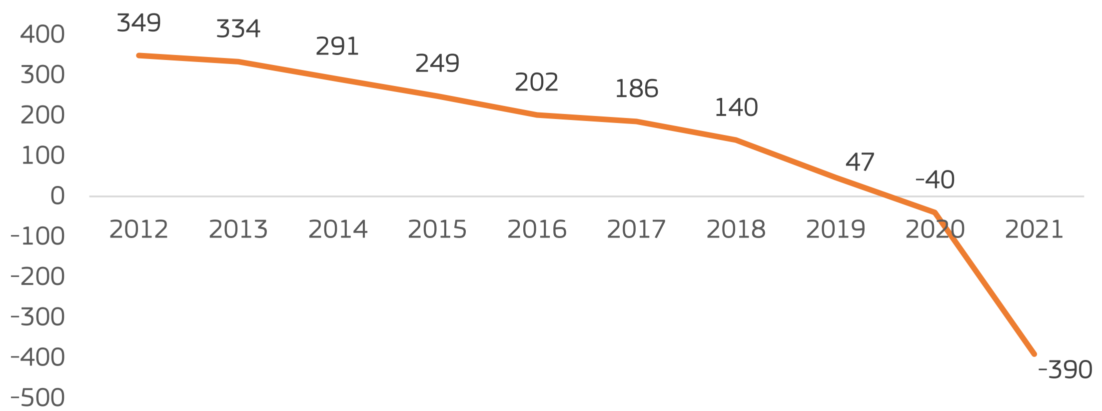
The EU is a recognised market leader in heat pumps, especially in larger heat pumps for the commercial and DHC segments. European manufacturers are technology leaders in air-water, ground-water and brine-water heat pumps (European Commission, 2021a). Within air-water heat pumps, European manufacturers lead in monoblocs while Asian manufacturers lead in split systems. The EU is a technology leader in use of natural refrigerants, in noise reduction and energy efficiency, and in sorption heat pumps.

The 'mainly heating' heat pump value chain is still mainly domestic (EurObserv'ER, 2022). The major suppliers of heat pumps in the EU are located in Europe (68%) but there is a growing share of heat pumps being imported, particular from China (see next section). Heat pump manufacturers assemble components, most of which they purchase from other companies based in Europe or further afield, mainly Asia.

4.2 Trade (Import/export) and trade balance

In 2020 the EU trade balance turned from a surplus to a deficit for the first time, mainly as a result of the growth in imports. By 2021, the deficit had grown to EUR 390 million, from a surplus of EUR 202 million five years previously (Figure 35).

Figure 35. Extra-EU trade balance, 2012-2021 (EUR millions)

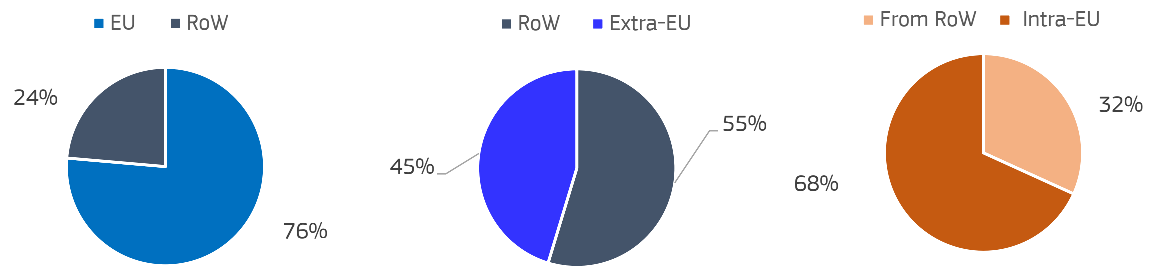


Source: JRC based on COMEXT, code 841861, mainly-heating heat pumps.

Notes: Data reported in COMEXT and UN Comtrade may present differences in reporting methodology, which for certain countries (e.g. the Netherlands) are significant. The level of inconsistency introduced depends on how active the country is in the value chain. Most charts rely on a single source to eliminate this effect. EU exports/imports are less than the sum of individual Member State imports/exports because it is calculated for the EU as a whole (i.e. subtracting intra-EU trade).

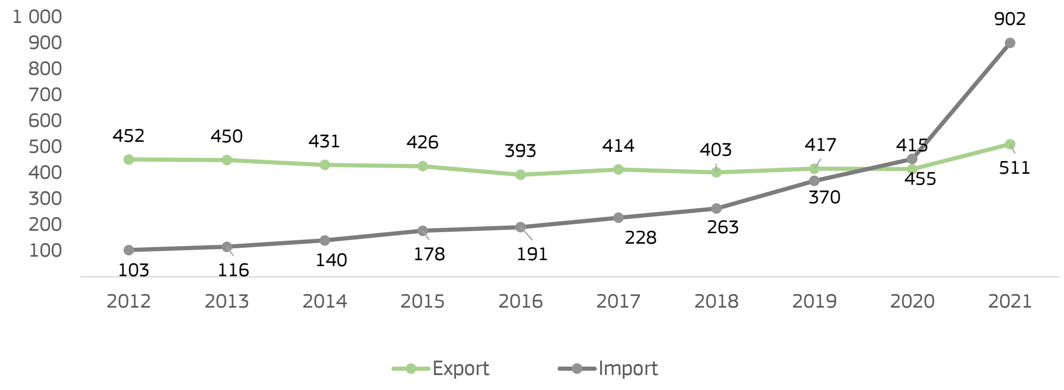
The extra-EU share of total world exports is strong at 45% (Figure 36). However, imports from outside the EU increased steadily over the past decade before more than doubling in 2021 (Figure 37).

Figure 36. EU share in world export (left), extra-EU share in world exports (middle) and EU member State imports (right), 2019-2021



Source: JRC based on UN Comtrade and COMEXT.

Figure 37. Extra-EU imports and exports, 2012-2021 (EUR millions)

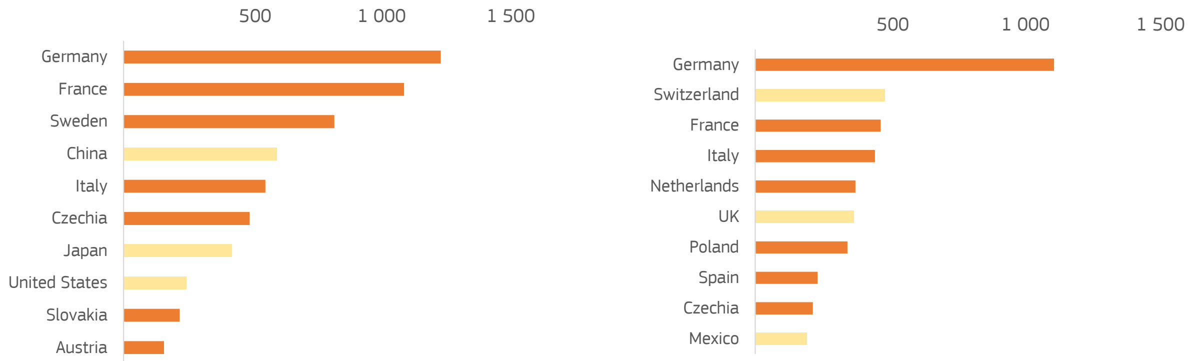


Source: JRC based on COMEXT, code 841861, mainly-heating heat pumps.

This shows the competitiveness of non-EU manufacturers in capturing EU market growth. The causes are discussed throughout this report but one explanation is that fragmented and nationally focused markets increase transaction and distribution costs, and reduce competition in both the manufacturing and the installation segments of the value chain (SWD(2021)307).

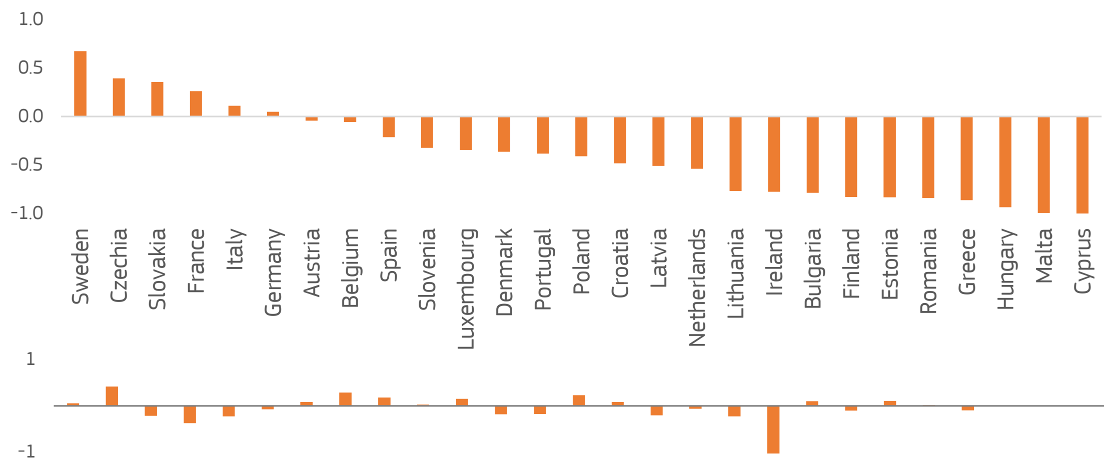
The top exporting countries over the period 2019-2021 by value were still European (Figure 38) and some Member States are managing to retain a positive trade balance (Figures 39 and 40).

Figure 38. Top ten exporting countries worldwide, 2019-2021 (EUR millions)



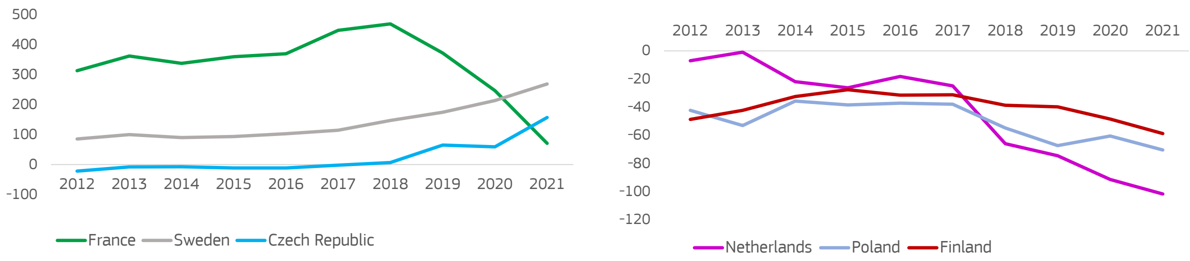
Source: JRC based on COMTRADE, code 841861.

Figure 39. Relative trade balance 2019-2021 (upper) and change from 2016-2018 (lower)



Source: JRC based on COMEXT, code 841861.

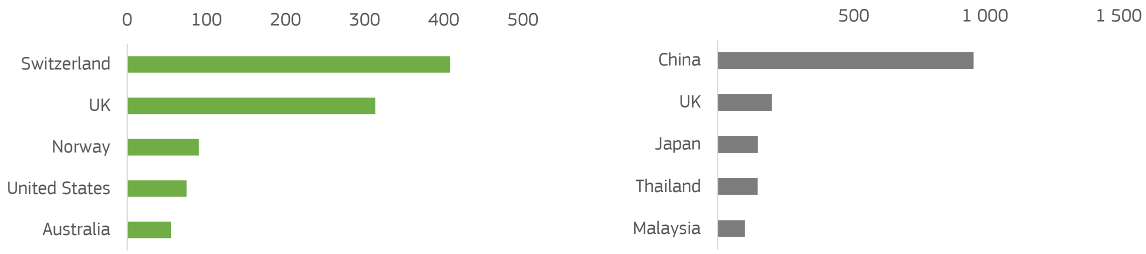
Figure 40. Top three Member States by positive (left) and negative (right) trade balance (EUR millions)



Source: JRC based on COMEXT, code 841861.

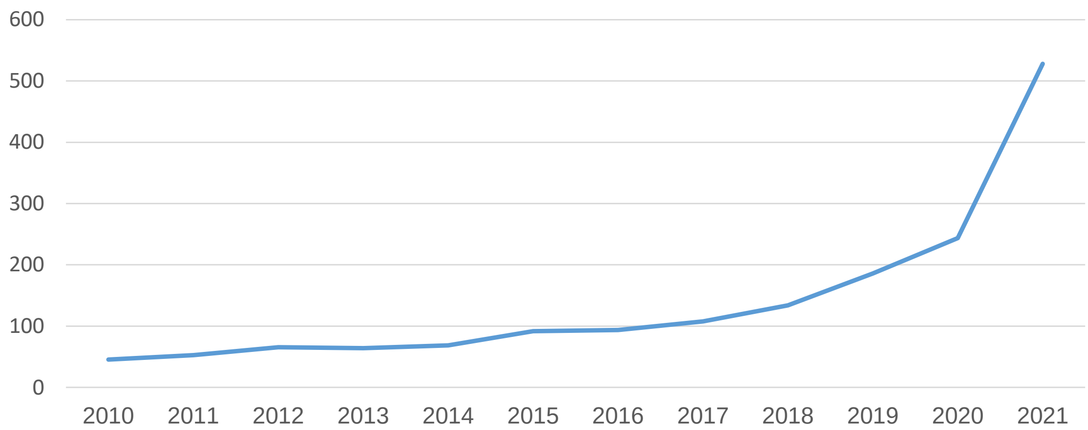
However, imports from China in particular have seen exponential growth in the last few years (Figure 41), reaching around EUR 530 million in 2021 (Figure 42). That is more than double the amount seen in 2020.

Figure 41. Top five importers from the EU (left) and exporters to the EU (right), 2019-2021 (EUR millions)



Source: JRC based on COMEXT.

Figure 42. EU imports from China, 2010-2021 (EUR millions)

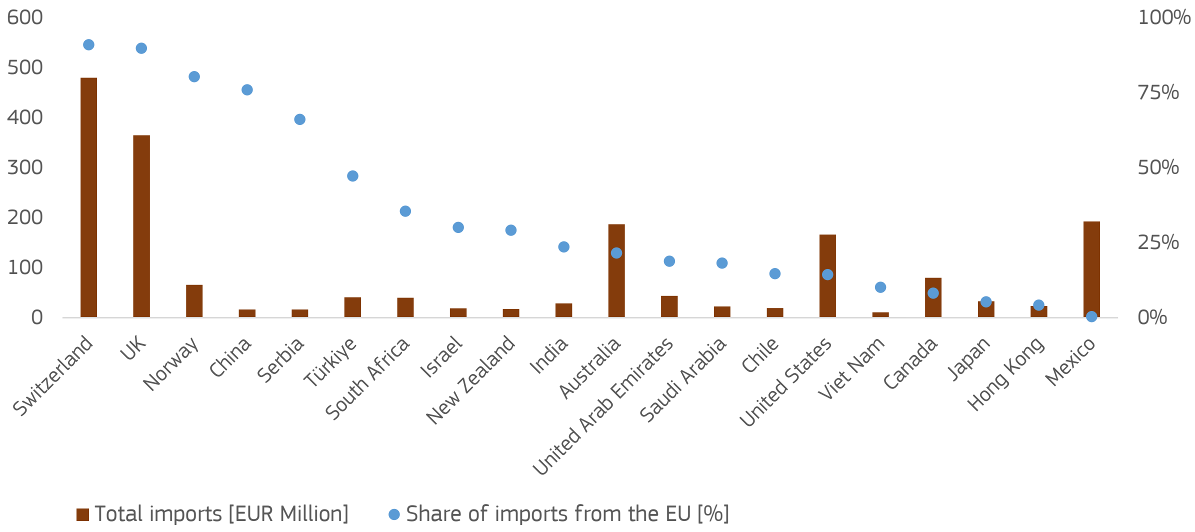


Source: JRC based on Comext.

There is a concern that big air-conditioner manufacturers who can produce equipment at low cost, especially ones based in Asia and North America, will turn their attention to capturing the EU heat pump market. This may already be happening in reversible air-air heat pumps, for which the EU is dependent on imports, and in air conditioners, for which the market in Europe is growing (Financial Times, 2022). However, other heat pump types rely to a greater extent on the expertise and recommendations of local networks of installers.

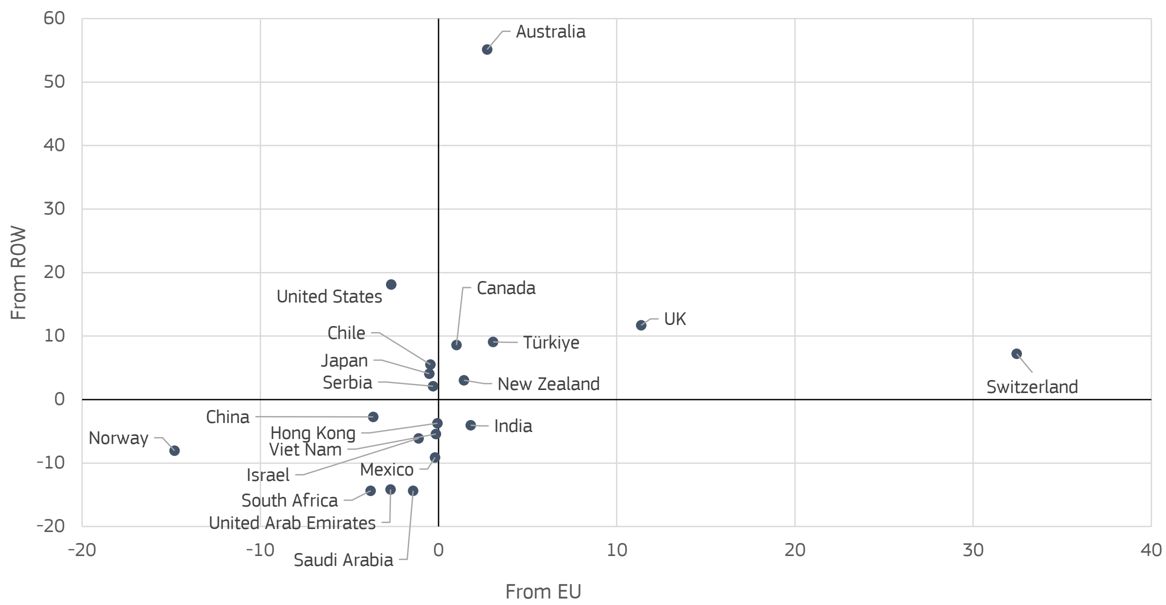
Competitors from other sectors can also be expected to enter the heat pumps market. For example, Chinese manufacturers of large solar collectors are expanding into heating more broadly, with half of them offering stand-alone heat pumps and solar heat pump systems (REN21, 2022). Both China and the United States are implementing policies to support heat pumps, for export as well as for supplying their domestic markets. Figures 43 and 44 show EU positioning in different markets.

Figure 43. Top 20 non-EU importers, 2019-2021



Source: JRC, 2022.

Figure 44. Two-year average change in imports from the EU and from the rest of the world by country (EUR millions)



Source: JRC based on UN Comtrade.

At the component level, compressors for air-air heat pumps are largely imported from China, either as part of the product or a prefabricated refrigeration cycle. This development seems to have occurred within the past decade. Most compressors for air-water and ground-source heat pumps are still sourced in Europe.

According to PRODCOM,[28] the quantity of compressors used for refrigeration equipment produced in the EU decreased by 30% between 2008 and 2020.[29] Domestic production has been replaced by imports, which grew by 44% over the same period.[30] Trade and production data suggest that the focus of EU companies shifted to higher value segments.[31]

[28] PRODCOM code 28132300: Compressors for refrigeration equipment and the corresponding HS code 841430.
[29] Production value in monetary terms dropped by 16% over the same period.
[30] Production value in monetary terms dropped by 38% over the same period.
[31] EU export quantity decreased by more than 30%, while export value increased by 8%. Based on trade and production data from PRODCOM, EU unit prices in 2008 were about the same as import prices, whereas in 2020 EU unit prices were 30% higher than those of imported units.

4.3 Resource efficiency and dependence in relation to EU competitiveness

In terms of resource efficiency, heat pumps are manufactured from similar raw materials to the boilers they replace, and hydronic heat pump systems have comparable plumbing systems to boilers as well. Many components are also not specific to heat pumps, and sourcing is closely linked to related sectors such as boiler, air conditioning, and refrigeration manufacturing.

Table 3. Material needs for replacing gas boilers with air-source eat pumps

	Air source heat pump (kg)	**Gas boiler (kg)**	**Difference (kg)**	**Total difference (tonnes)**
Polyester oil	2.7		2.7	54 000
R-134A	4.9		4.9	98 000
Rockwool		8	-8	-160 000
Low-alloyed steel	32	115	-83	-1 660 000
Reinforcing steel	120		120	2 400 000
Stainless steel	5	5	0	0
Copper	36.6	3	33.6	672 000
Aluminium		7.5	-7.5	-150 000
Brass		0.1	-0.1	-2 000
PVC	1.6		1.6	32 000
HDPE	0.5	0.9	-0.4	-8 000
Elastomers	16		16	320 000
Total	219.3	139.5		

Source: JRC based on Sevindik et al., 2021.

Heat pumps do not have specific materials vulnerabilities (Artelys and Trinomics, 2021) but are vulnerable to volatility in metals prices and the supply of semiconductors. More widespread integration of smart controls may exacerbate the latter vulnerability. Permanent magnets are a potential risk because there are few short-term solutions to a disruption to imports from China.

In the longer term, recycling and substitution can be effective strategies. For example, to address volatility in the supply of semiconductors, manufacturers could revert to simpler designs, such as alternating current fans. This is an area of increased focus for the European Commission and is the subject of ongoing work by the JRC, in particular with respect to critical raw materials.

5 Conclusions

Sales of heat pumps were on track to exceed the REPowerEU target in 2021 and there are signs that this momentum has been maintained during 2022. However, maintaining an annual growth of 20% will be challenging. There are a number of potential bottlenecks and barriers in the short term, such as a shortage of semiconductors and a lack of qualified installers and experts.

Installers of other heating technologies can be trained but this needs to be made a priority to ensure a smooth transition. A Pact for Skills would help. In the longer term, greater focus on education and training in all related technical fields is needed, and it could also be worth examining why such labour shortages are more acute in some Member States and whether there are barriers to mobility that could be alleviated.

Heat pumps have few specific materials vulnerabilities. They are however vulnerable to general volatility in metals prices and semiconductors supply. Heat pump deployment could benefit from consideration as an important product category in responding to those issues.

The electricity grid is expected to be able to cope with up to 50 million heat pumps under the usual network investment plans. Moreover, heat pump systems should be designed so as to contribute to grid stability.

The heat pumps sector is well positioned to benefit from increasing deployment. Imports from China have however increased in recent years. Both China and the United States are implementing policy to support heat pump deployment and their heat pump manufacturing, domestic including for export. Long-term policy ambition and supportive regulations are important in order to promote investment in EU manufacturing too.

Incentives to manufacturers to invest in new production lines, or convert existing production lines from gas boilers to heat pumps, would increase production capacity faster. An analysis of potential barriers to trade in the internal market (e.g. national building codes or certification requirements) could also help improve the competitiveness of EU manufacturers by exploiting economies of scale; the EU heat pumps sector is still somewhat fragmented and national laws and requirements differ.

In the short term, some stakeholders see F-gas phasedown as a limiting factor. However, in the medium term, the transition to greater use of natural refrigerants can be an opportunity for the sector to differentiate itself with respect to non-EU competitors and to reduce dependence on non-EU suppliers.

The EU is the world leader in innovative heat pump technologies and related patenting activity. It is important to boost collaborative RD&I funding to continue to drive down costs and enable new business models based on products that are easier to install and operate. By maintaining its technology leadership, EU manufacturing will be well placed to adapt to, and benefit from, market developments such as Ecodesign requirements and the shift to natural refrigerants.

Finally, tracking exercises such as this one rely on publicly available and transparent data. Member States should continue to invest in the timeliness, completeness and quality of statistics on topics such as market trends and RD&I spending, both via their national statistics offices and Eurostat.

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List of abbreviations and definitions

AC/DC	Alternating current / Direct current
APPLiA	Home Appliance Europe
AT	Austria
BE	Belgium
BG	Bulgaria
CETO	Clean Energy Technology Observatory
CINDECS	European Climate-Neutral industry Competitiveness Scoreboard
CO_2	carbon dioxide
CY	Cyprus
CZ	Czech Republic
DC	Direct current
DE	Germany
DHC	district heating and cooling
DK	Denmark
EE	Estonia
EEA	European Environment Agency
EHI	European Heating Industry
EHPA	European Heat Pump Association
EL	Greece
EPBD	Energy Performance of Buildings Directive
EPEE	European Partnership for Energy and the Environment
EPO	European Patents Office
ES	Spain
EU	European Union
F-Gases	fluorinated gases
FEC	final energy consumption
FI	Finland
FR	France
GW	gigawatt
GWh	gigawatt-hour
GWP	Global Warming Potential
HR	Croatia
IE	Ireland
IT	Italy
JRC	Joint Research Centre
kW	kilowatt
kWh	kilowatt-hour
LCA	Life-Cycle Assessment

LT	Lithuania
LV	Latvia
m^2	square metre
m^3	cubic metre
MW	Megawatt
MWh	megawatt-hour
NL	Netherlands
PFAS	Per- and polyfluoroalkyl substances
PL	Poland
PRODCOM	Eurostat database of the production of manufactured goods
PT	Portugal
PVC	Polyvinylchloride
RD&I	research, development and innovation
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU Regulation)
SE	Sweden
SET-Plan	Strategic Energy Technology Plan
SI	Slovenia
SK	Slovakia
SME	Small and medium-sized enterprise
TIM	JRC text-mining tool
TRL	Technology Readiness Level
UK	United Kingdom
WEEE	Waste from electrical and electronic equipment

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