What do Potential Users Seek? A Review of Households' Expectations, Experiences and Comfort Preferences with Respect to Making their Electricity Demand More Flexible

Work Package Market Uptake | Stakeholder Analysis Task

Deliverable 3.1: Report on Expectations and Experiences of (Potential) Users

Partner responsible: Energent

Partners participating: UGent CEEM, Ecopower, 70GigaWatt

Main authors: Nicolas Van Damme, Baptiste Rigaux

Review: Sam Hamels, Kris Voorspools, Marten Ovaere, Ine Swennen

This document is a deliverable of the FlexSys project (A Flexible electricity System contributing to security of supply) funded by the Energy Transition Fund of the Belgian federal government, managed by the FPS Economy, SMEs, Self-employed and Energy.

Contents

List of figures

List of tables

1 Introduction

This deliverable report is part of the FlexSys task **"Stakeholder Analysis" (T3.1)**. It serves one of the main objectives of the project, namely to develop a commercially viable business concept for distributed flexibility, enabling small-scale assets to contribute to Belgium's national Security of Supply (SoS). This requires research that goes beyond a purely academic evaluation. Scalable business models need to be developed, providing a solid value proposition to all stakeholders involved.

Small and midsize businesses, households, and other small-scale electricity consumers are potential suppliers of distributed flexibility and end-users of the products and services defined in this project. Collecting their input is therefore crucial for creating an economically viable model. This is achieved through a variety of surveys as well as a real-world pilot.

The first survey is aimed at members of cooperatives, which is one of the target groups for residential flexibility. The project partners Energent and Ecopower have a combined base of more than 67.000 cooperative customers. Together with UGent CEEM – responsible for the related task T1.2 on behavioural analysis – and 70GigaWatt, a survey was developed and launched to gather data on the preferences of these potential users.

A second survey focusses on the participants of the real-world pilot, which is organised in Work Package 2 (WP2). In this field experiment, a group of households with controllable heat pumps and home-batteries volunteered to help explore the realistic flexibility potential of their assets. The participants were surveyed as part of the experiment.

To get an overall picture of the general population's views on residential flexibility, UGent CEEM also launched a third survey through an online platform suitable for random population sampling. This is important, as cooperative members and pilot participants may have specific preferences that do not necessarily reflect those of the general population. All survey results contain information about the 'stated preferences' of customers, which also feeds into T1.2.

This report provides an overview of the main descriptive elements coming out of the aforementioned surveys and draws conclusions from them. A more advanced (statistical) analysis of some of the more detailed survey results are presented in upcoming project deliverables. All publications can be found on the project website (www.flexsys-project.be).

2 Overview of the performed surveys

2.1 Introduction

The FlexSys project focuses on the flexibility potential of assets found in the residential setting. The main assets that are of interest are heat pumps and electric vehicles, which are increasingly proliferating among Belgian households. The project assesses the purely technical (and therefore theoretical) potential of such assets, but also wants to go a step further. Namely, by exploring the ways in which the purely technical potential is constrained and limited in practice – due to the behaviour of the human users that are part of the story. In other words, the project aims to estimate the 'behavioural correction' that needs to be applied to the technical potential of residential flexibility. To do so, a survey framework was developed that probes different forms of heterogeneities. In particular, it focusses on:

- User heterogeneity.

The field experiment sample consists of participants from energy cooperatives. They may be considered as "early adopters" of household flexibility. Early adopters may differ from the rest of the population who will eventually also be involved in flexibility schemes. Therefore, attitudes, preferences and socio-demographic characteristics must be gathered and compared across the different target groups.

- Capability heterogeneity.

The potential providers of residential flexibility may own various assets, each resulting in different flexibility potentials. In order to scale up the results of the field experiment, the framework needs to collect insights about the assets distribution. Moreover, due to technical reasons associated with the innovative aspect of the project, some assets that may eventually contribute to flexibility are not yet probed in the field experiment. The survey framework must gather insights about these assets as well.

- A possible learning effect of flexibility.

The behaviour of users with regard to their flexible assets could change over time due to a "learning effect". A central point of the surveys is to allow for probing such an effect. This is ensured by performing both a pre- and a postsurvey on the participants of the field experiment, in addition to analysing the measurement- and feedback-data collected throughout the field experiment itself.

Table 1 below provides a visual overview and description of the four different surveys that are performed in the FlexSys project. It also shows how each of them relates to the three aforementioned forms of heterogeneity that need to be taken into account.

Table 1: The four FlexSys surveys

Presurvey • Experiment participants • Before the experiment started: October-November 2022	**Large scale cooperative survey** • Cooperative members of Ecopower and Energent • November – December 2022
Postsurvey • Experiment participants • During the FlexSys experiment	**Large scale general population survey** • Online database (Prolific) • December 2022 – January 2023

2.2 Presurvey of participants in the field experiment

The goal of the presurvey was to gather the stated preferences of the pilot participants before the first flexibility intervention was performed (i.e. before the actual experiment began). The stated preferences will be compared with:

(i) The way participants interact with their assets in the experiment (i.e., the preferences revealed from the field experiment data),

(ii) The participants' preferences towards the end of the experiment (see the "Postsurvey" below).

2.3 Postsurvey of participants in the field experiment

The postsurvey also targets the pilot participants. It will be sent later in the experiment, either after a year or near the end of the experiment.

As explained above, the objective is to identify a possible learning effect of flexibility as well as a potential difference between the stated and revealed preferences.

2.4 Survey of cooperative members and the online (general population) version

Along with the goals already mentioned above, these two surveys will enable us to scale up the results by:

- studying the user heterogeneity across the different target groups,
- studying the capability heterogeneity across the different target groups.

Tables 2 and 3 below show the amount of participants in these two surveys:

Table 2: Large scale cooperative survey: number of responses by respondents' energy cooperative

Cooperative survey	**Cooperative members Energent**	**Cooperative members Ecopower**
Participants (N=1515)	212	1303

Table 3: Large scale general population survey: number of responses by respondents' country of residence

General population survey	**Belgium**	**France**	**Netherlands**	**Germany**	**Luxemburg**
Participants (N=1256)	201	271	340	437	7

To find and survey respondents from the general population on such a large scale, we used a database on the platform Prolific (https://www.prolific.co, accessed on 09/01/2023).

Prolific is a company based in England which allows surveys to be distributed to a database of respondents. Researchers have the ability to target specific groups matching socio-demographic characteristics of interest and to remunerate them in exchange for taking part in a study. Prolific ensures a high standard of data quality and enables researchers to implement multiple test questions, checking for both attention and comprehension.

In FlexSys, the large scale general population survey was also distributed to respondents from Belgium's neighbouring countries, to study international heterogeneity and to check whether the sociocultural context and heating habits in those countries differed substantially. Depending on respondents' preferences, the survey could be taken in Dutch, French or English.

This deliverable specifically focuses on the results from the two large scale surveys: the one conducted amongst (Energent and Ecopower) cooperative members and the one conducted across the general population. In order to ensure an easy comparison between the two groups of interest, these surveys share the same structure and content. The next section presents an overview of the different components of this survey. The presurvey among pilot participants is also mentioned, but its results are not discussed in detail in this report.

2.5 Survey content

2.5.1 Introduction

The first section of the survey, which serves as an introduction to the participants, presents a short general description of the survey and its objectives. It also includes a consent form for anonymous data acquisition. Moreover, this section collects some basic information such as the type of assets they are equipped with and the one that Energent will be controlling (specifically in the case of participants in the field experiment).

2.5.2 Questions on controlled assets (only presurvey)

This section asks basic questions regarding the preferences concerning the asset that is going to be controlled by Energent in the experiment. This section is exclusive for the participants in the field experiment within the project.

2.5.3 Energy-related habits

This section asks several questions about energy-related habits: the ownership of a car, type of heating system and others. This creates insight into the variety of energy related behaviour across different households.

2.5.4 Pre-choice experiment questions

This section precedes the choice experiment. It asks for the willingness-to-accept interventions on heat pumps and electric vehicles.

2.5.5 Choice experiment

Choice experiment on electric vehicles and heat pumps. The participants received different choice cards, where they had to choose between two contracts concerning flexibility interventions on an electric vehicle or a heat pump, with the possibility to opt-out as a third option. For choice cards focussed on electric vehicles, the contracts varied in terms of the (remaining) autonomy of the car (after the interventions take place), the timing of the intervention, the frequency of interventions and the financial compensation for an intervention. When the choice cards presented a situation focusing on heat pumps, the contracts varied in terms of the lower limit of indoor ambient temperature, the timing of the intervention, the frequency of interventions and financial compensation for an intervention.

2.5.6 Attitudes and ecological preferences

This section probes some important notions such as self-identification within the cooperative, trust, transparency, privacy, user acceptance and the degree of control. To the maximum degree possible, all of these concepts were applied to the specific context of the field experiment. This section also probes the degree of pro-environmental behaviour, electricity conservation behaviour, self-assessed knowledge of several concepts in the realm of flexibility, and the motivation to enrol in demand-response programs.

2.5.7 Socio-demographic questions

The last section gathers socio-demographic data. This includes data about the dwelling itself, the composition of the household, its financial situation, as well as the employment status and education level of household members.

3 Results

In this chapter the survey results are discussed in four parts. The first three focus on general preferences and habits, while the fourth focuses specifically on interventions with heat pumps and electric vehicles. The data presented, is limited to the cooperative and general population surveys (i.e. it excludes data from the presurvey)

3.1 Socio-demographic data

An examination of the socio-demographic characteristics of survey participants reveals distinct differences between cooperative members and the general population.

Compared to the cooperative members, the general population group consists of younger participants and a more evenly balanced gender mix (which is well-balanced 'by design', as part of the Prolific procedure for selecting respondents). The general population group also consists of participants with an average monthly income (Table 4), living in relatively smaller (rented) dwellings (Table 5). In the group of cooperative members, the share of retired participants is significantly higher compared to the general population. Future flexibility programs are not necessarily targeted at retirees, which means that the results of the general population survey are of utmost importance as a complement to the cooperative survey results.

In the group of cooperative members, the age is relatively higher and participants are mostly men. Cooperative members also appear to live in bigger houses, of which they are also the owner to a larger extent. This group represents the somewhat older generation, where comfort can be of more importance and adaptation to flexibility schemes could be prove to be more challenging.

Table 4: Comparison of socio-demographic variables between the two groups.

Socio-demographic variable	**Cooperative members (N=1515)**	**General population (N=1256)**	**General population, Belgian respondents (N=201)**
Share of men (*)	75.6 %	48.4 %	46.3%
Share of women (*)	23.4 %	49.1 %	49.8%
Median age category (*)	55 – 64 years old	25 – 34 years old	25 – 34 years old
Share owning a university degree or equivalent (*)	79.8 %	78.0%	82.1%
Share employed full time (*)	47.7 %	47.6 %	59.2 %
Share retired (*)	34.1 %	1.2 %	0.5%
Median category of total net household monthly income category	4000 € - 4999 €	5000 € - 5999 €	4000 € - 4999 €

In Table 4, variables indexed by (*) relate to the person taking the survey. Belgian respondents are the ones who report Belgium as their current country of residence on Prolific. A university degree can be a Bachelor degree, a Master degree or a PhD.

Concerning the technical aspects of the houses themselves, large differences between cooperative memebers and the general population group are found as well (cf. Table 5). This is important to take

into account, because the state of a building can have a big influence on comfort levels and the relative impact triggered by heat pump interventions (as part of a flexibility program).

Table 5: Comparison of the housing characteristics between the two groups.

House properties	**Cooperative members (N=1515)**	**General population (N=1256)**	**General population, Belgian respondents (N=201)**
Median dwelling size category:	150 – 200 m^2	50 – 99 m^2	100 – 150 m^2
Share of dwellings built after 2006:	18.1 %	14.3%	16.9 %
Share of building that already received an energy renovation:	68.2%	33.3%	44.3%
Share of participants who own their dwelling:	95.8%	33.8%	53.3%

3.2 Energy-related habits

Many behavioural habits can influence the potential of residential flexibility. In this section, the most important energy-related habits that came out of the surveys are highlighted with a focus on controllable assets like heat pumps and electric vehicles.

3.2.1 Heating system

Most survey participants own a gas-fuelled heating system, which is in line with general data about the Belgian building stock. The presence of heat pumps is higher among cooperative members, compared to the general population sample. This can have an influence on the experience and expectations with respect to thermal comfort, because heat pumps are typically combined with underfloor heating. Compared to gas-fuelled heating systems which typically use traditional radiators, underfloor heating is associated with a larger thermal mass. This leads to a slower and steadier pace in terms of changes in indoor temperatures throughout the day. It also means that flexibility interventions which temporarily turn off the heat pump typically do not have an immediate drastic effect on indoor comfort levels.

Table 6: Comparison of the types of heating systems between the two groups.

Share who reports (as main heating system):	**Cooperative members**	**General population**	**General population, Belgian respondents**
Gas heating	66.1%	57.9%	62.7%
Electric heating	2.5%	18.0%	11.4%
Heat pump	12.7%	5.7%	5.0%
Wood/Pellet/Fireplace	8.7%	4.3%	4.5%

3.2.2 Controllable assets

Among the respondents of both surveys, the degree to which different controllable assets are present varies considerably. An overview of the ownership of different assets is presented in Table 7. Among cooperative members, higher rates of ownership of heat pumps and electric vehicles are found. Especially in terms of electric vehicles, where the share of ownership is roughly twice as high among cooperative members compared to the Belgian general population respondents. Households with an electric vehicle or heat pump could have a better understanding of the impact on comfort due to

flexibility programs and may therefore respond differently to some of the questions or statements in the survey.

Table 7: Comparison of flexible assets ownerships between the two groups.

Share who owns…	**Cooperative members**	**General population**	**General population, Belgian respondents**
Heat pump	17.76%	14.33%	10.45%
Electric boiler	22.11%	50.64%	52.24%
Home battery	9.50%	2.79%	5.97%
Electric vehicle	15.58%	5.57%	7.46%

3.2.3 Comfort indoor ambient temperature

Table 8 shows how survey participants express their limits in terms of acceptable indoor temperatures. Averages values are shown across all participants. These comfort limits indicate the boundaries within which the indoor temperatures can fluctuate as a result of heat pump flexibility interventions. The FlexSys field experiment mainly focusses on the flexibility potential of the *heating* functionality of heat pumps, but the temperatures shown in Table 8 also take into account the potential for heat pumps to *cool* in summer period. The survey data shows that the minimum temperature considered comfortable from a thermal comfort perspective is approximately 18.5°C, both in the winter and summer seasons. The highest comfort temperature in winter lies around 22°C and in summer around 24°C. Notice that the lower limit is lower for the general population. This is probably because of the higher representation of younger participants in the general population group. Within this report these temperatures will be verified with the preliminary results of the field experiment. (see section 4.2)

Table 8: Comfort temperature limits per season and per group.

Comfort temperature	**Cooperative members**	**General population**	**General population, Belgian respondents**
Winter, Min	19.09 °C (1.48 °C)	18.00 °C (2.66 °C)	18.18 °C (2.52 °C)
Winter, Max	21.65 °C (1.60 °C)	22.41 °C (2.69 °C)	22.15 °C (2.50 °C)
Summer, Min	19.34 °C (2.22 °C)	18.39 °C (3.36 °C)	17.88 °C (3.35 °C)
Summer, Max	24.39 °C (3.07 °C)	24.19 °C (4.14 °C)	23.15 °C (3.80 °C)

In Table 8, the standard deviations are reported between parentheses. Meanwhile, Figures 1 and 2 below depict the distributions themselves, with the means shown as vertical (dotted) lines.

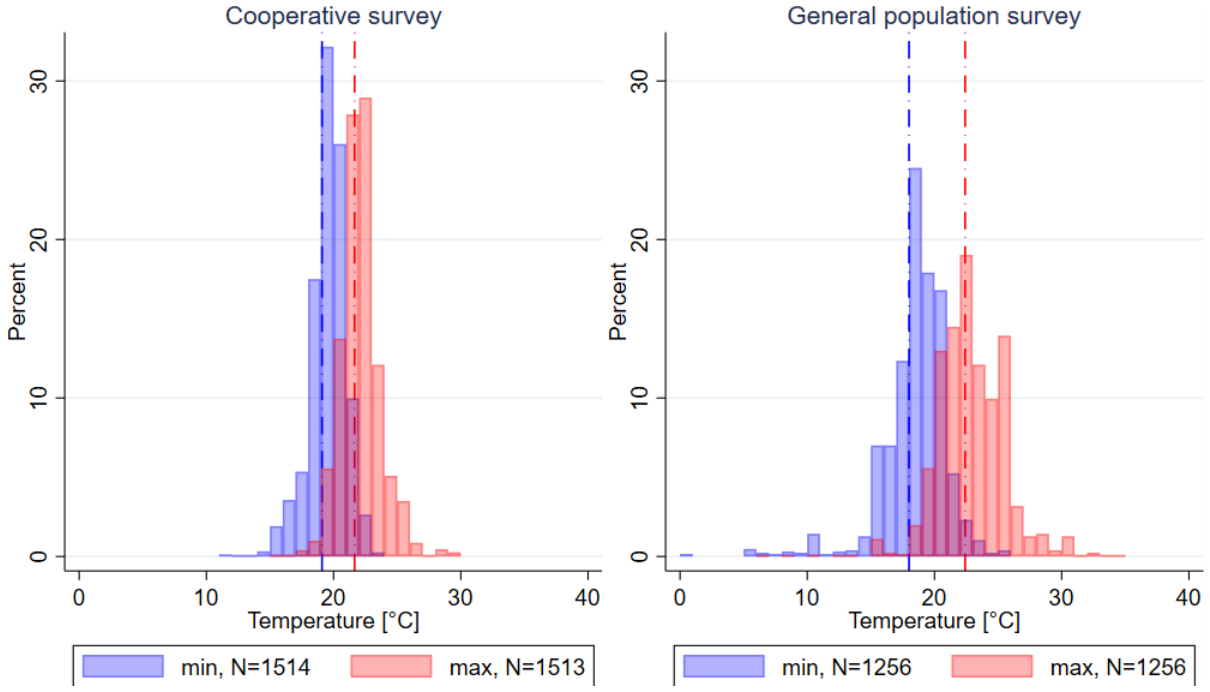

Figure 1: Stated comfort temperatures in Winter. The vertical lines indicate the mean values.

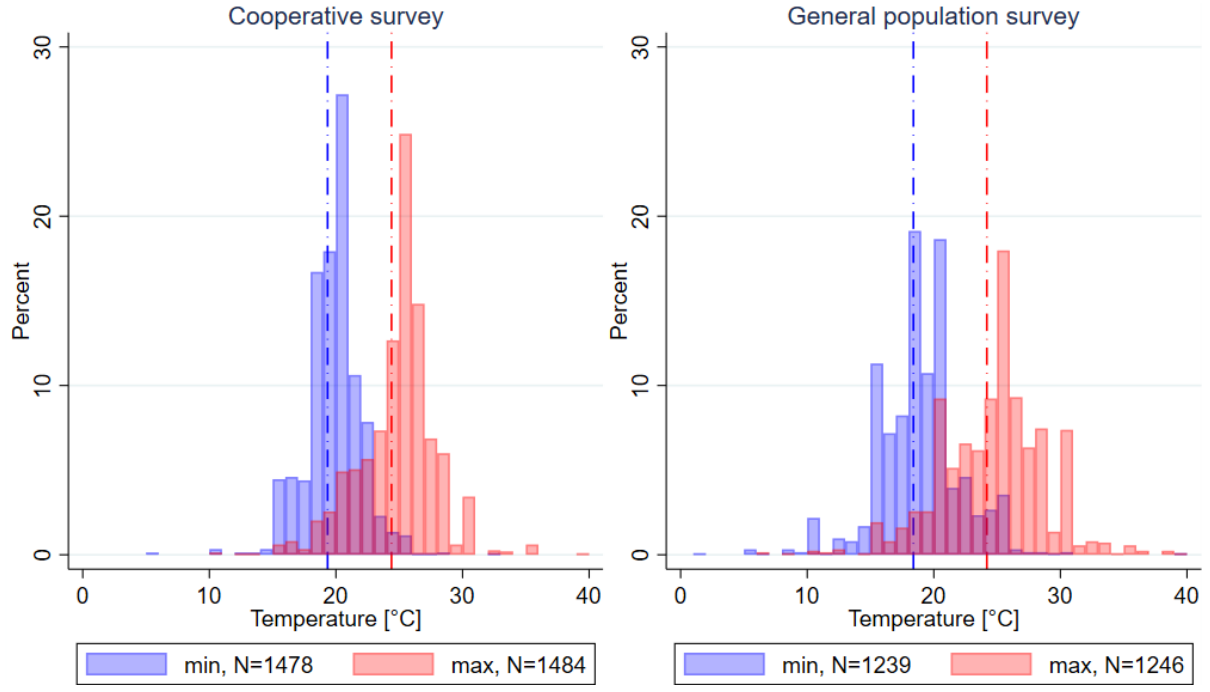

Figure 2: Stated comfort temperatures in Summer. The vertical lines indicate the mean values.

3.2.4 Working from home

For the general population group almost 40% of the participants (35% for the Belgian population) has somebody in the household working from home for more than three days. Cumulatively, about 80% of participants in the general population group work from home *at least* one day a week. For the cooperative members group this percentage is much lower, with only 50% of participants working from home at least one day a week. This is influenced by the fact that this group consists of retirees to a much larger degree, who often chose the "0 days" option instead of "Not applicable". This could have an

influence on the results, for example with respect to the degree to which cooperatives are (not) willing to accept flexibility interventions during certain times of the day, compared to the general population group.

Table 9: Telework frequencies by group.

Frequency of anyone in the household working from home [*]:	**Cooperative members**	**General population**	**General population, Belgian respondents**
0 day	47.2%	20.6%	22.9%
1-2 days a week	25.0%	26.4%	27.4%
3-4 days a week	17.8%	20.4%	23.9%
5 days a week	7.1%	15.1%	11.9%
More	1.3%	4.6%	1.5%

[*] *Other responses possible were "I'd rather not say" and "Not applicable".*

3.2.5 EV autonomy

Electric vehicles will play an important role in flexibility programs and were extensively given attention to in the survey. The table below shows the percentage of participants using a car as their primary mode of transport. For both groups, this share lies around 50%, from which it can be inferred that at least 50% of the participants can be expected to be sufficiently knowledgeable about driving requirements in terms of autonomy. This is important because exploiting the flexibility of EV-charging can result in a lowered autonomy (range) left in the car during or immediately after an intervention took place. Participants were therefore also asked about which "minimal autonomy" they deemed acceptable, meaning the autonomy that needs to be safeguarded when flexibility interventions take place. However, in the survey itself, only EV-owners who use their car as their primary mode of transport were asked which minimal autonomy they deemed acceptable. Average responses are shown in Table 11, indicating that across both groups a minimal range of approximately 150 km is deemed acceptable. This is a rather high amount, given the fact that unexpected drives – including for an emergency – are presumably much shorter than 150 km.

Table 10: Comparison of the shares of households who report a car as their primary mode of transport.

Car as the primary mode of transport	**Cooperative members**	**General population**	**General population, Belgian respondents***
Percentage	58.9 %	47.2 %	56.2 %

[*] *That is, respondents who report that Belgium is their current country of residence.*

Table 11: Minimum range of electric vehicles for comfort by group (households reporting an electric vehicle as their main mode of transport).

Minimal autonomy	**Cooperative members (N=128)**	**General population (N=33)**
Means (standard deviation)	159.83 km (86.16 km)	134.09 km (88.61 km)

3.3 Attitudes and ecological preferences

This section delves into the attitudes and ecological preferences of the survey participants. Here as well, there is value in having the two distinct groups that were surveyed. The group of cooperative members can be thought of as the likely "early adopters" of residential flexibility and may be more familiar with (and concerned about) "ecological" and energy-related topics, compared to the general population group. Among the general population, there is a balanced spectrum of early to late adopters, including some people who may *never* want to take part in flexibility schemes at all. Moreover, the general population *itself* also includes a degree of cooperative members, as shown in Table 12. In Belgium, this share is 3.5%, which means that this is the approximate share of the general population for which the FlexSys project has a *deeper* understanding through the separate cooperative survey and the field experiment (which also include exclusively cooperative members).

Table 12: Comparison of the degree to which participants own shares of an energy cooperative.

Share cooperative members	**Cooperative members**	**General population**	**General population, Belgian respondents**
Percentage	97.2 % [*]	2.6 %	3.5%

[*] *Note that the survey was also sent to subscribers of the Ecopower and Energent newsletters, , who are not necessarily cooperative members themselves, which explains why this value is not 100%.*

What is the self-assessed knowledge about these concepts? With this question the knowledge about energy related aspects was probed. The responses indicate that – in general –all participants have at least *some* knowledge about the energy transition and even energy flexibility. However, the general population group states that their knowledge is still limited, while cooperative members have already informed themselves in a more in-depth manner. A general introduction on flexibility was implemented in both surveys to make sure participants could answer the questions about these concepts with a basic understanding.

Table 13: Comparison of a measurement of self-assessed knowledge of different energy-related concepts between the groups (on a scale of 1 to 4).

Means (standard deviation)	**Cooperative members**	**General population**	**General population, Belgian respondents**
"Energy transition"	3.27 (0.76)	2.53 (1.00)	2.36 (1.03)
"Home automation or smart homes"	3.08 (0.70)	3.18 (0.69)	3.19 (0.64)
"Electricity flexibility"	2.88 (0.88)	2.10 (0.99)	2.06 (1.01)
"Energy cooperatives"	3.35 (0.60)	2.02 (0.91)	2.10 (0.93)

The self-assessed knowledge about these concepts was measured on a scale of 1 to 4:

1: "Never heard of it"
2: "I've heard of it, but I don't understand the concept"
3: "I know a little about the concept"
4: "I know a lot about the concept".

Table 13 reports the means for the different concepts and the standard deviations in parentheses.

(Scale adapted from: Li, R., Dane, G., Finck, C., Zeiler, W., 2017. Are building users prepared for energy flexible buildings?—A large-scale survey in the Netherlands. Applied Energy 203, 623–634. doi:10.1016/j.apenergy.2017.06.067)

3.4 Likelihood to enroll in residential flexibility

3.4.1 How likely are people to enroll in residential flexibility?

This is a first important question to be asked on the introduction of flexibility programs. As shown in the diagram below, a large share of participants are positive about these programs, with only a minimal difference found between cooperative and general population groups.. More than 70% (for the cooperative members) and 60% (for the general group) are interested to enrol in a residential flexibility program. Only a limited share (around 15%) deems it somewhat or even extremely unlikely.

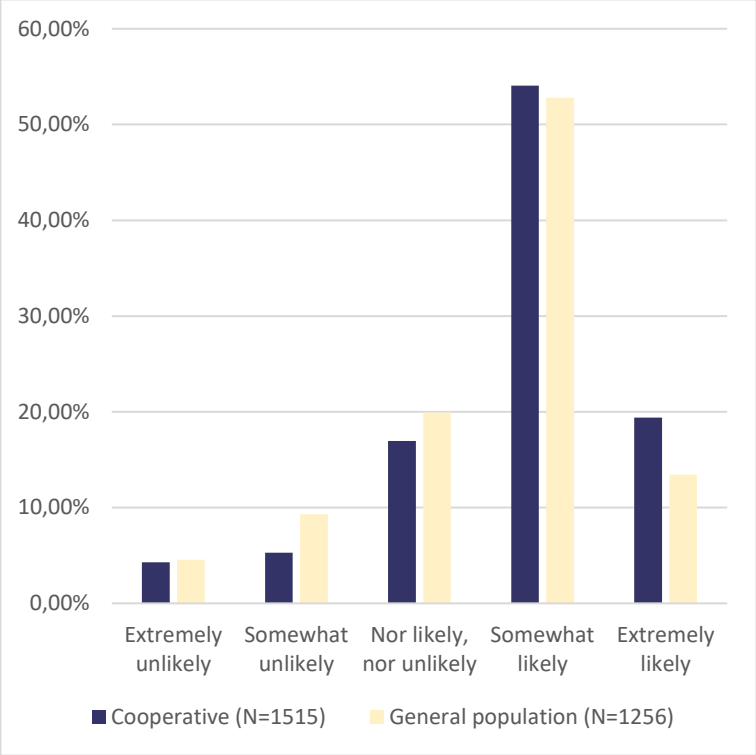

Figure 3: Likelihood to enroll in residential flexibility, comparison of the frequency of responses across the two groups.

3.4.2 Factors driving the decision to enroll or not in a flexibility program

The two tables below report the importance assigned to different explanatory factors of the decision to enroll (Table 14) or not (Table 15) in a flexibility scheme. The values are reported for both groups.

Contributing to the environment is the most important reason for enrolling in a flexibility program. Followed by energy independence and the contribution to grid stability. The differences between the two groups are small, making it clear that people are aware about the societal energy challenge and want to contribute in potential solutions.

The general population group attributes a higher importance to monetary compensation, which suggests that the cooperative members (early adopters) are somewhat more idealistic than the general population and less money-driven.

Table 14: Comparison of the importance assigned to factors driving the enrollment in flexibility programs per group (respondents interested in enrolling only).

Why enroll? (means)	**Cooperative members (N=1113)**	**General population (N= 832)**
Contribution to the environment	**4.28 (0.81)**	**4.24 (0.81)**
Contribution to [my country's] energy independence	**3.96 (0.98)**	**3.74 (0.94)**
Monetary compensations	2.70 (1.02)	3.67 (0.99)
On acquaintance's advice	1.91 (0.99)	2.51 (1.01)
Experimenting with new tech	3.19 (1.16)	3.02 (1.14)
Contributing to grid stability	**3.92 (0.87)**	**3.77 (0.85)**
Increase in comfort (automation)	2.76 (1.12)	3.08 (1.10)

The importance assigned to the factors driving the enrollment into flexibility schemes was measured on a 1-5 Likert scale ("Not import at all" – "Extremely important"). Table 14 reports the means for the different factors and the standard deviations in parentheses. Results are reported excluding the neutral answers: only respondents who reported being "Somewhat likely" or "Extremely likely" to enroll in a flexibility program in section 3.4.1 are taken into account.

Table 15: Comparison of the importance assigned to factors driving the non-enrollment in flexibility programs per group (respondents not interested in enrolling only).

Why not to enroll? (means)	**Cooperative members (N=145)**	**General population (N= 173)**
Loss of control over the assets	**3.72 (1.11)**	**3.90 (1.10)**
Lack of information	3.11 (1.30)	3.38 (1.21)
Concerns about the stability of the internet	**3.26 (1.36)**	**3.80 (1.29)**
Too low monetary compensation	2.56 (1.33)	3.25 (1.26)
Concerns about damaging the asset, warranty or lifespan	2.86 (1.37)	3.13 (1.27)
Reduction of comfort	**4.30 (0.92)**	**4.40 (0.83)**

The importance assigned to the factors driving the non-enrollment into flexibility schemes was measured on a 1-5 Likert scale ("Not import at all" – "Extremely important"). Table 15 reports the means for the different factors and the standard deviations in parentheses. Results are reported excluding the neutral answers: only respondents who reported being "Somewhat unlikely" or "Extremely unlikely" to enroll in a flexibility program in section 3.4.1 are taken into account

3.4.3 Role of the organisation managing the flexibility program

An important aspect of the project is to assess the difference in behaviour between energy cooperative members ("early adopters") and the general population. One of the potential differences between the two groups is the importance they attribute to *which* (kind of) organisation is in charge of the flexibility program. The surveys anticipated that some households may feel more 'attached' to certain kinds of organisations that could potentially manage flexibility programs (e.g. energy cooperatives versus generic private companies), and be more willing to trust them. Several questions were designed and included to probe these elements.

A first step in this regard is a breakdown of the statistics presented earlier in Table 12:

- 96.2% of respondents who took the cooperative survey shared via Energent own shares in Energent (i.e. a total of 204 people).
- 97.4% of respondents who took the cooperative survey shared via Ecopower own shares in Ecopower (i.e. a total of 1269 people).
- 2.6% of respondents who took the general population survey own shares in an energy cooperative (i.e. a total of 32 people).

This means that 54.3% of the total sample, across the two surveyed groups constitutes of energy cooperatives members. A specific survey question targeted this subsample to assess the importance they attach to *their energy cooperative* managing the flexibility program that they would enrol in. The results are reported in Figure 4.

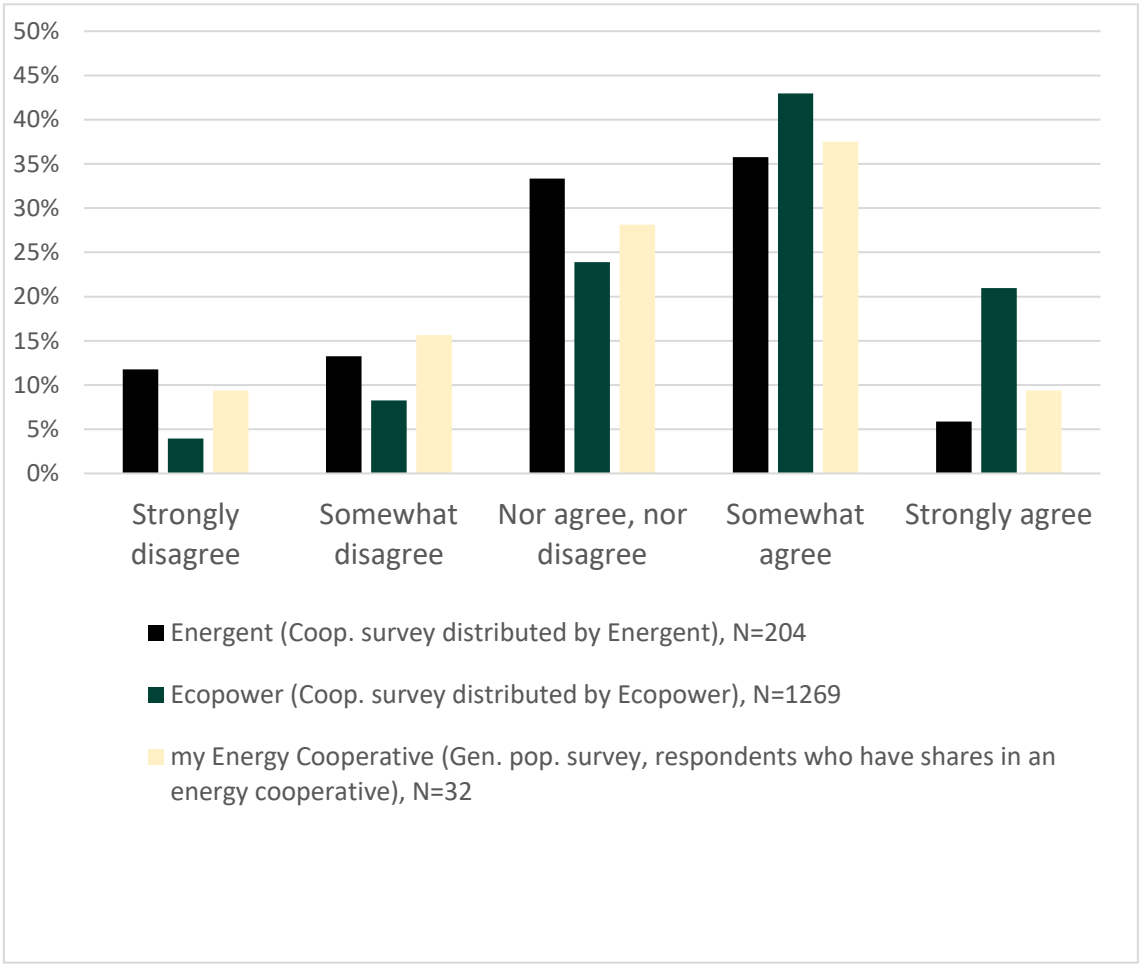

Figure 4: Share of respondents who would only enroll in a flexibility program if it was managed by their energy cooperative, by group (respondents owning shares in an energy cooperative only).

In order to gather similar data on non-cooperative members of the general population group, a similar question was conducted among them as well. Recalling that the survey included a short text explaining what an energy cooperative is, these respondents were asked to report the extent to which they agree with a similar question as above, now considering a flexibility program managed by any energy cooperative in general. Results are reported in the figure below.

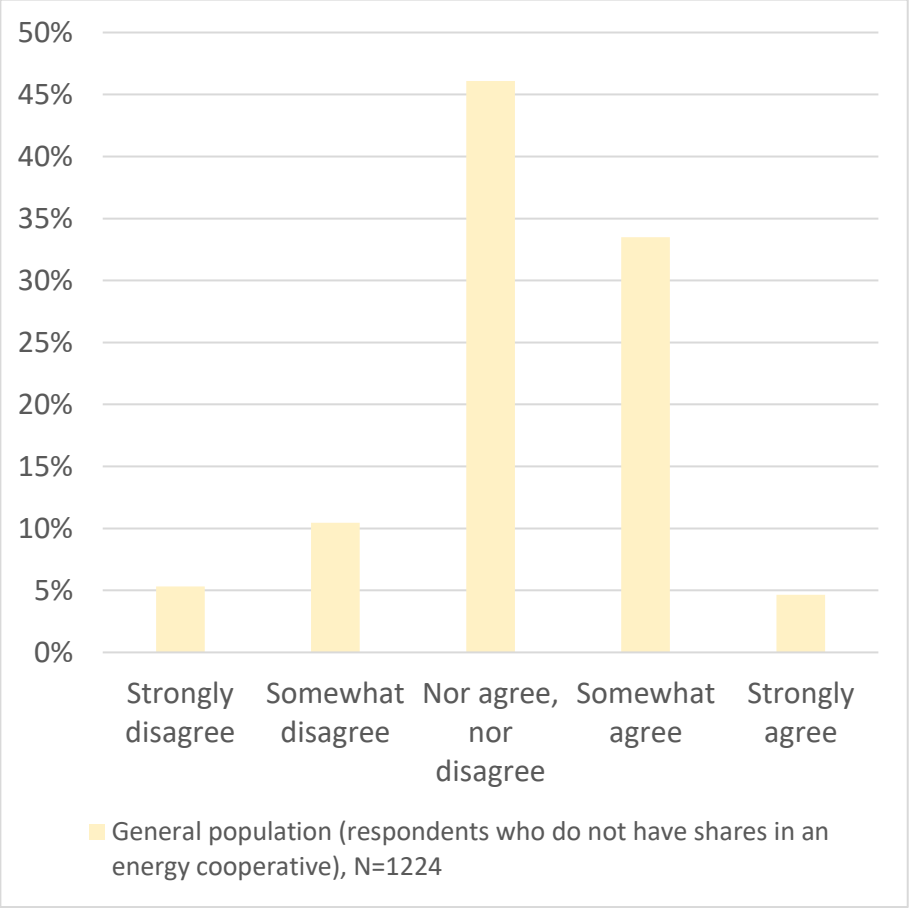

Figure 5: Shares of respondents who would only enroll in a flexibility program if it was managed by an energy cooperative, by group (respondents not owning shares in an energy cooperative only).

3.4.4 Willingness of giving a third party control to an asset

This section probes how willing the participants are to give full control to their assets.

For illustrative purposes, results are grouped into small appliances (ovens, dryer,…) and bigger assets (heating system, electric vehicle,…)

3.4.4.1 Small appliances

The results for washing machines, dishwashers and tumble dryers are similar for both groups. More than 80% of participants are willing to give full control over these appliances, although – for many of them – this is conditional upon having the option to overrule an intervention. Moreover, some of the participants also want to be notified when an intervention will happen. A noteworthy exception to these results are found in the case of ovens, where a much lower willingness to hand over control is found.

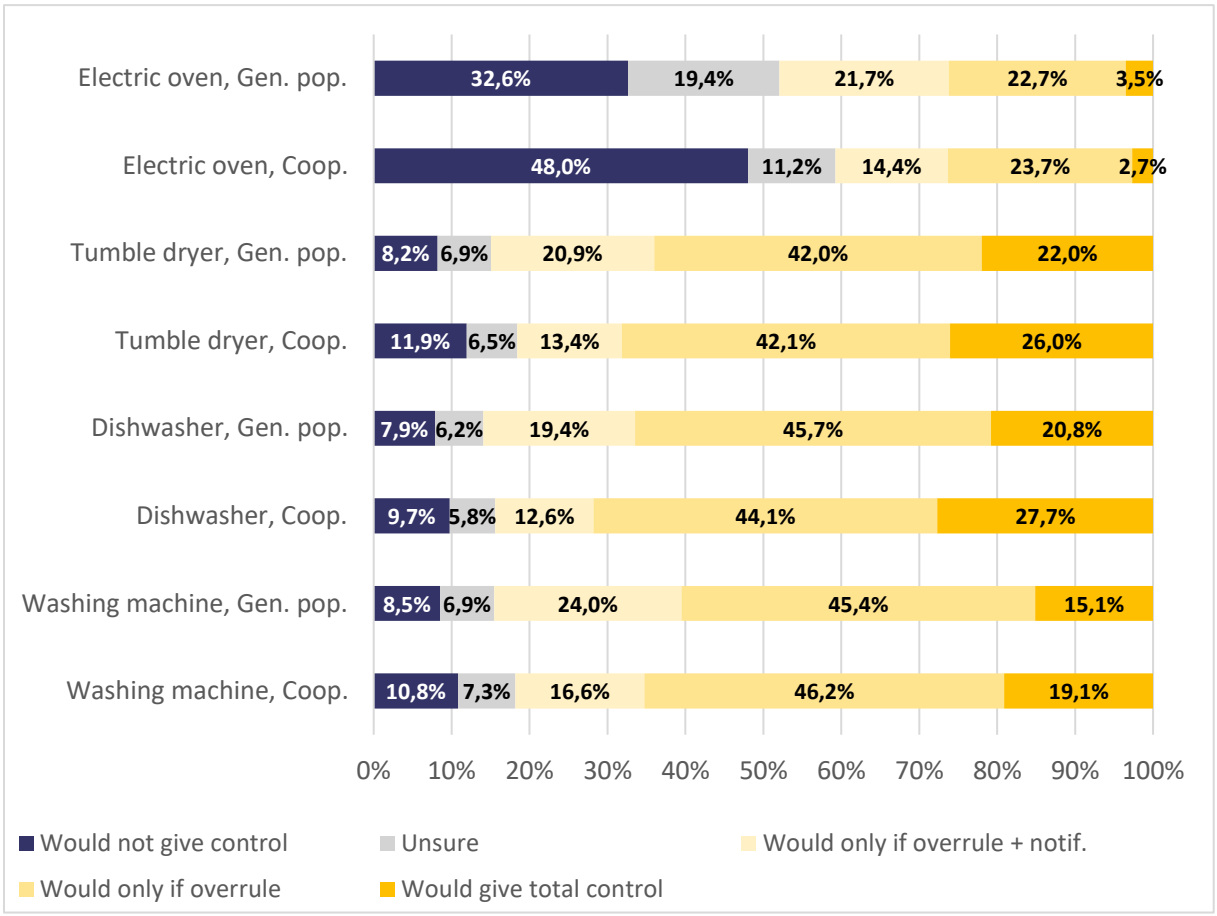

Figure 6: Willingness to cede control over appliances to a flexibility program

3.4.4.2 *Large domestic systems*

In general the participants are very willing to give control over their larger assets, although being notified about interventions and having the option to overrule them is found to be important in this case as well. The cooperative members are somewhat more flexible in comparison with the general population group. Moreover, a larger willingness to accept interventions on EVs (compared to heating systems) is found in both groups.

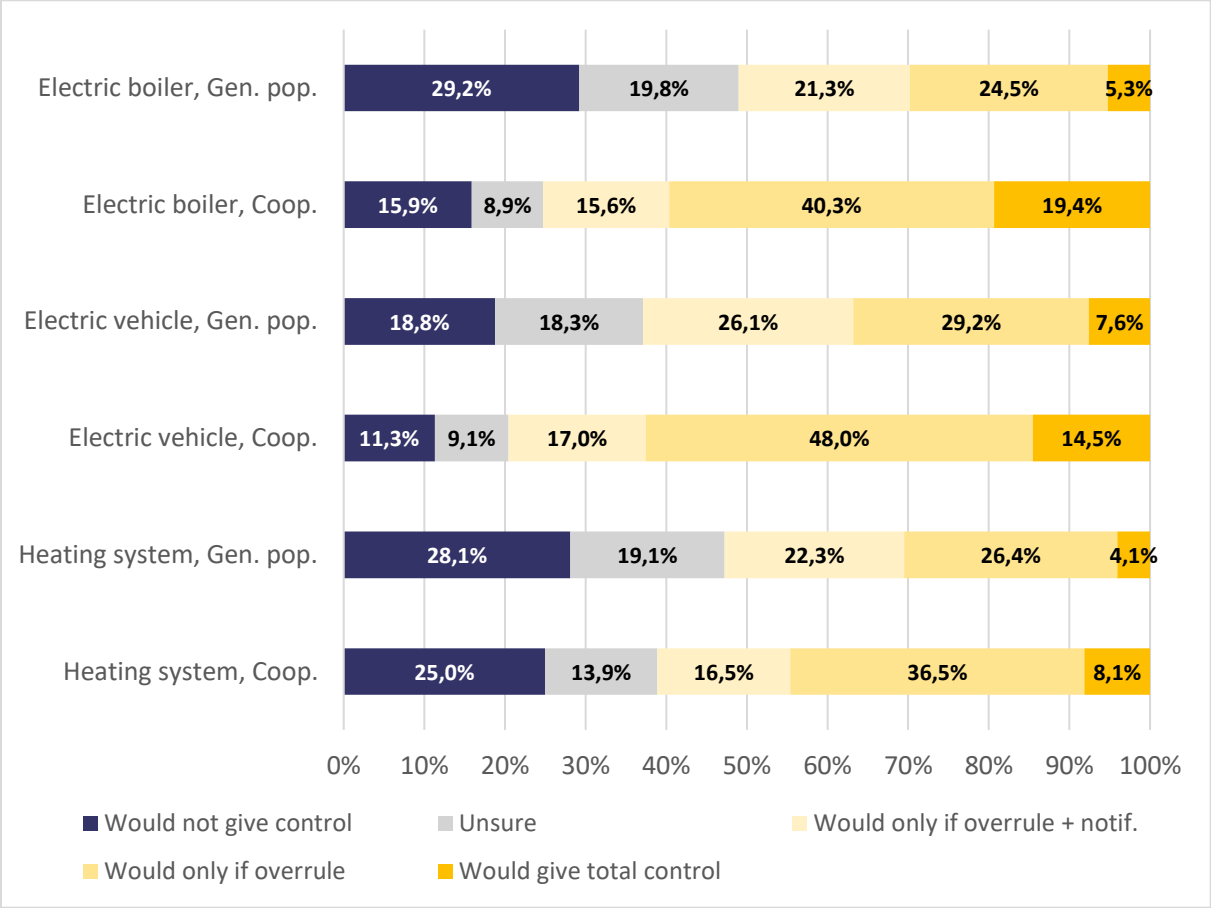

Figure 7: Willingness to cede control over larger assets to a flexibility program

3.5 Flexibility from heat pumps and electric vehicles

This section takes a closer look at comfort limits and potential monetary compensations for flexibility interventions.

To assess expectations in terms of monetary compensation, sliders were presented to survey participants, allowing them to choose between a range of pre-specified (discrete) amounts euros. This way, the participants in the survey had an idea about the potential order of magnitude, which they may have otherwise not been knowledgeable enough about. The results of these questions on the expected monetary compensation in return for interventions on (respectively) heat pumps and electric vehicles are presented in the following subsections.

Although the survey also included a choice experiment from which further insights with respect to monetary compensations can be derived, these particular results lie beyond the scope of this report. Instead, they will be included in an academic publication which will be made available towards the end of the project. Nevertheless, a few general conclusions derived from the choice experiment's preliminary results are briefly discussed below.

3.5.1 Relation between enrolling in a flexibility program and the expected financial compensation

As discussed above, the survey introduced the concept of residential electricity flexibility to respondents in a short descriptive text. This text mentioned that "Households could receive money in exchange for accepting this kind of [flexibility] intervention on their devices.". To deepen the understanding of the relation which might exist between the participants' willingness to enrol in flexibility schemes and the monetary compensations offered, participants were asked to report the extent to which they agree with the following statement: “I would mainly enroll in a flexibility program for financial reasons.”. The results for both groups are shown in the figure below.

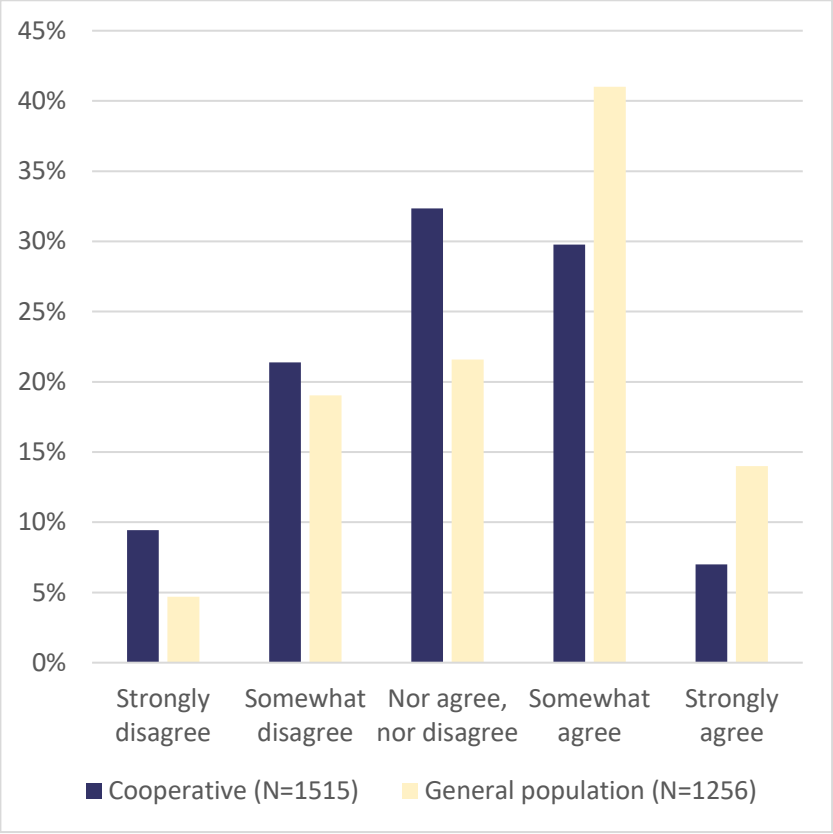

Figure 8: Enrolling in flexibility programs for financial reasons mainly

The figure, along with a statistical comparison of the mean response across the two groups, provides evidence of a difference in behavior (in terms of the responses across the two groups). On a scale from 1 to 5 (Strongly disagree – Strongly agree), the cooperative members report an average response of 3.04, whereas the general population reports 3.40. This provides a further confirmation of the fact that the motivations for enrolling are different across the two groups and, specifically, that cooperative members are less strongly attached to monetary compensations than the general population when it comes to participating in residential flexibility.

3.5.2 Heating comfort temperature

In the diagrams on the next page, the ratio between monetary compensations (per intervention) and the percentage of participants that would accept the intervention is presented in the case of four temperatures: 16°C – 17°C – 18°C – 19°C. These temperatures are also used in the field experiment as a trigger for automatically reactivating heat pumps after they are turned off during an intervention.

It is clear that for the maximum amount of monetary compensation (5€/intervention) every participant would accept the intervention regardless of temperature (even with a minimum of 16°C). A second observation is that the percentage of the general population is slightly higher in each case and that the difference increases with lower temperatures. This could be explained by the age difference between the two groups. The younger (general population) group will presumably have an easier time adapting to lower temperatures, as long as they receive a compensation which they perceive to be fair.

At first glance, 18°C and 19°C appear to be the most promising temperatures to use in flexibility programs. Here the percentage of acceptance is still high enough for a 'medium' level of monetary compensation. However, the economic viability of providing such a level of monetary compensation should be investigated in more detail before any conclusions can be drawn about the actual business case opportunities. This analysis will be presented in another deliverable, to be published on the project website.

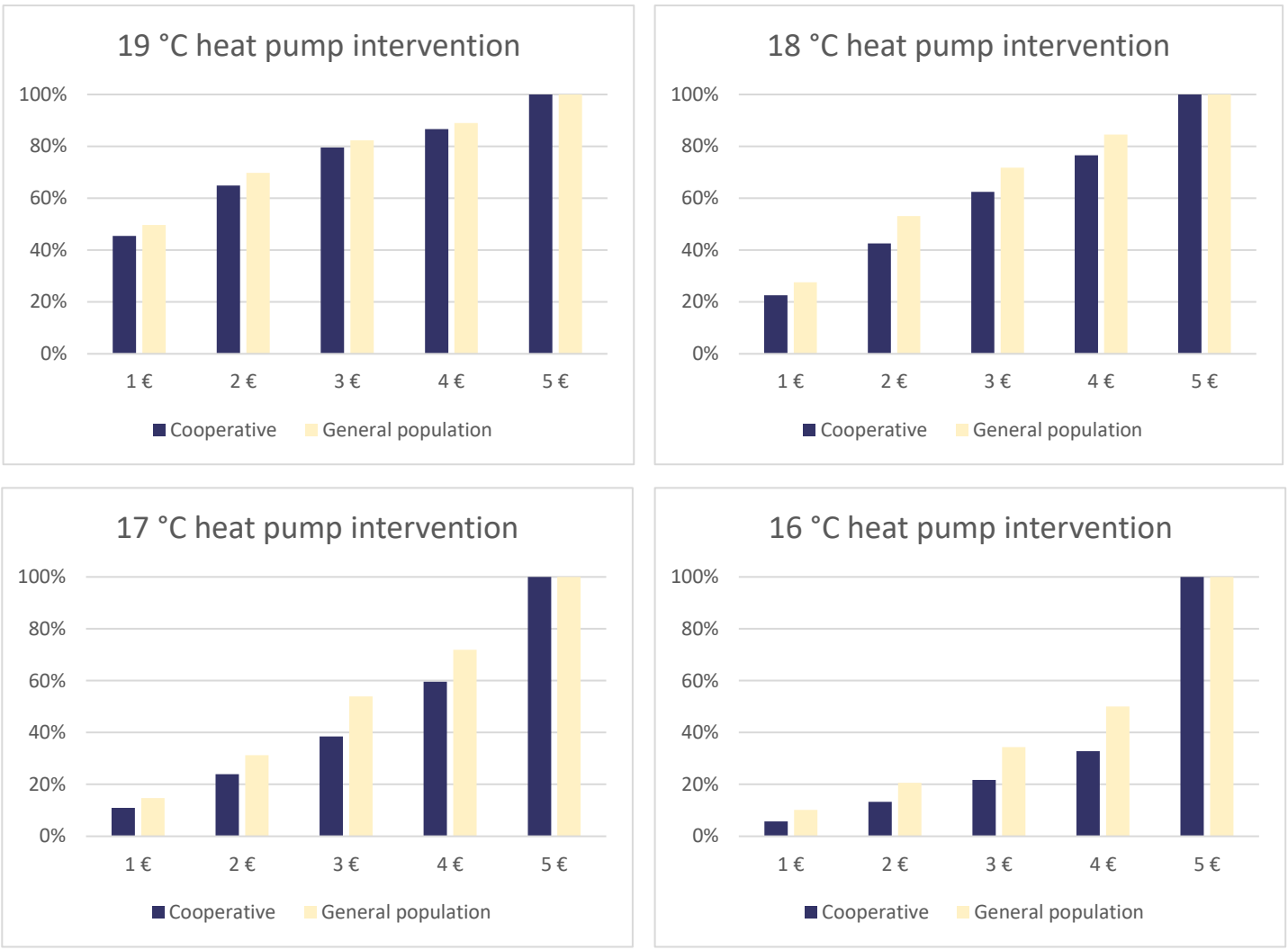

Figure 9: Monetary compensation levels for accepting different temperature thresholds (thermal comfort)

3.5.3 Minimal autonomy electric vehicle

In the following diagrams, the ratio between the monetary compensation (per intervention) and the percentage of participants that would accept the intervention is presented in the case of four potential amounts of remaining autonomy (range) throughout or immediately after an EV intervention: 50km – 100km – 150km – 200km. The survey explained to respondents that an intervention would last for a maximum duration of 8 hours, during which the stated minimal autonomy would be safeguarded.

Similar to the heat pump results, all participants indicated that they would be willing to accept interventions on their electric vehicles if they would receive the highest level of compensation offered in the survey, which was €25 per intervention. This willingness was expressed regardless of the remaining autonomy during and immediately after an intervention.. Generally speaking, the difference between both groups is small. The degree to which the acceptance of interventions rises together with increasing monetary compensations is very similar. The only noteworthy difference between the two groups is the fact that lower levels of monetary compensation are accepted to a higher degree by cooperative members. By contrast, interventions on heat pumps were not acceptable (to the same degree) by cooperatives in the case of the lowest level of monetary compensation. Presumably because heat pump interventions are associated with a larger potential impact on their comfort (being cold), compared to EV interventions.

At first glance, 150km and 200km appear to be the most promising temperatures to use in flexibility programs. Here the percentage of acceptance is still high enough for a 'medium' level of monetary compensation. However, the economic viability of providing such a level of monetary compensation should be investigated in more detail before any conclusions can be drawn about the actual business case opportunities. This analysis will be presented in another deliverable, to be published on the project website.

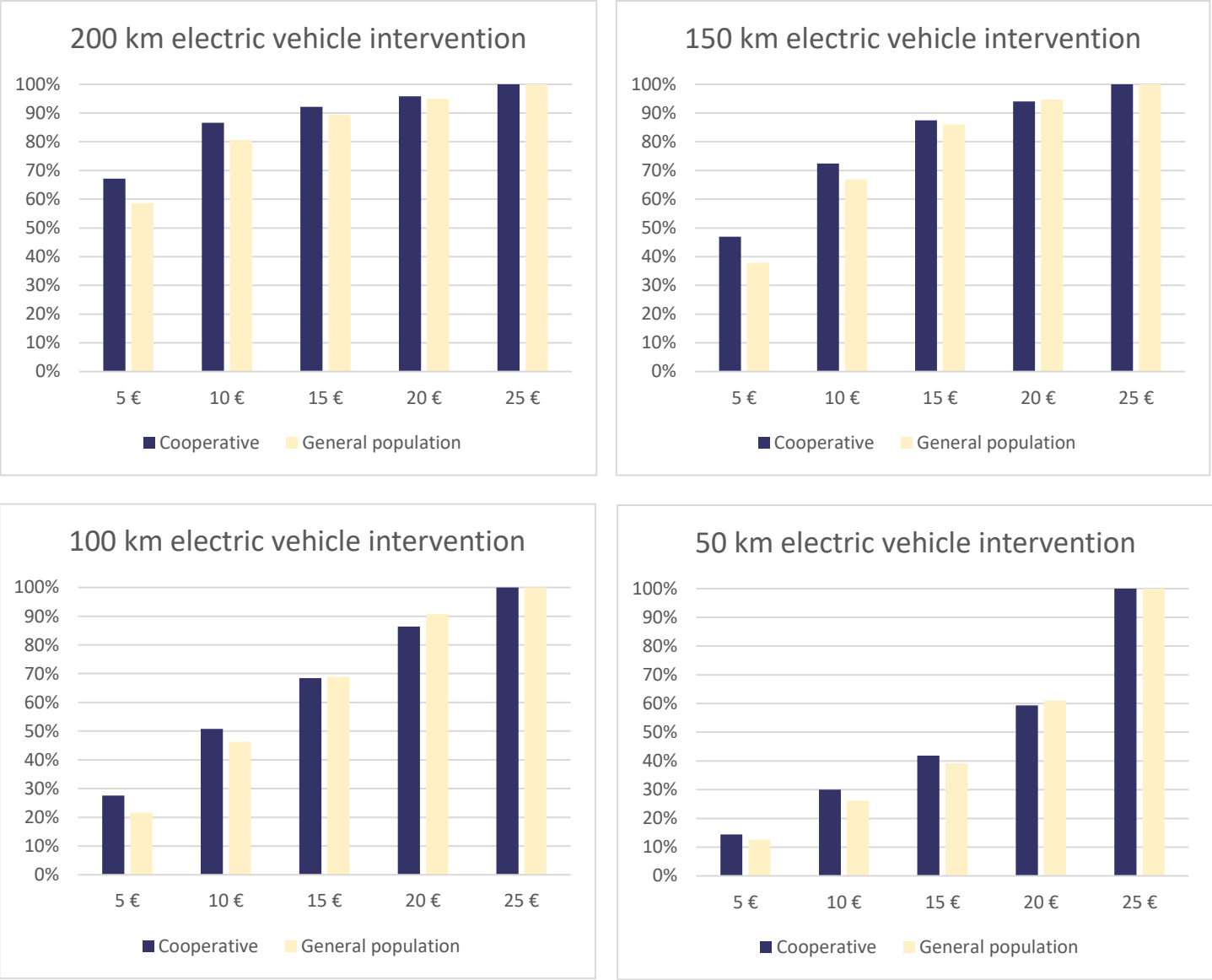

Figure 10: Monetary compensation levels for accepting different range values (range anxiety)

3.5.4 Choice experiment

In addition to the survey questions, a choice experiment was conducted. The purpose is to present survey respondents with a selection of different flexibility contracts which include interventions on their appliances and to request them to select the contract which would they choose for their households (based on their preferences). The participants were also allowed to select the option of "opting out", i.e. to select none of the two contracts that were presented to them. Each of these questions is called a "choice card". The choice cards were shown to every respondent, whether they own the asset in question or not.

The appliances covered by the choice experiment were electric vehicles and heat pumps. In total, respondents were asked to respond to five choice cards for each appliance. A single choice card always presented two contracts referring to the same appliance (i.e. there was no direct comparison of interventions on heat pumps and electric vehicles within the same choice card).

Table 17 present the features shown on the choice cards as well as the values they can take. Each choice card included a unique combination of these values (see Figure 11 and Figure 12 for examples of choice cards that were presented to the respondents). The choice cards varied across respondents.

Table 16: Contract features in the choice experiment on heat pump interventions

Contract feature	Possible values
Indoor temperature threshold (at which the heat pump starts again)	16 °C, 17 °C, 18 °C, 19 °C
Monetary compensation per intervention	1€, 2€, 3€, 4€
Timeslot at which an intervention starts	5h – 11h, 11h – 17h, 17h – 23h, 23h – 5h
Frequency at which such intervention takes place	Once a week, once every month, once every two months, once a year

Table 17: Contract features in the choice experiment on electric vehicle interventions

Contract feature	Possible values
Remaining autonomy that is left in an electric vehicle during and after an intervention	50 km, 100 km, 150 km, 200 km
Monetary compensation per intervention	3€, 5€, 10€, 20€
Timeslot at which an intervention starts	5h – 11h, 11h – 17h, 17h – 23h, 23h – 5h
Frequency at which such intervention takes place	Once a week, once every month, once every two months, once a year

Based on your household's heating preferences, which of these intervention contracts would you choose for your household?

	Contract A	Contract B	Opt out
Indoor temperature at which the heat pump restarts	17°C	16°C	No interventions
Compensation per intervention	2 €	1€	
Start of the interventions	5 p.m.-11 p.m	5am-11am	
Frequency of interventions	Once a week	Once every two months	

Figure 11: Example of a choice card (choice experiment on heat pumps)

Based on your household's mobility preferences, which of these intervention contracts would you choose for your household?

	Contract A	Contract B	Opt out
Remaining autonomy	100km	150km	No interventions
Compensation per intervention	20 €	10 €	
Start of the interventions	11pm-5am	5am-11am	
Frequency of interventions	Once a week	Once a year	

Figure 12: Example of a choice card (choice experiment on electric vehicles)

A first preliminary analysis of the results between the two groups shows that the respondents' stated preferences are in line with the results presented above. In particular, monetary compensation does not seem to be the most important factor driving the respondents' choice of a contract (this holds for both choice experiments). On the contrary, other dimensions such as the level of the intervention (i.e., temperature threshold or autonomy range) seem to be more important in the decision-making process. Moreover, the results seem to show that, when given the choice, users prefer, on average, to participate in a flexibility program (as opposed to selecting the "Opt out" option). This is consistent with the high likelihood to enroll that both groups report (cf. Figure 3).

4 Field experiment

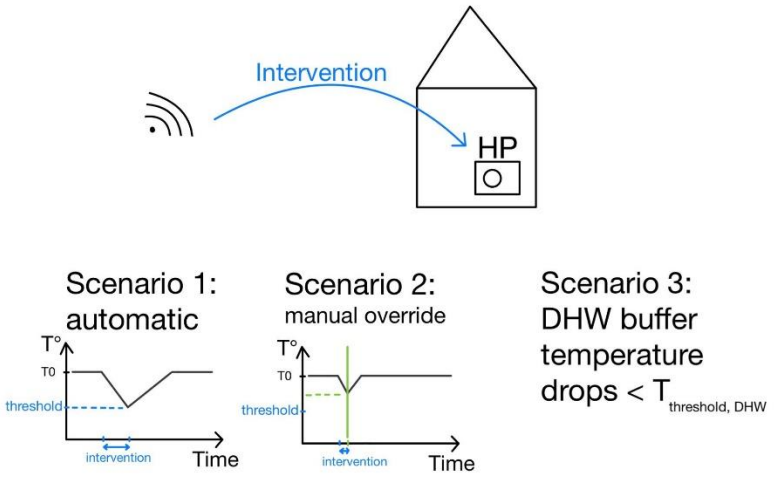

Figure 13: Flexibility interventions on heat pumps in the field experiment: the three scenarios of stopping an intervention

The field experiment of the FlexSys project started in November 2022. Eight households with heat pumps were enrolled in an experimental flexibility program. When an intervention takes place, heat pumps are turned off and only restart automatically when a predefined indoor temperature limit is reached, when the domestic hot water (DHW) temperature in the buffer becomes too low or when the participant overrules the system for any reason. A first goal of this field experiment is to analyse the reasons provided by participants for overruling the interventions if and when they decide to overrule them. A second goal is to study how participants experience these heat pump interventions. Finally, a third goal is to closely monitor how the heat pumps themselves behave and how the indoor temperatures react throughout the duration of each intervention. From this monitoring data, additional insights will be generated. While a separate publication will delve deeper into the findings from the field experiment, the preliminary findings presented below can already serve as a supplement to the survey results focussed on by this report.

4.1 Heat pump triggers overrule

In the field experiment, the same lower limit temperatures were used as in the survey (16-17-18-19°C). During each intervention, one of these temperatures is set as the 'trigger' for automatically reactivating the heat pump. As expected, the field experiment quickly showed that these temperature limits are reached very slowly in the case of well-insulated houses, which only lose their heat at a slow pace after the heat pump is turned off. The field experiment's preliminary results indicate that – depending on outside temperatures – it could easily take several days before the indoor air temperature would drop to 16 or17 degrees (after an intervention was initiated and the heat pump was turned off). This suggests that future flexibility programs in which such low temperature limits are used for automatic heat pump reactivations should be able to keep the buffer tank for domestic hot water (DHW) use operational throughout an intervention. If heat pumps are truly turned off throughout a period of several days, this would quickly lead to a shortage of hot water for sanitary purposes, which would likely diminish the popularity of heat pump flexibility schemes. However, the possibility of controlling the ambient temperature and the DHW temperature separately currently depends on the brand and type of heat pump.

The importance of keeping in mind the DHW functionalities of heat pumps was quickly confirmed in the field experiment. Besides the indoor air temperature triggering an automatic reactivation when reaching a certain level, a automatic reactivation trigger was set for the water temperature in the DHW buffer tank as well. The value of this trigger was always set at 40°C, across the different heat pump interventions. Preliminary results indicate that rather often, it was this trigger that automatically reactivated the heat pump and thereby ended the intervention long before the indoor temperature threshold could be reached.

4.2 Participant triggers overrule

Due to the phenomenon described above, the lower indoor air temperatures (e.g. 16 or 17 degrees) were never reached in practice and the overrule button was rarely used. Only in the case of a retrofitted house with a higher degree of heat loss, a regular use of the overrule button was observed, due to the fact that indoor air temperature tended to drop more quickly there. In the case of another household, a reason given for using the overrule button was the fact that someone in the household was ill. In most of the cases where interventions were overruled by the field experiment participants, they already did so before the intervention took place (on the basis of the message they received 24 hours beforehand).

5 Conclusion: the end-user as a source of flexibility

The purpose of this deliverable was to create a better understanding of the views and preferences of potential users with respect to future programs for residential flexibility. To gather data about this matter, two surveys were launched: one to the cooperative members of Energent and Ecopower and another (online) survey sent to a random sample of the general population.

It is clear that people are willing to participate in flexibility programs and give control of their assets to a third party. The main motivations behind this are the potential contribution to the environment, enhancing energy independence and contributing towards grid stability. Monetary compensations are found to be less important, although general population respondents (which are not a member of an energy cooperative) attributed a bigger importance to it. This provides a starting point for the development of future flexibility programs.

These programs will consist of interventions, which involve controlling assets such as heat pumps, electric vehicles, electric boilers and battery-systems in households. Participants must be notified in advance of any scheduled interventions and be given the option to overrule. The timing of these notifications and options to overrule must be investigated further in the context of contributing to Security of Supply in the Belgian electricity system.

In some cases, these interventions will impact comfort levels for the participants. The acceptability of this impact on user comfort was found to be highly dependent on the level of monetary compensations. As expected, higher levels of compensation are associated with a higher willingness to accept an intervention and its impacts. This was shown both for interventions on heat pumps and electric vehicles. The economic viability of the considered monetary compensations will be investigated further within this project, to make residential flexibility beneficial for both the end-users and the providers of the flexibility programs themselves. In subsequent deliverables, business concepts will be designed with a solid value proposition for all stakeholders involved.

Preliminary results of the field experiment suggest that the duration and boundary conditions of the interventions will also influence the energy capacity of flexibility. For example, the type of building (new vs. retrofitted) was found to have a big influence on the pace of temperature drops in the case of heat pump interventions. When the field experiment is completed in 2024, further insights will be derived and published.

To conclude, this report shows that there is a solid base for flexibility from the end-user side. Future research in- and outside of this project can continue to investigate the other aspects of residential flexibility.