



Accelerating the EU's shift towards natural refrigerant domestic heat pumps



About this study

This project is an effort undertaken by ATMosphere (shecco) and funded by the European Climate Foundation (ECF). The European Environmental Bureau (EEB) and the Environmental Coalition on Standards (ECOS) conceptualised the study and participated as managing organisations.

ABOUT ATMOSPHERE

ATMosphere is a global and independent market accelerator with a mission to clean up cooling. Its Intelligence Department collaborates with industry stakeholders such as policymakers, NGOs and academia to contribute knowledge for the acceleration of clean cooling solutions in the global RACHP.

ABOUT ECOS

The [Environmental Coalition on Standards](#) is an international NGO with a network of members and experts advocating for environmentally friendly technical standards, policies, and laws.

ABOUT EEB

The [European Environmental Bureau](#) is the largest network of environmental citizens' organisations in Europe. It currently consists of over 170 member organisations in more than 35 countries (all EU Member States plus some accession and neighbouring countries), including a growing number of European networks, representing some 30 million individual members and supporters.

ABOUT ECF

The [European Climate Foundation](#) is an EU-based NGO dedicated to managing philanthropic resources to respond to the global climate crisis by creating a net-zero greenhouse gas emissions society.

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Executive Summary

The aim of this qualitative research study was to highlight the potential impact of the existing HFC refrigerant phase down on the domestic heat pump sector in the European Union (EU), while also considering how an even stricter phase down, that is in line with EU climate neutrality objectives, can accelerate the shift from fossil-fuel-based heating systems to clean heat pumps.

Heat pumps are expected to contribute significantly to the decarbonisation of heating supplies in European households. **However, not all heat pumps are the same.** Despite suitable natural refrigerant-based alternative technologies being readily available on the European market, **domestic heat pump systems often rely on highly polluting synthetic substances like fluorinated greenhouse gases (f-gases) to transfer heat.** These gases are of concern due to their **high global warming potential** that can contribute considerably to the greenhouse effect and the worsening of climate change.

As EU policy tightens around the use of f-gases, **the path to changing to natural refrigerant alternatives in heat pumps becomes even more obvious for ensuring future-proof, sustainable installations.** On 5 April 2022, the European Commission proposed a new amended version of the EU F-Gas Regulation targeting climate polluting f-gases. The proposal **strengthens the HFCs phase-down schedule** (ca. 98% reduction on the allowed quantity by 2048 based on the level in 2015) and **introduces prohibitions targeting new heat pumps and air conditioners.**

Following the release of the proposal, trade bodies representing the interest of some of the industry's incumbents have cautioned against intrusive policy action in this realm, revamping old concerns related to climate objectives, energy efficiency and safety. They believe that a tighter phase down of HFCs and the proposed bans will risk undermining climate objectives by slowing down the deployment of heat pumps across the continent. This stance is stressed even more against the need to phase out Russia's imports of fossil fuels, in light of the country's invasion of Ukraine.

However, the European Commission explanatory memorandum, released with the proposal, is clear in this regard: **bans are introduced because alternatives are technologically ready and are available on the market.** Even considering the urgency of the deployment of the technology to reduce reliance on Russia's imports, the European Commission reports that a sufficient buffer is considered in place with the preferred HFC phase-down option.

The European Commission's increased ambition on this regulation is supported by the findings of this research. With specific reference to heat pumps, **systems running with naturally occurring working fluids** (such as hydrocarbons, carbon dioxide and/or ammonia) that do not deplete the ozone layer and have negligible global warming potential, **are a market reality today and can substitute those relying on f-gases. These systems are efficient and more climate aligned.** Interviewed companies operating with natural refrigerant heat pumps are **ready to scale up their production and meet an increasing demand triggered by decarbonisation policies.**

Our sample group interviews with heat pump manufacturers in Europe point to a **growing presence of original equipment manufacturers (OEMs) across Europe with systems running with natural refrigerants in their portfolio.** These companies are varied in size and their commitments to phasing down fluorinated gases. Companies that have already significantly detached themselves from fluorinated working fluids **reported confidence in their ability to quickly scale up production and reconvert old technology production lines pushed by the right policy framework.** Not only are decarbonisation policy efforts seen as paving the way for the deployment of heat pumps, **but also regulations affecting fluorinated greenhouse gases are held in high regard for determining the direction of travel.**

Analyses have proven that **fluorinated refrigerants are commonly more expensive than alternatives,** as they are subject to restrictions at the global and EU levels. According to interviewees, HFC

prices have increased and are expected to rise in the coming years. On the contrary, the **prices of natural alternatives have proven stable and low**; no interviewees have experienced price hikes with these heat carriers, and none have experienced any issues with availability on the EU market.

In terms of system costs, we have gathered from our research that the **price difference between HFC-based equipment lines and natural refrigerant alternatives is generally below 20%**, a difference that is mainly due to the need to handle flammable substances along the production line.

Costs related to setting up a production line vary according to the targeted capacity – the construction of a new facility is reported as being the most burdensome cost when this decision is taken at management level. **However, CAPEX costs are not seen as particularly demanding for setting up the line of production for products dedicated to natural refrigerants**, and companies' situations are very diverse in this regard. Interviewees estimate an increase ranging between 2 and 10% when setting up production lines for natural refrigerants heat pumps, mainly based on hydrocarbons.

In any case, both the equipment price and the production line costs' percentage difference seem relatively small compared to the **estimated percentage surcharge for HFCs** in tandem with the phase-down schedule proposed by the European Commission, **increasing 335% from 2025 to 2050**.

First-mover OEMs that have set up production lines based on natural refrigerants are experiencing up to **triple-digit growth in this market segment and high demand**. Driven by existing policy measures, some of these stakeholders **expect up to 90% of the heat pumps they produce to be based on natural refrigerants in a few years' time**.

The interviewees cited **policy as the main driver for innovation** (or lack thereof as the main obstacle to innovation) and gave information that points to the need to **raise awareness of the problem posed by fluorinated gases and to support the demand for natural fluids**, hence creating economies of scale that would eventually lower the small premium currently associated with producing these climate-aligned systems.

The critical nature of policy intervention is clear from the scale-up success story of natural alternatives in commercial refrigeration. **Carbon-dioxide-based installations in commercial refrigeration have grown from just 140 in 2008 to more than 38,000 in 2021**, pushed by the introduction of prohibitions in the sector and a general phase down of HFCs, despite conservative concerns that these provisions would have hindered the sector due to some considering natural alternatives as "unreliable", "unsafe" and "energy inefficient". These are the same messages currently being conveyed regarding heat pumps. For the commercial refrigeration sector, all these points have been debunked.

The insights shared in this report support the stance that **there should be no detachment between the timelines related to the decarbonisation of the heating sector and the wind-down of fluorinated substances used as refrigerants**.

List of Abbreviations

Air-to-Water (ATW)
Capital Expenditure (CAPEX)
Carbon Border Adjustment Mechanism (CBAM)
Chlorofluorocarbons (CFCs)
Coefficient Of Performance (COP)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Domestic Hot Water (DHW)
Emission Trading Scheme (ETS)
Energy Performance of Buildings Directive (EPBD)
Energy System Integration (ESI)
Environmental Coalition on Standards (ECOS)
Environmental Investigation Agency (EIA)
European Commission (EC)
European Environment Agency (EEA)
European Environmental Bureau (EEB)
European Heat Pumps Association (EHPA)
European Partnership for Energy and the Environment (EPEE)
European Union (EU)
Fluorinated gases (f-gases)
Global Warming Potential (GWP)
Greenhouse Gas (GHG)
Gulf Cooperation Council (GCC)
Heat Pump (HP)
Hydrochlorofluorocarbons (HCFCs)
Hydrofluorocarbons (HFCs)
Hydrofluoroolefins (HFOs)
Institute of International Refrigeration (IIR)
Intergovernmental Panel on Climate Change (IPCC)
International Electrotechnical Commission (IEC)

International Energy Agency (IEA)
International Energy Agency Heat Pumping Technology Collaboration Programme (IEA HPT TCP)
International Geosphere-Biosphere Programme (IGBP)
International Human Dimensions Programme on Global Environmental Change (IHDB)
Joint Research Centre (JRC)
Kilowatt (kW)
Kilowatt-hour (kWh)
Life Cycle Climate Performance (LCCP)
Million tonnes (Mt)
Million tonnes of oil equivalent (Mtoe)
Non-Governmental Organisations (NGO)
Original Equipment Manufacturers (OEMs)
Paris Agreement Compatible (PAC)
Particulate matters with a diameter that are generally 10 micrometres and smaller (PM10)
Per- and Polyfluoroalkyl Substances (PFASs)
Perfluorinated Chemicals (PFC)
Photovoltaics (PV)
Placing On Market (POM)
Organisation for Economic Co-operation and Development (OECD)
Original Equipment Manufacturers (OEMs)
Refrigeration, Airconditioning, and Heat Pump (RACHP)
Seasonal Coefficient Of Performance (SCOP)
Small and medium-sized enterprises (SMEs)
Staff Working Document (SWD)
Sustainable Development Scenario (SDS)
Terawatt/hour (TWh)
United Nations Environment Programme (UNEP)
United Nations Framework Convention on Climate Change (UNFCCC)

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1

Objective and Scope

The objective of this research is to highlight the potential impact of the existing HFC phase down on the domestic heat pump sector, while also considering how an even stricter phase down that is in line with EU climate neutrality objectives can accelerate the shift from fossil-fuel-based heating systems to clean heat pumps.

It will consider the applicable drivers and barriers impacting stakeholders in the EU's residential natural refrigerant heat pump sector, framed within the context of decarbonising Europe's heating sector and transitioning towards electrification. Regulations in terms of bans on fluorinated gases are considered a main driver to this aim, and focus is therefore placed specifically on the EU F-Gas Regulation.

It is our goal to demonstrate, by means of an in-depth qualitative study, how the climate objectives set by the European Commission can be achieved. We also aim to address the heat pump industry's fear of

losing the market to Chinese competitors, who are believed to be ahead in natural-refrigerant-based heat pump production, by trying to gauge this risk.

The scope of this research covers heat pumps for space heating and domestic- and sanitary-water heating applications. Combined units are included. It excludes, however, air-to-air and hybrid systems and reversible models.

The study focuses on heat pumps with a rated capacity of <12 kW as this segment is assumed to be relevant for the residential sector. It is also the cut-off point for heat pumps covered under Commission Regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regards to Ecodesign requirements for air conditioners and comfort fans.

2

Methodology

ATMOsphere undertook an EU-targeted research effort to investigate both the current and future demand for key natural refrigeration technologies in the EU region (27 countries).

To fully understand and analyse these markets, the ATMOsphere team used a combination of qualitative, quantitative, primary, and secondary research methods. Then, via the expansive global ATMOsphere network, EU-based experts tested and expanded upon the concepts.

The following methods were used:

2.1 DESK-BASED RESEARCH

An in-depth study of secondary sources was carried out to capture and synthesise the current state of the EU's domestic heating markets, policy trends and the available natural-refrigerant-based options.

In preparing this in-depth presentation of the current and future market, ATMOsphere leveraged a combination of external reports and academic, industry and media publications, together with its own articles and reports, to build an understanding of the market and where it is heading and to inform the questions for the subsequent manufacturers' interviews.

ATMOsphere is powered by a database of natural refrigerant and clean cooling information, diligently collected over the years by its analysts and journalists.

2.2 DATA COLLECTION DRIVE

The in-depth desk research was followed and enriched by extensive outreach to relevant original equipment manufacturers and industry stakeholders for primary research. A series of one-on-one interviews was conducted to gather information on additional qualitative and quantitative results. A total of 54 heat pump OEMs were contacted via the initial email outreach and briefed on the objective of this project. They were invited to take part in a conversation with ATMOsphere experts via a structured interview.

Stakeholders were given the option of participating via email or a live video interview. The list of questions was shared with interviewees at least three days before the time of the call.

In cases where no answers were received from relevant representatives of stakeholders of the EU heat pump industry, an email was sent to the official company's email address as found on the main webpage or to the contact listed in the EHPA website's member section.

Where possible, existing relationships established within the ATMOSphere Network and project partners were leveraged as a measure to obtain sensitive information. However, the willingness to participate in the study seems to correlate with the direct interest of the OEM in accelerating the natural refrigerant market, with greater difficulty arising around getting information from companies with a vested interest in not moving the market toward natural refrigerants.

The outreach and the analysis were conducted in the first quarter of 2022, using the video conferencing tool Zoom to interview seven manufacturers based in the following European countries: Belgium, Denmark, Germany, the Netherlands, Poland, Spain and Sweden. Additional interview responses were collected via email.

The interviews investigated four macro-topics: (1) costs (particularly differences in production costs using natural refrigerant or HFCs and costs to increase the production), (2) current capacity (focusing on the last two years of production), (3) scale-up plans and predictions and (4) energy efficiency. The results and key findings are presented later in the report.

2.3 MAIN CHALLENGES

One main obstacle this analysis encountered was the lack of harmonisation of information among sources referring to “heat pumps”. Heat pumps include various types of different technologies, and oftentimes stakeholders refer to the macro-term rather than its subcategories when providing data or estimates. To address this issue, the report has been aligned with the data and categories as collected by the EU’s industry body (EHPA) to strive for the highest possible consistency. When other sources have been used, the report will address potential inconsistencies.

The main and most reliable studies on heat pumps often use information relating to different European countries aggregating them in different ways. For geopolitical changes or other usefulness, some reports refer to EU21, others to EU27, or EU28 (if the UK is included).¹

Despite widespread outreach to the contact list of relevant OEMs, unfortunately, there was great difficulty in obtaining responses from the market; there was hesitancy to share sensitive information and current production numbers. Even some of those interviewees willing to contribute to the study did not disclose data on production or price, citing privacy concerns. However, where possible, percentages of rough estimates were given. In our ongoing research activities spanning several projects, a clear trend of mistrust has arisen. Companies no longer freely share their information and have become extremely competitive and often secretive about especially quantitative data.

The difficulty in organising interviews with heat pump OEMs was further exacerbated by the current momentum around this technology as a means to decouple heating demand from fossil fuels in the context of Russia’s invasion of Ukraine and the subsequent pressure on energy policies; we fear that companies are less prone to share data in such a sensitive period as they want to maintain a competitive edge. Moreover, we have found that the post-COVID-19 economic growth in this sector has reduced the capacity available within companies to take on additional tasks such as data sharing, preferring instead to focus on the day-to-day running of operations. This is particularly the case in small-to-medium companies, where there are no dedicated departments in charge of handling such collaborations on EU-relevant affairs.

3

Background and Policy Context

Heat pump technology is considered key to reaching decarbonisation objectives in the heating and cooling sector, and it has recently received targeted political support in Europe, North America, and China.²

Heat pumps have the potential to support climate-related policies in countries targeting the heating and cooling macro-economic sectors by allowing the efficient transition from fossil-fuel heating and cooling appliances to electricity-powered ones, assuming an increasing share of electricity generated from renewable sources.

Data and estimates from civil society and industry stakeholders firmly support this transition in an apparent communion of interest on this issue.

For instance, the Environmental Coalition on Standards (ECOS) calculated that removing fossil fuel boilers below 400 kW from the market by 2025 would bring about 30 Mt of annual CO₂ savings by 2030, 90 Mt by 2040 and 110 Mt by 2050 compared

to a business-as-usual scenario seeing a continuous market for boilers.³ The value of this transition is also appreciated by industry stakeholders. The transition away from fossil fuel boilers in favour of heat pumps can reduce final energy consumption in buildings by more than 66% and reduce heating-related CO₂ emissions by at least 60%, according to a letter signed by a coalition of major energy groups.⁴

Transitioning away from fossil-fuelled heating appliances not only contributes to mitigating climate change but also improves the air quality of European countries. In fact, a recent report by the European Environment Agency (EEA) identifies domestic heating as a main driver of excess PM₁₀ levels in the air of southern European countries.⁵ Seven civil society organisations have recently released a manifesto on the decarbonisation of heating and cooling, connecting both the issues of the climate and public health to the way Europeans heat their homes.⁶

3.1 HEAT PUMP TECHNOLOGY EXPLAINED

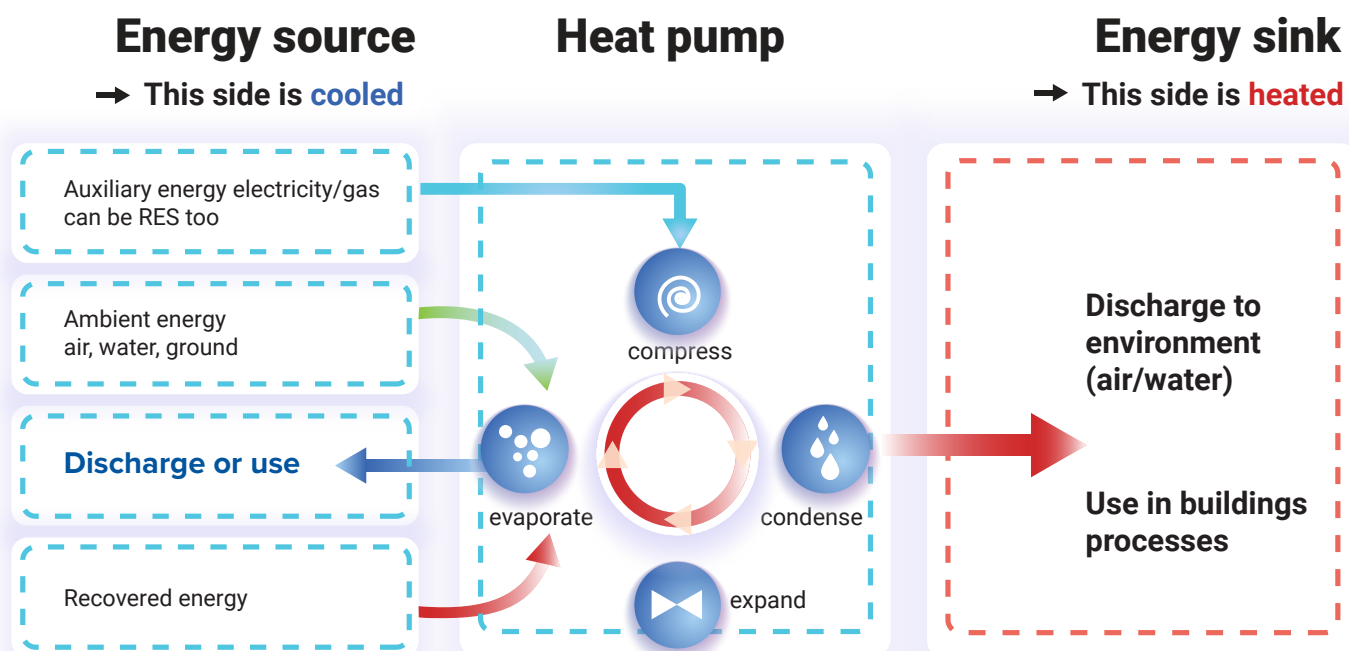
Heat pumps allow for the transfer of heat from a source to a sink, where it is consumed by end-users. Heat pumps transfer heat powered by electricity, and they generally require different amounts of energy depending on the temperature difference between the heat source and the heat sink. All heat pumps function similarly and have generally the same primary components: heat exchangers, an evaporator, a condenser, a compressor, expansion valves and a refrigerant or working fluid.⁷

Sources of renewable energy that heat pumps can tap into are ambient air, underground heat, industrial waste heat, water basins (such as lakes and rivers) and other available sources. Heating and cooling effects in buildings are then distributed where needed, normally through hydronic systems or air, using fan coils or ducted ventilation systems.

The source from where heat pumps take the heat/cool distinguishes them in the first instance; air-, water- and ground-source heat pumps are in fact the three macro categories defined within this technology. Air source equipment uses outside ambient temperature in the form of air or exhaust air from different processes for heating, cooling, and preparing hot water. These systems can be installed entirely outside or inside the building. Water source heat pumps use energy stored in groundwater, surface water or seawater. Finally, ground source heat pumps use energy stored in the ground.⁸

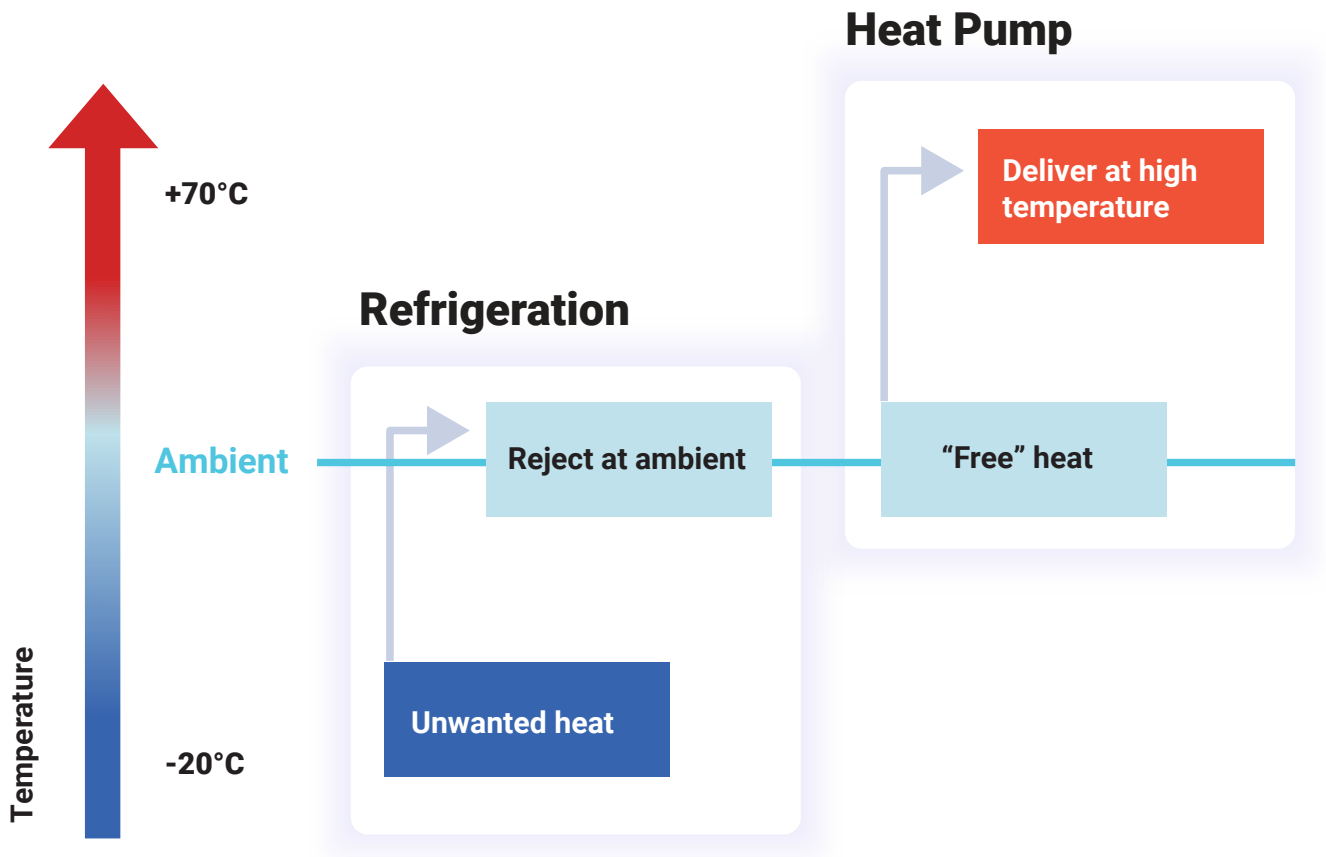
As with other refrigeration, air-conditioning and heat pumps systems (RACHP) based on vapour compression technology, heat pumps require a heat carrier, i.e., a refrigerant (also called working fluid), to move heat from an unwanted place (heat source)

Figure 1 - Visualisation of an example of a heat pump system



Source: EHPA

Figure 2 - Visual representation of the heat pump technology delivering heating



Source: Gluckman Consulting, 2015, FACT SHEET 11: Heat Pumps (heating only)

to a place where it is used (heat sink) through the refrigerants' phase change. Refrigerants can therefore be considered the blood to the body of heat pumping systems.

Heat pumps move refrigerants through the system with an electricity-powered compressor. The working phases of a heat pump follow the vapour compression system cycle: a compressor pumps the refrigerant along the circuit of the system, and an evaporator and condenser deliver heat/cool.

Heat pumps can play a substantial part in the decarbonisation of the heating and cooling sectors and are a cross-sectorial technology; they can be deployed in domestic, commercial and industrial contexts. The technology can provide both space and hot-water heating, which is why the technology is deemed important for the decarbonisation of the European building stock by featuring heavily in multiple climate-related policy efforts in Europe.

3.2 DECARBONISATION: POLICIES DRIVING HEAT PUMP UPTAKE

Decarbonisation is a broad policy objective. The EU is in the process of unfolding the EU Green Deal, an encompassing strategy that regards heat pumps as a fundamental cog in the decarbonised system of the future.

From an energy perspective, the EU Green Deal aims to reduce the amount of fossil-fuel-based energy generated and support the uptake of renewable energy and electrification across the continent.

Energy-specific directives such as Energy Efficiency, Renewable Energy, Energy Taxation and the extension of the Emission Trading Scheme (ETS) are considered instrumental for driving increased uptake of heat pumps. As of 2019, in fact, European electricity generation was still heavily relying on fossil fuels, meaning that heat pumps are likely to be powered by fossil fuels in 43.6% of the cases.⁹ In addition, electricity is more costly on average across Europe than other energy sources (average electricity price is €0.23 per kWh versus lower estimates for natural gas),¹⁰ adding an additional layer of complexity to energy decarbonisation policies.

Given these underlying facts, it is logical to strive for equipment that ensures the lowest possible consumption of electricity. The long-standing EU Ecodesign Directive and Energy Labelling Regulation are also key, ensuring that only energy-efficient appliances are sold to EU customers. Oftentimes, detractors of systems running with alternatives to fluorinated gases cite low energy performance as a pretext to hinder their development. However, recent findings from the International Energy Agency Heat Pumping Technology Collaboration Programme (IEA HPT CP) prove the contrary, listing systems charged with natural alternatives among the top performers.¹¹

In addition, with the EU's Energy Performance of Buildings Directive (EPBD), considerations are moved to a broader system level, i.e., buildings. Both a technology shift and renovation efforts will be needed to establish energy-efficient buildings as the norm. European buildings account for 40% of European energy consumption and are therefore considered the single largest energy consumer in the bloc. Energy for heating, cooling, and domestic hot water covers 80% of citizens' energy consumption, and the same buildings we live in are also responsible for 36% of energy-related greenhouse gas emissions.

Europe's goal is to improve the performance of 35 million houses by 2030 to achieve the goal of decarbonisation.¹² This dossier could grant heat pumps a definitive place in European households: the current proposal suggests a phase-out roadmap for fossil fuels in heating and cooling by 2040 at the latest and instructs that all new public buildings must have zero emissions as of 2027, and all new buildings as of 2030.¹³

The Sustainable Finance Taxonomy is another pillar of EU efforts to decarbonise the economy, directing private capital towards technologies and investments pivotal to climate mitigation and adaptation efforts. The drafting expert group working on this file lists heat pumps as an eligible technology on the conditions that it uses a refrigerant with a GWP below 675 and complies with the relevant provisions of the Ecodesign Directive and Energy Labelling Regulation.¹⁴ In a staff working document on the taxonomy screening criteria, the Commission holds the same line by stating that "heat pumps with a GWP of less than or equal to 675 represent the direction of travel for the market. Reinforcing that level through the Taxonomy criteria would serve as an incentive for the market uptake of the technology."¹⁵

The components of heat pumps can also be considered. According to the Commission report on the competitiveness of the EU's heat pump supply chain, four out of five raw materials (stainless steel, copper, aluminium, gold, and zinc) require imports from outside the EU, with aluminium and zinc making up more than 60% of the supply.¹⁶ Aluminium is currently one of the five initial goods that are included in the proposal of the European Union's Carbon Border Adjustment Mechanism (CBAM), indicating that its import has a higher carbon footprint than using identical goods produced in the EU.¹⁷ As shown below, heat pumps with fluorinated refrigerants are also likely to run with imported fluorinated greenhouse gases, topping with transport emissions the already high energy intensity required to manufacture these chemicals.¹⁸ From a life cycle climate performance aspect,¹⁹ the IEA HPT CP recently found that heat pumps charged with natural refrigerants score among the best in terms of climate friendliness.²⁰ The competitiveness report from the Commission concludes that heat pumps currently lack circular economy considera-

tions, suggesting that a full life cycle analysis should be developed for this equipment.

Refrigerant-related policies are also relevant, especially the EU F-Gas Regulation (Regulation (EU) No 517/2014) and the upcoming Restriction Intention at the EU level on per- and polyfluoroalkyl substances (PFASs).

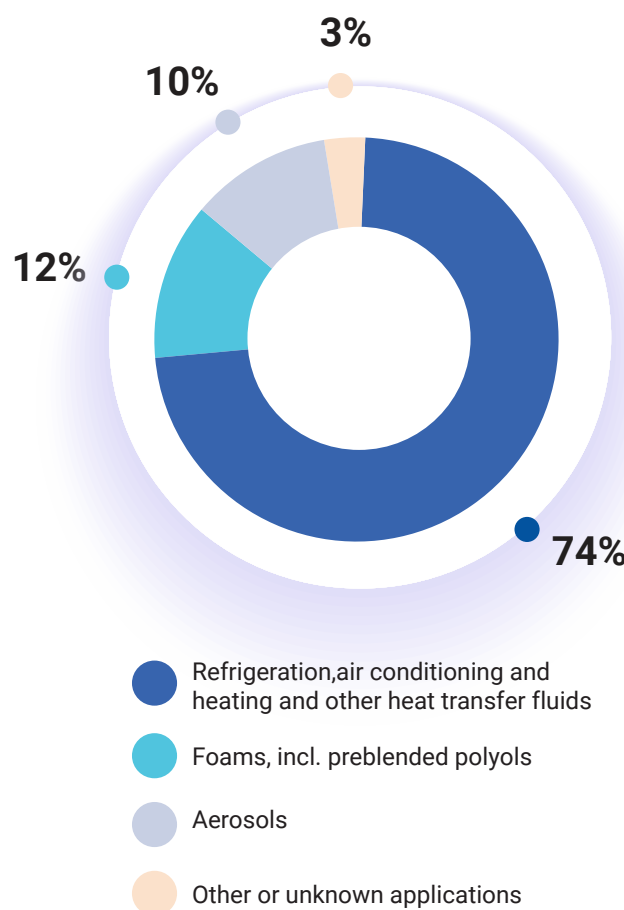
The EU F-Gas Regulation is a long-standing piece of legislation that dates to 2006. Along with the Regulation on substances that deplete the ozone layer (Regulation (EC) No 1005/2009, also proposed in its amended form),²¹ it has shaped the working environment of the RACHP industry.

According to the latest data from the EEA, f-gases are still predominantly used in RACHP sectors. These sectors consumed around 74% of all f-gases supplied to the European market in 2020.²² It is therefore evident that measures targeting f-gases will influence the development of heat pumps in Europe.

The F-Gas Regulation is a core piece of legislation in response to the climate crisis as f-gases often have considerable GWP that numbers in the thousands; f-gases alone amounted to 2.5% of EU GHG emissions in 2018.²³ These substances might leak into the environment at different phases of their life cycle, such as during their manufacturing, transportation, and storage, as well as from equipment during operation, servicing and at the end of life.

The European Restriction Intention workstream on PFASs is a unicum at the international level due to its scope; at the international level other regulatory bodies are starting to tackle the issue, though their approaches often differ. Regarding Europe, which aligns its working scope to the one recommended by the Organisation for Economic Cooperation and Development (OECD), one of the likely outcomes of this proposal is a prohibition on polymeric fluorinated substances in different products, which is likely to include many fluorinated refrigerants. This policy option was among those listed in the stakeholders' consultation that ran in the second half of 2021. The submission of the Intention by the five countries working on this dossier is expected by January 2023.²⁴

Figure 3 - 2020 EU supply by intended applications (% of tonnes)



Source: Figure 4.5 of the annex to the "Report on Fluorinated Greenhouse Gases 2021" by the European Environment Agency.

3.3 REVISED EU F-GAS REGULATION POLICY PROPOSALS

On 5 April 2022, the European Commission released its proposal for the revised EU F-Gas Regulation.²⁵

The Commission proposal “Annex V - Placing on the market prohibitions referred to in Article 11(1)” listed the following bans of relevance for this study:

- as of 1 January 2025, single split systems containing less than 3 kg of fluorinated greenhouse gases listed in Annex I, that contain, or whose functioning relies upon, fluorinated greenhouse gases listed in Annex I with a GWP of 750 or more;²⁶
- as of 1 January 2027, split systems of a rated capacity of up to and including 12 kW containing, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except when required to meet safety standards; and
- split systems of a rated capacity of more than 12 kW containing, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 750 or more, except when required to meet safety standards.

These bans were initially suggested by the consortium of consultancies entrusted to support the revision of this dossier.²⁷ The consortium comprises Öko-Recherche, Öko-Institut and Ricardo. Among the main findings is a suggestion that the European Commission could be confident in introducing these bans since equipment running with lower GWP gases are already present on the market.

For instance, alternatives often use natural refrigerants such as propane (GWP 100 years, GWP 20 years < 1) for space heating and domestic water heater.²⁸ Carbon dioxide (GWP 100 years, GWP 20 years = 1) is also used for heating water for domestic purposes,²⁹ and it is being proposed as an efficient refrigerant for heat pumps for older homes' hydronic systems for space heating by at least two providers.³⁰

3.4 REACTIONS TO THE PROPOSED UPDATED EU F-GAS REGULATION

Following the release of the European Commission's proposal, stakeholders from RACHP industries have released their positions.

Some conservative trade bodies representing part of the RACHP industry argued that the suggested bans could slow down the decarbonisation of the heating sector by obstructing the transition to heat pumps. Regarding the analysis provided by the consultants which informed the presented proposal, EHPA, EPEE and AREA pointed at a lack of granularity of data in the model adopted, unrealistic assumptions and disregard for the heat pump sector in terms of its contribution to climate targets.³¹ The same comments have been advanced after the release of the proposal by the same bodies, with a greater focus on bans affecting heat pumps.³² However, as a first consideration, Honeywell and Daikin (their French and Belgian entities, respectively) are listed as members of EHPA and EPEE; both chemical giants are manufacturers of fluorinated refrigerants and likely advocate no (or lenient) GWP bans on heat pumps, as well as slight HFC-phase-down reductions. Both companies, as members of the associations, are likely to steer their policy stance on this matter from within.

Besides arguing that limitations *per se* would affect the deployment of this technology, the position of these industry stakeholders assumes that the largest part of EU production is currently transitioning from the highly warming fluorinated gases to mid-GWP fluorinated refrigerants such as R32 (GWP 100 year = 677, now 771 in the Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), with a GWP 20 year of 2,530).³³ Even if true, such an effort could be pointless, as the same producers of

this fluorinated gas have publicly stated that this is a transitory solution.³⁴ Not only producers of this refrigerant, but also policymakers around the world have shown their scepticism towards embracing this new heat carrier.³⁵

Contrarily, progressive Europe-based companies from the Clean Cooling Coalition have welcomed the European Commission's proposal; a steeper phase down and the introduction of bans are a step in the right direction – which, however, could be greatly improved.³⁶ Operating mainly with refrigerants not subject to this regulation, these companies welcome more ambition across all measures proposed.

NGOs have criticised the proposal for lagging behind market evolution, asking for a more progressive position.³⁷ EEB welcomes the increased climate ambition, specifically the improved HFC phase down, where the final availability would correspond to 2% rather than 20%.³⁸ The EEB, however, believes that more ambition is needed to keep the EU in the lead in this sector, with more restrictive bans as a missing bit of the presented proposal. This view is shared by the EIA, which would also have preferred more ambitious bans,³⁹ as well as ECOS, which also argued for swifter provision against sulphur hexafluoride, SF₆, the most potent fluorinated greenhouse gas known.⁴⁰

Finally, authoritative studies from within the industry, civil society and European countries' environmental agencies call for caution in the deployment of new synthetic fluorinated substances.⁴¹ These substances are named hydrofluoroolefins, or HFOs, and even if they have low GWP values, allegedly solving the problem of global warming that HFCs typically have, they show worrisome indicators lacking future-proofness.

4

Current Refrigerant Landscape

Hydrofluorocarbons (HFCs) are synthetic chemical substances produced by chemical companies around the world that are used mainly in RACHP equipment as refrigerants. They were developed as a solution to CFCs and HCFCs, substances that, once emitted, deplete the ozone layer and trap heat in the atmosphere, contributing to the greenhouse effect.

4.1 HFC PHASE DOWN AND PHASE-OUT MEASURES

Even though they worked to solve the ozone-depletion issue that CFCs and HCFCs posed, HFCs have long been recognised as potent greenhouse gases, and in 2016, the Kigali Amendment to the Montreal Protocol restricted their production and consumption at the global level to limit their effects as climate-altering substances.⁴²

The use and production of HFCs permitted on the European Union market are also subject to restrictions under the EU F-Gas Regulation. Use in the market is regulated under the provision of Placing on Market (POM). Because it is a regulation, this piece of legislation applies uniformly across the European Union's countries without national differences. Restrictions on the use of fluorinated substances are deployed essentially in two ways:

either through the reduction of allowable quantities on the bloc's market of HFCs expressed in CO₂e at the EU level (i.e., phase down) or through bans of determined f-gases above a certain GWP value in specific equipment (i.e., phase out).⁴³

With the need to decouple Russian gas imports from entering European heating systems, the EHPA has release a set of suggested measures that would support the uptake of heat pumps across the bloc in the context of the EU landmark programme REPowerEU.⁴⁴

Among such measures, the trade body call for "giving priority to the supply of refrigerants to heat pumps, avoid bans and reduced availability of fluorinated gases that would limit heat pump deployment" in the context of the EU F-Gas Regulation.

If such measures would be translated into law, they could risk hijacking compliance with the Kigali Amendment to the Montreal Protocol. This fear is the same reasoning that led to the inclusion of metered dose inhalers (MDIs) into the HFC phase-down schedule in the current proposal, due to their rising emissions. This use is currently excluded from the phase down, but, as this exclusion is an incoherent provision with this internationally binding agreement, this could lead to possible incompliance due to unilateral action if emission from this use contribute to jeopardise the agreed reduction targets.

On the other hand, from a chemical perspective, recent studies warn that the planet's limit of novel entities has been surpassed, meaning that humanity has released into the environment a greater quantity of non-natural substances than Earth's dynamics can cope with. Novel entities, as these synthetic substances are labelled, are chemicals created entirely by humans. They include substances that can persist in the environment for a very long time, and their effects are potentially irreversible.⁴⁵ Fluorinated refrigerants such as CFCs, HCFCs, HFCs and the next generation of unsaturated HFCs – HFOs – can be considered novel entities, as they are synthetic substances and affect Earth's dynamics.⁴⁶

4.2 MORE AMBITIOUS MEASURES FROM EU F-GAS PROPOSAL

On 5 April 2022, the European Commission presented the revision of this legislation to finetune it to the ambitious climate goals enshrined in the EU's body of legislation with the European Union Climate Law.⁴⁷ Most notably, this regulation legally requires the bloc's greenhouse gas emissions to

be reduced to 55% of 1990's levels by 2030 (i.e., emitting only 2.08 Gt of GHG) and that climate neutrality be reached by 2050.⁴⁸

The EU F-Gas Regulation is a piece of the overarching strategy of the European Union Green Deal, a set of measures that are meant to allow the bloc to achieve the objective of climate neutrality.

To reach this goal, a more stringent phase-down schedule is being proposed. Both the European Commission and the European Parliament have, on multiple occasions in the past, shown their willingness to push for more ambition.⁴⁹ In a Motion for Resolution ahead of the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) the European Parliament expressed its desire to speed up the phase out of HFCs in Europe.

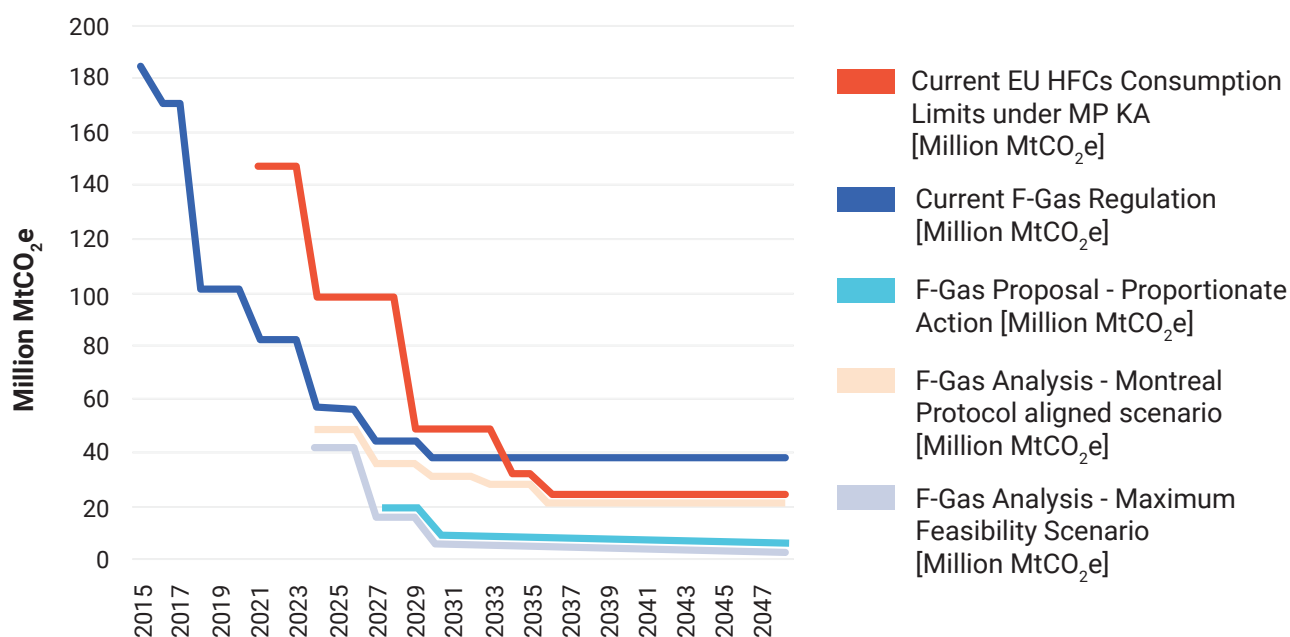
The European Commission proposal breaks with allowed percentages and introduces fixed limits of allowed HFCs to be placed on the market for the coming years up to 2048 in terms of CO₂e. Setting the baseline value as the 2015 reference value of 176,700,479 CO₂e, the Commission proposes the following maximum quantities:

Table 1 - Allowed quantity of HFCs on the EU market according to the presented proposal – proportionate action (2024-2048)

Years	Maximum Quantity in tonnes of CO ₂ e
2024–2026	41,701,077
2027–2029	17,688,360
2030–2032	9,132,097
2033–2035	8,445,713
2036–2038	6,782,265
2039–2041	6,136,732
2042–2044	5,491,199
2045–2047	4,845,666
2048 onwards	4,200,133

The current proposal envisages a steeper reduction in terms of an HFC phase down, reaching a ca. 2% allowed quantity as of 2048.

Figure 4 - Visual comparison of the HFC phase down scenarios in the proposal, the current schedule and the Kigali schedule



Source: European Commission EU F-Gas Proposal, own extrapolation

Phase down baseline for current regulation assumed constant for ease of representation

In addition, in alignment with the provisions of the Kigali Amendment to the Montreal Protocol, the European Commission also introduces production rights for HFCs producers, expressed in tonnes of

CO₂e. Setting the baseline at the annual average production of the years 2011–2013, for each producer the limits are proposed as follows:

Table 2 - Allowed production percentage

Period	Allowed production percentage
From 1 January 2024 to 31 December 2028	60%
From 1 January 2029 to 31 December 2033	30%
From 1 January 2034 to 31 December 2035	20%
From 1 January 2036 onwards	15%

4.3 HFCs MARKET PROJECTIONS

Following the economic law of supply and demand, higher ambition in the European-Economic-Area-wide phase-down scheme of HFCs would almost automatically trigger higher prices of these substances.

A 2020 report on the availability of HFCs on the Union market by the European Commission confirms the strict factual connection between measures targeting f-gases and their prices. High GWP HFCs prices spiked in 2017, reaching peaks of six to 13 times higher than their 2014 baseline price as reported by EU-based companies.⁵⁰ This can be connected to the steep reduction that was introduced during the period, i.e., a reduction of 30 percentage points from 93% to 63% of the allowed quotas on the EU market. Following this trend, the expected additional reduction of 18 percentage points as of 2021 is also likely to exert upwards pressure on HFC prices. As the reduction of allowable quantities come into force in terms of CO₂e, HFCs with a higher GWP will find it harder to access the market. Prices of these high GWP refrigerants were also climbing as of the final quarter of 2021.⁵¹

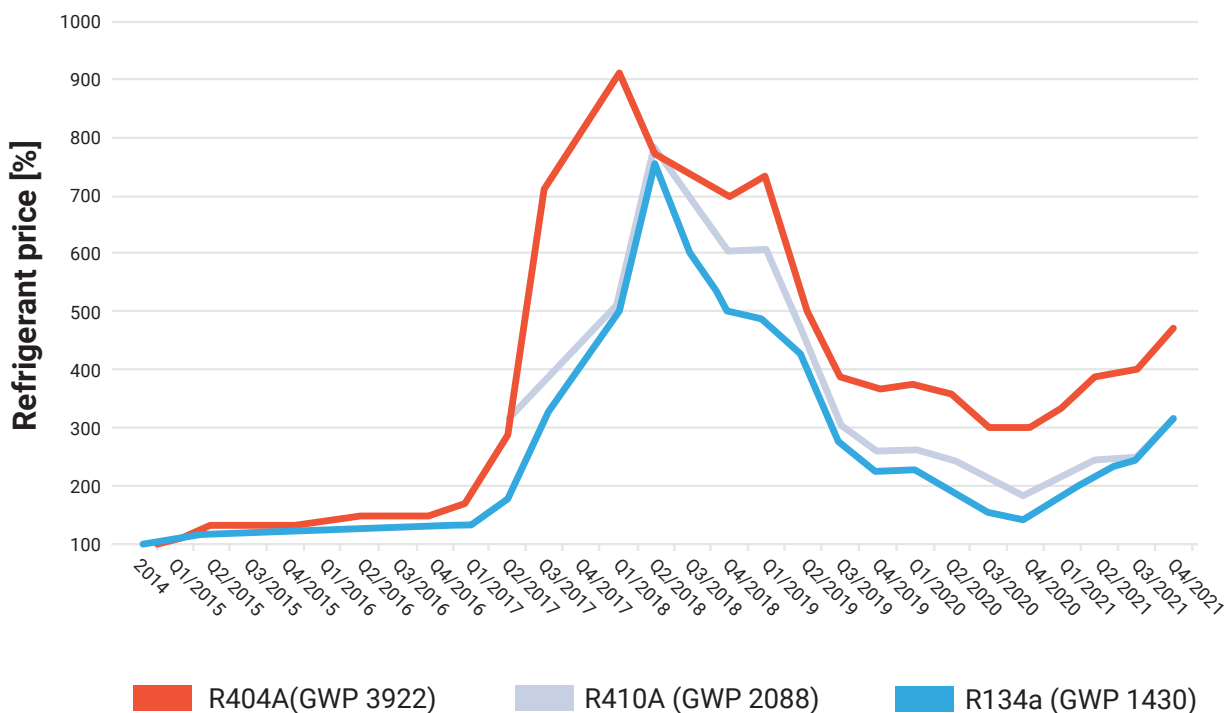
Moreover, quotas will need to be used to purchase a reduced bucket of available substances, and the higher the GWP of a substance, the higher the cost.

F-gases have constantly been a closely monitored cost for industry stakeholders. A snapshot of the price of some popular HFCs/HFOs was released by Öko Recherche during the summer of 2020 noting the high value – on average around €90/kg – of HFO-1234yf, even though it appeared to decline.

Some interviewed stakeholders link this decline in price to illegal imports of these substances that circumvent the regulatory system. This problem was also raised during the interviews conducted for this study: stakeholders expect fluorinated gas prices to rise, but they believe prices will not rise to the intended extent due to illegal trade exerting downwards pressure.

In the context of the external study compiled to support the revision of the current EU F-Gas Regulation, the consultants reported some estimated surcharges on HFC price levels according

Figure 5 - Evolution in price of some widely used fluorinated gases in the European market (gas producers)

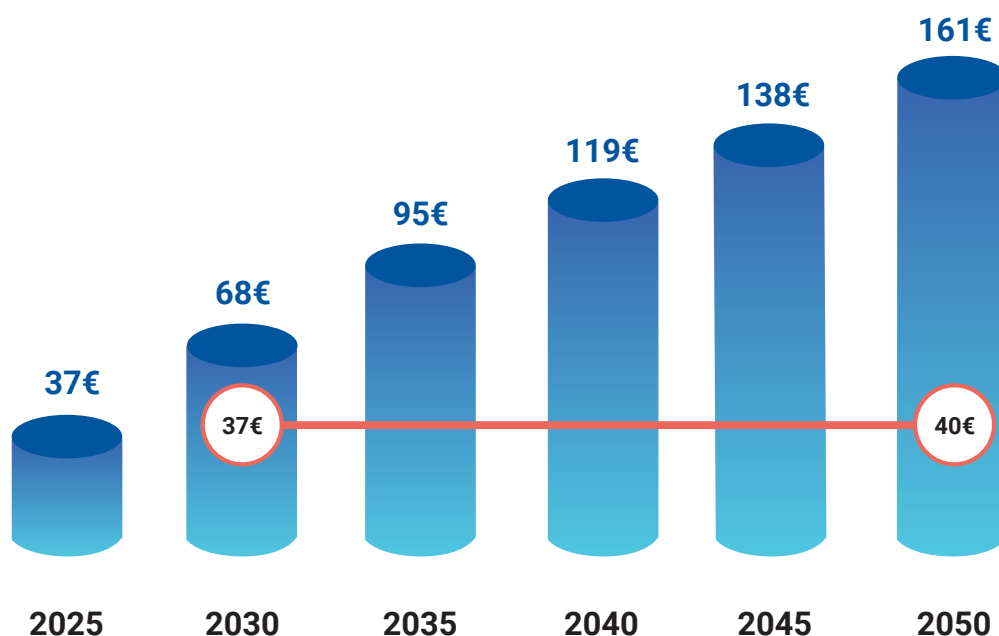


Source: Öko Recherche analysis

to the assumptions elaborated in four different scenarios of possible policy action. In the baseline scenario, i.e., no amendments to the current schedule, these surcharges are predicted to reach €37₂₀₁₉/tCO₂e in 2030 and €40₂₀₁₉/tCO₂e in 2050. With the HFC schedule proposed by the European Commission, part of the package of interventions labelled “Proportionate Action”, surcharges are estimated to reach €37, €68, €95, €119, €138 and €161₂₀₁₉/tCO₂e in 2025, 2030, 2035, 2040, 2045 and 2050, respectively.⁵²

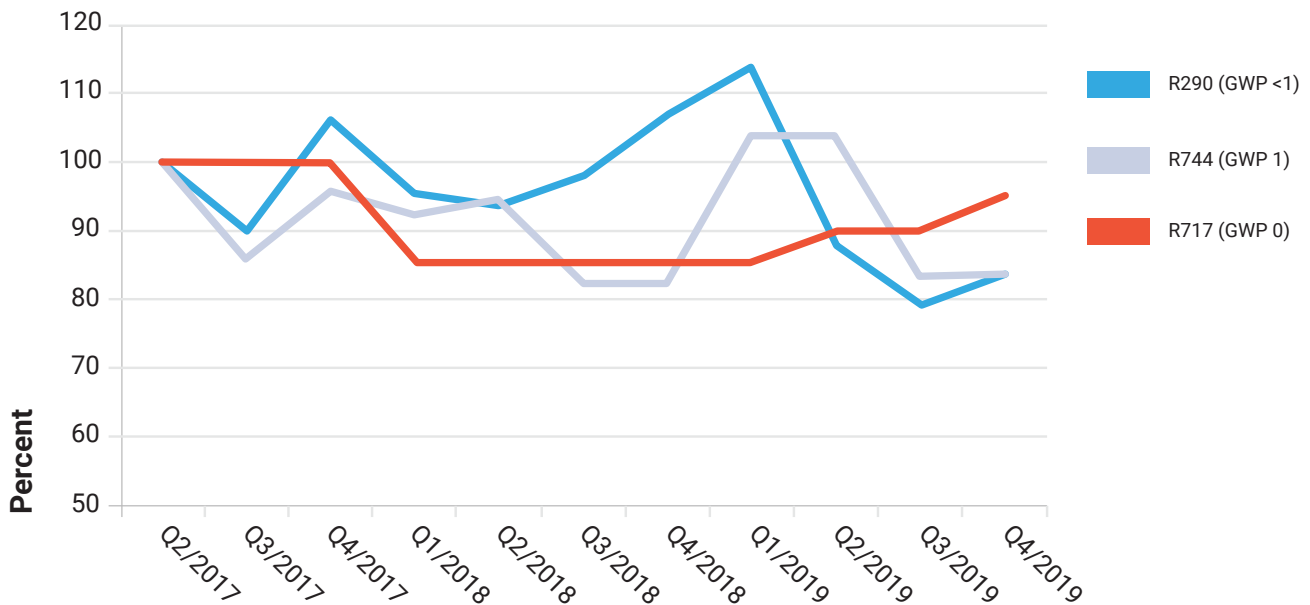
The cost of alternatives, however, such as natural refrigerants, has not experienced any upward trend in recent years, according to an analysis performed by Öko-Recherche for the period from 2017 to 2019. These heat carriers have in fact maintained stable prices, indexed to the baseline price level of 2017; carbon dioxide, propane and ammonia, three of the main alternatives to HFCs, have even fallen below the baseline price, as 2019 data show. The study specifies that the market for these fluids shows no sign of constraints, and their costs have proven to be below the baseline price.⁵³ This point was reinforced during the interviews conducted for this study; interviewees reported a 100% value difference for fluorinated gases in respect of natural gas prices, especially hydrocarbons.

Figure 6 - Estimated HFCs price surcharges for ‘baseline’ and ‘proportionate action’ scenarios (2025, 2030, 2035, 2040, 2045 and 2050)



Source: Own elaboration

Figure 7 - Development of average purchase prices of natural refrigerants at service company level [price index, Q2/2017= 100% (baseline)]



Source: Öko-Recherche analysis

Finally, the report depicts the issue of illegal imports of HFCs into the European Single Market. This is related to the customs evasion of f-gases coming from non-EU countries, with the likely effect of reducing the price and hijacking the efforts undertaken through the regulation's provision.⁵⁴

The July 2021 report "Europe's most chilling crime: The illegal trade in HFC refrigerant gases" by the NGO Environmental Investigation Agency (EIA) finds that the illegal trade of HFCs is driven by high profits and a low risk of detection or serious consequences, dumping their prices in the EU market. For instance, the EIA reported that, according to industry stakeholders, the tax-inclusive price of HFC-134a in Spain was found to be approximately €40/kg; however, the same NGO identified 18 vendors on eBay and the Spanish trading platform Milanuncios offering the same substance for below €20/kg.

The issue of illegal trade is of utmost relevance for the proper functioning of provisions aimed at controlling fluorinated gas emissions. The lack of harmonised measures across European countries to tackle illegal trade has been identified as one of the main outstanding issues that the current version of the EU F-Gas Regulation fails to address.⁵⁵ Interviewed stakeholders, in fact, expect a rise in fluorinated gases' prices, yet they believe the illegal trade will somehow calm this upwards trend, watering down the effectiveness of the restriction measures.

The EIA's report also sought to shine a light on the routes through which illegal HFCs are imported into the EU, reporting that Chinese f-gases are flooding into the continent mainly through Turkey and Romania.⁵⁶

4.4 CHINA AND HFCs

The market for fluorinated substances is international with multiple chemical companies involved.

Companies based in China are among the main global producers of HFCs. China consumes only half of the HFCs that it produces, implying that a large amount is exported or stockpiled.⁵⁷

The EEA's 2021 report on fluorinated substances underlines that EU production of fluorinated substances, HFCs included, has constantly decreased since 2007 – a likely effect of the bloc's regulation on these substances. From almost 60,000 tonnes produced in 2007, European producers manufactured less than 20,000 tonnes in 2020, equalling roughly 40 Mt CO₂e.

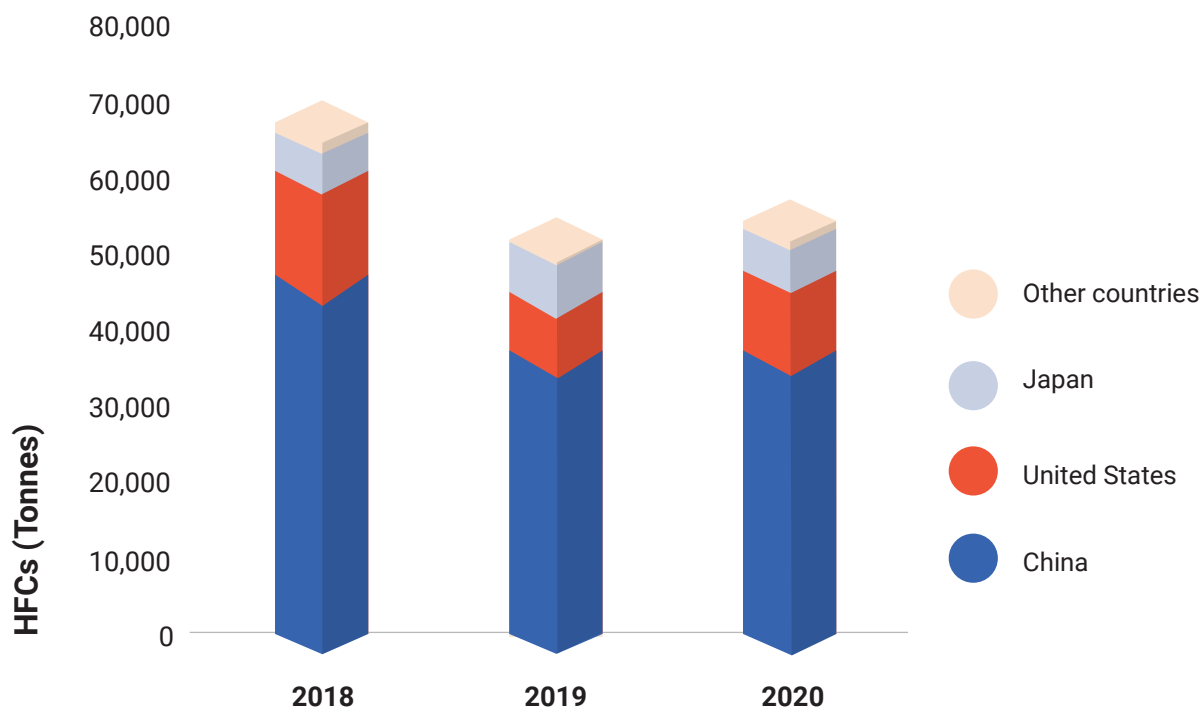
This number can be compared to the number of fluorinated substances imported into the European Union: around 80,000 tonnes of f-gases, including more than 60,000 tonnes of HFCs, were imported in

2020, with China being the first exporter, injecting almost 40,000 tonnes of HFCs into the EU market.

China, therefore, supplied around 66% of the HFCs imported into the bloc's market, with the US, the second largest supplier, accounting for only approximately 10,000 tonnes.⁵⁸ These data, in comparison with the decrease in European production, show that Chinese suppliers already provide the majority of HFCs to the bloc.

With this data in mind, 66% of the HFC-32 used in Europe is likely to be imported from China. Some EU-based stakeholders believe that by introducing stricter bans on appliances working with high GWP fluorinated gases, such as heat pumps, the competitiveness of EU companies compared with others based outside the bloc could be compromised. This reasoning assumes that the latter has a competitive advantage in the use of natural alternatives. This logic is often applied to Chinese and Indian companies.

Figure 8 - Imports of HFCs into the European Union



Source: Figure 3.5 of the annex to the "Report on Fluorinated Greenhouse Gases 2021" by the European Environment Agency.

As shown in Figure 8 above, this stance is shaky and should be compared with the factual situation of the EU industry of fluorinated substances, as reported in the EEA study. Data from the same report shows a clear negative trade balance when it comes to HFCs between the EU and China. The EU exported about 20 tonnes of HFCs in 2020, and China was not among the top nine destinations.⁵⁹

More doubt is cast on the above stance by the conclusions of a study presented at the 12th Institute of International Refrigeration (IIR) Gustav Lorentzen Conference on Natural Refrigerants in 2016 that defines the Chinese industry operating with natural refrigerants as being “at an early stage of commercialization”.⁶⁰ However, a recent report by the European Commission on the availability of fluorinated alternatives in air-conditioning appliances finds that Chinese and Indian manufacturers provide solutions in the air-to-air air-conditioning reversible segment, which according to industry terminology can be counted as air-to-air heat pumps.⁶¹

HFC-32 is considered by some stakeholders to be safe from Asian competitors. However, researchers dedicated to the industry reported high levels of HFC-32 production in China since at least 2013.⁶²

A recently published report by the US International Trade Commission on Difluoromethane (HFC-32) identifies China as a global heavyweight in HFC-32 production. The investigation focused on addressing import injuries to US stakeholders and found that “the industry in the United States is materially injured because of imports of difluoromethane (HFC-32) from China”.⁶³

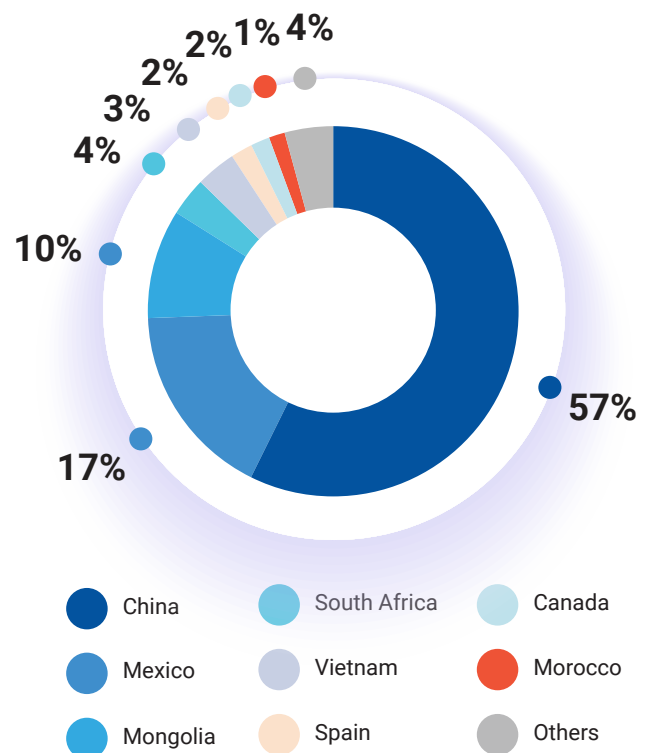
A parallel situation is taking place in India as well, where Chinese exports of HFC-32 have been found to create “material injury” to the domestic industry.⁶⁴ These analyses support the finding that China is a global market producer of HFC-32.

Finally, some consideration should be given to the market conditions of fluorspar, a critical component of all fluorinated substances, that are bound to raise the prices of HFCs.

Fluorspar is the dominant source of fluorine, which is a key chemical compound in the manufacturing of a wide range of industrial and domestic products, including hydrofluoric acids (HF, or hydrogen

fluoride), a precursor of multiple fluorochemicals used as refrigerants. Over the past decades, China has secured 57% of the global production of this key substance.

Figure 9 - Global Producers of Fluorspar



Source: Fluorspar Mineral Minute

Fluorspar was included in the list of critical raw materials by the European Union Joint Research Centre (JRC) in 2020,⁶⁵ and industrial stakeholders report that the fluorspar market is suffering from global environmental awareness movements, which are likely to force the shutdown of multiple operations worldwide and delay beginning operations. These phenomena, combined with China’s becoming an increasing importer of fluorspar to satisfy its growing internal chemical demand, are likely to influence the prices of fluorinated substances upwards, adding further costs to industry stakeholders relying on HFCs.⁶⁶ Recent increases in HFC prices reported by gas producers coincidentally list the lack of raw material as a cause of the upwards trend.⁶⁷

5

Heat Pump Demand

In this section, the deployment of heat pumps in buildings to supply space and water heating will be linked to electrification progress in the heating and cooling sectors.

5.1 GLOBAL LEVEL

According to the IEA, at the global level, the share of coal, oil and natural gas boilers in global heating equipment sales fell beneath 50% in 2020, and the sales of alternatives technologies, such as heat pumps and solar hot water systems, made up more than 20% of overall installations in 2020.⁶⁸

The IEA also noted that the energy efficiency of heating had risen due to the penetration of heat pumps in global markets, as they generally perform three to four times more efficiently than fossil-fuelled appliances: in fact, heat pumps can deliver heat with three times less energy input than boilers.

Almost 200 million heat pumps in heating mode were operational in 2020, and the agency estimates that this technology still meets no more than 7% of global heating needs in buildings.⁶⁹

Six hundred million heat pumps need to provide 20% of global heat demand for buildings by 2030 to be on track to meet the goal of net-zero emissions by 2050, the agency reports.⁷⁰ Many buildings that exist today will still stand in 2050 or beyond and need to be retrofitted to achieve zero emissions by then at the latest. To reach the emissions and energy intensity goals, 2.5–3.5% of buildings need to be retrofitted every year.⁷¹

The IEA report, “Net Zero by 2050”, also brings attention to the total amount of heat pumps that would be required at the global level to meet these targets. In 2020, the amount is estimated to be 180 million units, which should be scaled up to 600 by 2030 and 1,800 by 2050. These numbers would translate into heat pumps covering respectively 7%, 20% and 55% of the energy demand for heating with electricity.

Table 3 - Global heat pump stock according to the International Energy Agency

	2020	2030	2050
Stock – million units	180	600	1,800
Percentage of heating covered by electricity – heat pumps	7%	20%	55%

Regarding the installed stock, the agency reports that China is leading the way with 57.7 million units installed as of 2020.

However, the agency does not provide detailed data regarding the share of deployment of the different kinds of heat pumps.

5.2 EUROPEAN LEVEL

The IEA reports that the European heat pump market is steadily growing, counting 21.8 million units in 2020, and a quick expansion is underway, with around 1.8 million households purchasing a heat pump the same year, a 7.5% growth relative to the 2019 level.

Germany replaced Spain as one of the top three markets thanks to 38,000 new sales, the agency reports. Estonia, Finland, Norway and Sweden, however, show the highest penetration rates, with more than 25 heat pumps sold per 1,000 households each year.⁷²

In essence, the electrification of the building stock will determine the final amount of heat pumps that will be deployed globally and in Europe. Multiple policies are targeting this transition at different levels.

According to the EHPA, to achieve the European Commission's targets of electrification of 40% of residential buildings and 60% of commercial ones by 2030,⁷³ Europe should quadruple its heat pump stock in a decade.⁷⁴ The EHPA reports that this would mean having 50 million heat pumps deployed in 2030, without considering those used in the industrial sector.⁷⁵

According to data from the same trade body, and assuming a life expectancy of approximately 20 years, the European stock of heat pumps was counted as 14.86 million units in EU21.⁷⁶ This data would require the deployment of more than 30 million heat pumps in a decade.

Table 4 - EHPA estimates (reference is assumed for the EU21)

	Current stock – Residential – 2021	2030 (quadruplication of current stock)	Delta time – 9 years
Number of heat pumps	14.8 million units	60 million units (residential + commercial = 50; industrial = 10)	Around 35 million units in less than a decade for the residential and commercial sector

The trade body estimates that continuously larger and growing sales will result in lower production costs, as economies of scale are materialising at component and product levels.

The trade body stated in the press release following the communication from the European Commission “Powering a climate-neutral economy: an EU strategy for energy system integration” that more ambitious action is possible, as the European industry, as well as the electricity grid, is ready to meet these electrification targets.⁷⁷

To the same end, EU-based NGOs jointly drafted a letter with 13 other companies active in the heating sector to call for more ambitious policies aimed at phasing out fossil-fuelled gas boilers in Europe, a critical step also recommended by the IEA in its landmark report, in favour of the deployment of heat pumps.⁷⁸

In March 2022, due to Russia’s invasion of Ukraine and the need to decouple European electricity generation and heating system from fossil fuels – especially the amount imported from Russia – the European Commission published REPowerEU. The plan states that the Commission will push for the electrification of heating systems and intends to deploy an additional 10 million heat pumps over the next five years. This effort will come on top of the objective to install 30 million heat pumps by 2030 as reported in the Fit for 55 package.⁷⁹

These estimates do not provide complete details on the kind of technology, yet they are strictly referring to residential buildings according to the Commission’s publication. With these two policy initiatives, the European Commission is planning a deployment of at least 40 million heat pumps by 2030.

Following the release of the European Commission’s communication REPowerEU in May 2022,⁸⁰ EHPA released new computations raising to 20 million and 60 million the number of total heat pumps needed by respectively 2026 and 2030 to meet the Commission targets. Namely, EHPA details that the plan proposes to double annual sales, and add 10 million hydronic heat pumps in the next five years.⁸¹

These estimates tend to collide with the long-term projections provided in the report “Progress on competitiveness of clean energy technologies 4 & 5 - Solar PV and Heat pumps”, where the Commission attempts to estimate the heat pumps stock deployed in the heating sector only, with a focus on the residential sector.

Taking into consideration three relevant scenarios for electrification of the heating demand in residential buildings and the global growth of residential heat pumps,⁸² approximately 40 million heat pumps are estimated to be needed for 2030 and approximately 60 million in 2050.⁸³ This Commission paper considers EU21 countries, aligning itself with estimates provided by the EHPA.⁸⁴

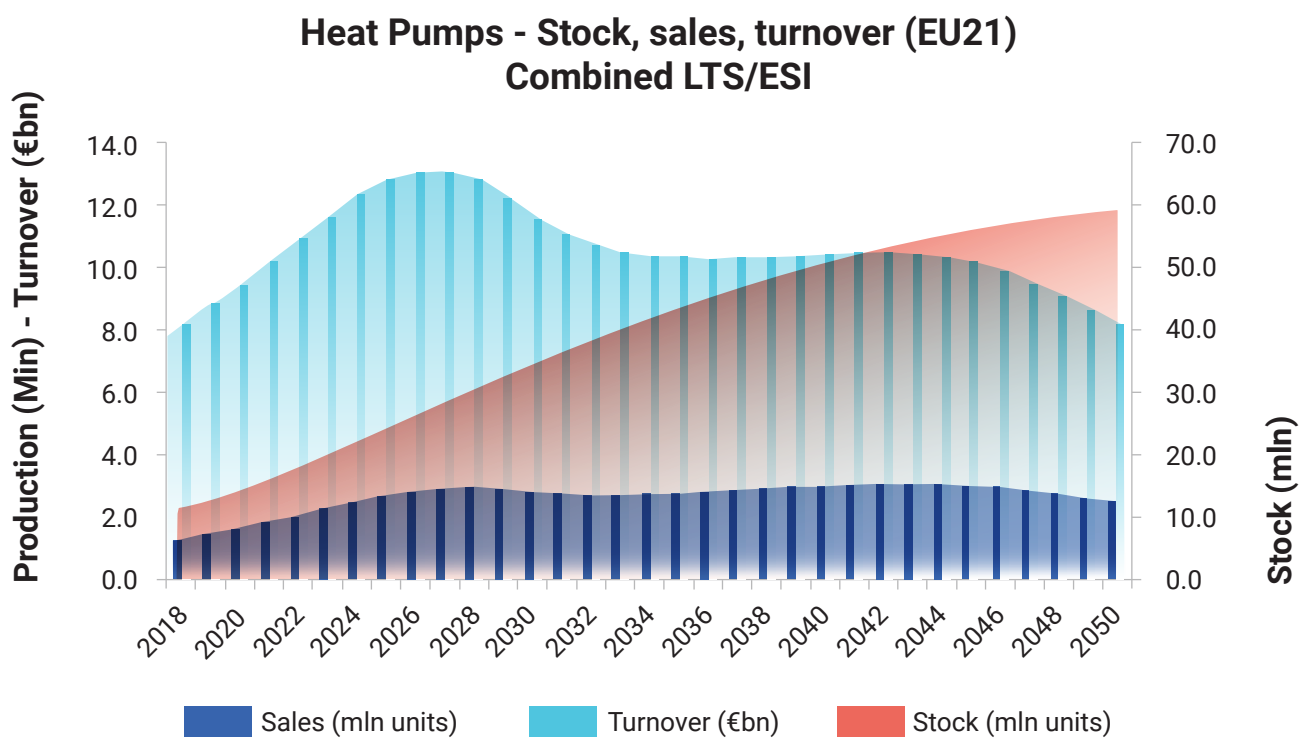
Table 5 - Cumulative heat pumps deployment as reported by the European Commission

Fit for 55	RePowerEU	Sum of two policy efforts
30 million by 2030	10 million over the next 5 years (i.e., by 2027)	At least 40 million heat pumps in Europe by 2030 (EHPA computation: 60 million)

This study assumes that the numbers above have been extrapolated by taking into consideration the threshold of the 12 kW, which the Ecodesign Directive fixes as the limit within which appliances are defined as for domestic use.

These estimates are also close to those from industry stakeholders that have informed the policy dialogue on this topic. They also roughly resemble those highlighted in both the Fit for 55 scenario and the focus on the RePowerEU strategy following Russia's invasion of Ukraine. These estimates are therefore taken as authoritative.

Figure 10 - Forecast of heat pumps “heating only” - stock, sales, turnover (EU21)



Source: Commission Staff Working Document Accompanying the document Report from the Commission to the European Parliament and the Council on Progress on the competitiveness of clean energy technologies 4 & 5 - Solar PV and Heat pumps

Table 6 - Stock of heat pumps in the European Union (EU21) (figures approximate)

	2020	2030	2050
Stock (EU21) - million units	15	40	60

Table 7 - Estimated amount of domestic heat pumps - two European Commission scenarios compared (figures approximate)

	EC report on Competitiveness of clean energy technologies 4 & 5 - Solar PV and Heat pumps (EU21)	Sum of REPowerEU and FitFor55
2030	40 million	At least 40 million
2050	60 million	(building on the results above)

5.3 THE PARIS AGREEMENT COMPATIBLE SCENARIO FOR HEAT PUMPS IN RESIDENTIAL BUILDINGS

The Paris Agreement Compatible (PAC) Scenario project is an effort undertaken by the European Environmental Bureau, Climate Action Network, Renewables Grid Initiative and REN21 since 2018. Funded by the German Federal Ministry for Economic Affairs and Climate Action, it aims to develop future energy scenarios for Europe which are compatible with the Paris Agreement reached in 2015 under the aegis of the United Nations Framework Convention on Climate Change.⁸⁵

Key findings of the project underline the overall need for greater ambition for European climate objectives in all significant sectors. The results of the analysis suggest that the European economy could aim to cut 65% of its emissions by 2030 compared to 1990 levels. Energy savings could also reach 45%, and the share of renewable energy in the electricity grid could amount to 50% in 2030 and 100% in 2040.

The analysis stressed that these goals can be achieved by quickly phasing out fossil fuels, limiting the use of non-fossil gases to where they are strictly needed, supporting the electrification of heating, industrial processes and transport, opening the door for greater uptake of renewable electricity for domestic uses and intensify efforts in energy-efficiency policies.

With regard to the residential sector, the report finds that both technology and behavioural changes will help to drive down the final energy demand by more than two thirds in 2050 compared to 2015 levels. The analysis finds that renovation rate and depth, the efficiency of new constructions and, the substitution of inefficient heating systems are major drivers of these savings.

According to the analysis, the final energy demand for space heating and hot water in residential buildings will decrease by 77% from 2015 to reach 572 TWh in 2050 (this data is reported for EU28).

The analysis provided in chapter 1.2 reports data in terms of ambient heat captured by heat pumps for the residential sector; EEB shared with ATMosphere the specific data of ambient heat demand for the residential sector in 2025, 2030, 2040 and 2050 as reported in the table below.

Table 8 - Assumed amount of ambient heat required by domestic heat pumps according to the PAC scenario

Year	Heat required
2025	151 TWh
2030	284 TWh
2040	422 TWh
2050	374 TWh

The amount of ambient heat used decreases after 2040, due to the assumption that renovation rate and depth will be scaled up significantly, therefore reducing the input required by heat pumps to generate the same required temperature. Given the underlying assumptions of this study, the amount of heat pumps required will be less than in other studies.

Assuming a fixed speed system with a seasonal coefficient of performance (SCOP) of 3 and capacity of 12 kW, fed by 8 kW of ambient heat and 4 kW of electricity from the grid, we can estimate the number of these appliances required to cover the different amount of ambient heat. We assume here that this appliance has a $\frac{1}{3}$ input of electricity and $\frac{2}{3}$ input of ambient heat.⁸⁶

For ease of calculation, we assume that the system is set to work for 1,850 hours a year. This number of hours is thought to be representative of the actual yearly working time for this kind of system.

The amount of time of use per year would generate the following amount of energy produced by the same equipment:

$$12 \text{ kW} \times 1,850 \text{ h} = 22,200 \text{ kWh (22.2 MWh)}$$

Thus, for the sake of our computation, 22,200 kWh (or 22.2 MWh) would be the heat produced in a given year by the assumed heat pump.

We can then input data reported for ambient heat in TWh (terawatt/hour) and calculate the amount of equipment needed to cover this energy input. In fact, considering the total ambient heat required in each scenario and having agreed on the specificities of the equipment, we can extrapolate the electricity produced. We can then divide the total electricity generated by the assumed equipment output to understand the number of assumed heat pumps required.

Table 9 - Computation for the EEB/CAN PAC scenario

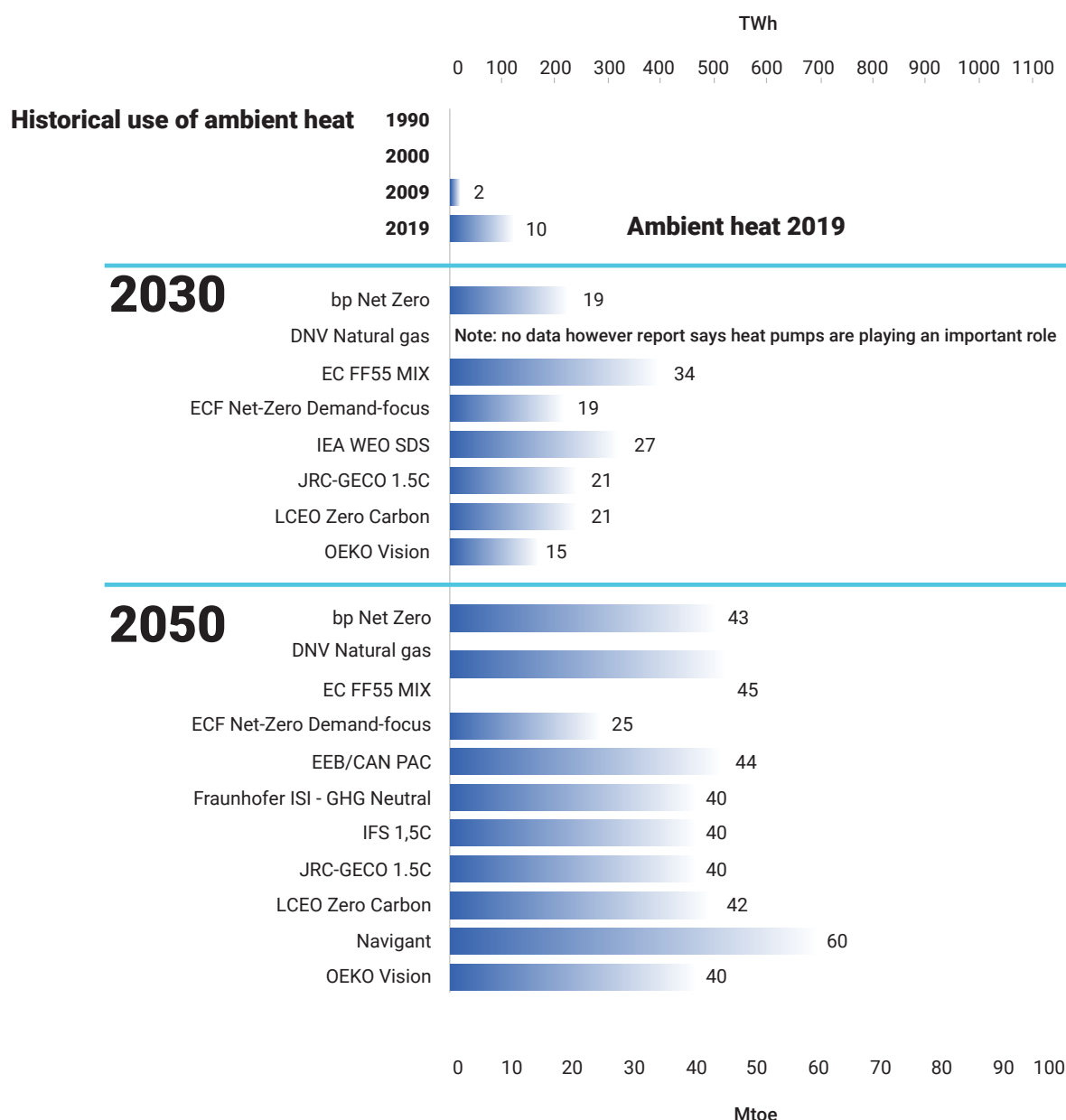
Year	Ambient heat (TWh)	Electricity from the grid (TWh)	Total output (TWh)	Amount of heat pumps (heat produced in 1 year – 22.2 MWh) required to meet the given ambient heat
2025	151	75.5	226.5	ca. 10 mln
2030	284	142	426	ca. 20 mln
2040	422	211	633	ca. 28 mln
2050	374	187	561	ca. 25 mln

We can compare these results with the amount of ambient heat reported for the Fit For 55 scenario by the European Commission. We extrapolate data from the section related to heat pumps in the publication by the Joint Research Centre of the European Commission “EU challenges of reducing fossil fuel use in buildings”. In this publication, the Centre compiles a list of different emission-reduction scenarios related to heat pump deployment. The projections are focused on heat pumps providing ambient heat for European buildings and are listed

in terms of TWh (terawatt/hour) that will be used and Mtoe (million tonnes oil equivalent) that will be replaced.⁸⁷ In its report, the Centre supports the stance that fossil fuels will gradually disappear from heating and cooling.

However, these data refer to the building sector in general, and thus also include commercial spaces. They are, nevertheless, indicative of a rough comparison.

Figure 11 - Historical and projected use of ambient heat for EU buildings – different estimates



Source: Joint Research Centre, figure 27.

Table 10 - Computation for the EC Fit for 55 scenario⁸⁸

Year	Ambient heat (TWh)	Electricity from the grid (TWh)	Total output (TWh)	Amount of heat pumps (heat produced in 1 year – 22.2 MWh) required to meet the given ambient heat
2030	395.42	197.71	593.13	ca. 27 mln
2050	523.35	261.7	785	ca. 35 mln

Table 11 - Estimates of 12 kW output equipment working for 1,850 hours a year needed to meet ambient heat input according to two different scenarios (figures approximate)

Total generated output divided by assumed heat pump output (22.2 MWh)	2030	2050
EEB/CAN PAC	ca. 20 mln	ca. 25 mln
EC FF55 MIX	ca. 27 mln	ca. 35 mln

Despite the high reliance on estimates that these computations involve, we can conclude that these are minimum numbers, as the parameters used involve those of a heat pump with maximum capacity (12 kW) for the domestic sector. It is also to be noted that these systems are assumed to be fixed-speed systems, where inverter-driven heat pumps are also part of the technology portfolio available to decision-makers. Inverter-driven heat pumps also are meant to work more hours than fixed speed equipment.

In addition, these calculations are intended to show the number of heat pumps required by each scenario and do not consider their lifetime, which would be around 15-20 years per equipment, and thus change the final number of heat pumps. Finally, according to the status of the building in which the appliance is supposed to be deployed, the household could deploy equipment of a smaller capacity, thereby increasing the amount of equipment to be used to cover the same amount of ambient heat as the scenario predicts.

5.4 EU HEAT PUMP SECTOR OVERVIEW

According to industry data, 80% of heat pump systems sold in 2019 in Europe use HFC-410A (a fluorinated refrigerant with a GWP 100 years = 2,088 and GWP 20 years = 4,400), with HFC-134a being the second option (GWP 100 years = 1,360 and GWP 20 years = 3,810).⁸⁹ The other two refrigerants in use are HFC-32 and propane (R290), but these are expected to increase in importance in a move away from R410A. The transition of the market towards the use of HFC-32 was also confirmed by some interviewees.

This data is worrisome not only from a climate perspective but also from an environmental and human-health one. HFC-125, a f-gas used to make HFC-410a, and HFC-134a have been listed by the OECD/UNEP Global Perfluorinated Chemicals (PFC) Group as a PFAS in the recently released Fact Cards of Major Groups of Per- and Polyfluoroalkyl Substances (PFASs),⁹⁰ and, should the Restriction Intention on PFAS at EU level keep the working definition of these substances as it currently stands,

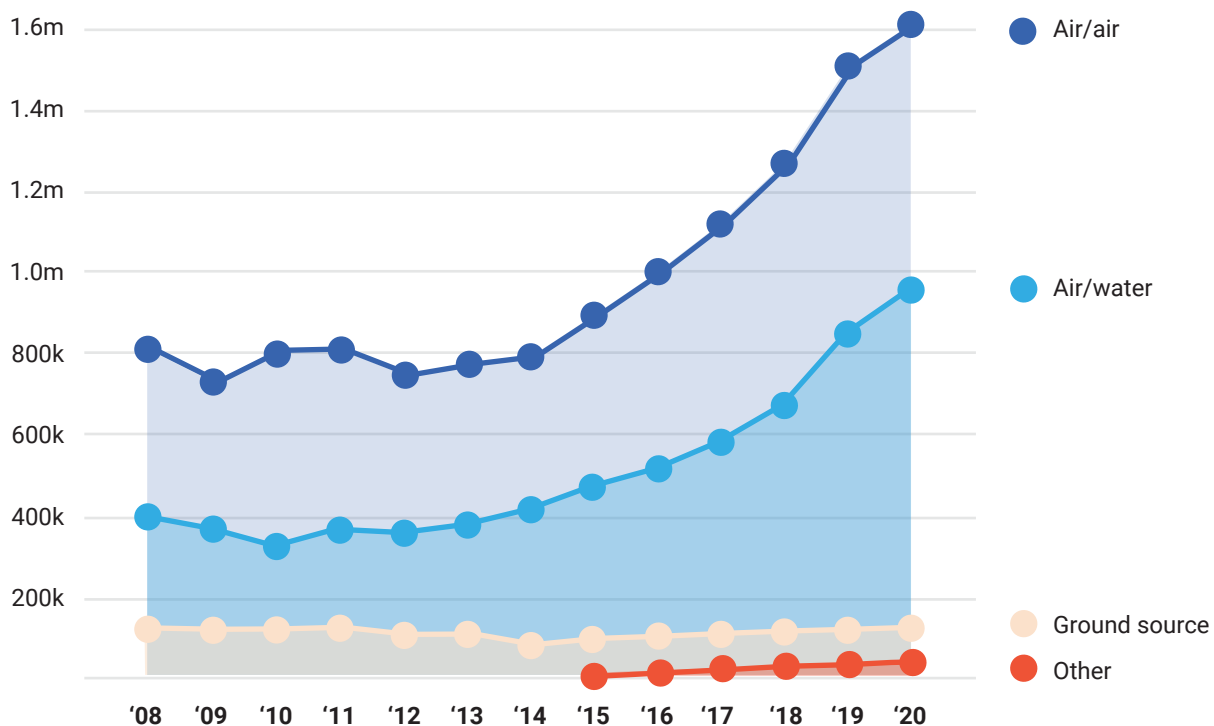
HFC-134a would be targeted by potential additional regulatory burdens.

In terms of types of heat pumps expected to meet the numbers reported in the chapter above, there seems to be common agreement across the industry that air source heat pumps will obtain the lion's share. This data is also backed by the recent growth of this specific technology, representing about 94% of the sales in 2020 according to data from the EHPA. Air-to-water heat pumps represented more than half of this, surpassing 8,000 units sold in 2020.

Given the data reported above, we can extrapolate the annual growth in terms of sales for air-to-water heat pumps across the EU21. The average annual growth rate from 2015 to 2020 can be identified at about 19%, with the growth in 2018–2019 being the largest value on a year-over-year comparison showing about 36% growth.

In terms of capacity deployed, market data show that domestic heat pumps make up the biggest share of the total EU21 heat pump market.

Figure 12 - Share of sales divided amongst heat pump technologies in the EU21⁹¹



Source: EHPA 2021

6

Analysis of Current EU Heat Pump Market

The following insights were gathered from a combination of desk research and interviews with a sample of key industry stakeholders.

6.1 EUROPE-BASED HEAT PUMP INDUSTRY OVERVIEW

A qualitative review of the existing Europe-based heat pump industry was undertaken for this project. It includes OEMs and component manufacturers that include fluorinated and/or natural refrigerant heat pump-related products.

This review aimed primarily to assess the current production capacity of OEMs and the capability (and willingness) to scale up the production of natural-refrigerant-based domestic heat pumps in the EU.

Figure 13 shows a map of Europe-based companies along the heat pump industry and their use of refrigerants. The data gathered seek to differentiate companies according to the use of natural refrigerant in their lines of production and the EU countries in which their HQs are located. The map has been built with information gathered from different available and reputable sources within the industry; however these can be subject to uncertainties due to companies' internal considerations

and availability of public information in given regions and languages.

When considering “mainly-heating” heat pumps (excluding air conditioners), the industrial landscape in the EU consists of many SMEs – which are supplying mainly national markets. A few larger companies (but smaller than Asian competitors also active in air conditioners) supply mainly European countries, both EU and non-EU. According to our research, the country with the most OEMs appears to be Germany.

Of the 63 companies considered, 47% offer products with a natural refrigerant in their portfolios. Interviews were arranged according to replies and feasibility; the team interviewed 20% of the latter category, recording stories of success, positive growth rates, commercially available technology and good potential.

The companies represented in the interviews are varied. The European market ranges from OEMs with more than 25 years' experience working with natural refrigerants to others that switched just two years ago.

The majority of companies interviewed currently have at least one EU-based production line with natural refrigerants.

A Belgian-headquartered company has natural refrigerant domestic hot water heat pumps in its portfolio but is not currently manufacturing them in the EU and does not intend to promote them in the bloc.

An EU-based Japanese manufacturer instead produces natural-refrigerant-charged domestic hot water heat pumps and provides them to other EU-based OEMs that sell them in the market.

Additional manufacturers outside the scope also provided contextual inputs for this report. However, as their product portfolios do not include the appliances targeted in this report, we considered their inputs only tangentially.

All these companies have welcomed this study, though some more warmly. More interested ones provided data extensively during the interviews and replied to follow-up questions in a timely and informative manner to inform the study to the best of their ability.

The Belgium-based manufacturer instead, shared only surface-level quantitative data and estimates with us, focussing primarily on CO₂ domestic hot water and air-to-air heat pumps running with HFC-32. The company representatives cited confidentiality issues as a reason for not giving more in-depth information. Another manufacturer also cited privacy concerns related to manufacturing numbers and shared only a small amount of information.

6.2 AIR-TO-WATER (ATW) HEAT PUMPS

6.2.1 CURRENT MARKET SIZE

The sample of manufacturers interviewed shared 2021 production numbers ranging between 4,000 and 40,000 ATW heat pumps (including all refrigerants), around 40% of which were charged with natural refrigerants and fell within the < 12 kW scope of this study.

However, the 2021 numbers are not indicative of a “normal” production year as COVID-19-related delays, together with supply chain issues, resulted in various production delays.

The annual production capacity is much higher.

ATW heat pumps manufacturers operating with natural refrigerants have shared plans to expand current production and dedicate new lines to the use of natural refrigerant systems, particularly with R290.

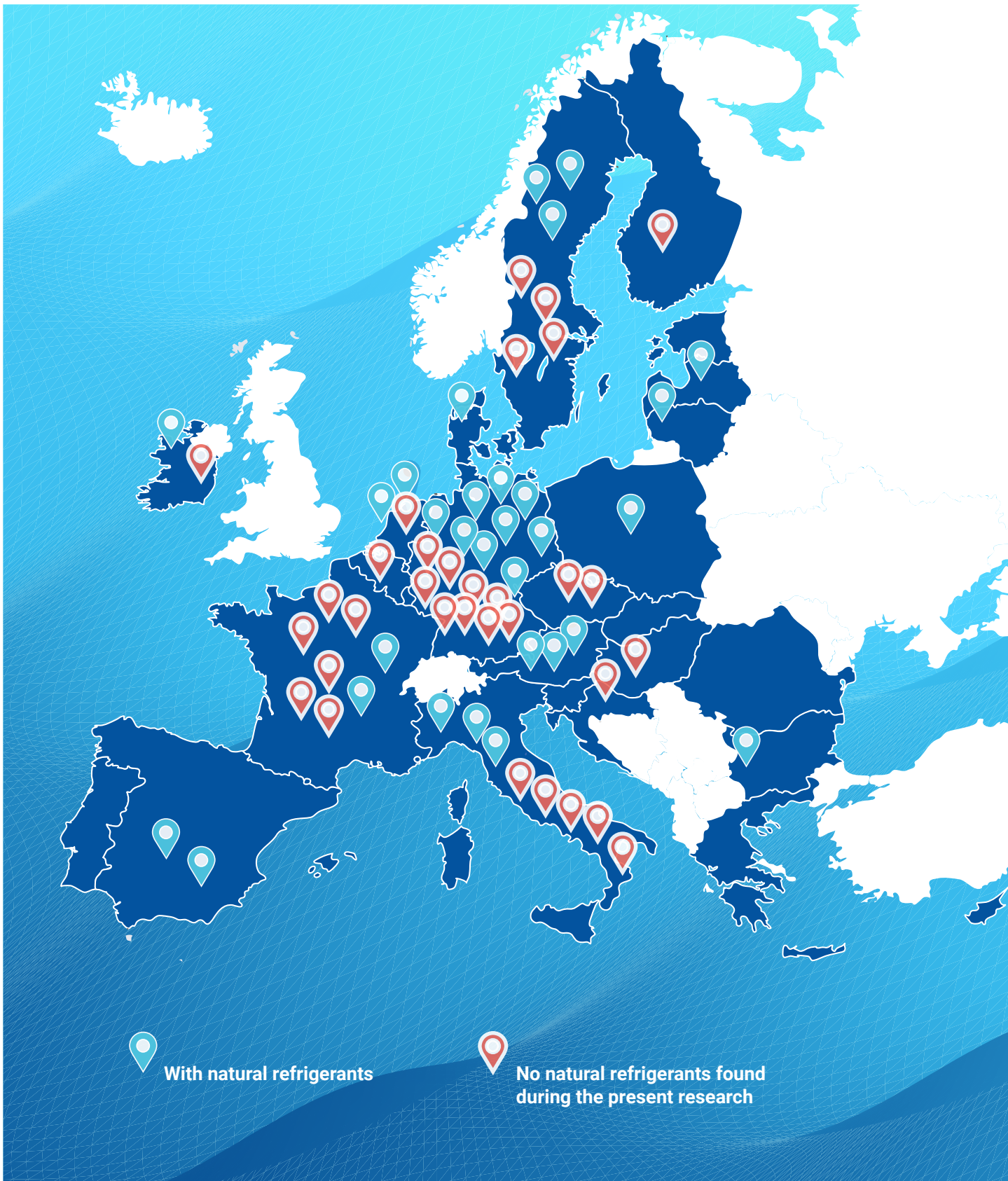
The increase in production of natural refrigerant heat pumps from 2020 to 2021 exceeded 100%. Some manufacturers reported year-on-year production increases in excess of 300%. This can be attributed to investment in new factories. However, this is a new product line growing from a low base, and thus the growth number can appear high.

The companies interviewed underlined that the market for natural refrigerant heat pumps is still considered a niche, even if recent sales have increased, but they are confident in faster further growth. They expect EU-based regulation to drive the demand since technologies and resources are ready to be deployed. Moreover, swift reconversion of the production line is also possible, given the right policy context in place. Some of the large OEMs, already manufacturing large numbers with natural refrigerants, underlined the uselessness of taking intermediate steps (adopting other solutions such as HFC-454b or HFO-454c), rather than directly moving to R290.

6.2.2 COST OF CONVERTING PRODUCTION LINES

As revealed by the interviews, the time necessary to change the production line is estimated to be between two years for the medium industry and five years for a large one. Some components and processes coming from the refrigeration and gas boiler sector, have been in the market for a long time and can be used for heat pump process lines. Of course, other components need to be adapted to the new product. Our interviewees remarked that the market and components suppliers need to move towards natural refrigerants; with the direction of travel towards the adoption of natural-refrigerants-based equipment, OEMs can lead these transitions. Once there is demand, suppliers will provide what is necessary for the new production line. Interviewees stressed that there is a need to show commitment from governments, targeted policy actions and established third-party certification to guarantee the quality and safety of the equipment.

Figure 13 - Overview of Europe-based companies along the heat pump industry and their use of refrigerants



Different price estimates for heat pump production lines using natural refrigerants were reported. Most of the respondents indicated a 10-15% increase in price compared to the HFC line. Their reasons were because it is a new, more efficient product, and some components (such as compressors) are more expensive. Others took opposing positions: the difference in price between the two lines of production was estimated as double due to safety reasons, the necessity of third-party certification, additional costs in components, training staff and low competition between components suppliers. On the other extreme, some claimed there were no significant price differences at the moment because the differences in the price of components can be managed through specific contracts (once there are economies of scale), and the initial costs of a new production line can be controlled without reflecting on the final price, so as not to scare consumers.

Compressors are being optimised for heat pump applications, whilst expansion valves, three-way valves and control systems are getting more standardised and are sold in much larger numbers. In this way, the market expansion, the increase in volume and the entry of new companies/OEMs operating with natural refrigerant equipment will generate economies of scale, lowering the final prices in the future.

6.2.3 PRODUCT PRICE COMPARISON

Obtaining detailed information about the price difference between producing a natural refrigerant heat pump versus an HFC-based heat pump proved challenging during interviews.

According to the respondents, there can be an estimated 10-15% of additional costs in HP production using natural refrigerants. How much of this increase is reflected in the final price of the product and if there is a relevant difference in the price that can affect the market has been further analysed. Online manufacturers' catalogues and specialised web markets provide reliable information.

All products considered have at least an energy label of A+; they are divided into two groups according to their heating capacity: 7-8 kW or 11-12 kW.

The following brands' products are included in the sample: AUER, Ecoforest and NIBE for heat pumps with R290 and Daikin, LG, NIBE and Panasonic for products with f-gases.

The average price for a monobloc ATW heat pump using R290 as a refrigerant with a heating capacity of 8 kW is €10,855 versus €9,630 for similar products using f-gases, with a percentage difference of 11.29%.

Considering a higher heating capacity of 12 kW, the market research team found an average price of €12,550 for HP with natural refrigerants versus €10,217 (monobloc) and €13,067 (bibloc/split systems) for fluorinated ones. Percentage differences are 18.59% and -4.12%, respectively. In the latter case, the average price for a bibloc heat pump with fluorinated gases is higher than those with natural refrigerants.

Percentage price differences appear below 20%; some products have the same range of price or slightly above. Considering that heat pumps using natural refrigerants are relatively new models in a growing market that has not yet developed adequate economies of scale and will not be affected by the various legislative restrictions currently being discussed, the price differences at this moment do not appear to be a relevant element that can substantially hinder their development in the market.

When comparing prices, a Swedish OEM noted that, in some instances, R290 units can be considered a more premium solution as compared to their HFC-R410A unit, which makes it impossible to directly compare the products.

A representative from an interviewed company added that other factors such as improved efficiency and lower noise levels should also be considered when comparing prices as the natural refrigerant units may be more costly on a direct price comparison but offer additional benefits in some instances.

6.2.4 POTENTIAL TO SCALE UP

The results obtained by the team during OEM interviews show optimistic estimates for the future production of natural-refrigerant equipment with growing trends and an easy production-re-conversion process. In some cases, new facilities (intended for natural-refrigerant-based heat pumps) are planned to be constructed to respond to growing requests. Their construction would entail a large financial investment. In other cases, converting production lines to natural refrigerants would not result in new plants, but rather in the reconversion of old ones, for instance, dedicated to technologies being phased out.

Production expectations for natural refrigerant heat pumps are to at least double turnover in 2022, considering the effects of new regulations and socio-political trends. EU regulations will have an impact on both the design of the product (energy efficiency, refrigerant etc.) and market opportunities. Interviewees were confident that this exponential growth would continue every five years, considering the milestones of 2025, 2030 and 2040. Interviewees reported triple-digit growth (up to 300%) since 2020 for the capacity of air-to-water heat pumps with natural refrigerants.

Overall, both the EU F-Gas Regulation and the envisaged PFAS Restriction Intention will play an important role in driving market uptake towards alternatives in the heat pump sector. Representatives from industries operating with natural refrigerants consistently expressed their desire to see ambitious targets regarding heat pumps with measures preventing their free deployment with f-gases.

A company that produces space heating heat pumps operating with solely fluorinated substances (especially HFC-32) said in an interview that tighter measures in the EU F-Gas Regulation do not pose a problem to the mass deployment of heat pumps in Europe. This stance is in contrast with a recent article where industry trade bodies named regulation on fluorinated gases as an impediment to this technology's deployment in Europe.⁹²

AIR-TO-AIR HEAT PUMPS

Air-to-air heat pumps are not included in the scope of this study. These are commonly referred to as "split air conditioners". Air conditioners normally provide a cooling effect; however, they can work in reverse mode and provide heat too. These appliances are powered by electricity and provide heat or cool effects using the phase change of a refrigerant running through a system that can be installed both inside and outside the place to be heated or cooled. When air is the medium through which heat or cool disperses, the system usually deploys fans to blow air on coils or is a ducted ventilation system.

If the EU f-gas proposal is enacted, this segment will be targeted by bans in stationary air-conditioning and heat pump split systems.

Even if examples of this technology running with natural refrigerants do exist, this specific technology's transition towards full operation with natural refrigerants has been slow, especially in Europe. The European market only recently (in 2021) received one of the first air-to-air heat pumps working with R290, produced by the Chinese company Midea. The uptake of this equipment with refrigerant charges higher than 150 g (and therefore higher capacity) is also likely to be supported by the recent approval of the revised IEC 60335-2-40 ED7, which allows for greater charges once additional safety measures are added to the system.

Finally, European manufacturers such as Innova have brought to the market a propane (R290)-based monobloc unit that can be a substitute for split systems in the lower capacity range, providing yet another solution for European customers.

6.3 DOMESTIC HOT WATER HEAT PUMPS

Domestic hot water heat pumps (DHW HP) are a key technology to replace gas boilers used to provide hot water for sanitary purposes in residential buildings across Europe. DHW HP can be installed as a free-standing unit or together with a storage water heater, where the water is kept and distributed where needed.

Three companies producing water heater heat pumps charged with natural refrigerants are included in the sample of manufacturer input.

A Danish manufacture of DHW heat pumps with R290 started in 2015 to produce heat pumps charged with this natural refrigerant in collaboration with the Danish government. The company's current capacity of DHW HP is 30,000 units a year, produced in its factory in western Denmark.

The company shared that 10% of their hot water heat pumps sold in 2020 were charged with propane. However, they are investing heavily in this technology, due mainly to the regulations tackling fluorinated refrigerants and the constantly higher price these substances have. They reported that prices for fluorinated refrigerants currently deployed in their equipment have risen by more than 50% on a month-by-month comparison, reaching €50 per kg. The company representative confirmed that, contrarily, the price of propane has remained low and constant, and no disruption in its supply has been experienced or is anticipated.

The same company elaborated that scaling up costs depends heavily on the needs of the investment. For example, building a new factory would be a much greater cost than updating some production lines in an existing facility. Regarding the price difference, the company suggested a 5–10% increase in the final price of using propane versus an HFC. This is due to the slightly higher manufacturing costs associated with bringing the propane production line into compliance with required safety standards.

The entity cited the lack of dedicated components to satisfy the growing demand for DHW propane-charged heat pumps – specifically compressors – as the main barrier to this technology's growth. Nevertheless, the company has set ambitious targets for the expansion of this natural refrigerant technology in its manufacturing portfolio: in 2023 it aims to reach more than 50% and in 2024 more than 90%. The representative confirmed that its factory, built in 2015, can support greater production than its current output, and the company is ready to quickly switch the entire production. Demand and regulations were cited as the main drivers of this commitment.

One of the interviewees raised concerns about CO₂ (R744) water heater heat pumps and the water supply infrastructure present in continental Europe: European buildings (except the UK) are designed in a way where cold water comes into the water tank to top up the water used. The representative explained that this means that the water temperature constantly has to be heated only a small amount to return to the desired temperature after refilling with cold water. With this short temperature delta, R744 is inefficient.

However, other industry experts contended that this connection between COP and temperature delta applies to *all* heat pumps, including heat pumps with fluorinated gases as a refrigerant. This particular issue appears to *not* be related to the use of R744.

In fact, another company manufacturing R744 DHW HP for the European market does not lament their efficiency, but rather the lack of demand for the scale-up of this technology on the bloc's market. Currently, this company produces predominantly DHW HP with capacities of around 6 kW for the residential market. However, it has recently embarked on a joint-venture with another EU-based company to also bring an R744-charged air-to-water heat pump with hydronic distribution which fits into the radiator infrastructure of old houses to the market. This equipment is designed to cover both space and water heating needs and is expected to be released into the Dutch market by mid-2022.

DISTRICT HEATING AND HEAT PUMPS

District heating is a technology that provides multiple households with heating services (space and water heating) through a centralised system. Where feasible, district heating infrastructures are preferred to individual solutions due to their high energy efficiency and better pollution control, mainly due to the centralisation of the systems. These systems can run with fossil fuels, the majority at the global level. Heat pumps are also deployed in this sector, tapping into different heat sources.

Heat pumps that serve district heating are outside the scope of this study, with capacities reaching up to multiple megawatts. However, installations charged with natural refrigerants, such as ammonia and carbon dioxide, are gaining market share in Europe, and some countries are pushing strongly in this direction (such as Denmark and Sweden). A Denmark-based company reported in the interview that their domestic sales are not as relevant as those in Germany or Austria, mainly due to district heating infrastructures that are preferred instead of individual heating systems in Denmark.

6.4 MEETING DEMAND

Given current EU policy efforts to decouple heating from fossil fuels and the focus on replacing fossil-fuelled boilers, we assume that the deployment of heat pumps will at least meet the numbers stated above, providing policies supporting the electrification of heating are implemented swiftly.

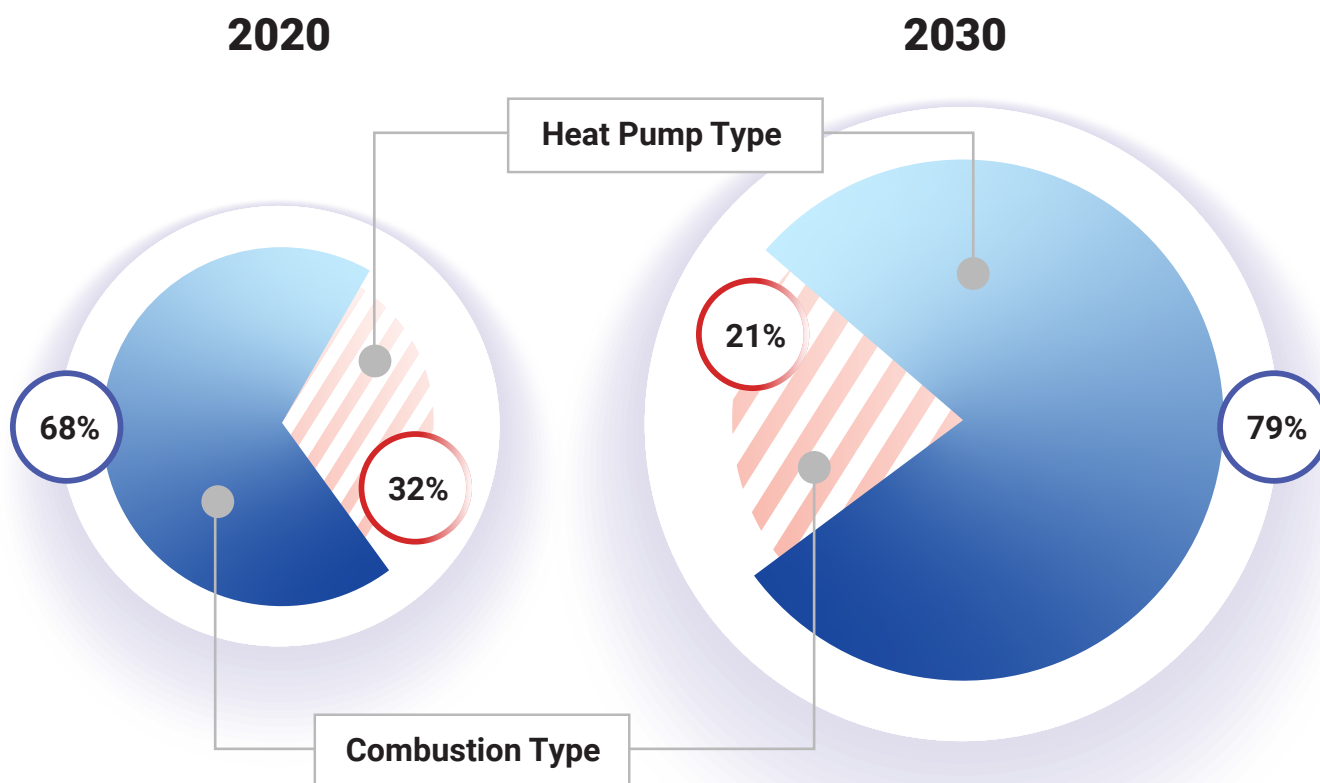
Coolproducts and ECOS highlight that 129 million oil- and gas-fuelled boilers are installed across the European building stock, with the majority being installed before 1992 and being highly inefficient.⁹³

Estimates reported by industry media outlet JARN suggest that, due to the need to speed up the substitution of boilers with heat pumps and the maturity of air-to-water solutions for the domestic sector, these conditions can create a favourable environment for this technology, with forecasted sales over the next 20 years roughly equivalent to the number of natural gas boilers sold in the same sector over the last 20 years.⁹⁴

Across the board, interviewees working with natural heat carriers communicated that they plan to increase production in this specific technology segment and are willing to tap into the space left on the market by the phase out of fossil-fuelled boilers.

A strong policy signal is listed as the main driver for further investments in this technology. Some stakeholders also confirmed their commitment to repurposing old technologies' production lines and reconverting them to scale up this technology in relatively short timeframes. A German company has also recently publicly embraced the shift towards natural-refrigerant-based heat pumps in an effort to align its production with its climate strategy.⁹⁵

Figure 14 - Changes in the European Residential Heating Market



Source: JARN (July 2021) - World ATW Heat Pump Market - 2021 Update

6.5 DRIVERS AND BARRIERS

The interview group is optimistic regarding the feasibility of scaling up production relatively quickly. However, this view is not necessarily shared by the manufacturers of HFC-charged equipment that have a vested interest in delaying a transition to natural refrigerants. There are also additional external factors that hinder an accelerated uptake of natural refrigerant heat pumps for the residential sector.

Specific input was collected on the type of refrigerant's effect on HP production. Interview respondents maintained that natural refrigerants are *not* viewed as a limitation in the scale-up of heat pump production in Europe. There is no lack in the availability of these gases. Experts monitoring the refrigerant market at the European level also support this claim.⁹⁶

Some of the issues highlighted when interviewing EU stakeholders were backlogs due to COVID-19 restrictions, lack of readily available components (such as semiconductors and compressors), the

lengthy processes related to the building of new factories and the lack of skilled personnel specialised in installing heat pumping technologies. Additionally, the electricity grid may require reinforcement in some areas to cope with increased numbers of heat pumps and other electric appliances. The ongoing war in Ukraine seems to have also created transport issues for some northern European manufacturers.

Additional barriers include training, services after sales, flammability and more restrictive safety standards. The length of the supply chain could also slow down the capacity to respond to growing demand, particularly related to components coming from outside the EU's borders. There are also some challenges around educating end-users, particularly end-users who are used to working with HFC refrigerants only. Misinformation around natural refrigerants is also a concern as it is negatively impacting the perception of these products in the market.

The need for a more balanced energy taxation framework is also an outstanding point. There is still a discrepancy between the price of electricity and that of other energy sources which hinders heat pumps' deployment.

Generally, the main barrier to the uptake of natural refrigerant charged heat pumps cited was the lack of regulatory measures to phase out higher GWP working fluids in these systems. More ambitious regulations would create the space for natural-refrigerant-based technologies to prosper and drive innovation in the market.

Although currently, natural refrigerant heat pumps are slightly more expensive than HFC counterparts in the EU when looking at CAPEX, this is likely to

change in the longer term. Natural refrigerant gases are not subject to capping measures such as the EU HFC phase down or the Kigali Amendment HFC phase down, which will consequently keep their prices low and stable. Natural refrigerants are also not patented, making them freely available to all.

The latest IPCC report has cast doubt on HFC-32's feasibility going forward. The report found that this refrigerant's GWP (which currently is valued at 675) is in fact higher – 771.⁹⁷ This would put it above the threshold of any sectoral bans where the limit is 675 or 750, and leave it subject to a phase out. End-users leapfrogging directly to natural refrigerants would save money in the long term due to the future-proofness of these substances.

Figure 15 - Main drivers and barriers to the uptake of natural refrigerants heat pumps as mentioned during the interviews with industry stakeholders



6.6 THE CASE OF COMMERCIAL REFRIGERATION: A POLICY-DRIVEN SCALE-UP EXAMPLE

To understand the scale-up potential of the natural refrigerant residential heat pump sector, parallels can be drawn between this sector's growth and that of natural refrigeration products in the EU's commercial refrigeration sector. The influence of sectoral bans there was a clear driver for the rapid uptake of natural refrigerant technologies, exceeding even the most ambitious growth projections.

The current F-Gas Regulation was published on 20 May 2014 in the Official Journal of the European Union; it entered into force on 9 June 2014 and applied from 2015 onwards. Table 12 presents the bans targeting the commercial sector that the current regulation introduced.

Just like the current situation in the residential heat pump sector, conservative stances from the fluorinated gases industry and trade bodies of RACHP sectors strongly opposed the introduction of sectoral bans in the commercial refrigeration market segment; they judged these as too obstructive.⁹⁸ Trade bodies are currently parroting the same concepts that were used in 2013, citing bans as obstructive to reaching the EU's climate and energy goals.⁹⁹

As the EIA's reaction following the agreement between the European Commission and Parliament shows, there was already room for greater ambition at that time; progressive stances were obstructed by other interests playing against the swift phase-out of fluorinated gases across the spectrum of RACHP sectors.⁹⁹ In the sector of commercial refrigeration, conservative stakeholders tried to transmit to

Table 12 - F-Gas Regulation (2014) for the commercial sector

SECTORS	BANS	DATE
Refrigerators and freezers for commercial use (hermetically sealed equipment)	that contain HFCs with GWP of 2,500 or more	1 January 2020
	that contain HFCs with GWP of 150 or more	1 January 2022
Stationary refrigeration equipment	that contains, or whose functioning relies upon, HFCs with GWP of 2,500 or more (except equipment intended for application designed to cool products to temperatures below -50 °C)	1 January 2020
Multipack centralised refrigeration systems for commercial use with a rated capacity of 40 kW or more	that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1,500 may be used	1 January 2022
Service or maintain refrigeration equipment with a charge size of 40 tonnes of CO ₂ equivalent or more	that use of fluorinated greenhouse gases, with a global warming potential of 2,500 or more	1 January 2020

policymakers the fear that the sector was not ready to transition away from fluorinated substances. There was the feeling that the technology was immature and not ready to overtake fluorinated-refrigerant-based systems. However, as the figure below shows, the opposite turned out to be the case.

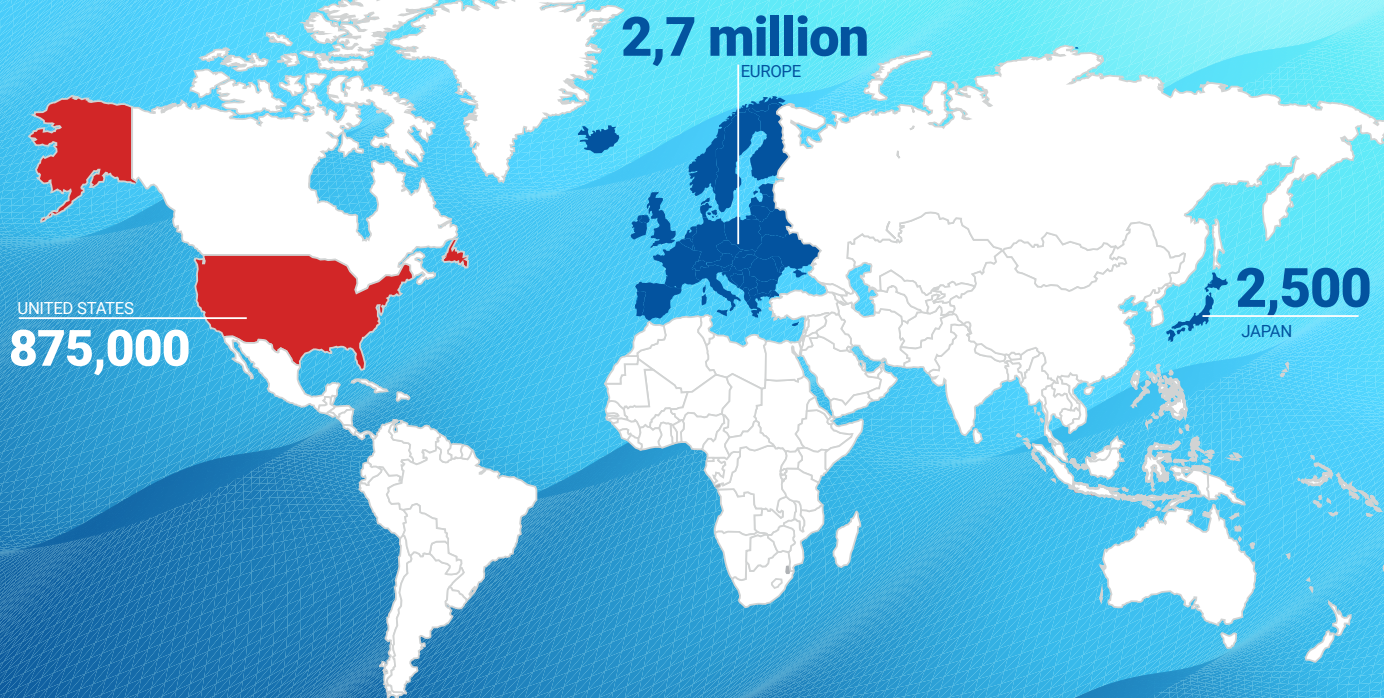
Thanks to the introduction of specific bans on higher GWP's in commercial refrigeration systems and hermetically sealed refrigeration units starting in 2020, the growth of systems charged with R744 and hydrocarbons has rapidly increased, gaining market share in the European market. Even before the bans officially came into play, the industry started readying itself for the upcoming changes. Rather than simply

lowering the GWP of the refrigerant in their systems, thus being subject to possible continuous lowering thresholds, a great number of OEMs and end-users leapfrogged directly towards R744. (See Figure 17)

Data collected directly from European OEMs shows that today, 14% of systems used in commercial refrigeration in Europe (38,400 units) are deployed using CO₂-transcritical systems.

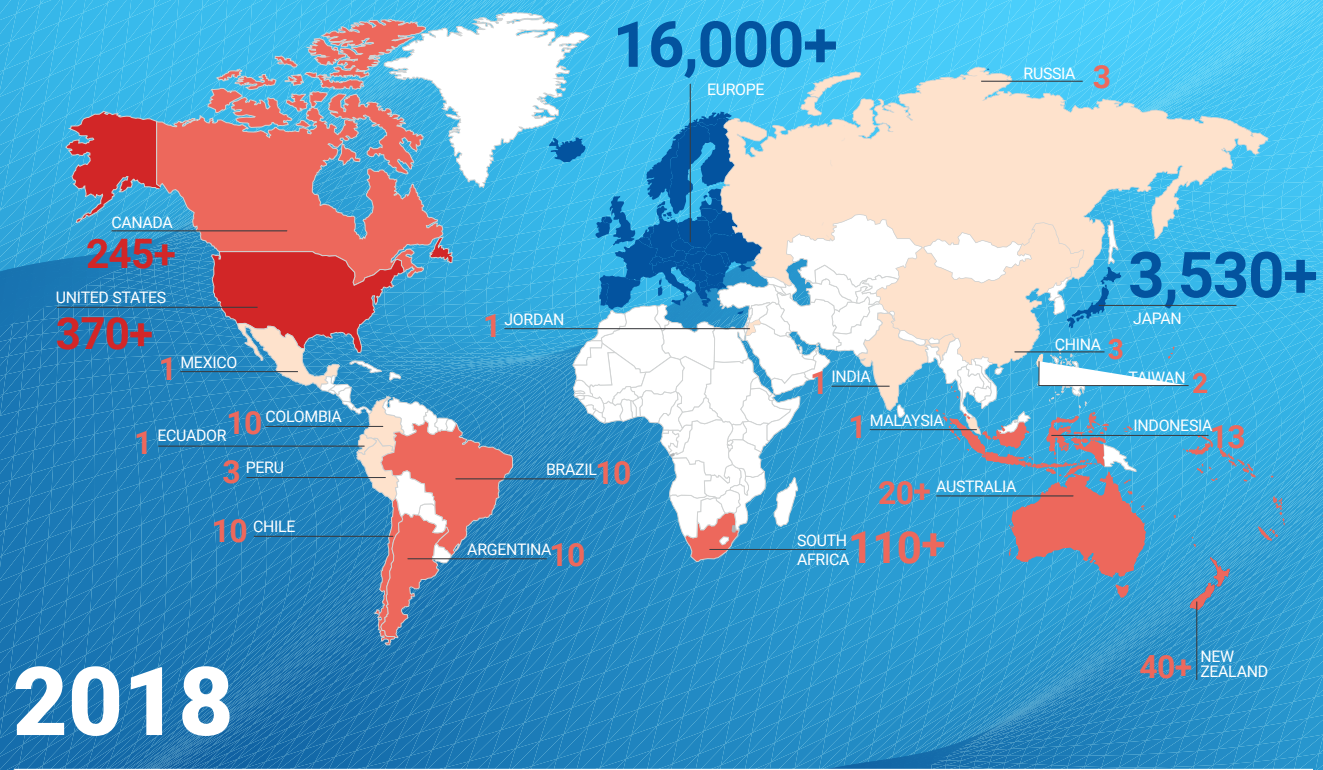
Besides CO₂-based systems, the uptake of hydrocarbons systems was also decisively strengthened by the adoption of bans in the commercial sector; this swift technology uptake occurred mainly in stand-alone plug-in display cases and reached about 2.7 million units in Europe.¹⁰¹

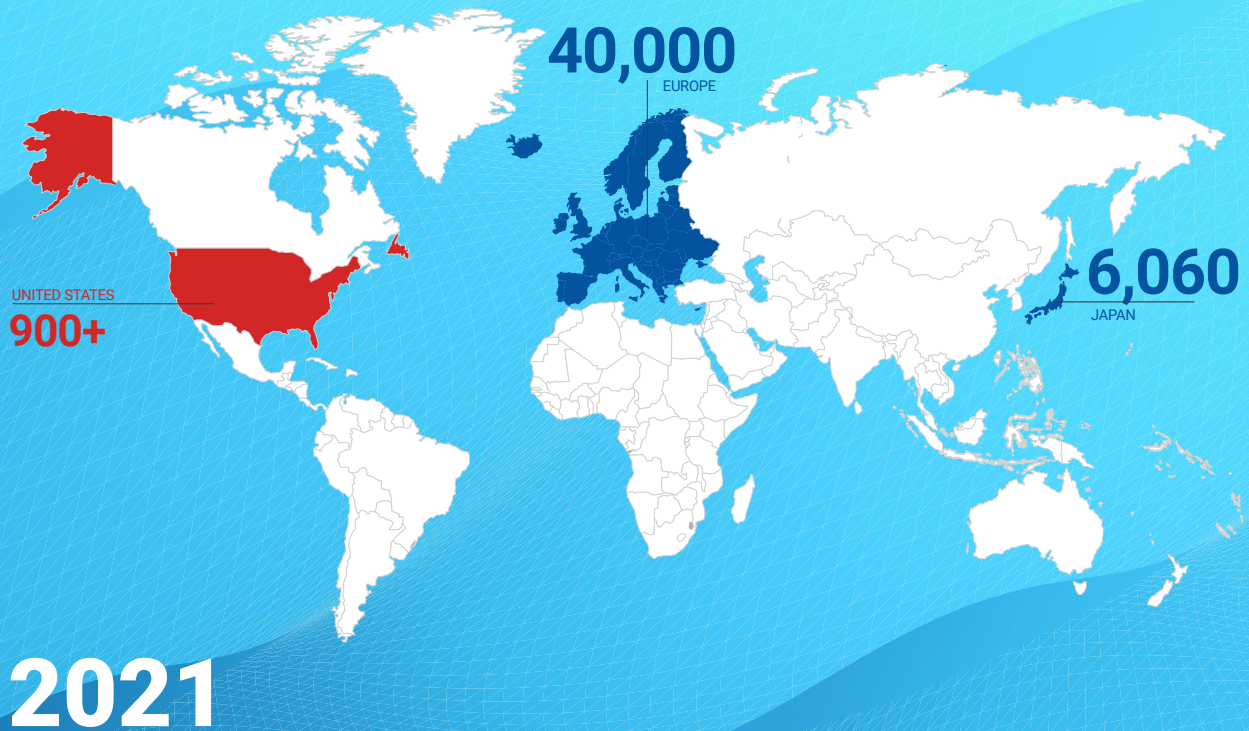
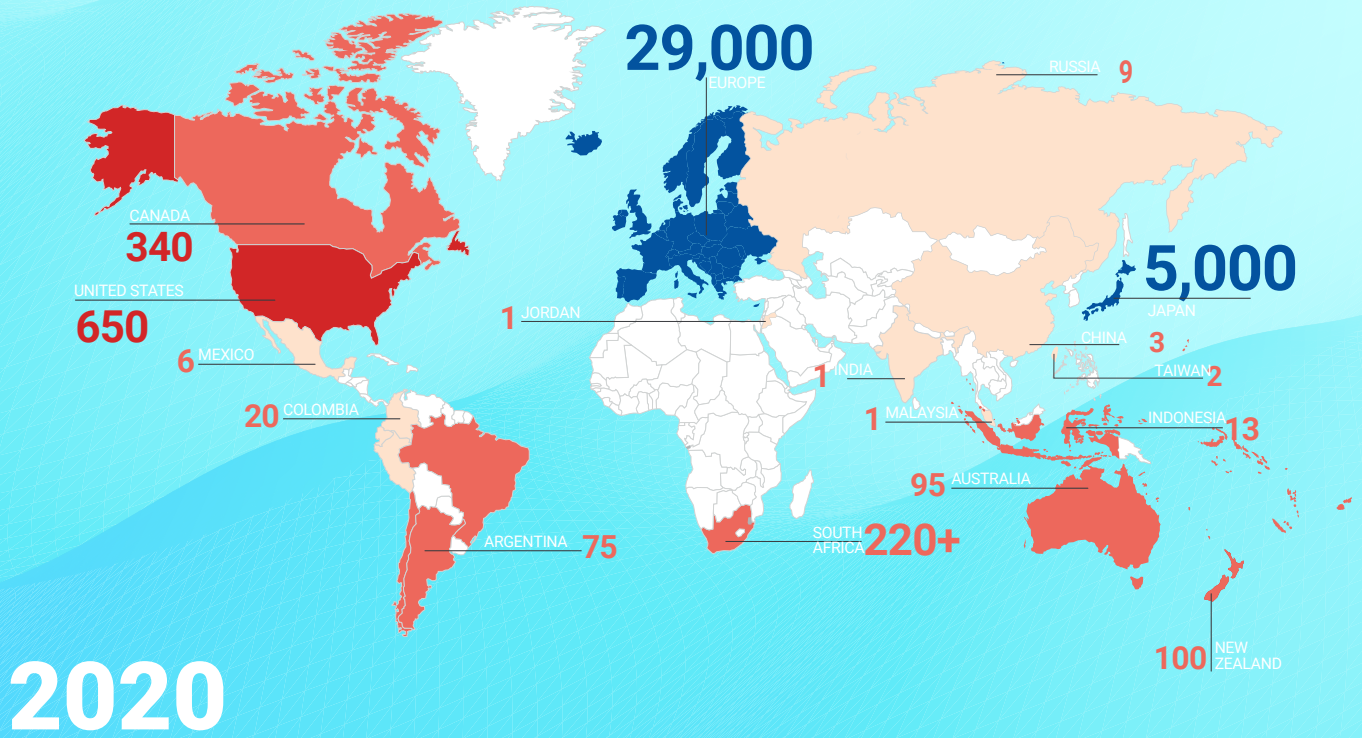
Figure 16 - Estimated number of hydrocarbons units in the commercial sector in main regions: Europe, Japan and U.S.



Source: ATMO Report 2021 Edition – Natural Refrigerants Market Forecast

Figure 17 - The evolution – CO₂ Transcritical installations in the world (2008-2021)





The number of transcritical CO₂ installations for the commercial sector has increased exponentially, from just 140 in 2008 to more than 38,000 in 2021. With an average annual growth of 39%, the years in which there was the strongest growth correspond with the entry into force of the regulation: 67% between 2014 and 2015 and 59% between 2015 and 2016. This relation proves that market players are attentive to policy regulations and can respond promptly. During the interviews, in fact, it was emphasised that one of the main drivers that would push the industry of natural-refrigerant-based heat pumps forward is clear signalling from policymakers in terms of prohibitions, widely considered as the most effective and clear signals.

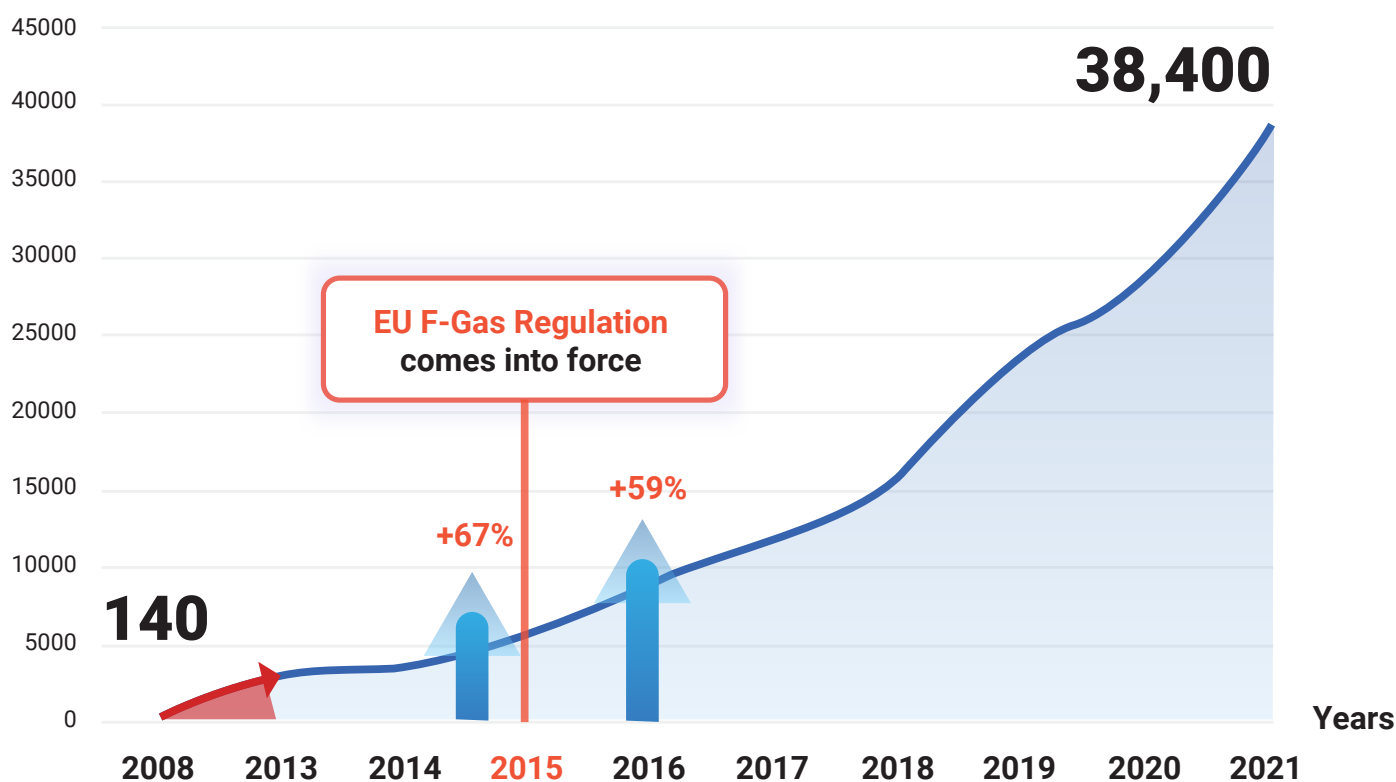
Both examples show how regulation can be a key driver for creating demand for natural alternative-based technologies. These specific bans, even if targeted at GWP levels much higher than those of natural alternatives, supported the implementation of very-low-GWP-charged installations.

These sectoral bans for the commercial refrigeration industry occurred in a context of a much lower production base than the current production of heat pumps charged with natural refrigerants, which is already a mature market.

The bans introduced in the commercial refrigeration sector were the signal needed to persuade industry stakeholders to shift directly towards ultra-low GWP

Figure 18 - Evolution of the number of transcritical CO₂ installations in Europe – commercial applications only (2008–2021)

Number of installations

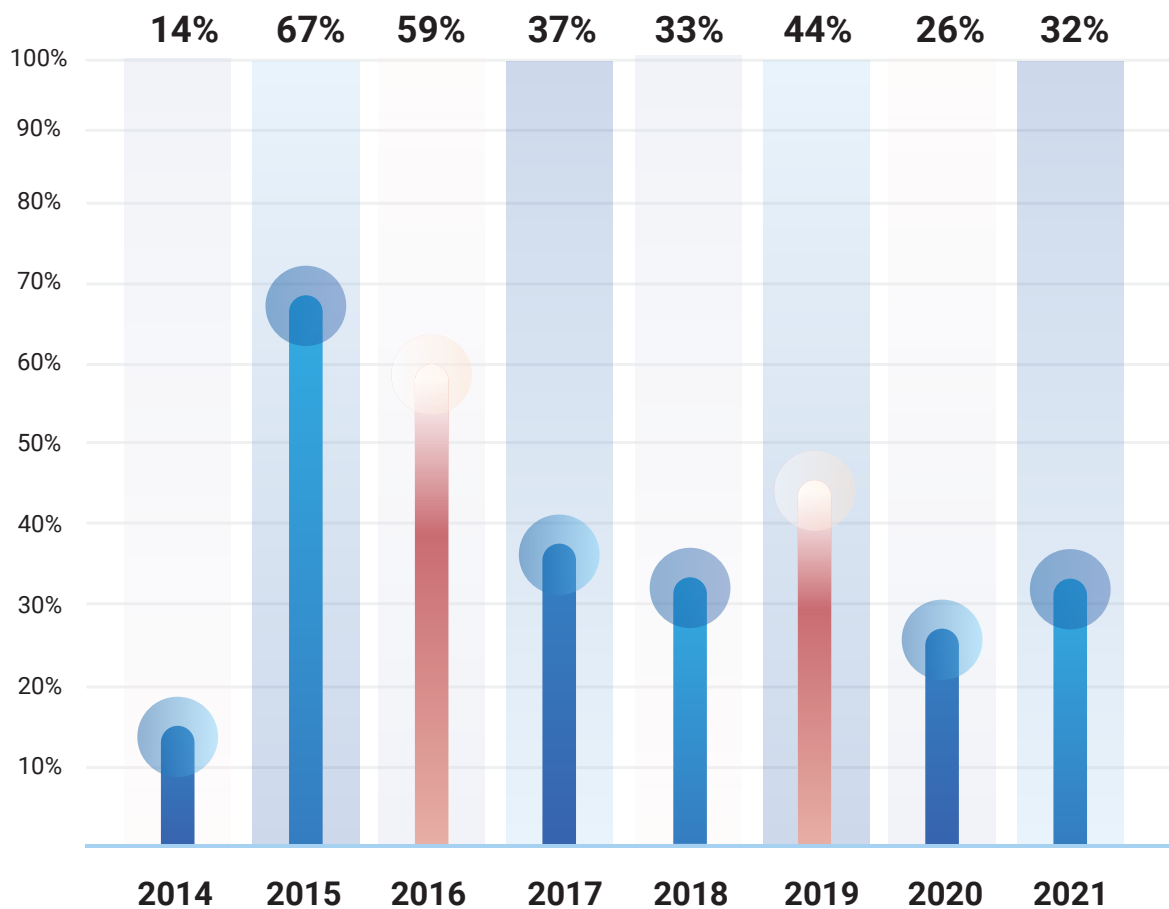


Source: Own analysis

natural heat carriers. Even if the average GWP level across bans on end-uses in the commercial sector was 1,550 (much higher than the R744's GWP of 1, used in transcritical installations) operators increasingly opted for climate-aligned solutions not relying on fluorinated gases and having ultra-low GWP, reporting considerable growth in the years following the entry into force of the regulation. With more tailor-made bans and measures preventing fluorinated gases to be locked into these appliances, together with the market readiness of natural refrigerant-based technology, we can assume that the story will repeat itself, and operators investing in these future-proof technologies will be able to secure sizeable market shares in the European heat pump market landscape.

As shown by the analysis, policy intervention clearly has been one of the main drivers of the widespread uptake of low-GWP systems relying on R744 and R290; market players sped up the uptake of these available technologies as soon as the current regulation came into force in 2015, implemented the changes much earlier than the actual start date of the bans (e.g., starting five years in advance) and future-proofing their investments adopting natural alternatives not subject to increasing measures under the EU F-Gas Regulation.

Figure 19 - Year-on-year percentage growth of transcritical CO₂ systems in Europe's commercial refrigeration



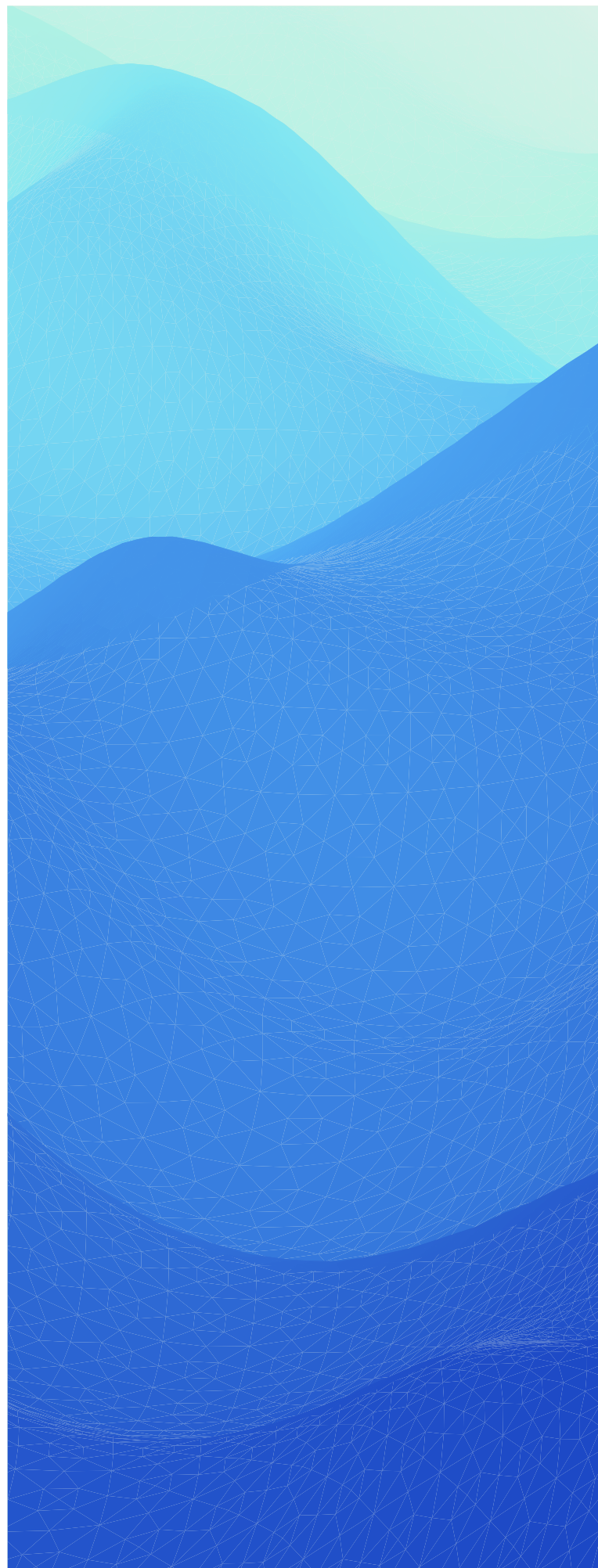
Source: Own analysis

6.7 IMPORTS AND COMPETITORS

The report on the competitiveness of the EU-based heat pump industry released by the European Commission suggests that, although Asian and American companies are dominating the global market in terms of air conditioning, EU companies are leading the world for mainly-heating heat pumps. In the past five years, though, Asian manufacturers have gained market share in this segment.¹⁰²

The sample group was also questioned about their level of concern around the possibility of losing market share to competitors outside the EU. Opinions differed, with some companies suggesting that, in fact, EU heat pump manufacturers see manufacturing heat pumps with natural gases (such as R290) as a way to gain a competitive advantage against Chinese producers, which are considered very highly skilled in the production of equipment with fluorinated refrigerants, particularly HFC-32.

The responses were unanimous in terms of not considering importing full heat pump units from outside the EU when meeting the growing demand, except in one isolated case. Imports of components and cooperation with non-EU manufacturers can exist, but the commitment is to scale up local production. R&D and production should be in the same factory. In addition, some manufacturers expressed concerns during the interviews about the quality and safety of non-EU products; European regulations are seen as essential to ensure safety standards in Europe, while products from outside struggle to meet them.



Conclusion

7

The aim of this exploratory research study was to provide decision-makers with support in showing that the decarbonisation of the European heating systems can be achieved without omitting action on fluorinated greenhouse gases.

To achieve this, the study has shared qualitative insights gathered from the European heat pump industry on its journey towards the uptake and scale-up of natural-refrigerant-based solutions.

In the residential sector, the decarbonisation of heating systems in Europe is often associated with the technological transition from fossil-fuel-powered appliances (such as gas or oil boilers) towards those using electricity, with primary reference to heat pumps.

Heat pumps deliver heat by means of renewable energy (temperature present in the environment surrounding the system) and electricity from the grid. This technology shows high energy efficiency, assuming that electricity from the grid will increasingly be generated by renewable sources. As such, heat pumps can contribute significantly to the decarbonisation of heating supplies in European households.

Heat pumps are set to play an important role in reducing emissions and energy consumption from the building sector, which accounts for roughly 40% of European energy consumption and is therefore considered the single largest energy consumer in the bloc. Energy for heating, cooling and domestic hot water accounts for 80% of citizens' energy consumption, and the same buildings we live in are also responsible for 36% of energy-related, indirect greenhouse gas emissions.

Industry stakeholders and forecasts from the European Commission suggest that approximately 40 million heat pump units are expected to be deployed by 2030 and approximately 50 million by 2050, according to different decarbonisation scenarios. Our research suggest that air-source heat pumps will be the technology bound to gain the lion's share of this deployment.

Not all heat pumps are the same, and equipment often relies on highly polluting synthetic substances to transfer heat from a source to a sink, i.e., moving heat to where it is used. These substances are identified as fluorinated greenhouse gases and are substances of concern primarily for their high global warming potential that contribute considerably to the greenhouse effect, especially when compared to available natural refrigerant alternatives with negligible impacts on direct emissions. Hydrofluorocarbons, or HFCs, are the most well-known substances in this group and are targets of a specific amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer (the Kigali Amendment).

This amendment, adopted in 2016, plans for the global reduction of production and consumption of HFCs; only meeting the goal of this amendment could reduce the temperature increase by up to 0.5 degrees Celsius. The European Union has long regulated these substances under regulations on ozone-depleting substances (Reg. (EC) No 1005/2009) and fluorinated greenhouse gases. The latter was first introduced in 2008 (Reg. (EC) No 842/2006) and then revised in 2014 (Reg. No 517/2014).

On 5 April 2022, the European Commission proposed a new amended version of the EU F-Gas Regulation, pursuing an alignment of this climate-related legislation with the overarching climate objectives enshrined in the European Union Climate Law. These would include reducing greenhouse gas emissions by 55% by 2030 compared to 1990 levels and reaching climate neutrality by 2050. All economic sectors need to contribute to these emission reductions, and the European Commission has stated multiple times that “business as usual” must change. Overall, the proposal strengthens the HFCs phase-down schedule (ca. 98% reduction on the allowed quantity by 2048 based on the level in 2015), and introduces prohibitions targeting heat pumps and air conditioners, namely:

- as of 1 January 2025, single split systems containing less than 3 kg of fluorinated greenhouse gases listed in Annex I that contain, or whose functioning relies upon, fluorinated greenhouse gases listed in Annex I with a GWP of 750 or more;
- as of 1 January 2027, split systems of a rated capacity of up to and including 12 kW containing, or whose functioning relies upon, fluorinated greenhouse gases with a GWP of 150 or more, except when required to meet safety standards; and

- split systems with a rated capacity of more than 12 kW containing, or whose functioning relies upon, fluorinated greenhouse gases with a GWP of 750 or more, except when required to meet safety standards.

Following the release of the proposal, trade bodies representing the interest of some of the industry’s incumbents have cautioned against intrusive policy action in this realm, revamping old concerns related to climate objectives, energy efficiency and safety. They believe that a tighter phase down of HFCs and the proposed bans will risk undermining climate objectives by slowing down the deployment of heat pumps across the continent. This stance is stressed even more against the need to phase out Russia’s imports of fossil fuels, in light of the country’s invasion of Ukraine.

However, the European Commission explanatory memorandum, released with the proposal, is clear in this regard: bans are introduced because alternatives are technologically ready and are available on the market. Even considering the urgency of the deployment of the technology to reduce reliance on Russian imports, the European Commission reports that a sufficient buffer is considered in place with the preferred HFCs phase-down option.

In addition, we have gathered from our interviews that these trade bodies’ stance on this regulation does not seem to be shared by all companies operating mainly with fluorinated refrigerants. A key manufacturer outright said that the regulation was not considered a barrier to the deployment of heat pumps.

Heat pumps running with naturally occurring working fluids, such as hydrocarbons, carbon dioxide and/or ammonia, are a market reality. With no ozone depletion and negligible global warming potential, these heat carriers are considered future proof -- unlike the new synthetic substances with low GWP being proposed as substitutes, which show worrisome features. In addition, domestic systems charged with natural refrigerants have also been found to be potentially less polluting on a life cycle climate performance analysis.

Our sample group interviews with heat pump manufacturers in Europe point to a growing presence of original equipment manufacturers across Europe with systems running with natural refrigerants in their portfolio. These companies are varied in size

and their commitments to phasing down fluorinated gases. Companies that have already significantly detached themselves from fluorinated working fluids reported confidence in their ability to quickly scale up production and reconvert old technology production lines pushed by the right policy framework. Not only are decarbonisation policy efforts seen as paving the way for the deployment of heat pumps, but also regulations affecting fluorinated greenhouse gases are held in high regard for determining the direction of travel.

These companies prefer to “leapfrog” their technologies directly towards ultra-low GWP solutions that are not subject to climate- or chemical-related regulatory constrictions, seeing intermediary steps – such as using HFC-32 or hydrofluoroolefins (HFOs) – as clouded in uncertainty and possibly leading to additional costs.

Fluorinated refrigerants are commonly more expensive than alternatives, because they are subject to restrictions at the global and EU levels. According to interviewees, HFC prices have increased and are expected to rise in the coming years; illegal trade is believed to have had a dumping effect on the market, preventing regulatory measures from fulfilling their original purpose. With the steeper phase down proposed, and assuming limited influence from illegal trade, surcharge estimates reach up to €37₂₀₁₉/tCO₂e in 2025 and €161₂₀₁₉/tCO₂e in 2050, with an average year-over-year growth of 35%.

In addition, China has recently adopted the Kigali Amendment, and, as the main producers of fluorinated substances at the global level and a major exporter of HFCs to the European market, a reduction in the tonnes produced is likely to increase the prices of these fluorinated substances. However, the prices of natural alternatives have proven stable and low; no interviewees have experienced price hikes with these heat carriers, and none have experienced any issues with availability on the EU market. Relying on natural alternatives to scale up the deployment of heat pumps was not listed as a concern in the interviews.

The science targeting fluorinated greenhouse gases is constantly improving, and, unfortunately, it is only uncovering the problems caused by these substances on Earth’s dynamic after the fact, forcing the global community to address the problem. This is the case for the ozone depletion and the global warming potential; more specifically, the same

HFC-32’s GWP 100-year value has been updated increasing from 677 to 771 in the Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) in 2021. In addition, its GWP 20-year is a staggering 2,530, which is a more realistic value to consider due to its short-lived presence in the atmosphere. Recent studies consider these synthetic substances as novel entities and point to Earth’s finite ability to cope with their exponential release into the environment, sounding the alarm on the deployment of the next generation of potential synthetic substitutes.

As European production of HFCs is being phased down due to successful regulatory efforts, RACHP stakeholders are relying on imports from outside the EU to satisfy their needs for fluorinated refrigerants. Sixty-six per cent of imported HFCs come from China, whose companies are pursued by other countries in their anti-dumping efforts, attesting to their ability to flood markets. Some EU-based stakeholders believe that operating with the HFC-32 working fluid would favour EU-based companies as extra EU market players are thought to have a competitive advantage when operating with alternatives, especially when it comes to heat pumps.

However, interviewees often held the opposite position, signalling that EU-based companies might have a competitive advantage in operating with natural flammable refrigerants due to the strict safety standards forcing European companies to excel in their products; non-EU companies are perceived to be more skilled in handling HFC-32 than hydrocarbons, specifically in the air-to-water heat pump market segment. This is also reinforced by interviewees’ commitments to opt for increasingly sourcing raw materials rather than importing off-the-shelf, pre-packed systems to sell in the EU market. Our findings also suggest that, besides a few exceptions, the Chinese industry operating with natural refrigerants is still “at an early stage of commercialization.”

We have seen from our research that the price difference between HFC-based equipment lines and natural refrigerant alternatives is generally below 20%, a difference that is mainly due to the need to handle flammable substances along the production line. This is also related to the need to source specific components capable of meeting the required standards. However, given the right policy framework in place, contributors to the study suggested that economies of scale can be easily

achieved as most of the components used in heat pump systems can be adapted from other RACHP sectors. The critical nature of policy intervention for the development of specific technologies is clear from the success story of natural alternatives in commercial refrigeration: both hydrocarbons- and carbon-dioxide-based technologies have been scaled up quickly.

Our research finds that carbon-dioxide-based installations in the commercial sector have grown from just 140 in 2008 to more than 38,000 in 2021, pushed by the introduction of prohibitions in the sector and a general phase down of HFCs, despite conservative concerns that these provisions would have hindered the sector due to natural alternatives considered unreliable, unsafe and energy inefficient. These are the same messages currently being conveyed regarding heat pumps. For the commercial refrigeration sector, all these points have been debunked.

Costs related to setting up a production line vary according to the targeted capacity – the construction of a new facility is reported as being the most burdensome cost. This cost is, however, not unique to natural refrigerant production lines; it applies generally to all projects. Likewise, other costs affecting industries, such as supply chain bottlenecks, energy costs and sourcing raw materials, also apply across the board. CAPEX costs are therefore not seen as particularly demanding for setting up the line of production for products dedicated to natural refrigerants, and companies' situations are very diverse in this regard. Interviewees estimate an increase ranging between 2 and 10%.

However, both the equipment price and the production line costs' percentage difference seem relatively small compared to the estimated percentage surcharge for HFCs in tandem with the phase-down schedule proposed by the European Commission, increasing 335% from 2025 to 2050.

EU-based companies active in the heating industry are also reconverting their old technology production lines to scale up the production of natural-refrigerant-based heat pumps with a delay of a few years (and with a commitment of up to three years). Besides some administrative barriers related to upgrading production sites for flammability-related

requirements, no other impediments were listed across the interviews. It is expected that production could be scaled up fairly quickly should additional sectoral bans on high-GWP refrigerants accelerate the demand for natural refrigerant heat pumps.

At the same time, first-mover OEMs that have set up production lines based on natural refrigerants are experiencing up to triple-digit growth in this market segment. Driven by existing policy measures, some of these stakeholders expect up to 90% of the heat pumps they produce to be based on natural refrigerants in a few years' time. Nevertheless, the same stakeholders fear that a lack of targeted regulatory measures might hinder the development of this market and relegate this product to a "niche".

The interviewees cited policy as the main driver for innovation (or lack thereof as the main obstacle to innovation) and gave information that points to the need to raise awareness of the problem posed by fluorinated gases and to support the demand for natural fluids, hence creating economies of scale that would eventually lower the small premium currently associated with producing these climate-aligned systems. By creating the mass demand for natural-refrigerant-based heat pumps through clear policy measures, the interviewed companies are set to gain from their early mover status; EU-based companies aim to meet the required amount of heat pumps as European households decarbonise.

The insights shared above support the stance that there should be no detachment between the timelines related to the decarbonisation of the heating sector and the wind-down of fluorinated substances used as refrigerants. To ensure a truly sustainable, future-proof heating industry, the two policy schemes must unfold in parallel, be aligned and be complementary. Transitioning to natural refrigerant heat pumps would eliminate a technically unnecessary middle step and achieve carbon-neutrality targets faster. The technology to leapfrog towards natural refrigerants in all kinds of heat pumps is already available in the EU market.

In light of the climate emergency we currently face, every single GWP reduction we can achieve counts greatly, and coordinated action across all policy realms should be considered the standard working method, not an obstacle.

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