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Heating flexibly with heat pumps

An economic pilot study

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FACULTEIT ECONOMIE EN BEDRIJFSKUNDE

KEY FINDINGS

- **We used large-scale surveys and a field experiment to explore households' interest and expectations in schemes that adjust their heat pump to match electricity demand with renewable production.**
- **People are interested in such programs:** Over 70% of survey respondents expressed willingness to join flexibility schemes, primarily to contribute to environmental goals. The difference in interest between early adopters (energy cooperative members) and the general population is minimal.
- **But they expect money in return for this:** In the surveys, we asked how much money people expect in return when a heating interruption of unspecified duration lowers their indoor temperature. Our analysis shows households expect €1.40 to €3.04 for each additional degree of temperature drop. Surveys also showed that households expect to always stay partly in control over their heating, wanting advance notice of interruptions and/or the option to stop them and restore normal heating if needed.
- In addition to the empirical research based on surveys, we conducted a flexibility program in practice in nine well-insulated homes in Ghent, where a total of 287 heat pump interventions were conducted during the winters of 2022—2023 and 2023—2024. The heating was remotely interrupted until it was either automatically resumed or manually restarted by the household.
- Flexible heating reduced electricity demand. On average, the net reduction of electricity demand was 1 kWh per intervention per heat pump.
- Most interventions maintained thermal comfort. Even during the interventions that were manually stopped by households (19%), indoor temperatures had only dropped by 1°C on average.
- **In well-insulated houses, there is plenty of room for playing with heating flexibility:** Our findings show that when heating is paused or shifted by a few hours, indoor temperatures cool down only slowly. This means households with good insulation can benefit from flexibility without being noticeably discomforted. With a dynamic electricity contract, such flexibility can also save money.
- Maximum savings on heating bills can be achieved in the future when fully automated systems for smart heat pump control enable frequent interventions on a continuous basis, without households noticing much of it. This is the way to maximize savings from heat pump flexibility in the long term. While this advanced "automation concept" falls outside the scope of our experiment, recent academic studies show that such setups can reduce electricity bills by up to 18%, even when households are allowed to set temperature limits to ensure comfort.
- Policymakers should focus on encouraging the development of protocols and standards for finer, adjustable settings to optimize heat pump flexibility within each household’s comfort boundaries. **Not only should the transition to heat pumps *per se* be facilitated, but also their operation in the smartest possible way to minimize operational costs**.

INTRODUCTION

THE NEED FOR ELECTRICITY FLEXIBILITY

As renewable energy grows, new challenges and opportunities emerge for electricity systems. Unlike conventional generation, the output of renewables like wind and solar is variable. Given that **electricity demand must match production at every moment**—otherwise risking blackouts or curtailments—**electricity demand needs to be made flexible to align with the availability of wind and solar energy**. Even as battery storage in various forms becomes cheaper and more widely adopted, it remains valuable to complement it with a more flexible electricity demand.

Not only is this necessary for grid stability, but it also benefits the environment. Demand flexibility reduces reliance on fossil fuel plants, which emit CO_2 and often set marginal electricity prices, driving up electricity bills. By making better use of renewables—which produce at very low marginal cost—**flexibility lowers emissions, enhances energy security and increases independence**. The latter became critically evident during the energy crisis caused by disruptions in Russian gas supplies due to the war in Ukraine.

The European Union has recognized this need and projects that demand flexibility for managing daily electricity consumption peaks will double between 2021 and 2030, reaching up to 362 TWh annually[1] (about six times Belgium's annual electricity consumption). Households are a key part of this. As discussed in a previous *Gents Economisch Inzicht* (see section "For more information"), where we analyzed 150 empirical estimates of household flexibility across 44 academic studies, **residential electricity demand must become more flexible**. In fact, many households are already contributing to it in small ways. For decades, day-night tariffs have incentivized households with the appropriate electricity meter and contract to shift energy-intensive tasks, such as using dishwashers and washing machines, to off-peak hours, for instance at night or during weekends.

Such incentives are no longer enough to address the challenges of a system largely based on renewables. Nowadays, utilities are beginning to offer dynamic contracts, with prices that vary on a hourly basis. Flexibility incentivized by such tariffs is referred to as "implicit flexibility". In our previous *Gents Economisch Inzicht*, we explained how such contracts can help households lower their electricity bills. However, as we also highlighted, academic research shows that, **without technologies to automate flexibility, these tariffs alone are not enough, as smart control requires too many manual actions**, such as obtaining timely price information and manually adjusting the consumption of various appliances.

Residential heating, particularly through heat pumps, offers a unique opportunity for flexibility. **Like electric vehicles, heat pumps are large electricity consumers that simultaneously offer the possibility to adjust (to a certain extent) *when* and *how much* electricity is consumed, *without* significantly impacting the end result experienced by the user** (i.e., having a sufficiently charged car and a heated home). Unlike other appliances (such as white goods), which inevitably trigger constant electricity consumption *while* performing their intended function, a heat pump is technically capable of consuming slightly less or more electricity at strategic moments without noticeably affecting the perceived indoor temperature. This is what is meant by the "flexibility" of heat pumps. However, it can be very challenging for households to implement this in practice, for example by adjusting heating schedules to dynamic prices that fluctuate hourly. Factors well-documented in the behavioral economics literature, such as "status quo bias", "bounded rationality", "risk aversion", and "response fatigue" can limit individuals' ability to respond to flexibility incentives. This complicates achieving benefits in practice, such as lower electricity bills for households, while simultaneously reducing the amount of flexibility "available" to the wider electricity system at critical moments.

One way to address these challenges is by implementing alternative forms of heat pump control known as "explicit flexibility." This is organized by market players called "flexibility aggregators." These new players enter into contracts with households to remotely control their devices, such as heat pumps or electric vehicle charging stations, and optimize their operation (e.g., based on grid needs). Aggregators pool the flexible electricity demand of many households into a "virtual power plant", allowing them to deliver large amounts of flexibility to the grid when needed, in exchange for financial compensation to the households involved.

In this *Gents Economisch Inzicht*, **we present the results of our research on how households respond to the remote management of their heat pumps, by combining large-scale surveys with a field experiment** that implements a simplified flexibility scheme in practice. We investigate how temporarily interrupting heating—as could be done in the future to match it to periods of high national electricity demand and/or low renewable electricity production—affects household comfort, and how much financial savings can be achieved. Before presenting our research, we provide a brief overview of the current state of heat pump flexibility in Belgium and neighboring countries.

OVERVIEW OF INITIATIVES IN EUROPE

While many European countries offer subsidies to encourage the installation of heat pumps[2], **incentives designed to promote their flexible use in response to renewable production remain relatively rare**. However, some of these initiatives are worth mentioning here.

In the United Kingdom, the pioneering (and very large) energy provider Octopus Energy offers contracts specifically designed for electric vehicle and heat pump owners. Their research[3] indicates that **customers with heat pumps who switch to these tariffs save on average 18%** on their annual electricity bills. Most of these savings come from using smart thermostats to optimize heat pump operation during cheaper off-peak hours.

Some providers in **Germany offer dedicated contracts specifically for heat pump electricity consumption**[4]. These contracts require heat pumps to be connected to their own meters, allowing them to operate under a separate, lower tariff. In exchange, the utility has the option to temporarily interrupt heat pump operation in specific periods, offering additional flexibility to the grid. These interruptions are so rare and brief that users barely notice them.

In Flanders, energy providers are expected to introduce dedicated contracts for heat pump consumption by 2026[5]. However, these contracts will presumably not include the option for utilities to remotely control and optimize heat pump consumption. Nevertheless, the introduction of such device-specific energy contracts marks an important step toward more dynamic and flexible energy use. Since the beginning of this year, nine energy providers in Belgium offer dynamic contracts based on day-ahead prices that vary hourly. While these contracts can also be adopted by households without heat pumps or electric vehicles, **they offer the greatest potential for households with appliances capable of shifting large amounts of consumption over time**. Since electric vehicles and heat pumps still require some time before they are (very) widely adopted, the number of households using dynamic contracts remains relatively low for now.

OUR RESEARCH ON HEATING FLEXIBILITY

In this *Gents Economisch Inzicht*, we present the findings of a joint research project between the UGent and market and technological partners (Energent, Ecopower, EnergieID, 70GigaWatt and Next Kraftwerke Belgium). Over this three-year project, we investigated key questions about the future of heating flexibility, including:

1. **Who will likely participate** in future household flexibility schemes?
2. **What is the actual contribution** of heat pumps to demand-side flexibility, **when human factors** (such as individual comfort preferences) are taken into account?

Given that heat pump adoption remains limited in Belgium, and even more so for flexibility schemes, a significant portion of the project focused on designing our own experiments. **First, we conducted survey experiments** to assess participation potential. **Second, we designed and executed an innovative field experiment** where we implement one of the first heat pump flexibility schemes in practice in Belgium.

SURVEYS

A large online survey with 2,935 respondents was conducted to understand household energy behaviors and the willingness to participate in heat pump flexibility programs. Since flexibility programs are still relatively unfamiliar to most people, we ensured that all respondents had a full understanding by providing a clear introduction to the topic beforehand.

To compare the willingness of different groups to enroll in flexibility schemes, we created a unique sample. Out of the 2,935 respondents, **1,420 were members of**

Belgian energy cooperatives (Ecopower and Energent), who have an above-average interest in the energy transition and are likely among the "early adopters" of flexibility. Understanding their expectations and behavior is crucial for shaping how these programs must be initiated. **The remaining 1,515 respondents were non-cooperative members**, recruited via an online platform. Among these non-cooperative members, 19% live in Belgium, while the rest are from France, the Netherlands, Germany, and Luxembourg. Since this group was paid to complete the survey, attention and comprehension checks were included to ensure data quality.

Neither of the groups studied—cooperants and non-cooperants—is representative of the Belgian average. Cooperative members tend to be slightly older and wealthier, while non-cooperative participants are generally younger than the national average. However, these two groups are **highly relevant target audiences** for future flexibility schemes: **cooperative members**, as presumably more environmentally conscious individuals, **will likely be among the first users**, followed by younger individuals who are not necessarily cooperative members.

FIELD EXPERIMENT

To gain deeper insights into how individuals actually experience heating flexibility, we also conducted a field experiment. Over a two-year period, **we had remote control over the heat pumps of nine voluntarily participating households**, selected by Energent in the Ghent region.

All heat pumps in the experiment were of the air-to-water type with the technical capabilities for remote monitoring and control. This allowed us to conduct what we call **"flexibility interventions"**, which simulate future "smart heat pump activations" for flexibility by **temporarily interrupting heating until one of three predefined scenarios occurred**. **The first scenario occurs when the household manually stops the intervention**, usually due to (the anticipation of) discomfort. To do so, the household accesses a website we provided, clicks a button to stop the intervention, and gives a brief explanation of why they want to stop it. **The second scenario triggers a stop if the indoor temperature drops below a predefined threshold**, ranging from 16°C to 19°C. **The third scenario is an automatic stop when the domestic hot water tank temperature falls below 40°C**, ensuring households can still access hot water (e.g., for showers and baths).

The design of the interventions was largely influenced and limited by the protocol used to control the heat pumps. We used the "Smart Grid Ready" standard, which is a standardized communication interface that allows for requesting or forcing heat pumps to turn on or off. The four available commands are quite limiting, and we only used the "force off" command to stop the heat pump's operation. For example, the protocol did not offer the possibility of controlling the set temperature at which rooms are heated, which would have allowed more sophisticated interventions, whereby homes would, for instance, be "preheated a little extra" before a heat pump intervention starts.

We conducted these interventions over two winter seasons: 2022-2023 and 2023-2024. We randomly allocated interventions throughout the experimental period beforehand, without targeting specific periods of low renewable generation. In the first year, households received a notification one day in advance for each intervention. In the second year, only half of the interventions were announced beforehand, enabling us to test how notifications influenced household responses. In total, we conducted 287 interventions across all heat pumps.

We found that **households did not significantly change their behavior in response to notifications**, such as strategically adjusting their thermostat to reduce discomfort beforehand. Most interventions (70%) were automatically stopped when the domestic hot water tank temperature dropped to the 40 °C threshold. Of the 11% of interventions that were stopped automatically due to the indoor temperature threshold, most ended at 19°C. The lowest recorded indoor temperature during all interventions was 16.5 °C, meaning the 16 °C threshold was never triggered. As they provide rich insights into how participants feel discomfort, manual stops are discussed further in the following sections.

Note that participants in the field experiment reflected early adopters of sustainable technology. They typically had larger households, higher educational attainment, and higher incomes than the national average. They lived in newer, well-insulated homes, all equipped with solar panels. This selection bias was expected, as heat pump ownership typically coincides with better-than-average insulation levels. Most homes in Belgium are heated with fossil fuels and are poorly insulated. Switching to a heat pump is usually accompanied by simultaneously improving the building's insulation—although not necessarily to the level of new-build homes (*as it is, in fact, a myth that such 'top' levels of insulation are a requirement for using a heat pump*).

THREE KEY RESULTS

1 SURVEYS SHOW STRONG INTEREST IN FLEXIBILITY, BUT COMPENSATION AND AUTONOMY ARE ESSENTIAL

The surveys revealed a strong interest in residential flexibility programs. As shown in Figure 1, which illustrates responses to the question ***"If offered, how likely are you to sign up for a flexibility program?"***, over 70% of respondents indicated they were either likely or very likely to enroll, while only about 12% said they would be (very) unlikely to participate. Surprisingly, **this overall enthusiasm is consistent across both cooperant and non-cooperant** respondents: 73.5% of cooperants expressed interest compared to 66.6% of non-cooperants, a difference of just 7 percentage points.

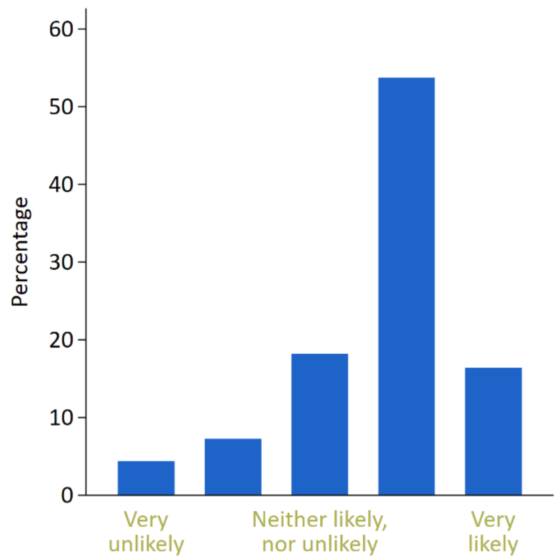

Figure 1: Responses to "If offered, how likely are you to sign up for a flexibility program?". Full sample of 2,935 respondents, including cooperative members and non-members.

The top three motives for joining flexibility programs were analyzed by asking respondents to rank seven proposed reasons. Both cooperants and non-cooperants ranked **contributing to the environment** as their top priority and **to grid stability** as their third. However, their second-ranked priorities differed: **financial rewards** for non-cooperants and **contributing to energy independence** for cooperants. Notably, financial rewards ranked 6th for cooperants, highlighting differing priorities: **cooperants tend to value societal benefits of flexibility schemes, while non-cooperants put more focus on individual financial savings**.

However, this does not necessarily mean that cooperants would accept lower financial compensation to participate. To examine this, and more broadly to assess how much individuals expect to be compensated for discomfort in flexibility schemes, we used a discrete choice experiment. This method has been shown to be particularly effective in valuation studies in contexts where the service or concept remains niche or hypothetical. Our choice experiment presented respondents with four "choice cards", each comparing two different flexibility contracts on heat pumps. These contracts varied based on the minimum guaranteed temperature during interventions, the financial compensation per intervention, their timing, and their frequency. Respondents were asked to choose a contract (or reject both), allowing us to calculate the financial compensation needed for individuals to accept changes in other contract characteristics.

We found that, irrespective of all other characteristics (e.g., duration, frequency, timing, starting temperature), **non-cooperants want, on average, €1.44 per 1°C decrease** in ambient temperature per intervention, while cooperants want around twice that amount, at **€3.04 per degree**. This presents an interesting finding: **although cooperants report placing less emphasis on financial compensation, they still expect higher compensation.** This may be due to their stronger attachment to comfort. For instance, cooperants reported a narrower tolerance range around their desired indoor temperature in winter (a range of only 1.3°C on average) compared to non-cooperants (2.2°C). This may be linked to the fact that energy cooperative members tend to be older than non-members, as shown by research from colleagues[6] based on rich data representative of Belgian energy cooperative members. Older individuals might place greater importance on maintaining comfort, explaining the narrower range.

This shows that many people are willing to enroll in demand response programs, although not at any financial cost. Similarly, they are also not willing to participate if it means losing too much control over their devices. In the survey, participants were asked under what conditions they would allow a third party to control their heating for flexibility purposes. Among those willing to give up some control, **89.4% stated they would only do so if they could retain a certain level of control**, such as being notified of interventions, having the option to stop them, or both.

Over 70% of respondents indicated they would participate in a flexibility program, primarily to support the environment. Individuals are willing to accept financial compensation for minor, occasional impacts on their comfort, but they want to maintain control over their heating at all times.

2 EXPERIMENT SHOWS HEAT PUMP FLEXIBILITY HAS MINIMAL IMPACT ON COMFORT

Surveys are a practical method for studying goods or services that are not yet widespread, but *stated* preferences may differ from *actual* preferences observed in real-life settings. To better understand how individuals experience and accept discomfort in flexibility schemes, we also conducted a residential heating flexibility experiment.

Of the 287 interventions in the experiment, **households manually stopped only 19% of them**. Each time they themselves chose to stop an intervention, households were asked to provide a brief explanation. We analyzed these to identify patterns regarding when and why discomfort occurred. As illustrated in Figure 2, we found that the top three reasons for overriding interventions were: (1) the indoor temperature being too low, (2) health-related concerns—e.g., illness requiring stricter indoor temperature conditions—and (3) the need for comfort when someone is working or studying at home during the day. Other, less common reasons include when coming home to a colder house after a longer absence, wishing for higher temperatures when receiving guests (e.g., for a dinner party), or simply preferring a warmer house on weekends.

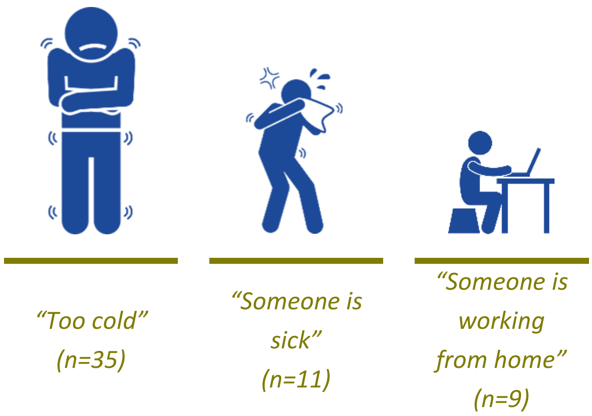

Figure 2: Illustration of the most frequent themes behind flexibility interventions manual stops.

These qualitative results reflect how households experience discomfort, but they do not provide a quantitative measure of it. To assess whether overruling patterns align with objective measures of discomfort, we analyzed the impact of interventions on indoor temperatures. Our analysis shows that **interventions caused a modest temperature reduction**. On average, the temperature dropped by 0.69°C from the start to the end of the intervention. For interventions that were automatically stopped (due to the indoor or domestic hot water tank temperature falling too low), which made up the majority of cases, the temperature drop was 0.62°C. However, as shown in Figure 3, when interventions were manually stopped by the households, the temperature drop was significantly higher, averaging 1.06°C. This suggests that **participants responded rationally to increased discomfort by overruling** when the temperature dropped significantly more than on average. However, this behavior was not entirely consistent, as many interventions with similar or greater temperature drops were not manually stopped.

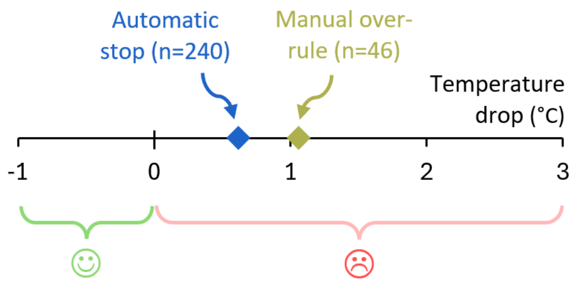

Figure 3: The full spectrum of temperature drops observed during the heat pump interventions, indicating the averages for manually and automatically stopped interventions.

As shown in Figure 3, not all interventions lead to a temperature drop (i.e., discomfort, illustrated in Figure 3 by ☹). In fact, **around 10% of interventions even resulted in a temperature increase** (a negative temperature drop, illustrated in Figure 3 by ☺). This occurs in situations where cooking activities, combined with mild outdoor temperatures or sunny weather, are sufficient to warm the house during the intervention, despite the heat pump being switched off at that time.

In the well-insulated homes of our sample, comfort is generally maintained with flexible heating, with minimal temperature drops and few manual stops by the participants.

Finally, a post-experiment survey was conducted to gather participants' feedback, which confirmed these findings. Most participants rated their discomfort during interventions as low to moderate.

3 FLEXIBLE HEAT PUMPS HELP RELIEVE GRID LOAD

From the perspective of an energy supplier or grid operator, the benefit of heat pump flexibility lies in its ability to reduce total power consumption on the grid during periods of high demand or low renewable energy production. To illustrate how the heat pumps in our sample contribute to balancing the grid, we introduce the concept of **"flexibility events"**. Flexibility events offer a new perspective by **looking at how all the heat pumps react together in aggregate after an intervention is started simultaneously across the entire fleet**. In the future, such a fleet could be managed for flexibility purposes by operators like flexibility aggregators. In contrast to interventions on individual heat pumps—where we previously focused on what happens inside the home while the device in question is switched off—flexibility events examine the net effect across the entire fleet at any given moment. At a specific point in time, this may involve a combination of heat pumps still switched off and others that have already resumed operation due to one of the three scenarios occurring in the respective household (see the "Field Experiment" section above).

Figure 4 shows the average power consumption per heat pump in our sample over time relative to the start of the event. The event starts when an intervention is simultaneously initiated on all units in the fleet. The **blue line** represents the actual observed consumption after the intervention starts, while the **green line** shows what the average consumption would have been if no intervention had occurred. The peaks in the **green line** represent the two typical consumption peaks of heat pumps, usually observed in the morning and early afternoon, adjusted for the time relative to the event start.

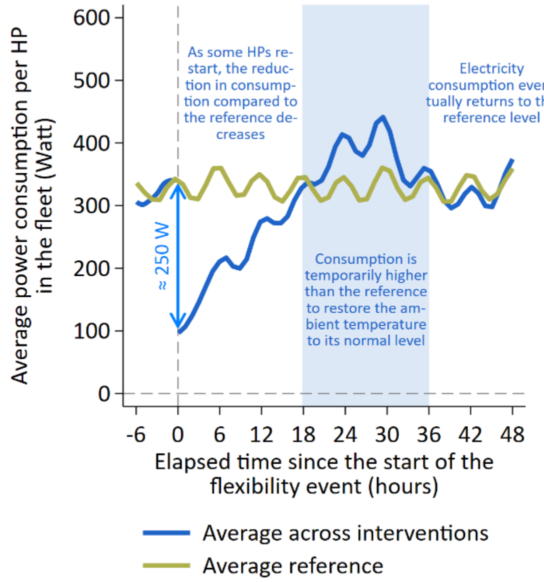

Figure 4 : Average observed and control power (in Watts) per heat pump ("HP") across the various flexibility events, analyzed over all individual heat pump interventions.

Before the intervention begins (left of the vertical dotted line), the **blue** and **green** curves align, as no heat pumps are blocked yet. Once the event starts, average power consumption drops from about 350 W to 100 W. The **difference of 250 W is a key research result, highlighting the average maximum electricity demand reduction per heat pump at the start of an event**—valuable for aggregators considering residential heat pumps for future demand response fleets of assets. Interestingly, the power consumption during the event does not drop to zero. This is partly because heat pumps sometimes could not be switched off and continued to operate normally, for instance because the indoor temperature or the domestic hot water temperature was already too low for the intervention to start. Another reason is that a baseline consumption of about 50 W per heat pump is needed to maintain the internal circuits of the unit and to stay connected to the Internet, even when heating is not active. These two aspects contribute to rising the **blue curve** so that it does not reach zero.

As time progresses, the gap between the **blue** and **green curves** decreases, and the **observed power consumption** gradually returns closer to the **green baseline**. This happens because some heat pumps in the fleet reactivate, either automatically when their temperatures drop too low, or manually when triggered by the household. **As units reactivate, the fleet net power reduction shrinks and reaches zero after about 18 hours.**

After this point, the fleet begins consuming more power than usual, as shown by the **blue curve** rising above the **green one**. This happens because the heat pumps that have been unblocked resume normal operation from a lower temperature than they would have without the event, **requiring additional electricity to catch up and reach the desired temperature set by the user on the thermostat.**

Eventually, after 36 hours on average, the **blue** and **green curves** converge again, as power consumption returns to normal.

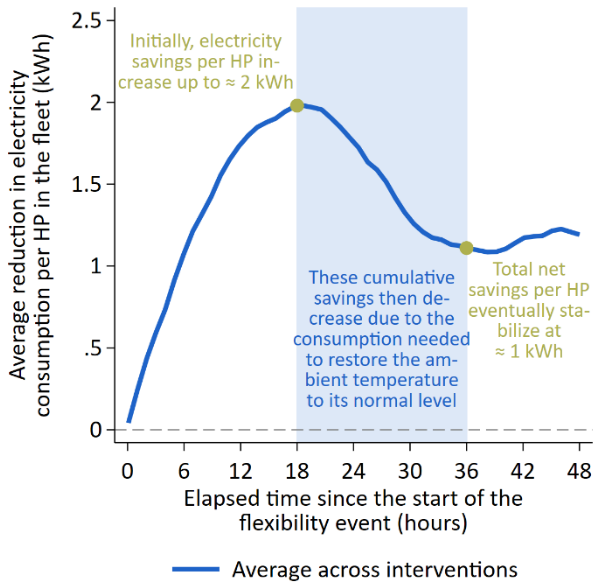

Figure 5: Average cumulative electricity consumption reduction (in kWh) per heat pump ("HP") in the fleet, across the various flexibility events, analyzed over all individual interventions.

While Figure 4 shows how the average power consumption of heat pumps changes during a flexibility event, Figure 5 shows the total cumulative energy savings (in kWh) accumulated over the course of the event In the initial phase of events, up to 18 hours after the start, the power consumption of the heat pumps is reduced, resulting in accumulated savings of 2 kWh on average. In the subsequent phase, from 18 to 36 hours after the start of the event, this saving is reduced by an increase in power consumption, stabilizing the net saving around 1 kWh.

Flexible heating reduces electricity demand by up to 250 W per HP, a 70% power reduction, gradually decreasing to 0 W after 18 hours. On average, each flexibility event realizes a net-reduction in electricity demand of 1 kWh per heat pump.

WHO IS HEATING FLEXIBILITY MEANT FOR?

Our research allows us to formulate hypotheses about the future of heating flexibility and, in particular, formulate paths under which it can **benefit everyone**.

First, owning a heat pump is key to accessing flexibility benefits, but with prices between €5,000 and €9,000 for an air-to-water type[7], **these devices remain (too) large of an investment for many households in Belgium**. As of 2022, fewer than 5%[8] of Belgian households own one, and our surveys show that adoption is heavily dependent on income. However, with a *coefficient of performance* (COP) between 3 and 5, heat pumps are a highly efficient way to decarbonize heating, especially when paired with flexibility schemes to take benefit of high renewable generation periods. On this aspect, **Elia even considers heat pumps a "no-regret" solution for heating decarbonization**, as they ultimately result in cost savings compared to not installing them[9].

Moreover, **research shows that heat pumps perform well even in older homes with traditional radiators**—countering the widespread misconception that they are only suitable for newly-built, very highly insulated homes[10].

Second, we expect flexibility schemes to become more financially attractive to households in the future. Although our results are already promising, we acknowledge that the limitations of the "Smart Grid Ready" interface used in our experiment limited our ability to test other (more promising) flexibility methods. Rather than implementing long heat pump interruptions as tested in our experiment, we envision **a future where heat pumps preheat homes (slightly) above the desired indoor temperature during hours of high renewable energy availability and low electricity**

prices, and just before high prices occur (which often overlap). As illustrated in Figure 7, interrupting the heat pump directly after a period of preheating would enable a similar period of low consumption but without necessarily reducing indoor temperatures by as much—compared to when the flexibility relies on turning off the heat pump alone (without preheating). This approach, also explored in academic studies[11], could reduce or even eliminate negative comfort impacts, as **households may tolerate or even enjoy mild, short-term temperature increases above what they requested as the setpoint**. Smartphone apps could further facilitate this by allowing users to define acceptable temperature deviations above and below their set comfort level.

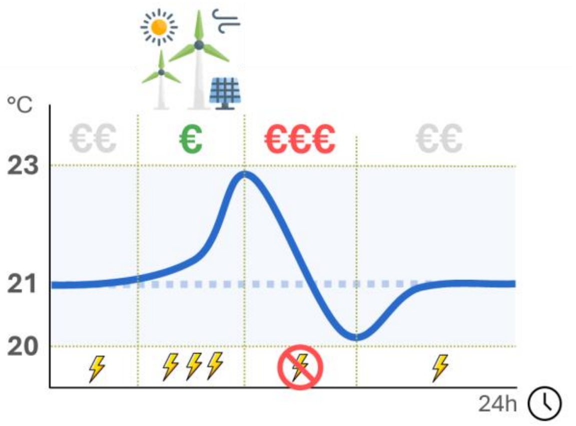

Figure 6: How we envision the future commercial deployment of flexible heating to unfold: rather than only temporarily lowering temperatures as in our experiment, households could also experience slight, short-term increases in temperature.

If such a concept of **continuous flexible control of a heat pump (24/7/365) is fully automated through smart, user-friendly apps,** this will lead to substantial annual savings on household heating bills. Moreover, **targeting periods of high grid strain allows flexibility aggregators to unlock multiple revenue streams**. By bundling large numbers of heat pumps, they can sell grid-support services to operators and help energy suppliers reduce imbalance costs. This can generate significant **earnings, a part of which flows back to heat pump owners**, further lowering their annual heating costs.

Our research focused on understanding how households interact with flexible heating and its impact on comfort, rather than optimizing heat pump scheduling for maximum cost savings. As a result, it did not aim to estimate the total savings that could be achieved through continuous adjustments, which recent studies have shown can significantly reduce energy bills. As mentioned above, a study from the UK[3] found that **time-of-use tariffs specifically tailored for heat pump owners enabled them to save 18% annually on their energy bill on average**, primarily through automated demand shifting via smart thermostat. Similarly, a study[12] in Denmark reported **average savings of 9.4% on electricity bills** from continuous remote adjustments of heat pumps via algorithms; for one household**, yearly savings even reached as high as 17%**. These algorithms maintained indoor temperatures within household-defined tolerance ranges, which averaged 3.3 °C around comfort temperatures. Whether through smart thermostats or user-specified tolerance ranges, **the setups observed in both studies allow households to keep control over their comfort**, minimizing or managing discomfort within their limits.

Third, flexibility can be delivered in various ways, **enabling all households to contribute to and benefit from the energy transition**. When the national electricity system requires a strong and rapid reduction or increase in electricity consumption over a short period, (de)activating heat pumps in *less-well-insulated* homes is the optimal choice. For more limited drops or increases in electricity consumption that can be sustained over longer periods, well-insulated homes are more ideal. Together, **both types of households play complementary roles** in maximizing the potential of flexible heating.

To ensure **an inclusive energy transition, these aspects must be reflected in policy actions, including tax shifts that favor electrification over gas use and additional subsidies for heat pump adoption**. These measures are essential to drive broader adoption across a wider range of households, making heat pumps a central part of an energy transition that benefits all.

CONCLUSION

Our research highlights the critical role of heat pumps and their flexible use in decarbonizing heating within the Belgian residential sector. While large-scale adoption is still not fully achieved, there is significant interest in future schemes that remotely and automatically manage part of the heating, allowing households to benefit from flexibility with minimal effort, without the need to manually adjust their consumption. Notably, this interest is not limited to early adopters of sustainable technologies but extends across diverse population groups. However, for flexibility to scale effectively, the design of these schemes must be carefully considered. They must provide attractive compensation while ensuring households retain control over their devices.

Our innovative field experiment confirms the potential for heat pumps to contribute to the energy transition with minimal comfort loss in well-insulated homes. While households did occasionally stop heating interventions, mostly due to discomfort or personal situations like sickness or working from home, the overall use of this feature was limited. Nonetheless, the potential for flexibility remains significant, with power reductions of up to 250 W per heat pump. This flexibility unlocks multiple value streams that help lower household electricity bills—either by reducing consumption when prices are high or by allowing aggregators to manage heating in exchange for a share of the revenues they earn from selling grid-support services.

To scale up these benefits and achieve the goal of decarbonizing heating, policymakers should focus on the following key aspects of heat pump flexibility adoption.

First, policymakers should further promote broader heat pump adoption through subsidies, ensuring that these incentives are not solely focused on the best-insulated homes. Heat pumps are a viable and effective solution in older homes too, and they can contribute significantly to flexibility. Expanding subsidies to include these households will not only support the transition from gas to electricity but also ensure that all households can benefit from the savings that flexible heating generates on annual energy bills.

Second, to minimize the impact of flexibility schemes on thermal comfort, particularly for households with poor insulation, policymakers should invest in the development of advanced communication standards that go beyond the current Smart Grid Ready standard. Heat pumps should be controllable in more advanced ways, such as allowing homes to be preheated slightly before reducing heating for several hours. This can significantly reduce the impact of flexibility on thermal comfort compared to the heating interruptions tested in our experiment. This is especially important for less well-insulated houses, where such interruptions can affect comfort faster.

Third, energy suppliers should introduce new electricity contracts specifically tailored for the electricity consumption of heat pumps (as already exist in other countries)—a matter in which our policymakers also have a role to play. These contracts would not only encourage greater adoption of heat pumps but also support the integration of renewable energy into the electricity grid—together significantly reducing Belgium's dependence on fossil fuel imports.

FOR MORE INFORMATION

This Gents Economisch Inzicht (GEI) is based on our academic paper (with some sections reproduced verbatim) available at:
Baptiste Rigaux, Sam Hamels, and Marten Ovaere. December 6, 2024. *The Proof of the Pudding is in the Heating: A Field Experiment on Household Engagement with Heat Pump Flexibility*. Ghent University Working Paper, 2024/1101. Available at: https://ideas.repec.org/p/rug/rugwps/24-1101.html.

Our previous GEI on a related topic (with colleagues): Marten Ovaere, Brent Bleys, Mariateresa Silvi, Sam Hamels and Baptiste Rigaux. January 18, 2024. *How to make Electricity Demand More Responsive to Variable Renewable Generation: A Summary of 150 Empirical Estimations of Demand Flexibility.* Gents Economisch Inzicht, number 12. Available at: https://www.ugent.be/eb/economics/en/research/gei/gei12en.

More on the FlexSys project *(with 70GigaWatt Consulting, Next Kraftwerke Belgium, Energent, Ecopower, and EnergieID) at* https://www.flexsys-project.be/.

Notes:

[1] European Environment Agency. (2023). *Flexibility solutions to support a decarbonized and secure EU electricity system* (tech. rep.). European Environment Agency. Publications Office of the European Union. Available at: https://www.eea.europa.eu/publications/flexibility-solutions-to-support.

[2] European Heat Pump Association (EHPA). (2023). *Subsidies for Residential Heat Pumps in Europe.* Available at: https://www.ehpa.org/wp-content/uploads/2023/03/EHPA_Subsidies-for-residential-heat-pumps-in-Europe_FINAL_April-2023.pdf.

[3] Bernard, L., Hackett, A., Metcalfe, R. D., & Schein, A. (2024). *Decarbonizing Heat: The Impact of Heat Pumps and a Time-of-Use Heat Pump Tariff on Energy Demand* (Working Paper No. 33036). National Bureau of Economic Research. Available at: http://www.nber.org/papers/w33036.

[4] See (in German): https://www.stromvergleich.de/waermepumpenstrom, 02/12/2024.

[5] See (in Dutch): https://www.livios.be/nl/artikel/100411/apart-en-voordeliger-elektriciteitscontract-voor-warmtepomp-en-laadpaal/,/, 10/12/2024.

[6] Melita Van Steenberghe, Aislinn D'hulster, Johannes Weytjens, Marten Ovaere, and Koen Schoors. 2024. *Tracking Demographic and Financial Trends in Renewable Energy Cooperative Membership in Belgium using Survey and Bank Transaction Data.* Ghent University Working Paper, 2024/1093. Available at: https://ideas.repec.org/p/rug/rugwps/24-1093.html.

[7] See (in Dutch): https://warmtepompenadvies.be/warmtepomp-prijzen/#prijs-per-soort, 09/12/2024.

[8] Rosenow, J., Gibb, D., Nowak, T., & Lowes, R. (2022). *Heating up the Global Heat Pump Market. Nature Energy,* 7(10), 901—904. Available at: https://doi.org/10.1038/s41560-022-01104-8.

[9] Elia, *Belgian Electricity System Blueprint for 2035-2050*, 24/09/2024. Available at: https://issuu.com/eliagroup/docs/20240924_belgianelectricitysystemblueprint2035-205.

[10] The open data initiative "Heat Pump Monitor" provides real-time data on heat pumps, primarily from the UK. Notably, among several dozen units listed, one of the top-performing heat pumps, with a coefficient of performance of 5, is installed in a pre-1939 home with conventional radiators and basic renovations only. For more details, see: https://heatpumpmonitor.org/system/view?id=68, 9/12/2024.

[11] See for instance recent works from the Centre for Net Zero, part of the British electricity provider Octopus Energy: *Automating Heat Pump Flexibility: Results from a Pilot* (Centre for Net Zero & Nesta, 2023) and *HeatFlex: The Untapped Potential of Heat Pump Flexibility* (Centre for Net Zero & Nesta, 2024). (Centre for Net Zero & Nesta, 2023) available at: https://www.centrefornetzero.org/papers/automating-heat-pump-flexibility-results-from-a-pilot. (Centre for Net Zero & Nesta, 2024) available at: https://www.centrefornetzero.org/papers/heatflex-the-untapped-potential-of-automated-heat-pump-flexibility.

[12] Jensen, R. H., Kjeldskov, J., & Skov, M. B. (2018). *Assisted Shifting of Electricity Use: A Long-Term Study of Managing Residential Heating.* ACM Transactions on Computer-Human Interaction, 25(5), 25:1—25:33. Available at: https://dl.acm.org/doi/10.1145/3210310.

Pictograms in Figure 2 are courtesy of:
https://www.flaticon.com/authors/leremy.

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