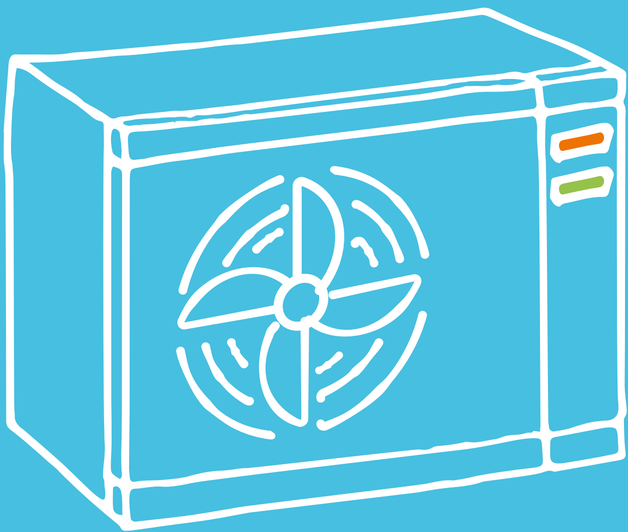

RETROFITTING HOMES WITH HEAT PUMPS: 12 STORIES ACROSS THE EU

HIGH TEMPERATURE HEAT PUMP IN EXISTING HOMES IN THE NETHERLANDS, POLAND, AND ITALY

COMFORT AUDIT 2 - FULL REPORT

Coolproducts is a coalition of European NGOs working to ensure that ecodesign and energy labelling truly work for Europeans and theenvironment. The campaign is led by the European Environmental Bureau (EEB) and ECOS.

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For a comprehensive analysis of the myths and questions associated with heat pumps you can also refer to this document.

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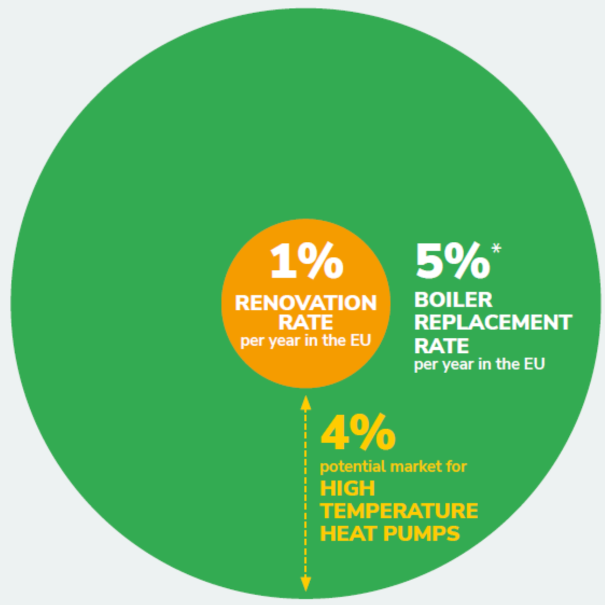
INTRODUCTION AND OBJECTIVE

Russia's illegal invasion of Ukraine has underscored the importance of reducing gas consumption in the heating sector – the bloc's second-largest gas market - to cut dependence on energy imports and to emphasize the need for sustainable and self-sufficient heating and cooling solutions within the EU. As a result, the urgency to decarbonize the sector has become a key priority for the EU, highlighting the importance of transitioning to cleaner and more resilient heating and cooling systems. An integral part of achieving these decarbonization targets is the use of heat pumps, which have gained increasing attention and public awareness, although some social, economic, and political challenges remain.

One foreseeable challenge of a mass heat pump roll out is the slow renovation rate in Europe. While gas boiler replacement rate in the EU is well above 5%[1] while the rate of renovation currently stagnates at only 1% of the building stock[2]. This means that there is a growing group who are at the moment switching from their boilers to electric alternatives but might hesitate and choose another boiler as their poorly insulated home might not reap the benefits of a conventional heat pump. This gap is where a market for high temperature heat pumps (HTHPs) lies: these are units that can replace old boilers in yet-to-be-renovated buildings to achieve temperatures above 55°C.



*considering 20 years as the average lifespan of a boiler, we get 100%/20 years = 5% per year

Traditionally used in industrial settings, HTHPs might have unexplored applications in many domestic settings that are ill-fitted to conventional pumps. However, the full potential and benefits of incorporating high temperature heat pumps in non-industrial settings have yet to be fully explored and understood. This lack of research may result in a missed opportunity to scale up an innovative technology that can provide clean heating and cooling solutions for different types of buildings, particularly in retrofit scenarios.

This report, drawing from previous literature (Section 1) as well as through in-depth interviews with 12 homeowners (Section 2), investigates the application of high temperature heat pumps (HTHPs) as a

[1] Turnover rates vary depending on the country, but considering 20 years the average lifespan of gas boilers this is a credible cautious estimate

[2] According to a figure from a 2022 report from Buildings Performance Institute Europe

retrofit option for non-industrial, domestic buildings, focusing specifically on scenarios where the entire heating system does not need to be renovated, with flow temperatures above 55°C. In order to assess the suitability (and benefits, if any) of HTHPs in non-renovated buildings, three factors will be investigated: 1) the potential for achieving financial savings, 2) the potential for energy savings, while also examining 3) the impact on occupants' quality of life. Beyond feasibility, this report also seeks to identify the challenges yet to be overcome, in order to feed the debate on the F-Gas Regulation and the Ecodesign and Energy Performance of Buildings Directives.

It should be stressed that the EEB does not in any way intend to promote the installation of heat pumps in non-renovated buildings when the possibility of renovation exists. The renovation rate of 3% per year should be reached as soon as possible and all renovations should achieve the highest possible energy efficiency ("deep renovations"). Only where this is not possible, i.e., where there are financial or logistical problems, should HTHPs be considered as a positive solution and a first step towards renovation.

SECTION 1 – DESK ANALYSIS OF EXISTING LITERATURE

DEFINITION OF A HIGH TEMPERATURE HEAT PUMP

The precise definition of a high temperature heat pump (HTHP) and the specific conditions under which a heat pump can be considered 'high temperature' remain the subject of ongoing debate within the industry. Various definitions have been considered in the studies published over the years, but no consensus has been reached.

Heat pumps cover a wide temperature range, from a heat sink temperature of 0°C to 140°C. In Arpagaus et al. (2018), three categories of heat pumps are presented, each based on the relationship between their heat sink and heat source temperatures. High temperature heat pumps (HTHPs) are specifically classified in the range of 80°C to 100°C for heat sink temperatures. These three categories are also mentioned in Hamid et al. (2013), where HTHPs fall into a heat sink range between 80°C and 100°C and a heat source temperature between 40° C and 60° C.

In their Hassan et al. (2022) study focusing on the design and performance of HTHPs in thermal energy storage applications, the authors' HTHP design includes a heat source between 40°C and 100°C and a heat sink above 130°C. Notably, this range slightly overlaps with the results reported by Arpagaus et al., highlighting the similarities between the temperature ranges considered for HTHPs in both studies.

An additional classification of heat pumps is based on their flow temperature, which refers specifically to the temperature of the water in the supply pipe within a heating system or its different components. In Shah et al. (2018) study on field trials of HTHPs in domestic retrofit systems, the authors identify heat pumps with a flow temperature of 75°C as HTHPs.

In addition, the outlet temperature appears to be another metric used to define an HTHP. According to the Carbon Trust (2016), high temperature heat pumps are classified as products that are capable of producing an output temperature of 65°C or higher. This criterion serves as an additional parameter to differentiate HTHPs from other heat pump systems.

In our study, we decided to focus on the output temperature. In the interviews we conducted alongside this analysis, **we assumed that a high temperature heat pump is one that achieves an output temperature greater than 55°C.** This criterion is based on the understanding that achieving higher temperatures is less common in the domestic sector, reflecting the range of HTHPs currently available on the market. Therefore, from this point forward, HTHP will refer specifically to the above definition, recognizing that discussions on this classification are still ongoing.

HIGH TEMPERATURE HEAT PUMPS IN DOMESTIC SETTINGS

The use of high temperature heat pumps in residential buildings is a relatively new field with limited research available. A comprehensive analysis of the existing literature reveals a remarkable disparity, with most studies focusing primarily on the industrial application of HTHPs, overlooking the unique considerations and challenges associated with residential applications.

Furthermore, the limited inclusion of practical examples further exacerbates the gap in understanding the potential of HTHPs in domestic settings. The existing literature does not adequately address the performance evaluations, user satisfaction and operational considerations that are critical in the residential sector.

As a result, the current body of research on HTHPs in domestic settings is comparatively sparse, hindering a comprehensive understanding and exploration of their full potential in residential applications. The following subsection will analyse existing studies on the use of HTHPs in the domestic environment, while the subsequent Section 2 complements the review with insights from interviews with 12 individuals who have successfully integrated HTHPs into their homes.

LITERATURE ANALYSIS

To gain a comprehensive insight into the current public perception and market dynamics of high temperature heat pumps, we conducted a literature analysis of available research papers. Focusing on papers no older than 10-11 years to maintain relevance, we primarily looked at users' feedback, insights into changes in energy consumption and expenditure patterns, and the rationale behind the adoption of high temperature heat pumps. Our analysis also spans different climate zones and housing scenarios with limited or no retrofitting possibilities.

Navigating through the literature was challenging due to the predominant industrial focus of high temperature heat pumps. Out of a total of 20 publications reviewed, only 9 met the criteria for inclusion in our literature review. These papers were selected based on their ability to either show concrete examples of high temperature heat pumps deployed in the domestic sector or offer comprehensive market analysis, including public feedback.

In this literature review, we have carefully examined several studies that deal with high temperature heat pumps (HTHPs), both from a broad perspective and on a country-specific level, covering Greece, the United Kingdom and Italy. Our initial approach was to examine broader studies to gain insights into the overarching landscape of the HTHP market. This approach allowed us to delve into essential facets such as definitions and temperature characteristics, such as that found in the works of Arpagaus et al. (2018), Hamid & et al. (2013), and Shah et al. (2018).

We then turned our attention to studies that focused on specific countries. For example, the Greek context was explored through a study by Bellos et al. (2023), hereafter referred to as 'the Greek study'. This study analyses the use of HTHPs in two prominent Greek cities: Athens and Thessaloniki.

Finally, we turn our attention to the United Kingdom, with a closer look at Northern Ireland. A study by Shah and Hewitt (2015), hereafter referred to as 'the UK study', examined the impact of HTHPs on test houses designed to 1900s specifications to mimic "hard to heat" domestic conditions.

In the following subsections, we will examine three key areas of interest that have emerged as critical in the context of pre-HTHP and post-HTHP scenarios, drawing on insights from comprehensive studies. First, we will look at the energy savings attributed to the implementation of an HTHP system in the residential sector. Our aim is to determine whether the introduction of an HTHP offers any discernible benefits in terms of energy savings compared to the previous heating system, typically fossil boilers or biomass. We will then focus on the financial costs and benefits associated with owning an HTHP. Finally, our focus will shift to the comfort dimension, looking particularly at heating comfort and ease of maintenance.

ENERGY SAVINGS

When considering a transition from traditional oil or gas boilers to heat pumps, concerns about energy savings often arise. The prevailing belief is that heat pumps require more energy to achieve the same level of heating compared to gas or oil boilers. However, the studies we looked at have shown promising results that challenge this assumption, even when HTHPs are taken into consideration.

According to the Carbon Trust (2016), in the UK, installing a high temperature heat pump instead of a gas or oil boiler can result in significant energy savings of up to 70%, ranging from 9,480 to 11,710 kWh/year. In addition, this switch offers a significant reduction in CO_2 emissions, with potential savings ranging from 30% to 64% in terms of $kgCO_2/yr$.

The Greek study showed that when comparing HTHPs with oil boilers, the former achieved a combined 10% reduction in primary energy consumption in both cities. In addition, HTHPs contribute to a reduction in CO_2 emissions of more than 30%, especially when the heat pump uses an environmentally friendly working fluid.

In an interesting theoretical study by Carella et al. (2023), the authors analysed the potential benefits of installing high temperature air-to-water heat pumps in buildings equipped with radiators without the need for major renovations in the cities of Milan and Salerno. The results of the analysis showed remarkable potential improvements in terms of energy efficiency and CO_2 savings. In particular, the study showed a significant reduction in primary energy consumption, ranging from 34% to 54% in Milan and from 43% to 60% in Salerno, taking into account different levels of renewable energy in electricity generation. These results underline the significant potential for energy and environmental gains from retrofitting homes with high temperature heat pumps in both cities.

FINANCIAL SAVINGS

Financial savings is one of the most important concerns for people considering switching from a gas or oil boiler to a heat pump. A common assumption is that a heat pump would use more energy to achieve a comparable level of heat compared to a gas or oil boiler. In addition, people are also discouraged by non-operational costs: from the purchase, installation, maintenance costs to the perceived cost of having to renovate first for the pumps to perform. The perceived high costs often discourage people from investing in heat pumps, unless financial incentives and policies are put in place.

However, both our desk research and our interviews show a clear case financial savings after the switch.

The Greek study, the only academic study which takes financial savings into account, calculates the life cycle cost which shows a range of current net savings, estimated at between EUR 5,000 and EUR 7,500 over the life of the product. In addition, the investment has an attractive payback period of 6 to 8 years. These results strongly suggest that the investment is a highly profitable venture, with significant returns to be expected.

The level of energy cost savings will depend on the current market price of gas, oil and electricity. However, as highlighted above, the decision to invest in a high temperature heat pump (HTHP) will often result in significantly reduced energy consumption in the long run and therefore posing the investment as one that pays back.

COMFORT

The use of heat pumps in retrofit scenarios has often been met with scepticism due to concerns about the extensive renovations required to accommodate these new heating systems. However, HTHP studies have challenged this notion by demonstrating that these pumps can still operate successfully in non-renovated or lightly renovated buildings, unlike conventional pumps which may require major renovations to the heating system to provide adequate heating.

The UK study examines the practical application of high temperature heat pumps as retrofit technology in domestic buildings. Specifically, these were purposely built with poor insulation, rented out to families, and then subsequently fitted with different heating technologies, including an HTHP, to compare their performances. The HTHP successfully replaced the existing gas boilers without requiring any modification or replacement of the existing controls or radiators in the house. The study showed that such heat pumps can be conveniently installed in domestic buildings, even in areas with weak gas or low voltage networks, without the need for additional insulation or replacement of existing radiators or control systems. The results of the study are promising even with a “hard to heat” condition. This suggests that a high temperature heat pump can effectively maintain a comfortable temperature in unideal conditions comparable to the heat of a gas or oil boiler, regardless of their success in providing energy savings.

A recent study conducted by Shah et al. (2018) delved into the analysis of integrating a HTHP with thermal energy storage to assess its potential for improving comfort and achieving cost savings in a retrofit scenario in the UK. The study showed promising results, indicating that HTHPs can be installed and used effectively without the need for extensive modification or replacement of existing radiators and controls. In addition, this integration ensures that user satisfaction is not compromised and the need for frequent maintenance is minimised.

Finally, the Greek study on high temperature heat pumps in retrofit scenarios in the north and south of the country compared two buildings in Athens and Thessaloniki, where an air-to-water HTHP was considered as a replacement to the existing oil system, keeping the existing radiators and avoiding a renovation scenario.

The study showed that the HTHP studied was an optimal solution in terms of comfort for both locations, despite differences in the usage patterns of each city. According to the authors, Athens is in a climate zone with a milder and generally warmer climate, while Thessaloniki is in a more humid, subtropical climate. The authors noted that by keeping the existing radiators and curbing renovation might have also had positive impacts such as quieter operation compared to underfloor heating and a reduction in the spread of dust throughout the house, which were some common concerns associated with pumps at the time.

Overall, research shows that HTHPs not only maintain a comfortable temperature comparable to traditional boilers across different EU climate zones, but also significantly reduce pollutant emissions, contributing to improved air quality in urban areas. In addition, the studies emphasize the minimal invasiveness of HTHPs, ensuring user satisfaction and providing long-term solutions for reducing air pollution while achieving energy and environmental cost savings.

CHALLENGES

The primary challenges in the domestic sector identified by the various studies mostly concern installation and investment costs rather than the technology itself. Moreover, user perception, limited awareness, and high capital costs continue to be significant barriers that prevent individuals from adopting innovative technologies.

The study conducted by Hamid & et al. (2013) offers a comprehensive examination of the significant challenges faced by HTHPs in the residential sector, many of which are still applicable as of today. The research sheds light on several key obstacles encompassing technological limitations, economic factors, regulatory issues, policy uncertainties, and public acceptance concerns.

Beyond the process barriers, technological challenges seem to arise from the strain on electrical networks due to increased electrification in the heating sector, while economic barriers stem from the high upfront investment and installation costs associated with HTHPs. Regulatory challenges include the absence of standardised guidelines and mandatory policies, further complicating the widespread adoption of HTHPs. Additionally, the Carbon Trust (2016) states that installation and maintenance challenges in older generations of HPs might have an impact on people's perception of the investment, which might not necessarily apply to newer generations.

Policy uncertainties and a lack of clear pathways for heat decarbonisation and technology uptake hinder progress within this domain. Additionally, public acceptance issues such as unwarranted fear, misperceptions, misinformation, and past experiences regarding heat pump reliability pose obstacles to broader awareness and acceptance of HTHPs. There is a need to enhance public understanding of the financial and environmental benefits associated with HTHP integration currently. Addressing concerns regarding noise pollution, a potential drawback of HTHPs, can be mitigated through the implementation of noise barriers to maintain noise levels within acceptable limits, ensuring minimal disruption to neighbourhoods.

PART 2 – INTERVIEWS WITH 12 CASE STUDIES

INTERVIEW METHODOLOGY

In order to complement our desk research with more recent evidence, we conduct a qualitative analysis on a small sample of HTHP users throughout the European Union.

The interviews were conducted in The Netherlands, Italy and Poland, covering three relevant climate zones in Europe for the heating sector. Specifically, we focused on the northern, coldest areas of these countries. The participant from The Netherlands is a part of a pilot project, whose review of the heat pump system is representative of six identical homes of the same complex fitted with the same technology in Heemskerk.

For our interview process, we used a qualitative approach and reached out to individuals who have integrated an HTHP into their residences. Additionally, we communicated with HTHP manufacturers to gather more insights.

We obtained the names of the customers either via installation companies or EEB members and we reached out to them via email or phone. The questionnaire was the same for everyone and was translated into the local language of the country. The questions were designed to allow for both multiple-choice responses and open-ended insights.

The questionnaire was structured to cover a range of essential subtopics identified already in the research in Section 1. This includes the assessment of comfort improvements, financial outlay, applied subsidies, installation timeline, energy consumption patterns, quantifiable financial and energy savings, as well as the specifics of the dwelling types involved.

We cooperated with the EEB's member Institute for Sustainable Development in Poland, with TEON in Italy and with Vattenfall in the Netherlands. All interviewees agreed to have their data collected and published in this document.

The overview of participants can be found below.

12 homes

11 towns

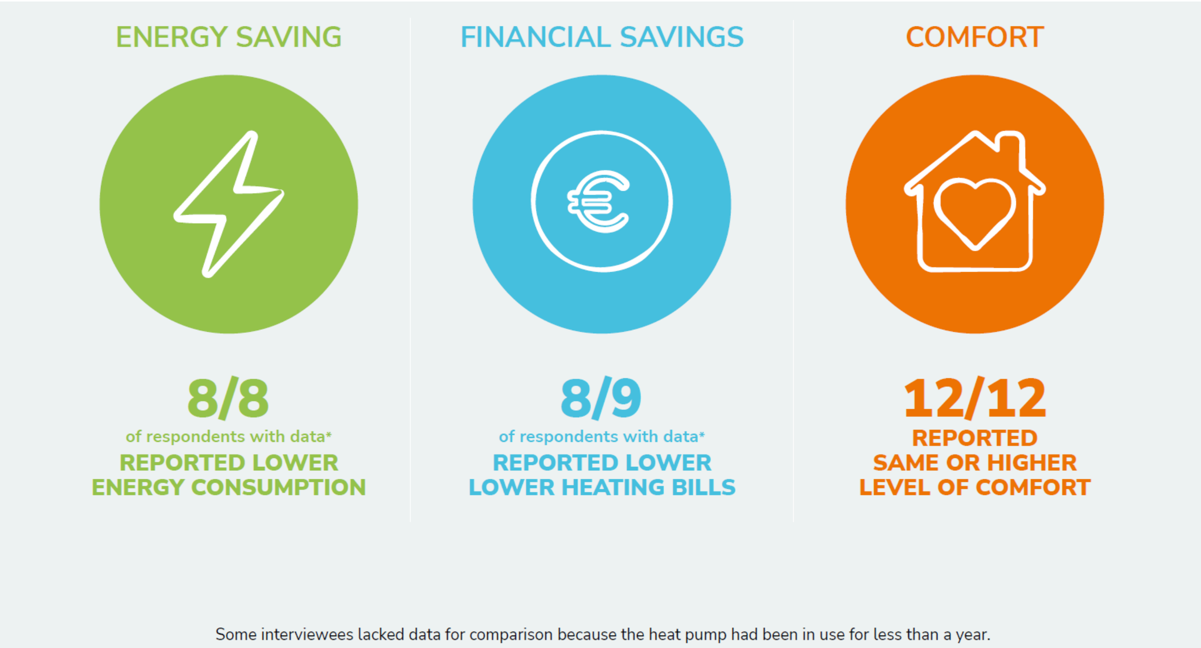
3 countries

4 types of refrigerants

5 heat pump producers

INTERVIEW FINDINGS

The findings in our interviews were largely positive, with the majority reporting lower energy consumption, lower heating bills, and the same or higher level of comfort. The section below deep dives into each of these aspects.



MOTIVATION FOR THE CHANGE

When asked what motivated them to transition to HTHPs, respondents listed factors such as increased comfort, avoiding the rising costs of gas and pellets over time, reduced maintenance needs, a need for adequate heating without having to change radiators and a positive impact on the environment. Our interviews revealed that one of the main reasons people choose high temperature heat pumps was because of their old heating system set up (e.g., radiators) was the most compatible with HTHPs. Two interviewees mentioned having been suggested to opt for an HTHP by the installers themselves. Some participants were already familiar with HTHPs prior to installation, which helped them foresee the benefits.

In our Dutch interview, we discussed a special case where the local social housing management body decided to switch to HTHP to improve the energy efficiency of their publicly owned neighbourhoods. The interview took place in a complex of six houses, each approximately 110 m2 in size. All houses were equipped with the same type of heat pump. The switch enabled them to move from a lower energy class to B.

On the reason for why respondents preferred HTHPs over conventional HPs, the majority cited challenges related to radiators replacement and better warming capacities as factors in their decision-making process. A few also mentioned friends' or acquaintances' recommendations as a motivation to choose HTHP instead.

ENERGY SAVINGS

Out of the 8 participants with the data, 8 reported lower energy consumption overall after switching from a fossil fuel or biomass system to HTHP. The findings from our interview corroborate the findings from previous literature.

One interviewee, G.Z., experienced a significant reduction in energy consumption. Before adopting the HTHP, his family used 1,885 cubic meters of gas and 4,115 kWh of electricity. After installing the HTHP, with the gas consumption dropped to zero, their total electricity consumption increased to 5,731 kWh. However, they installed photovoltaic panels and sold the surplus energy (2,403 kWh), resulting in a net energy consumption of 3,328 kWh. Essentially, this household achieved a double-fold energy saving by shedding both electricity and gas usage, showcasing the substantial benefits of the combination of both HTHP and solar technologies.

Before the intervention, R.A.'s annual energy consumption included approximately 1,000 litres of heating oil (equivalent to roughly 10,000 kWh) and 1,300 kWh of electricity for domestic hot water and other purposes. After the intervention, the interviewee estimates that electricity consumption will increase to around 4,400 kWh, with 3,500 kWh allocated to the heat pump. R.A. also installed photovoltaic panels that generated approximately 8,000 kWh, of which 2,000 kWh were used on-site, and the remaining 6,000 kWh were fed back into the grid.

F.G. stated that the annual consumption for heating and domestic hot water in his block of flats was around 7,000 to 7,500 cubic meters with gas. Now, the overall energy consumption is approximately 75 MWh, hence slightly lower than before They installed a hot water tank storage alongside a HTHP.

In Poland, two interviewees reported using 3,000-5,000 kg of pellets per year for their previous heating systems, which equates to around 14400-24000 kWh[3]. However, after installing a heat pump, their energy consumption significantly decreased. C.B. now reports an annual consumption of 3,600 kWh, while P.K. reports a consumption of 7,000 kWh.

The results illustrate the tangible energy savings achieved in Italy, The Netherlands and Poland and confirm the effectiveness of high temperature heat pumps in improving energy consumption patterns.

FINANCIAL SAVINGS

Overall, interviewees consistently reported reduced heating expenses as the main financial benefit, and interviewees overwhelmingly reported reduced energy-related costs and financial savings. Out of the 9 interviewees with data, 8 reported already observing lower heating costs, highlighting the financial ease of running a heat pump. However, three of them believed cost savings would have been possible without PV panels. Purchase and installation costs, on the other, vary depending on the country and can pose as an economic barrier to some.

With regards to operational cost, R.F. in Italy mentioned a 50% cost reduction for each block of flat, decrease the expenditure from EUR 11,000 to EUR 6,000.

[3] It is important to mention that in Poland, most of our respondents had a pellet stove as their heating system prior to the conversion. To aid with comparison, we use kWh as the main unit of energy measurement, applying a conversion of 4.7-4.9 kWh per kg of pellets (World Bioenergy Association, 2014).

In Poland, two of the interviewees reported lower costs and more savings than before. It is important to note that 4 out of 5 Polish interviewees had installed or were using photovoltaics alongside the heat pump, resulting in reduced energy costs compared to the cost of pellets. C.B. acknowledges that the photovoltaic panels generate enough energy to fully offset the costs. Without them, expenses would be around PLN 4,000 PLN (approx. EUR 900). Lastly P.P. reported a 60% decrease in expenses, from PLN 7,268 (approx. EUR 1,660) to PLN 3,630 PLN (approx. EUR 830). Two interviewees mentioned higher costs due to higher electricity prices in Poland, an issue that can be overcome through PV installation.

H.B., who took part in the Dutch pilot project, also mentions higher costs due to increased electricity consumption but does not provide information on the previous costs of the gas heating hence a comparison with the previous heating system cannot be done. His family also had their bills covered during a trial period by the project; a measure to prevent possible initial increase of the energy bills for the families. They have also installed solar panels and are waiting for a battery to reduce costs.

A slight majority of interviewees mentioned using national subsidies designed to incentivise the transition to HPs.

In Italy, the "*Superbonus*" is the primary subsidy for heating system upgrades. R.F.'s family installed an HTHP with the help of the "*Conto termico 2023 GSE*" national subsidy for thermal energy and a bank loan to cover the remaining expenses. By using this subsidy, tenants in the block of flat did not have to pay any upfront cost for the transition. F.G. also mentions a loan/subsidy that covers 50% of the investment costs, which means payback time was merely 7 to 8 years from purchase.

In The Netherlands, H.B. is a part of a pilot project where the social housing management body decided to switch to HTHP to improve the energy efficiency of their real estate. As a resident of such social houses, the family was able to benefit from this investment.

In Poland, only two households got access to public support: P.P., mentions employing a subsidy provided by their City Council, which covered 30% of the total costs, approximately amounting to EUR 4,000. M.P. mentions not receiving any subsidy but benefiting from a tax deduction. They also mention the estimate payback time for their investment is 10-12 years. One Polish participant remarks that the cost of purchasing a heat pump in Poland was around PLN 50,000 (EUR 11,000) at the time the interviewees made the purchase. This amount can pose a significant financial challenge for families with limited incomes, highlighting the importance of subsidies to address affordability concerns.

COMFORT

All of our interviewees have reported feeling more comfortable after installing a high temperature heat pump for heating. This is due to improved heating in the home and reduced maintenance and control requirements.

R.A. stated that their comfort level increased after installing a HTHP, as the indoor temperature is now more consistent. The time required to reach a comfortable temperature (18°C) has decreased. Previously, it took at least 24 hours, but now the time has halved to around 12 hours.

Interviewee R.F. also notes a heightened sense of comfort following the installation of the HTHP. They highlighted their satisfaction with the improved and comprehensive management of the heating system, coupled with the advantage of reduced maintenance requirements.

Multiple interviewees having used biomass for heating purposes have stated that decreased maintenance and refill time of HPs leads to an overall increase in perceived comfort, even if thermal comfort remains unchanged. This is particularly true for Polish interviewees. C.B. notes that while thermal comfort remains the same, the overall comfort related to daily life has become 'incomparably greater' due to the elimination of the need to add fuel to the stove.

P.K. shares that the heat pump provides the same level of perceived thermal comfort as a boiler, but much easier and more comfortable since the heat pump does not require constant control and fuel additions by the user.

P.P., who retrofitted their home with a mid-temperature heat pump, mentions experiencing uncomfortable temperature spikes when using a gas boiler. In contrast, the heat pump keeps the temperature of the radiators stable, resulting in a consistent room temperature.

CHALLENGES

Overall, our interviews showed that homeowners did not face many challenges when discovering, installing, and financing an HTHP system. This positive experience was in some cases due to the availability of subsidies during the installation phase, which significantly simplified the decision-making process. The tone of the replies was overall positive: interviewees did not mention any significant obstacles they encountered; instead, they expressed satisfaction with their decision.

Although most interviewees did not express concerns about time constraints, a few instances stood out where the installation process was connected to other projects or where the length of the permitting procedure and subsidies led to delays in the installation timelines.

In Poland, two interviewees highlighted how the high national cost of electricity might be a challenge or even an obstacle to installing heat pumps in their country. One respondent noted that in his case the HTHP brought him heating costs roughly 20% higher than those of pellet stoves. Both planned on installing photovoltaic (PV) panels to reduce overall utility expenses, however one interviewee noted that the installation of PV panels is no longer as economically advantageous as it used to be, adding that this increases payback time and may not completely offset the expenses associated with using a heat pump.

Discomfort linked to noise from the HTHP, a common criticism of heat pumps, was mentioned in only one interview. The interviewee acknowledged that the problem stemmed from an improper installation of the heat pump within the building. The problem was quickly resolved. The interviewee went on to emphasise the significance of proper installation practices as a key to ensuring optimal performance and user satisfaction for heat pumps.

Despite the challenges, it is worth nothing that none of the 12 interviews regretted the choice of installing a HP or planned to revert it.

OVERALL CONCLUSION

The European Union's focus on decarbonising heating and cooling has made the deployment of self-reliant, reliable and sustainable solutions more urgent. High temperature heat pumps have shown itself to be a worthy alternative to fossil fuel heating in homes that require higher temperatures than conventional heat pumps, particularly those which cannot be renovated or has yet to do so. Both our literature analysis and interviews, covering a large climatic range for heating needs in the EU from Greece, United Kingdom, Italy, The Netherlands and Poland have shown that replacing traditional boilers and stoves with HTHPs can result in significant energy savings, lower bills, at no sacrifice of comfort.

Our sample of interviews revealed that the adoption of HTHPs is driven by key factors such as energy savings, financial gains, and enhanced comfort. These findings are based both on the literature review and the interviews. HTHPs play a significant role in non-renovated buildings by reducing maintenance needs and decreasing dependence on fossil fuels. Positive environmental impacts are also another driver for adopting more sustainable heating solutions.

Despite the common perception that heat pumps are consuming more energy due to higher electricity consumption, our research suggests that HTHPs are highly energy efficient, and can result in up to 70% lower energy consumption when taking in consideration the massive energy use of fossil fuel and biomass heating systems.

Although the energy savings are evident, lower bills depend on the mix of local policies concerning installation subsidies to electricity pricing compared to fuels. In some Polish households cost savings can only be achieved when coupled with photovoltaics and/or storage due to comparatively high electricity pricing. However this integrated approach demonstrates the versatility of heat pumps coupled with solar systems in reducing expenses and minimising the environmental impacts.

When it comes to comfort, both the analysed studies and interviews show the success of HTHPs in various climates, addressing challenges such as heating comfort and maintenance needs, which in cases of biomass are perceived as an important improvement of comfort.

Drawing from previous literature complemented with our own case studies of the current market, we are confident to say that high temperature heat pumps offer a viable solution for decarbonising heating, particularly in cases where retrofitting is not feasible as that they can provide the same level of comfort while reducing energy consumption and considerably lowering bills, particularly when combined with solar.

POLICY RECOMMENDATIONS

Taking into consideration the benefits and current challenges faced by HTHP users, the following are our policy suggestions:

1.

Ensure a dedicated electricity tariff enjoying the lowest possible taxation is present in every Member State: many interviewees report that their investment would not be paying back without the support of self-produced electricity and/or storages to offset peak consumption. These solutions might not be available in all buildings.

2.

Whenever possible, promote solar and storage alongside HTHP, particularly in renovation, as this improves the payback time of the investment and guarantees lower running costs compared to fossil solutions.

3.

Promote dedicated training and awareness raising on these technologies in the existing heating workforce and future professionals: the technical expertise has been mentioned as a key factor for the adoption of HTHP in several interviews.

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ANNEX 1 - SURVEY ON THE SWITCH FROM BOILER TO HEAT PUMP: DWELLINGS, MOTIVATIONS, AND BENEFITS

This survey aims to collect information regarding the transition from a gas boiler to a heat pump, specifically high temperature heat pumps. We seek to understand the motivations behind this choice, the type of dwellings involved, and evaluate the benefits obtained. The data collected are essential for an in-depth study on high temperature heat pumps in homes without or with minimal renovation. By choosing to participate in this survey, you authorize us to use your name and city for the purpose of analysing responses and providing aggregated results. We assure you that all personal information collected will be treated with the utmost confidentiality, nonprofit, and used solely for research purposes.

1- Please write your full name.

2- Please write your current city and country.

3- In what kind of dwelling are you living?
   a. Rural house
   b. Individual house
   c. Terrace house
   d. Flat with individual heating
   e. Flat with centralized heating

4- Do you live in a heritage building?
   a. Yes
   b. No

5- Why did you decide to switch from a gas boiler to a heat pump? What motivated this change, and what other factors played a role in your decision?

6- What type of heat pump do you have now?
   a. A high temperature heat pump that can reach more than 55°C b
   b. A mid temperature heat pump that can reach between 45°C and 55°C
   c. A low temperature heat pump that can reach below 45°C

7- Please specify the brand and model of your current heat pump.

8- What is your level of perceived comfort compared to before? Feel free to elaborate further.
   a. Higher than before
   b. The same as before
   c. Worse than before

9- How long did it take you to install the heat pump?

10- Have you carried out other works other than substituting the boiler? For example, insulation installation or radiator replacement?

11- If you have a high temperature heat pump, why didn't you opt for a conventional low-temperature heat pump?

12- How much did you spend on the project? Did you get any subsidies for it?

13- Is your expenditure for heating your home higher or lower with the implementation of your new technology? Feel free to elaborate further.
  a. Higher
  b. Lower

14- Do you have an estimation of the number of years it will take to recover your investment? If yes, could you please provide the approximate duration?

15- What was your yearly energy consumption measured in terms of cubic meters of gas or liters of oil when using a boiler? Could you provide information on your current energy consumption with the heat pump?

16- Would you recommend switching to a heat pump? Do you have any complaints?

17- Faces and images would help the decision makers, the main recipients of the study, understand that we are discussing of real-life cases. In this sense would you:
  a. be happy to be mentioned with my first name and my town
  b. be happy to be mentioned with my first name and my town and happy to provide a picture of my home or my family
  c. prefer to remain totally anonymous