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Evaluation of the use of Home Energy Monitoring and Management Systems (HEMS) to support adoption of renovation measures

D2.3.1. Evaluation report HEMS

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Interreg 2 Seas Mers Zeeën

Triple-A

Awareness + Access = Adoption

European Regional Development Fund

Evaluation of the use of Home Energy Monitoring and Management Systems (HEMS) to support adoption of renovation measures

Triple-A: Stimulating the Adoption of low-carbon technologies by homeowners through increased Awareness and easy Access

D2.3.1. Evaluation report HEMS

22 June 2021

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Abstract

In the current context of energy transition, practices for reducing energy consumption are encouraged by many local authority schemes, in particular for households. Homeowners are called upon to change their energy practices to save money, while ensuring better comfort in the home.

Home Energy Monitoring or Management Systems (HEMS) are tools that homeowners can use to increase their energy awareness. Municipalities hope that – by providing HEMS to homeowners - this will lead to the adoption of energy-saving measures. This study therefore aimed to explore how LAs can adopt HEMS distribution actions, and if the adoption of provided HEMS by homeowners can affect the energy use behaviour and willingness of homeowners to adopt also other low-carbon technologies.

The study used innovation adoption theory and a qualitative research method on the adoption of HEMS, supported by quantitative insights. It uses the insights from seven Local Authorities (LAs) from four countries (Belgium, France, The Netherlands, UK), who evaluated their actions to have homeowners adopt HEMS, as well as the energy behaviour in target areas using demo exemplars.

The study first categorises HEMS types based on the factors that might affect the adoption of home energy renovation measures. Second, it investigates adoption parameters according to each adoption phase for local authorities, as well as homeowners. Third, it analyses homeowners experiences through an ex ante and ex post HEMS installation survey. Finally, it assesses the recommendations suggested by participating local authorities.

The study finds that HEMS actions can be embedded in other LA actions regarding sustainability awareness raising and housing renovation. LAs particularly value that HEMS can support them with more accurate real-time energy use and comfort data. However, HEMS should be carefully selected and tested based on cost efficiency, ease of installation, compatibility with the energy management and legal system, simplicity of the feedback and supporting administration and data access arrangements.

The majority of homeowners who installed the HEMS were (highly) satisfied with the HEMS installed in their house and already convinced before the installation that the HEMS would help them to save energy. More than half of the individuals also reported energy-related behavioral change. About 30% of the individuals invested in energy-saving measures, while 70% had not adjusted anything. The adoption of HEMS can support homeowners' behavioral change but does not necessarily lead to adoption of renovation measures by homeowners.

On the one hand, homeowners are likely to change their behaviour if they would get options beyond simple digital meters, on the other hand LAs find their role to help homeowners adopting more advanced HEMS as a complex one-off experiment. Collaboration is key for upscaling the adoption of HEMS.

Terminology

Compatibility: a state in which two things are able to exist or occur together without problems or conflict. (e.g., compatibility with an app, a website, or an in-house display)

Effectiveness: the capability of producing the desired result or the ability to produce the desired output.

HEMS: Home energy monitoring or management systems

LA: local authority

Relative advantage: what the adopter perceives as an advantage compared to business-as-usual

Simplicity: the state, quality, or instance of being easy to understand and use

Trialability: the context with which stakeholders can try a new product, service or instrument before adopting it

Visibility: the quality or state of action or instrument being visible

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1. Introduction

Home Energy Monitoring and Management Systems (HEMS) have been commonly used to monitor, measure and control the energy consumption. According to Faruqui and Sergici (2010), smart technologies in household increase homeowners' responsibility regarding electricity energy use. A HEMS allows homeowners to gather data and insight into how much a household uses energy, for example gas and electricity. If the system provides control, it is called a management system and if the system provides insight into energy consumption, then it is a monitoring system (Mørck et al., 2020). In the framework of the implementation of the EU Clean Energy for all Europeans Package homeowners are expected to become active energy users and prosumers, meaning being involved in the use and gaining of cleaner, more sustainable energy sources. It is hoped that energy monitoring systems will encourage a reduction in energy use (McCoy and Lyons, 2017).

Darby (2001) and Ehrhardt-Martinez et al. (2010) reported that energy-related feedback could contribute to reducing energy consumption about 4 to 12% . A later study by Wilson et al. (2017) stated that the impact of sensors and monitors on energy demand is not proven; however, there are potential benefits to trigger homeowners to save energy. In the framework of the Triple-A project a scoping report (Meijer et al., 2018) was produced that gives further insights into the current use and possibilities of HEMS.

Distribution of HEMS to households intends to give them direct insight into their energy use. A first step to achieve this goal is that homeowners become more aware of their energy use and production through HEMS. However, to realise a structural change of the energy use behaviour, it must become customary for residents to use the feedback system. The need for forming an energy-saving habit also sets demands on the functionality and design of the feedback system. It must meet the preferences, capabilities and interest of a heterogonous group of homeowners and residents or should be designed for specific customer segments.

Currently local authorities pay a lot of attention to the distribution of smart meters. A smart meter is defined as a digital meter that measures energy consumption. Potentially, a smart meter could transmit energy data using a form of electronic communication to give feedback about actual residential energy consumption and costs to encourage households to lower their energy use. However in practice, a smart meter often only helps energy providers by sending energy metering data to them through a digital network. Installing a smart meter thus does not mean that homeowners can receive real-time energy consumption.

In contrast, HEMS provide energy consumption and patterns to users. Energy providers or local authorities could play a role in the rollout of HEMS. 'Improved' smart metering and HEMS could be an instrument to local energy-saving programs and community-based reinforcement strategies of local authorities. Local authorities (LAs) can play a role to facilitate this activation in collaboration with supply-side actors such as network operators and energy service companies.

At the same time LAs also try to upscale the adoption of renovation measures by homeowners. A neighbourhood approach aims to enable more positive outcomes for energy savings and uptake of renovation measures, and it is expected that disseminating and using HEMS in such neighbourhoods could help to increase the adoption of renovation measures. LAs thus look for a coupling of the roll-out of HEMS with stimulating renovation measures.

Next to the potential role of the LAs for HEMS distribution, it is not known yet whether the adoption of HEMS leads to the adoption of renovation measures. This report aims to answer the question: do HEMS affect the structural change of energy use behaviour and willingness to adopt low-carbon technologies? Generally, the implementation of the Triple-A HEMS should appeal to (1) end-users (households), (2) local authorities, and (3) suppliers.

In the next chapter, an introduction is given on HEMS types and their relation with adoption parameters. In chapter 3, we investigate the HEMS adoption through the lens of the local authorities; in chapter 4 through the experiences of the homeowners.

2. Research approach

2.1. Context of the Triple-A project

This report is written in the framework of the Interreg 2 Seas project "Triple-A: stimulating the Adoption of low-carbon technologies by homeowners through Awareness and easy Access" (http://www.triple-a-interreg.eu), funded by the European Fund for Regional Development and the Provinces of South Holland and West Flanders. In Work Package 2 of the project, seven Local Authorities (LAs) – SPEE Hauts-de-France in France; cities of Rotterdam and Breda in the Netherlands; cities of Antwerp, Mechelen and Ostend in Belgium; Kent County Council in the UK - monitored the energy behaviour in target areas using demo exemplars. They also evaluated the effectiveness of the use of HEMS for stimulating pro-energy-saving behaviour.

In the Triple-A project these LA partners - supported by the Universities of Delft (TU Delft) and Ghent and distribution net manager Fluvius - looked at how the awareness of HEMS - and easy access provided by local authorities - can be improved to influence energy saving by homewoners. In the Triple-A project the partners provided HEMS to households to encourage them to change their energy behaviour and to trigger interest in the adoption of low carbon technologies. They also assessed if the HEMS could be used to monitor the energy consumption of households and analyse consumption data before and after applying low carbon technologies.

This report is written as a follow-up on a previous HEMS scoping report (Meijer et al., 2018), which recommended:

- HEMS should be easy to use and accessible, and fit for purpose.
- Feedback should be real-time, frequent feedback enables the user to link behaviour to consequences.
- The specifications of the HEMS should match with the household characteristics and the willingness to use HEMS. A distinction between user groups is advisable: some users explicitly have more interest in more functionalities (and thus a more complex HEMS, others want a more intuitive user interface.
- HEMS should appeal to certain conditions of the homeowner (segments) or to solving issues within the home.

Overall recommendations for LAs to choose specific HEMS included (Meijer et al., 2018):

- The HEMS should be cost-effective.
- The installation of the HEMS should be easy (preferentially without electricity connection).
- The intrusion time for installing in the home should be minimized.
- A preference is given for HEMS that local authorities can experiment with free-of-charge to avoid de minimis statements.

The LAs thus chose a HEMS by themselves which was influenced by local needs to follow-up homeowner requests and interests, and the compatibility with their own energy management system for analysing building stocks. In the next section we give an overview of the types of HEMS that were selected and how we related this to adoption parameters.

2.2. Types of HEMS

Triple-A partners provided HEMS to homeowners to raise their awareness about energy use, to encourage homeowners to change their energy behaviour and to trigger interest in the adoption of low carbon technologies. LAs used HEMS in neighbourhoods that recorded annual energy use gas and electricity within the properties for 12 months before and after installation to monitor actual CO_2 savings within the demonstration areas. Next to baseline requirements, LAs chose discretionary functions and requirements of HEMS, including measuring grid energy use and comfort performance. Technically, HEMS can also facilitate sensing, measuring devices, connection with home appliances, and ICT link (Asare-Bediako et al., 2012).

Since many HEMS are available, it was challenging for LAs to determine if the HEMS themselves needed changes to support the collection of suitable data, without having a test phase. In the end, LAs selected 16 different HEMS based on the following criteria.

- Cost efficiency
- Ease of installation
- Compatibility with energy management system
- Simplicity of administering
- Feedback type

LAs reasoned that HEMS should be cost-effective and easy to install, preferably without an electricity connection. The specifications of the HEMS should match with the household characteristics and the willingness to use HEMS. Although the LAs didn't know how good the homeowners might be with technologies in few cases, a distinction between user groups was considered. Some users explicitly had more interest in more functionalities (and thus a more complex HEMS), others wanted a more intuitive user interface.

LAs agreed compared to previous findings that HEMS should also be easy to use and accessible, and fit for purpose. HEMS should appeal to specific conditions of the homeowner (segments) or to solving issues within the home. Feedback should be quick (in maximum one day). Frequent feedback enables the user to link behaviour to consequences.

The HEMS choice by local authorities was also influenced by the need to follow up KPI's for energy saving, and thus by the compatibility with their energy management system for analysing building stocks.

Detailed information on HEMS devices is available in the scoping report D.2.1.1.The types of HEMS that were used are classified below (Table 1) based on the way energy consumption data can be accessed by homeowners, feedback types, the type of information HEMS offers, compatibility with the monitoring platform.

TABLE 1HEMS CLASSIFICATION

HEMS characteristics that might influence adoption of energy-saving behavior	**Variables**
• Type of access to the data	• Software (app, webpage login) • Hardware (through the device)
• Type of feedback	• Indirect (Historical feedback) • Direct (Real-time feedback)
• Type of information	• Energy consumption (heating, cooling, ventilation) • Temperature • Indoor air quality (such as humidity, CO_2 level, etc.)
• Compatibility with a monitoring platform	• A platform created by a supplier • Other platforms

We briefly discuss how we considered each aspect in this study.

TYPE OF ACCESS TO THE DATA

HEMS users can access their data in various ways. The way of access to the data may affect the easiness of browsing one's energy consumption. The energy consumption is displayed on the HEMS device (**hardware**), or the users can access the data with a webpage login or a mobile app. Both methods are easily accessible and personalised. Users can access their energy consumption report via **software tools** such as a mobile app, website (platform), and energy bill.

TYPE OF FEEDBACK

Zangheri et al. (2019) stated that how, when, and to whom the feedback is delivered can influence the resulting impact on energy consumption. HEMS should be accessible and attractive to use for all household member. Ideally, feedback information should become part of the occupants' daily life and readable and comprehensible. **Real-time feedback** instruments primarily influence quick-win measures. Users can browse their energy use on a daily or hourly base through an in-house display or web-connected device immediately. Real-time feedback given by a HEMS can only be effective over time if households remain using it frequently: the HEMS should therefore easy to use and accessible (Kobus, 2016).

Not all direct feedback systems directly provide an overview or energy use patterns. In contrast, **historical feedback** from energy providers doesn't imply one's effort or awareness to check energy use. For example, a standard paper bill or e-bill can provide monthly or yearly cost overviews. Through this indirect feedback, a homeowner can get more insight and full comprehension of overall energy consumption and compare historical energy consumption. Research by the European Environment Agency (EEA, 2013) indicates that combining direct and indirect feedback from energy providers has been (so far) the most successful in changing consumer behaviour and achieve energy savings.

TYPE OF INFORMATION

HEMS users can receive three types of information. The amount of **energy consumption** for heating, cooling, and ventilation is displayed or provided to HEMS users. Some devices also provide **temperature and humidity**, so that homeowners can adjust the temperature for their indoor comfort. **Indoor air quality** considering CO_2 level and Volatile Organic Compounds (VOCs) is significantly related to ventilation rate.

COMPATIBILITY WITH A MONITORING PLATFORM

Different communication methods and interactions between devices can hinder HEMS adoption (Rosselló-Busquet and Soler, 2011). Technical incompatibility thus can hinder the dissemination of HEMS. HEMS should meet the compatibility requirement. For LAs and energy suppliers, it is also important that HEMS are compatible with other monitoring systems and platforms managing by them and that data can be shared.

Table 2 and Figure 1 show the HEMS types and models selected by LAs following the classification above. In total, local authorities have installed 14 HEMS models, one energy platform (website), and two thermostats. The thermostats were combined with smart meters.

TABLE 2 HEMS MODEL CLASSIFICATION

Type of feedback	Data access	Type of information	HEMS models
Historical data	Software	Energy	Energie ID
	Hardware+software		Fluvius digital meter
Real-time feedback	Hardware+ software		Plugwise, Smile P1, Victron, CEMM, Smappee, 2wire, June, Flukso, iungo, Toon/Eneco, V-smart
	Hardware+ software	Energy + comfort	Netatmo, Nest, Quart'home
	Hardware	Comfort	Woonmeter

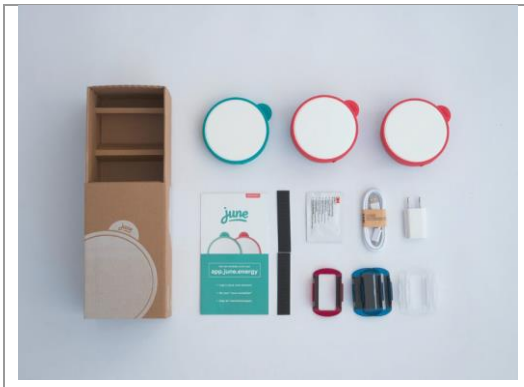
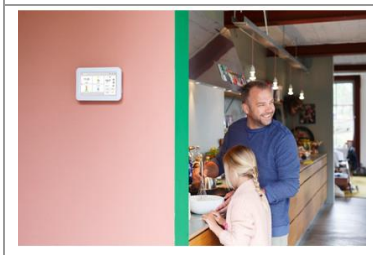
	
June Energy	Fifth Play
	
Toon	Quart'home kit
	
Netamo	Smappee
	
iungo	Plugwise Smile P1
	
CEMM	Fluvius digital meter

FIGURE 1 APPLIED HEMS TYPES

2.3. Adoption by local authorities

The use of HEMS by LAs is an action that is perceived as new by the LAs and can therefore be considered as an 'innovation'. In this framework it makes sense to use innovation adoption theory, e.g. Rogers (2003), to analyse the adoption of the action by the LAs. Amongst other, Rogers verified the validity of innovation adoption characteristics from multiple studies coming to the conclusion that the higher the perceived relative advantage, simplicity, trialability, visibility and compatibility of an innovation, the more likely it is that it will be adopted (Rogers, 2003).

LAs were asked to think from this innovation perspective, on the one hand them being the 'adopter' and the HEMS action being the innovation to be adopted, on the other hand the homeowners being the adopter of the HEMS. From this perspective, TU Delft distributed a questionnaire to Triple-A partners to figure out what are the essential aspects and specifications to select HEMS types (see Appendix A.1). The parameters analysed from these questionnaires comprise:

- ✓ *Relative advantage: what the adopter perceives as an advantage compared to business-as-usual;*
- ✓ *Visibility: the quality or state of action or instrument being visible;*
- ✓ *Simplicity: the state, quality, or instance of being easy to understand and use;*
- ✓ *Trialability: the context with which stakeholders can try a new product, service or instrument before adopting it;*
- ✓ *Compatibility: a state in which two things can exist or occur together without problems or conflict.*

LAs were asked to reflect upon the five adoption parameters and the relevance of these parameters in each step of the adoption process (slection, procurement, implementation, installation, monitoring) .

2.4. Homeowner adoption

The impact of HEMS on the structural change of energy use behaviour and willingness to apply low-carbon technologies was analysed with qualitative data that were collected through a closed questionnaire generated by the University of Ghent. LAs sent a pre-installation survey to homeowners who were willing to install the HEMS. After using the HEMS, LAs distributed a post-installation survey to the homeowners who have used one of the HEMS devices. Furthermore, a questionnaire was sent to the LAs to identify process-related issues.

The following categories of variables were used:

Independent variables pre and post:

- Characteristics of households, for example age, number of persons, plans for renovation, opinions about energy savings
- Type of feedback: Indirect (energy bill through paper or e-bill), direct (through device)
- Type of feedback data: Energy only, energy+comfort, comfort only
- Frequency of feedback: hourly, weekly, monthly, yearly or how often do homeowners check?
- Characteristics of the houses, for example built year, house type, energy consumption

Dependent variables, pre and post:

- Satisfaction, ease of use of HEMS, perceived behaviour changes

The two questionnaires for HEMS users and one questionnaire for LAs are available in Appendix B.1 and B.2. In the next chapter we address the results from the perspective of the HEMS adoption by LAs, in the chapter thereafter the results regarding HEMS adoption by homeowners.

3. Experiences of local authorities

3.1. Relative importance of adoption parameters

This chapter reflects the findings of TU Delft on the adoption of HEMS by LAs. It evaluates the local authorities' experiences for disseminating HEMS to households and provides an overview of the local authorities' actions and process to manage the HEMS adoption. The hypothesis is that when relative advantage, visibility, simplicity, trialability, and compatibility are higher, the adoption can increase. Key issues that could lead the increase of HEMS adoption were identified based on LAs' feedback. Apart from the previously discussed selection of HEMS, we discuss the four action phases that were planned after the selection of the HEMS: procurement, implementation and installation of HEMS, monitoring phase, and evaluation (overall satisfaction about the activity).

The LA self-reporting showed that for the procurement phase LAs mainly looked at relative advantage. In the implementation phase the testing opportunity was considered very important. For the installation phase, LAs emphasized the need for simple installation compatible with the homeowner environment. For the monitoring phase, the data visibility was highlighted. Figure 2 relates the perception of adoption parameters by LAs to the different process stages.

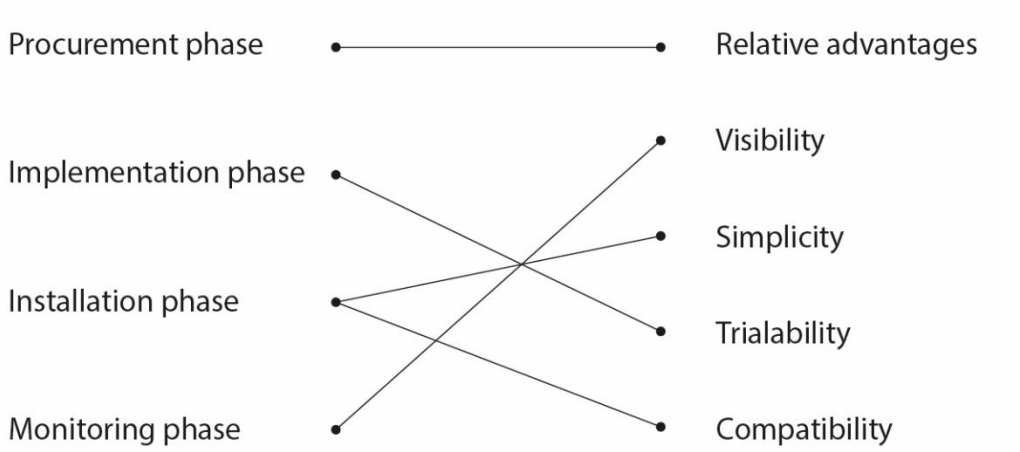


FIGURE 2 PERCEIVED RELATION BETWEEN ADOPTION PHASE AND ADOPTION PARAMETERS

A remark we can make is thus that LAs did not look into detail at each parameter in each phase. We further look into the perception of each adoption parameter.

3.2. Relative advantage

LAs confirmed that a general advantage of selected HEMS was the **real-time monitoring function**. Some LAs reflected that smart meters are developed to provide an overview of energy use to energy suppliers, which not necessarily brings them advantage. They saw as a relative advantage of the procured HEMS that these mainly focus on homeowners' functionality: homeowners can browse their energy consumption pattern whenever they want to check.

The HEMS installed by Hauts-de-France, Rotterdam, and Ostend, had **a thermostat function**. Those LAs confirmed literature findings that people are not necessarily interested in looking at the amount of energy use, but more in the energy bill and information about indoor climate and comfort. LAs reflected that it was still not clear if homeowners were thus made aware of energy-saving as they can see how much they consume, and if this will lead them to make some investments. Antwerp and Kent said **an overview through an online platform** was an advantage. Antwerp emphasised that HEMS could monitor not only energy use but also energy production.

Moreover, the LAs reported that HEMS they chose offered more **accurate data** than other similar devices and **an overview of energy-saving and use patterns**. On the other hand, Mechelen

reported it was still tricky to highlight the benefits of using HEMS and promote the HEMS to homeowners.

Why LAs would adopt HEMS actions (to increase relative advantage)

- HEMS can provide real-time monitoring
- HEMS can provide information about indoor comfort
- Data are more accurate
- HEMS can provide an overview for both energy consumption and production

3.3. Trialability

LAs reflected on the aspect 'trialability' mainly from their experiences related to testing HEMS model options.

For example, during the selection process, the city of Antwerp launched an **e-tendering** to buy HEMS or meter readers in the summer of 2018. Antwerp wanted to measure electricity and gas uses, and produced energy by solar panels. They also wanted to control the energy reduction before and after executing works to see what the (technical) performance is of the taken measures. Antwerp had a meeting in 2017 with the company that provides the digital meter reader June. They consequently tested two types of HEMS: digital/smart meter readers and smart thermostats to provide insight to homeowners into their energy consumption (models Fifthplay and Smappee). Although Antwerp did not collect homeowners' feedback, they **based their decision also on experiences from other LAs**.

Hauts-de-France used the Quart'Home Monitoring System, offered by Quartum/EcoCO2. The software was patented by Quartum and developed by EcoCO2, which ensures its maintenance and evolution. The French LAs associated with Hauts-de-France **conducted a value assessment**. They perceived that the Quart'home system helped homeowners to understand, monitor and reduce their electricity consumption by displaying multiple data: power, load curve, electricity and gas consumption, indoor and outdoor temperatures, indoor and outdoor humidity, comfort zone diagram and advice offered by "eco-coaching". An account was created on the Quart'Home website to have all information about the house, occupancy, energy consumption, etc., with a homeowner who had a contract with Quart'Home to assure data privacy.

Kent County Council considered utilising HEMS to understand the overall benefit to domestic properties in financial terms, from operating battery systems in tandem with solar panels. Kent wanted to establish a detailed understanding of the pattern of energy use within the property, how the technologies perform, and how residents use them to maximise their energy use efficiency.

Since energy monitoring required technical knowledge, Mechelen had to **make decision with experts**. It was complicated for them to explain technical information to homeowners. The LA did not have a real testing period and immediately purchased HEMS devices after a market consultation.

Ostend also **performed value assessment tests** with the digital meter reader June and smart thermostat Netatmo (See Descriptions 4.3.2). As the June equipment was initially developed to help people switch between energy suppliers (based on their energy consumption and energy prices), there is very limited interaction with the user (no alerts or tips & tricks to influence the user behaviour). Therefore, this device seemed less useful to sensitise people about their behaviour and/or possible energy savings. EOS had quite some experience with Netatmo for energy monitoring and remote control of heating installations. Based on the tests with both solutions, EOS selected the Netatmo smart thermostat to manage/monitor gas consumption for heating and to sensitise people about their energy usage. Ostend recommended that having experience with HEMS made it much easier to evaluate HEMS.

Rotterdam invited **homeowners to review** the HEMS devices instead of selecting the device by the LA in the pre-selection phase. The LA did not test the HEMS by themselves but used the highest review scores on neutral platforms.

Rotterdam criteria for value assessment test were based on specs and review scores and included:

(See below for the dutch long list):

- Review score
- Easiness of installation (do it yourself, internet router)
- Measurement possibilities (gas, electricity, water, solar, charging pole, individual appliances, programmable plugs)
- Suitability for smart meter
- Other monitoring/steering possibilities (thermostat, fire detection, shared energy use)
- Measurement specs (realtime electricity, realtime gas, individual appliances)
- User interface (own device (phone, tablet), display)
- User interaction (graphs, share consumption, compare periods, set target, get tips)
- Data (storage time, privacy choices)
- Costs (investment, yearly payments)
- Independency (of energy supplier)

For Fluvius, the most important aspects **were reliability of data, monitoring energy consumption, and high compatibility and simplicity** to increase trialability.

How LAs can test HEMS actions

- Have LA staff do value assessment tests
- Use experts' review on HEMS
- Facilitate homeowners' review on HEMS
- Check reliability of data
- Review if the HEMS assures high compatibility and simplicity

3.4. Simplicity

The LAs confirmed that the design of HEMS should look as simple as possible and mainly reflected on the **ease of use** of HEMS. The LAs therefore also offered the HEMS with **a direct feedback function** (Antwerp, Hauts-de-France, Ostend, and Fluvuis) highlighted **ease of use, the need for a user-friendly app, and easy accessibility** to data. Antwerp and Hauts-de-France mentioned that HEMS had **an easy online platform format** that provided very easy access to the data. Rotterdam specifically also collected user reviews and selected devices with a high average score. **Easy installation** was also essential to choose HEMS devices (Rotterdam), and Ostend and Hauts-de-France asked **suppliers and energy coaches to install the devices** to avoid technical faults.

Concerns regarding complexity were also raised. For example Rotterdam commented that each HEMS had its own downloading system and different data elements. SPEE further reported that the cleaning of energy data is a complicated matter that is best left to experts. Thus, **the data analysis process was complicated and difficult**. Rotterdam and Fluvius also had concerns regarding reliability and good privacy and data security during the HEMS device selection. In Antwerp, homeowners struggled to receive feedback through HEMS due to the WIFI network. So, homeowners having HEMS with cloud-based feedback needed to be convinced that they have **a good internet connection** for browsing the data and collecting accurate energy data. In Kent, the system was straightforward to use, but Kent County Council also encountered barriers related to internet connections. The installer showing the residents on how to use the system was considered very helpful.

Again it can be noted that LAs did not reflect that much from the perspective of how simple or complex it would be to increase the uptake of HEMS actions within their organisations. A general concern was that to reduce complexity increased collaboration is needed with energy providers (e.g. to gain easier access to data) and with other persons within the LA (e.g. on legal and privacy issues).

How LAs can simplify HEMS actions

- Select simple devices that are easy to use, and that provide easy accessibility
- Choose for an easy access and user-friendly online platform format to collect data
- Facilitate easy installation, engaging the installer or energy coach to take up responsibilities regarding information provision, internet access and coaching
- Ensure an easy data analysis process
- Engage in stakeholder collaboration for sustaining HEMS actions

3.5. Compatibility

LAs were concerned that they had to choose HEMS that are GDPR compliant. During the HEMS selection process, LAs aimed to select HEMS that are compatible with the living conditions and existing installations in single-family homes and building blocks, matching with the household characteristics and the willingness to use HEMS. However, this was difficult to assess ex ante.

Another aspect that LAs reported regarding compatibility was that for various house types with HVAC systems, solar panels, battery packs, and other devices, LAs were required to check the HEMS compatibility with these various systems. Antwerp remarked that it is also essential to assess the compatibility between analogue and digital meters.

The energy consumption data can be stored by connecting the device to an online platform. Particularly, for HEMS with an online platform such as EnergieID, homeowners should be able to connect their account to the platform. Unfortunately, homeowners intentionally disconnected their account so that it hindered storing the data in the cloud.

An observed barrier was a rapid market evolution of HEMS models. Mechelen experienced while distributing the HEMS devices, there were already updated models with better functions. Moreover, the older HEMS had low compatibility, which made it challenging to integrate the new HEMS.

It can be remarked that LAs didn't particularly reflect on the compatibility of distributing HEMS as an action being compatible with other LA actions. This is however inherent to the Triple-A set-up where HEMS actions are being developed to have compatible connections with additional online information tools, neighbourhood consultancy actions and the use of demo exemplars.

How LAs can increase compatible HEMS actions

- During selection aim for high compatibility with other devices, control systems, home appliances, and systems
- Aim for integrating historical energy use data
- Check compatibility with (possible future) renewable energy systems, e.g. PV panel and battery system
- Assure connectivity with an online platform
- Embed HEMS actions in other LA actions regarding sustainability awareness raising and housing renovation

3.6. Visibility

LAs confirmed that it is recommended that HEMS devices should be visible to increase the frequency to check the data, thereby leading homeowners to be aware of energy reduction. They identified visibility in two ways: one is the **visibility of a device itself** and energy use data through a display or device. Another is the visibility of the **website showing intuitive graphs or data**. Visibility can be considered during monitoring phase. Whether the HEMS action itself was visible to other members within their own organisation was not assessed by LAs.

Hauts-de-France reported that **energy feedback through a tablet** increases visibility. Ostend highlighted **a good HEMS design displaying temperature, and the schedule** for heating and cooling would attract homeowners. Although Rotterdam chose the HEMS without display, they experienced that the HEMS metering device with a display showing graphs could give additional feedback to homeowners and LAs.

Why LAs would adopt HEMS actions (to increase visibility)

- Visible well-designed devices support homeowner energy awareness raising
- Well-designed displays can also give better feedback to LAs

3.7. Assessment per phase

Table 3 provides an overveiw from the perspective of identifying LA barriers and opportunities per adoption phase, in view of identifying key issues that can support risk assessment for initiating LA HEMS actions.

TABLE 3 OVERVIEW OF HEMS ADTOPTION PHASES AND PARAMETERS

Adoption phase	Adoption parameters	HEMS use risk assessment parameter
Procurement phase	Relative advantage	Real-time monitoring
		Information about indoor comfort
		Overview for both energy consumption and production
		Accurate data
Implementation phase	Trialability	Value assessment test
		Expert's review
		Homeowner's review
		Relaibility of data
Installation phase	Simplicity	Ease of use and accessibility
		User-friendly format
		Ease of installation
		Ease of data analysis
	Compatibility	Compatibility with devices
		Integrating historical energy use data
		Compatibility with renewable energy systems
		Connectivity with an online platform
Monitoring phase	Visibility	Visible well-designed devices and display

3.7.1. Selection phase

The LAs qualitatively assessed the five adoption parameters from the perspective of HEMS being adopted by LAs. We also asked the LAs to give a score (5 Likert scales): 1=low, 2=moderately low, 3=neutral, 4=moderately high, and 5= high. Table 4 shows the overall scores of adoption parameters assessed by six LAs, compared to the four previously discussed types based on combinations of delivered information, feedback type and data access.

TABLE 4 ADOPTION SCORE FOR HEMS TYPES

	Relative advantage	Visibility	Simplicity	Trialability	Compatability	Average value	N
Energie ID	4.5	3	4	3.5	4	3.8/5	6
Fluvius digital meter	5	4	5	4	5	4.6/5	
Plugwise, Smile P1 Victron, CEMM, Smappee, 2wire, June, Flukso, iungo, Toon/Eneco, V-smart	4.3	3.5	4	3.2	4.2	3.8/5	6
Netatmo, Quart'home	4.5	4.5	4.5	4.5	4.5	4.5/5	6
Average value	4.6/5	3.7/5	4.4/5	3.8/5	4.4/5		

The HEMS model (Vsmart) that provides direct feedback, both on the HEMS and through a software tool, on both energy use and home comfort received the highest score. The second-highest score was for the HEMS, which provides only indirect feedback through a web portal and only information about energy consumption. This HEMS scored lower on visibility since homeowners had to consult a website to get insight into their energy consumption. In addition, the score of trialability was not high either because of various testing phases, fast development of HEMS or lack of available HEMS models. The HEMS that provides direct feedback on energy use scored much lower compared to the HEMS that provides indirect feedback. Detailed analysis showed that this is due to lower scores on visibility and trialability.

Unexpectedly, the HEMS functioning direct feedback received a relatively lower score for visibility and trialability. The reasons were that the HEMS were not placed on the wall in a living room or other living places but in the cellar or technical places where people did not go that often.

LAs confirmed that one of the barriers that hinder the implementation of HEMS is the **initial installation cost** (Bolla et al., 2010).

We also explored how the LAs promoted the HEMS towards homeowners and for the other phases we also asked the LAs about their satisfaction regarding HEMS adoption in different adoption phases.

3.7.2. Procurement phase

Table 5 shows the satisfaction level of local authorities regarding the procurement process. In general, **procuring HEMS from suppliers was not easy** because suppliers were unwilling to join the project. Furthermore, contractors were not familiar with thermostats, and they did not see the benefits in terms of profit margin. In addition, it didn't make sense to procure a small number of HEMS . Supply-side actors preferred larger buildings than housings and a larger number of HEMS than a few.

Nevertheless, most LAs obtained the HEMS through public procurement with financial support from the Triple-A project. One **LA collaborated with three other local authorities** and a consultant in the procurement process. A **group purchase** could be organised at the province level which could speed up the process. One LA also recommended to arrange an **internal procurement management team** within the local authority.

TABLE 5 SATISFACTION LEVEL OF LOCAL AUTHORITIES IN THE PROCUREMENT PROCESS

	Unsatisfied	*A little unsatisfied*	*Neither satisfied nor unsatisfied*	*Satisfied*	*Very Satisfied*
Antwerp				X	
Breda	X				
Kent			X		
Mechelen type 1 *				X	
Mechelen type 2 **			X		
Hauts-de-France			X		
Ostend					X

* Mechelen type 1: Energie ID, Energiewijzer, and woonmeter

** Mechelen type 2: June Energy, 2-Wire LoWi, Flukso, and Digital meter Fluvius

3.7.3. Promotion phase

Table 5 shows various promotion methods that LAs used for promoting HEMS towards homeowners. LAs conducted a virtual promotion through LAs web site, digital newsletter, social media, leaflets, as well as through promotional events and pop-up consultancy centres. Some LAs combined both virtual and physical promotion or focused on one of the methods. Mechelen collaborated with the community manager, who worked out a communication strategy to improve the engagement with LAs community on the energy platform. LAs **combined virtual and physical promotion** and could reach various types of homeowners such as different age ranges, size of family, etc. Nevertheless, it was difficult to reach homeowners who have limited digital skills or do not have easy access online.

Breda, Hauts-de-France, and Ostend promoted HEMS in a pop-up consultancy centre. This promotion allowed to have direct contact with homeowners, but this was only limited to pop-up visitors. Kent County Council and Hauts-de-France applied the HEMS to demo houses, so the home renovation and HEMS installation could be conducted at once. Renovation coaches offered information to homeowners. Hauts-de-France sent informative documents about HEMS, but they experienced that homeowners sometimes did not fully understand the documents without explanation.

TABLE 6 PROMOTION METHODS FOR HEMS IMPLEMENTATION

Local authority	**Method**
Antwerp	Virtual and physical promotion
Breda	Pop-up consultancy centre
Kent	Demo homes
Mechelen type 1	Virtual advertisement, communication manager
Mechelen type 2	Virtual promotion
Hauts-de-France	Demo homes
Ostend	Pop-up consultancy centre

3.7.4. Installation phase

When homeowners agreed upon having a HEMS a contract had to be signed, including data sharing and GDPR. Rotterdam and Mechelen noted **GDPR compliance** as a hindrance for the adoption of HEMS. Most LAs provided HEMS to the homeowner free of charge. Some LAs asked for a deposit or take-back after a period. In contract, the HEMS remained the property of the LA. In practice it mostly remained at the homewoners' residence because it would cost more to retrieve the HEMS than it was worth. Homeowners signed a **contract with both the LA and the supplier**. Every stakeholder could access the collected data through the energy monitoring platform. There was also a property sign-off to confirm the installation had taken place.

Various LAs remarked that homeowners would abandon adoption of HEMS once they also had to sign a contract. One of the essential conditions was also having Wi-Fi and using a smartphone or PC for the HEMS dashboard. A **digitally vulnerable group of homeowners could not participate** in HEMS installation. Antwerpen and Fluvius also mentioned that residents were **afraid of sharing their information**, and it was sometimes **complicated to explain technical issues to homeowners by LAs** (Antwerp). Some LAs only provided **a limited option to choose a model** (e.g., Kent) which might have hindered adoption.

There were two ways of installing HEMS: by suppliers or by LAs. The supplier, who had to have technical experience, installed the HEMS device. In this case, the LAs had to rely on the supplier to make an appointment with homeowners for the installation. While, the city of Mechelen installed HEMS by themselves for homeowners since the specific models were easy to use and install. By doing so, installation cost could be saved for the LA. Local authority employees in PSEE Hauts-de-France also placed HEMS for homeowners. For some LAs who installed HEMS by themselves, LAs could not ensure that the HEMS was correctly placed as a HEMS installation was not easy to install without IT skills. The drawback of this was that LAs frequently lost valuable time doing additional tasks due to installation defects. This explains some of the satisfaction level differences, which are presented in Table 6.

TABLE 7 SATISFACTION LEVEL OF LOCAL AUTHORITIES IN THE IMPLEMENTATION PHASE

	Unsatisfied	*A little unsatisfied*	*Neither satisfied nor unsatisfied*	*Satisfied*	*Very Satisfied*
Antwerp		X			
Breda					
Kent			X		
Mechelen type 1 *					X
Mechelen type 2 **		X			
Hauts-de-France				X	
Ostend					X

* Mechelen type 1: Energie ID, Energiewijzer, and woonmeter

** Mechelen type 2: June Energy, 2-Wire LoWi, Flukso, and Digital meter Fluvius

LAs from Antwerp and Mechelen (for type 2) were dissatisfied with the implementation phase because of several reasons. Firstly, it was not easy to make **fair agreements with the supplier**. Secondly, **not every homeowner connected their HEMS to an energy monitoring platform**. LAs needed to contact the homeowners many times for the request. Thirdly, one LA focused on the device and technical information too much, wthout **paying much attention to the service** as well. Fourth, one energy meter-reader (June) was not compatible with the new digital meter installed in homeowners' houses. Next, homeowners or LAs who would install 2-Wire LoWi **required technical and IT skills**. Lastly, the **HEMS device evolved quickly** within the Triple-A project period. It would have been better if the testing phase was longer and if more appliances were tested before making the final HEMS selection.

In contrast, Mechelen (for type 1) and Ostend were very satisfied with the implementation phase. Mechelen successfully expanded the energy platform community due to the communication campaign and offered **HEMS as a reward** when homeowners registered the energy measuring platform. Ostend also had an external contractor, with whom the collaboration went well. Since LAs could speak to the homeowners who wanted to install the HEMS in a pop-up, there was also a **relationship that induced homeowner confidence**. As a result, homeowners committed to the agreements (registering energy monitoring platform, signing GDPR, offering their energy use history, joining the user survey).

3.7.5. Monitoring phase

The HEMS could monitor most household energy systems. In the monitoring phase, LAs analysed how homeowners have used the HEMS and how LAs managed the data collection with stakeholders. More than 50% of LAs were not fully satisfied with the monitoring phase (see Table 7). Many LAs struggled to convince homeowners about the **privacy issue for sharing the energy consumption data**. For example, Mechelen mentioned that data and privacy was a significant concern for homeowners. In addition, homeowners needed to activate their account to follow their energy consumption; however, the **activation process was not user-friendly**.

Interestingly, **homeowners were much more interested in thermal comfort** than energy consumption. Antwerp experienced that for gas **monitoring consumption was not always correct** due to a technical issue. Moreover, some homeowners did not connect to the monitoring platform, thereby being difficult to trace their energy consumption. Also, deploying energy monitoring requires **capacity and skills to support homeowners and to conduct data analyses**.

On the other hand, Kent County Council was very satisfied with their monitoring phase. The LA installed HEMS in demo homes, which gave them good data and allowed the residents to enjoy being able to check their energy use. However, there were also **Wi-Fi connection issues** in some areas with a poor internet connection.

TABLE 8 SATISFACTION LEVEL OF LOCAL AUTHORITIES IN THE MONITORING PHASE

	Unsatisfied	*A little unsatisfied*	*Neither satisfied nor unsatisfied*	*Satisfied*	*Very Satisfied*
Antwerp			X		
Breda					
Kent					X
Mechelen type 1 *			X		
Mechelen type 2 **		X			
Hauts-de-France			X	X	
Ostend					X

* Mechelen type 1: Energie ID, Energiewijzer, and woonmeter

** Mechelen type 2: June Energy, 2-Wire LoWi, Flukso, and Digital meter Fluvius

3.7.6. Risk factors of LA HEMS actions

Reviewing the previous discussion on phases, the following items can be withheld that LAs should consider when setting up a HEMS action. We present them here as a checklist of items for a risk assessment.

RISK ASSESSMENT FACTORS FOR LA HEMS ACTIONS

- Homeowners are possibly more interested in thermal comfort information than energy information
- Homeowners are reluctant to sign a contract to share data
- Digitally vulnerable homeowners might not be able to participate
- Homeowners' adoption is influenced by trusted relations
- Lack of connection with online information can hinder physical promotion
- There might be not enough choices for homeowners to choose appropriate HEMS devices
- HEMS suppliers are not eager to engage in small-scale HEMS distribution actions
- Some actions might suit better on a higher (e.g. multi-LA or provincial) level, for example group purchases
- Some HEMS installations and maintenance require technical and IT skills
- Selected devices can become obsolete sooner than planned
- It can me more costly to retrieve a HEMS then the price of a HEMS
- Additional data analyses and user-friendly activation processes are needed to monitor data
- Correctness of monitoring data should be regularly checked
- The home should have a recognizable 'demo' status; HEMS 'award' status can help

3.8. Conclusion

This chapter aimed to assess the experiences of LAs regarding the incorporation of HEMS actions. The underlying reasoning of the LAs is that distribution of HEMS could potentially affect a structural change of energy use behaviour and willingness to adopt low-carbon technologies.

Overall, factors that can be related to the efficient use of HEMS could also be related to the reasoning of LAs. For example, the HEMS feedback type and monitoring capabilities, the cost efficiency and the ease of installation, the compatibility with the energy management system and legal procedures play a consistent role in the decision-making of LAs regarding the adoption of HEMS.

By looking more in depth into experiences regarding adoption parameters we found that LAs particularly value that HEMS can support them with more accurate real-time energy use and comfort data. Despite this perceived value LAs still need to check if the data are reliable and historically relevant and if the HEMS are compatible with the homeowners' situation, internet connection and user profiles.

LAs prefer to use simple HEMS devices that are easy to use, and that provide easy accessibility, a user-friendly online platform format to collect data and an easy data analysis process. In such cases LAs engaged in facilitating collaboration with stakeholders, installation and follow-up, either organized by themselves or contracted parties such as installers and energy coaches. The selection and testing of HEMS required a specific effort from the LAs, for example to do value assessment tests or to engage with experts or in organizing homeowner feedback.

While on the one hand, there is a pertinent need to upscale HEMS purchases to get the market moving, on the other hand the demand by homeowners can be low due to perceived lack of trust, technical know-how and digital vulnerability. The required data contracting, legal issues regarding privacy and the lower-power positioning of LAs compared to energy providers regarding data access are perceived as some of the most important barriers to upscale LA HEMS actions.

Overall it is perceived that HEMS actions will probably not be developed further as stand-alone actions by LAs. They always need to be embedded in other LA actions related to their strategy plans regarding sustainability awareness raising and housing renovation. Collobaration with actors within LAs, other LAs and higher authorities are key for upscaling the adoption of LA HEMS actions.

4. Experiences of homeowners

In order to get insights in how satisfied people are with the HEMS before and after installation, LAs sent out a questionnaire. Two questionnaires were designed to understand how HEMS might affect people's behaviour regarding energy efficiency. The first questionnaire was launched shortly after the installation of the HEMS in people's home. The other questionnaire was sent on average 8 months later. The pre- and post-installation surveys were linked for the respondents who completed both questionnaires (N = 62). In this chapter University of Ghent first reports on the results of the pre-installation questionnaire and afterwards the results of the post-installation questionnaire.

4.1. Sample

All participating cities contacted homeowners who recently have installed a HEMS. 348 participants completed the first pre-installation questionnaire. 66.1% (230) male and 33.9% (118) female participants filled in the questionnaire. 57.5% (200) of the participants originated from France and 42.2% (147) originated from Belgium. Participants had an age between 24 and 86 (M= 47.23, SD=12.17). Furthermore, 37.9% (132) of the participants lives in a semi-detached house, 33.6% (117) lives in a terraced house, 23% (80) lives in detached house and 5.5% (19) of the participants lives in an apartment.

Regarding the installed HEMS, 57,5% (200) of the respondents have installed the Quart'Home HEMS, 10,9% (38) have installed an 'other' (Vsmart, Woonmeter) HEMS, 9,5% (33) have installed the Netatmo HEMS, 8% (28) the June HEMS, 5,7% the EnergieID HEMS, 4% (14) the Fluvius digital meter, 3,2% (11) the Smappee HEMS and 1.1% (4) did not know which HEMS was installed.

More demographic statistics of the respondents can be found in the graphs below. 83,7% of the respondents lived in a house build before 1980. 37,9% of the respondents lives in a semi-detached house, 33,6% lives in a terraced house, 23% lives in a detached house and 5,5% lives in an apartment.

4.2. Pre-installation survey

The first pre-installation questionnaire was sent to homeowners shortly after the installation of the HEMS. We aimed to measure how satisfied people were with the installation and whether they think the HEMS could help them safe energy. The questionnaire started with some demographic data, the type of HEMS that was installed, and the characteristics of their house. Next, five constructs were measured to estimate their (1) perceived energy efficiency, (2) perceived satisfaction with HEMS, (3) perceived effectiveness HEMS, (4) importance of EEM, (5) intention to adopt low carbon technologies.

In the post-installation questionnaire, we measured the overall satisfaction with the installed HEMS and the changes in behaviour due to the installation of the HEMS. An overview of the questionnaires can be found in Appendix 1.

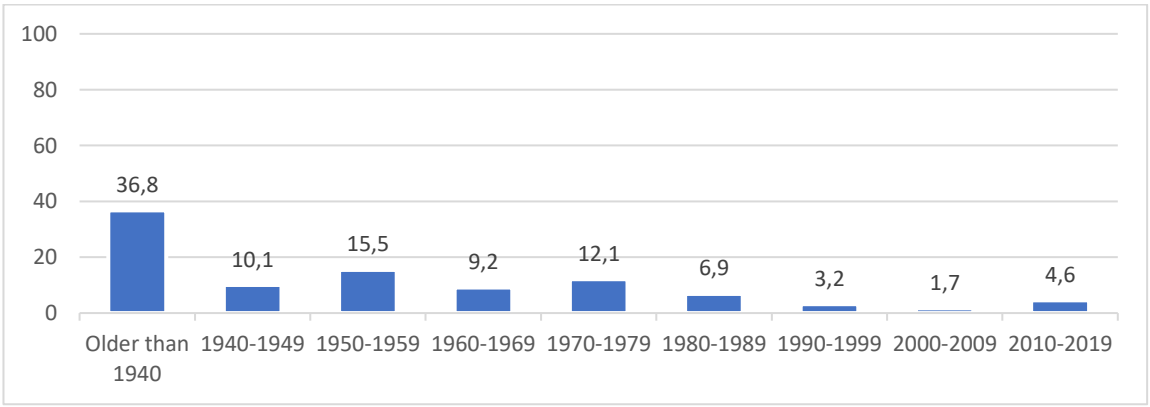


FIGURE 3 CONSTRUCTION YEAR OF THE RESIDENCE

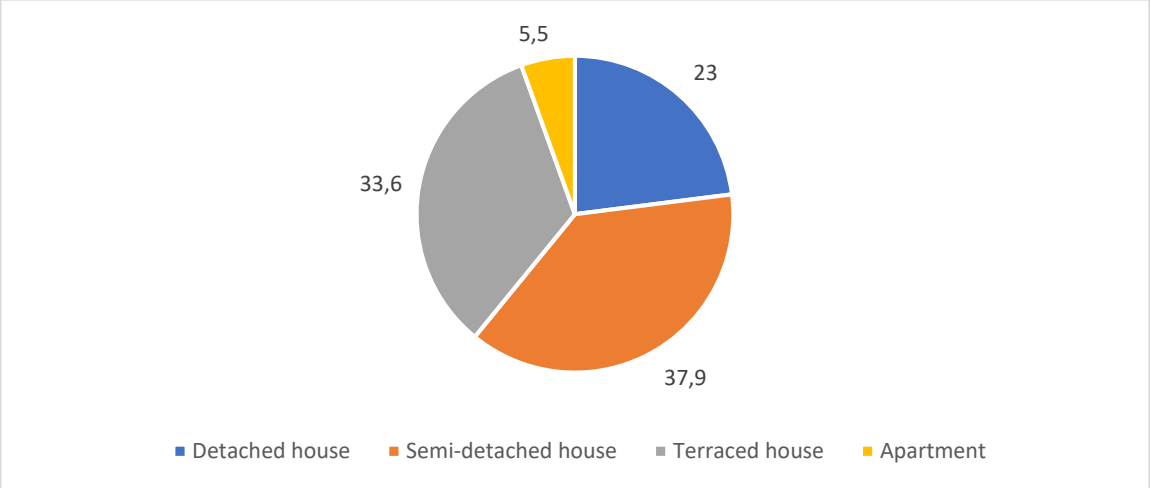


FIGURE 4 IN WHAT KIND OF PROPERTY IS THE HOME ENERGY MANAGEMENT SYSTEM INSTALLED?

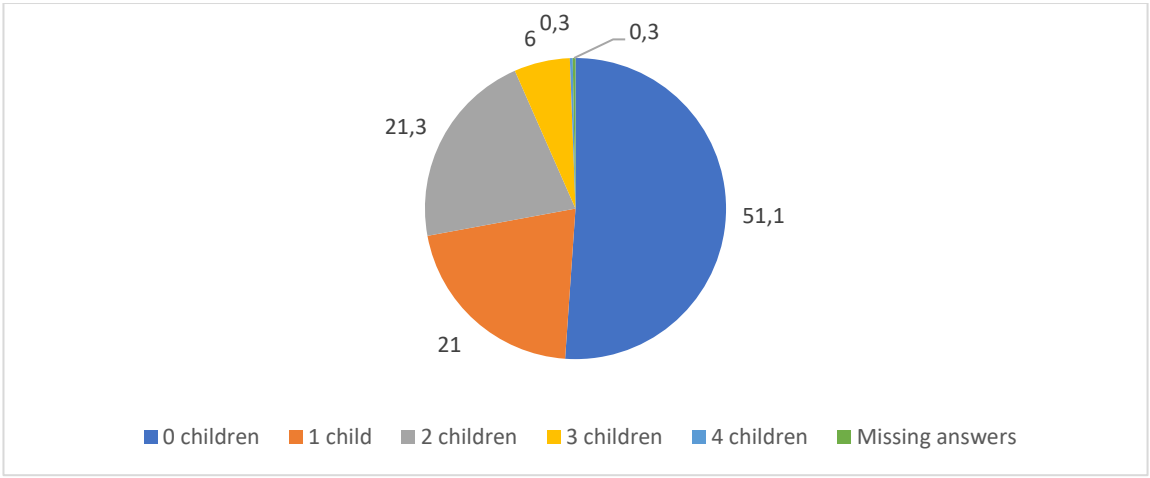


FIGURE 5 NUMBER OF CHILDREN LIVING IN YOUR HOUSE (UNDER 16 YEARS)

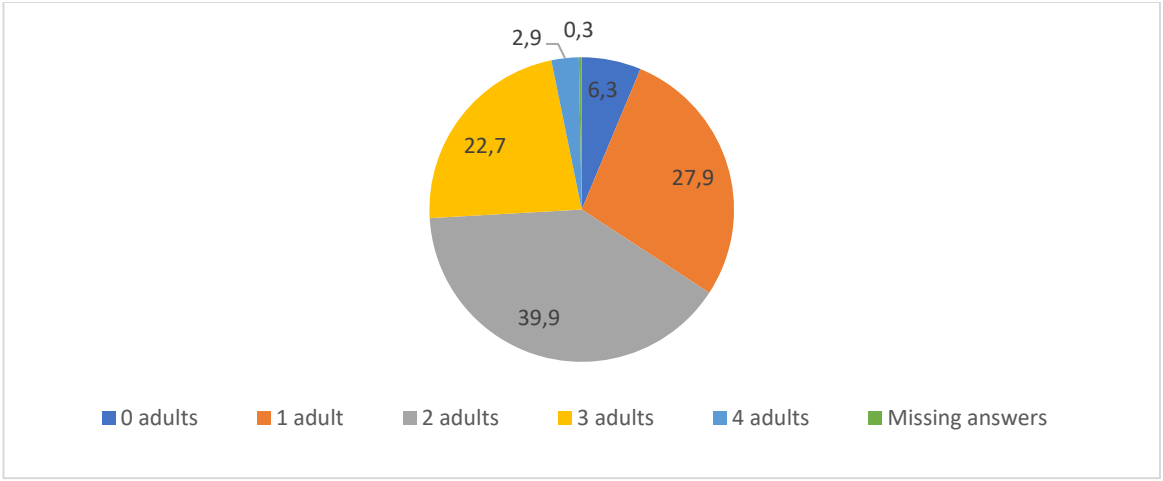


FIGURE 6 NUMBER OF ADULTS LIVING IN YOUR HOUSE (OVER OR EQUAL TO 16 YEARS)

More than half of the respondents (51,1%) have no children living in their house. 21% has 1 child, 21,3% has 2 children, 6% has 3 children and 0,3% has 4 children living in their house. Only 6,3% has zero adults living in their house. 27,9% has 1 adult, 39,9% has 2 adults, 22,7% has 3 adults and 2,9% has 4 adults living in their house.

4.2.1. Energy-saving attitudes

More than half (51,4%) of the participants think their house uses a lot of energy. 31,6% thinks their house uses energy on average. Only 1,1% of the respondents thinks that their house doesn't use energy at all (figure 9). In addition, 77,3% of the participants thinks it is important to save energy. Only 4% of the respondents thinks it is slightly important.

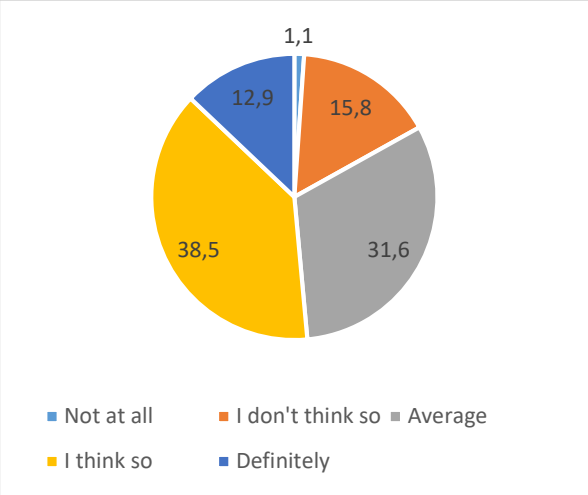


FIGURE 7 DO YOU THINK YOUR HOME USES A LOT OF ENERGY?

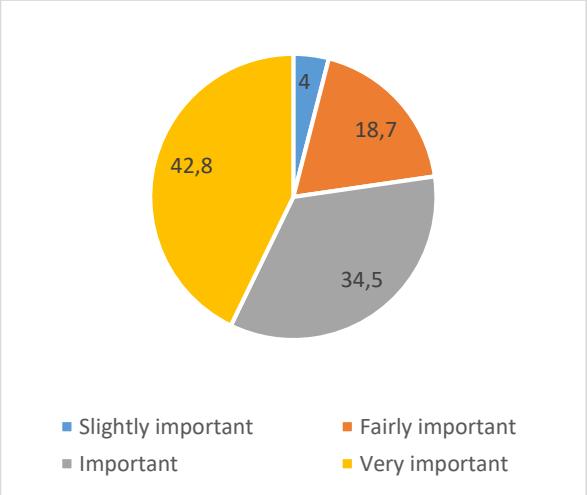


FIGURE 8 DO YOU THINK IT IS IMPORTANT TO SAVE ENERGY IN YOUR HOUSE?

71,3% of the respondents think the new HEMS will help them save somewhat or very much energy. Only 0,6% thinks the HEMS will not help them save energy.

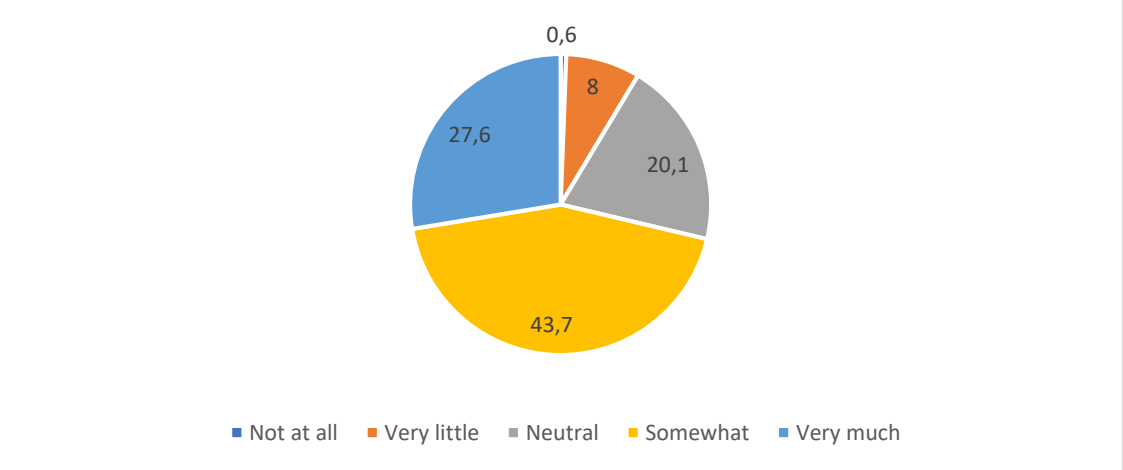


FIGURE 9 DO YOU THINK THE NEW HEMS WILL HELP YOU TO SAVE ENERGY?

Men and women do not think differently about the use of energy in their home (t(346) = -1.85, p= .065). However, women think it is more important (M= 4.34, SD= 0.78) to save energy in their house in comparison with men (M= 4.07, SD= 0.90) (t(346) = -2,77, p= .006) (figure 12). In addition, female participants are more convinced (M= 4.04, SD= 0.87) by the fact that the HEMS will help them save energy compared to men (M= 3.82, SD= 0.93) (t(346) = -2,13, p= .034) (figure 13). Nonetheless, men and women do not differ significantly about how satisfied they are by their newly installed HEMS. What the results do show is the fact that women are more willing (M= 3.93, SD= 0.94) to plan energy efficient investments than men (M= 3.59, SD= 1.13) (t(276,67) = -3,02, p= .003) (figure 14).

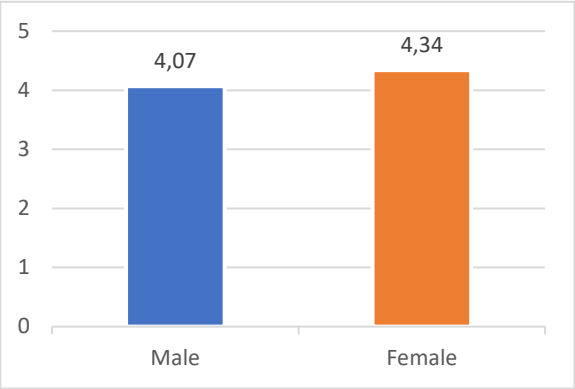


FIGURE 11 DO YOU THINK IT IS IMPORTANT TO SAVE ENERGY IN YOUR HOUSE?

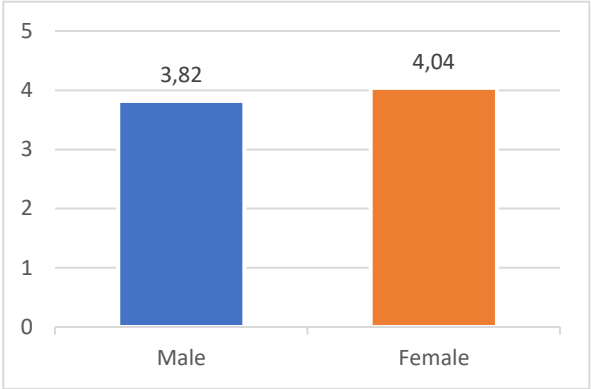


FIGURE 10 DO YOU THINK THE NEW HOME ENERGY MONITORING SYSTEM WILL HELP YOU TO SAVE ENERGY?

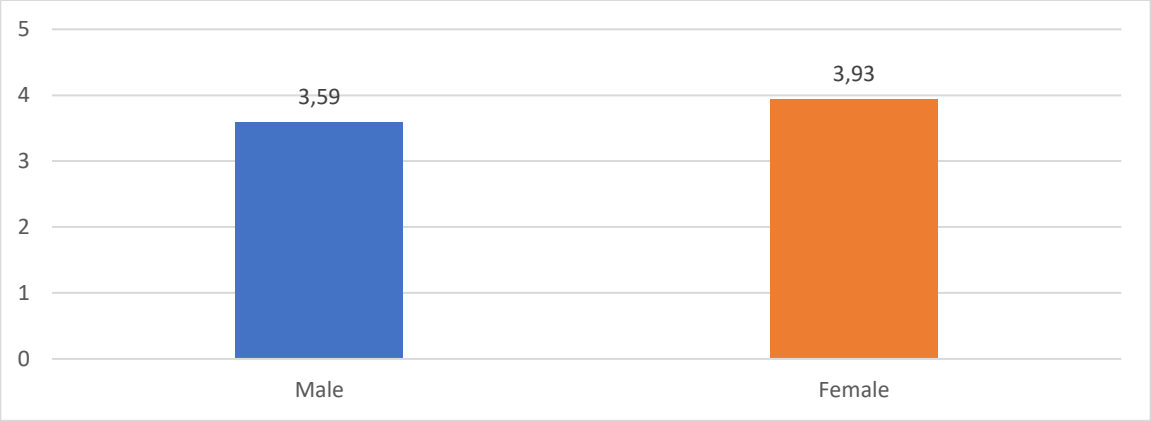


FIGURE 12 ARE YOU PLANNING TO MAKE SOME INVESTMENTS TO SAVE ENERGY IN YOUR HOUSE?

People who live in an apartment (M= 2.68, SD= 1.00) think their home uses less energy compared to people living in an detached house (M= 3.59, SD= 0.88) or semi-detached house (M= 3.64, SD= 0.86) ($F(3, 344) = 7.99$, $p<.001$). In addition, people living in a terraced house (M= 3.30, SD= 0.99) think their home uses less energy compared to a semi-detached house (M= 3.64, SD= 0.86) ($F(3, 344) = 7.99$, $p<.001$).

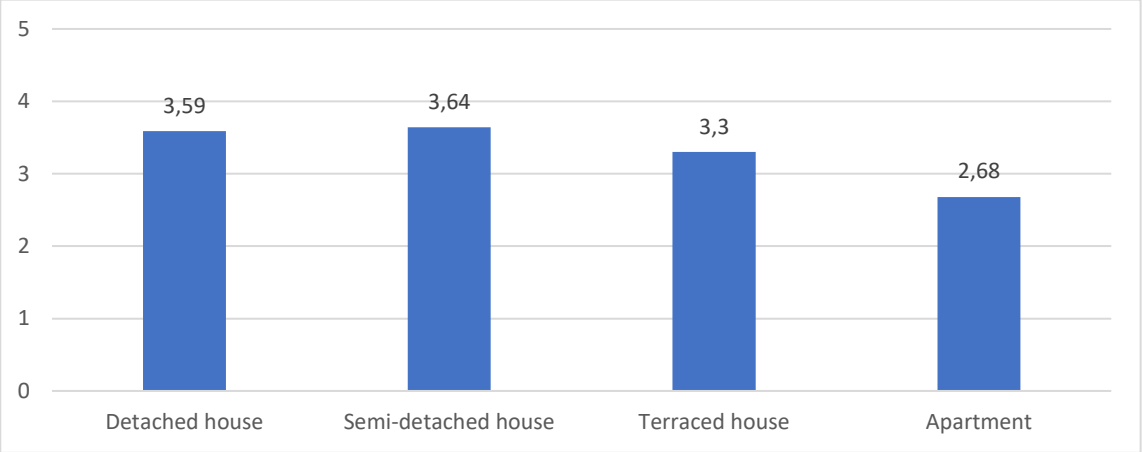


FIGURE 13 DO YOU THINK YOUR HOME USES A LOT OF ENERGY?

Participants who have installed a Quart'Home HEMS think their home uses more energy (M= 3.82, SD= 0.80) compared to people who have installed an EnergieID HEMS (M= 2.85, SD= 0.88), June (M= 3.04, SD= 0.96), Netatmo (M= 3.18, SD= 0.77) or another HEMS (M= 2.82, SD= 0.98) ($F(7, 340) = 12.331$, $p < .001$) (figure 16).

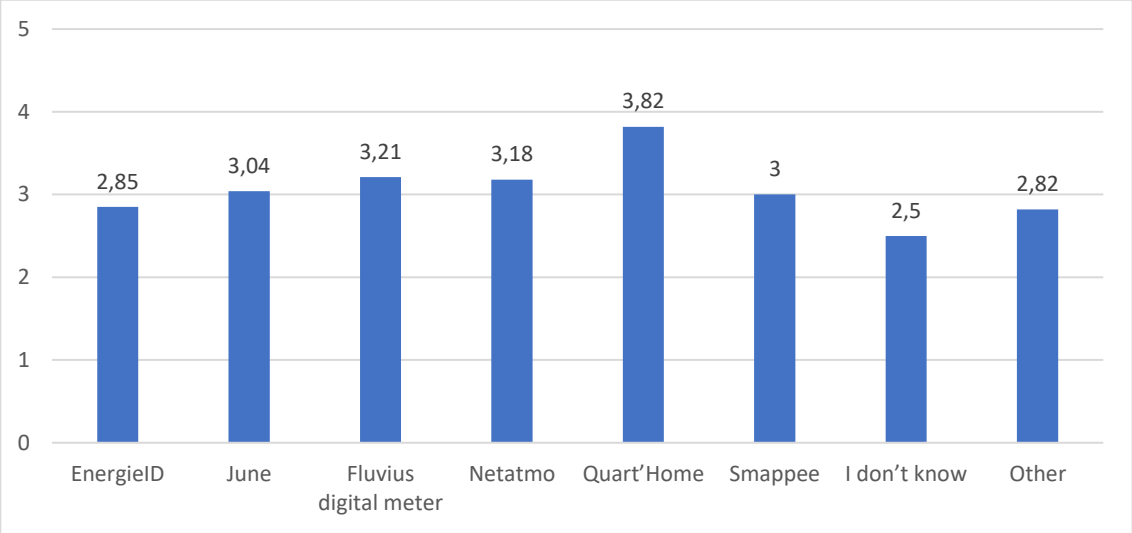


FIGURE 14 DO YOU THINK YOUR HOME USES A LOT OF ENERGY?

Participants who have installed a Direct HEMS think their home uses more energy (M= 3.52, SD= 0.05) than participants who have installed an Indirect HEMS (M= 3.00, SD= 0.99) ($t(343) = -3.07$, $p= .002$).

Participants who have installed an Energy + Comfort HEMS (M= 3.78, SD= 0.83) think their house uses more energy than participants who have installed an Energy HEMS (M= 3.00, SD= 0.95) or a Comfort HEMS (M= 2.97, SD= 0.87) ($F(2, 341) = 35.041$, $p< .001$).

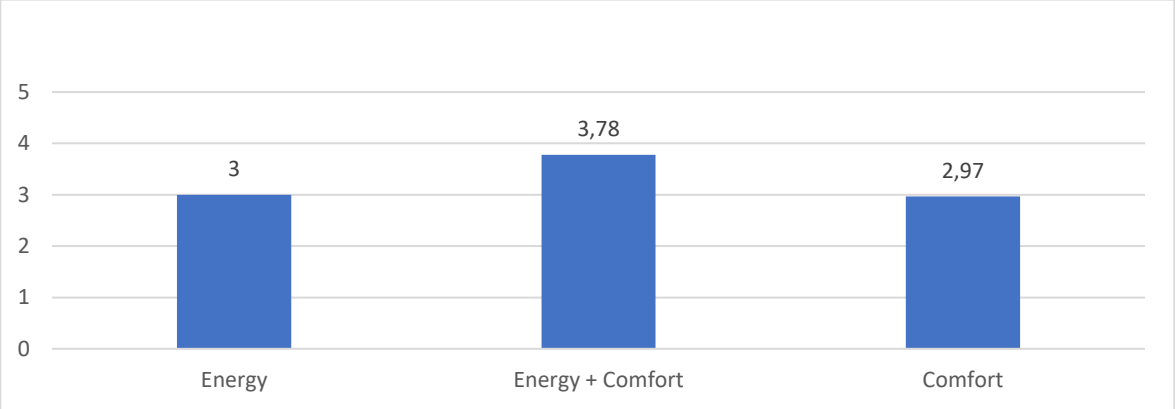


FIGURE 15 DO YOU THINK YOUR HOME USES A LOT OF ENERGY?

In addition, the results showed that the older respondents are, the more they think there houses uses a lot of energy ($r = .115$, $p = .032$). In addition, the older the house, the more respondents think the house uses a lot of energy ($r = -.262$, $p < .001$).

People who have installed an Fluvius digital meter HEMS (M= 3.57, SD= 0.51) think it is less important to save energy than people who have installed an Netatmo HEMS (M= 3.97, SD= 0.93) or another HEMS (M= 4.61, SD= 0.60). Furthermore, people who have installed a Netatmo HEMS (M= 4.58, SD=0.61) or another HEMS (M= 4.61, SD= 0.60) think it is more important to save energy than people who have installed an Quart'Home HEMS (M= 3.94, SD=0.93) ($F(7, 340) = 6.444$, $p < .001$).

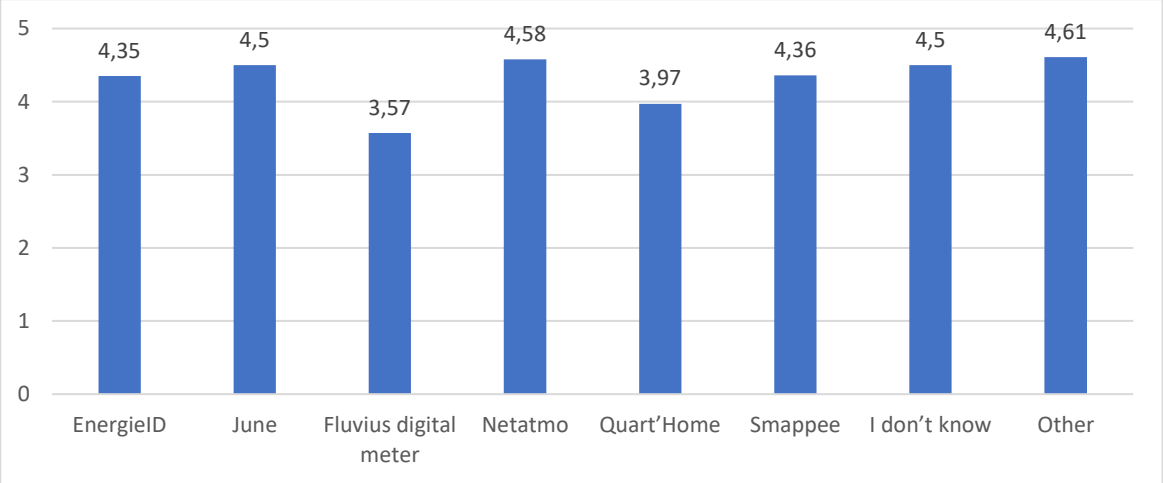


FIGURE 16 DO YOU THINK IT IS IMPORTANT TO SAVE ENERGY IN YOUR HOUSE?

The group of participants who have installed a Comfort HEMS (M= 4.58, SD= 0.62) think it is more important to save energy in their house compared to the group of participants who have installed an Energy + Comfort HEMS (M= 4.00, SD=0.93) ($F(2, 341) = 12.185$, $p < .001$).

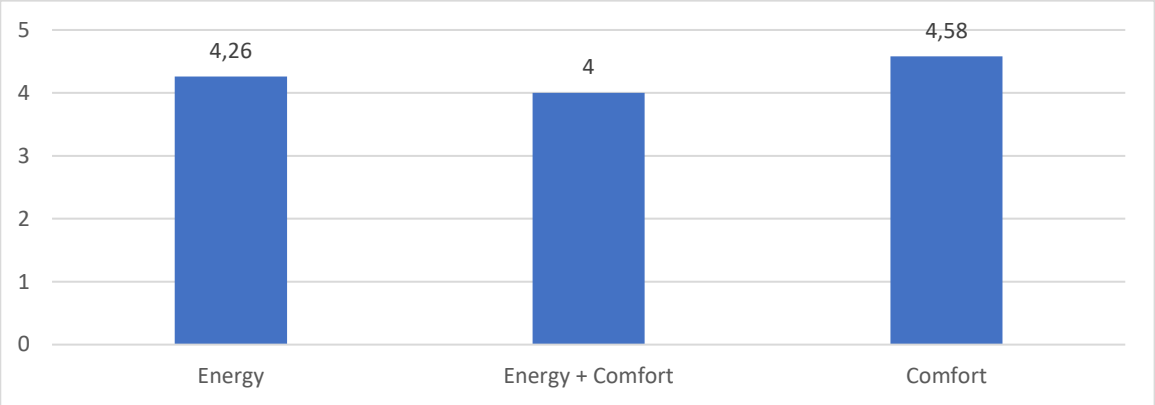


FIGURE 17 DO YOU THINK IT IS IMPORTANT TO SAVE ENERGY IN YOUR HOUSE?

Respondents with a Netatmo HEMS installed think the new HEMS will help them save energy (M= 4.36, SD= 0.60), more than respondents with a June HEMS (M= 3.46, SD= 0.88) or a Fluvius smart meter HEMS (M= 3.21, SD= 0.89) ($F(7, 340) = 3.859$, $p < .001$).

People who have installed a Comfort HEMS are more convinced (M= 4.06, SD= 0.85) that the HEMS will help them save energy than people with an Energy HEMS installed (M=3.64, SD=0.89) ($F(2, 341) = 4.247$, $p=.015$).

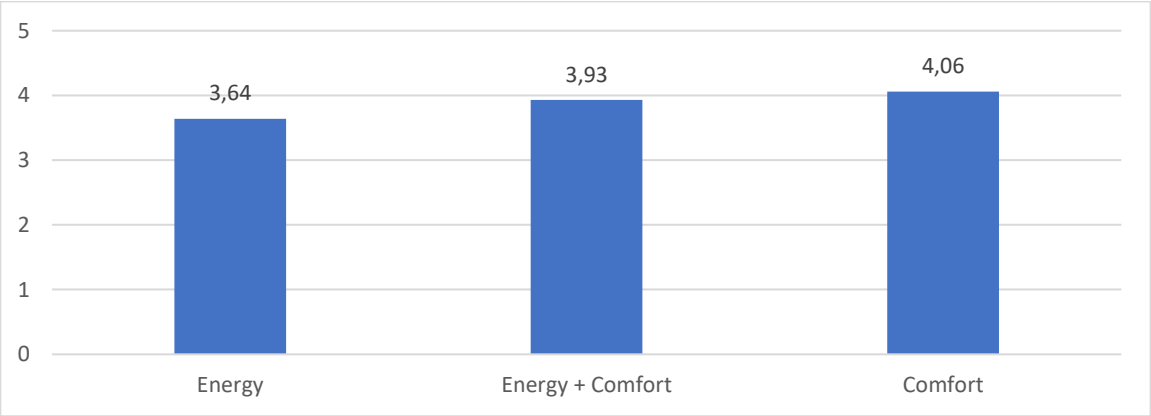


FIGURE 18 DO YOU THINK THE NEW HOME ENERGY MONITORING SYSTEM WILL HELP YOU TO SAVE ENERGY?

4.2.2. Planning Energy efficient investments

67,5% of the respondents are planning to some extent energy efficient investments. 4,6% of the participants are not planning any investments at all.

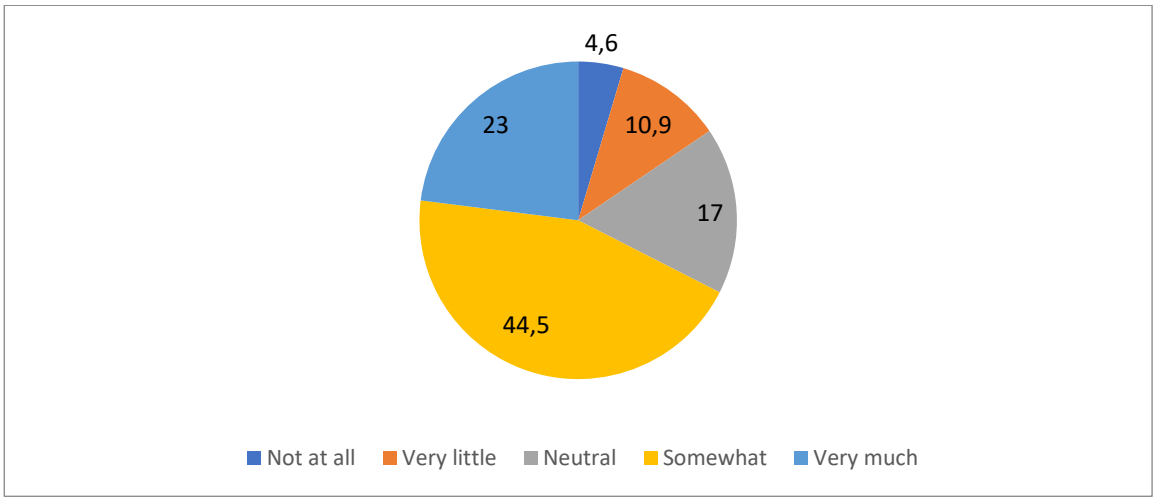


FIGURE 19 ARE YOU PLANNING TO MAKE SOME INVESTMENTS TO SAVE ENERGY IN YOUR HOUSE?

People who live in an apartment are less likely to plan energy efficient investments compared to other house types ($F(3, 344) = 3.45$, $p = .017$). No other significant differences were found regarding the type of house.

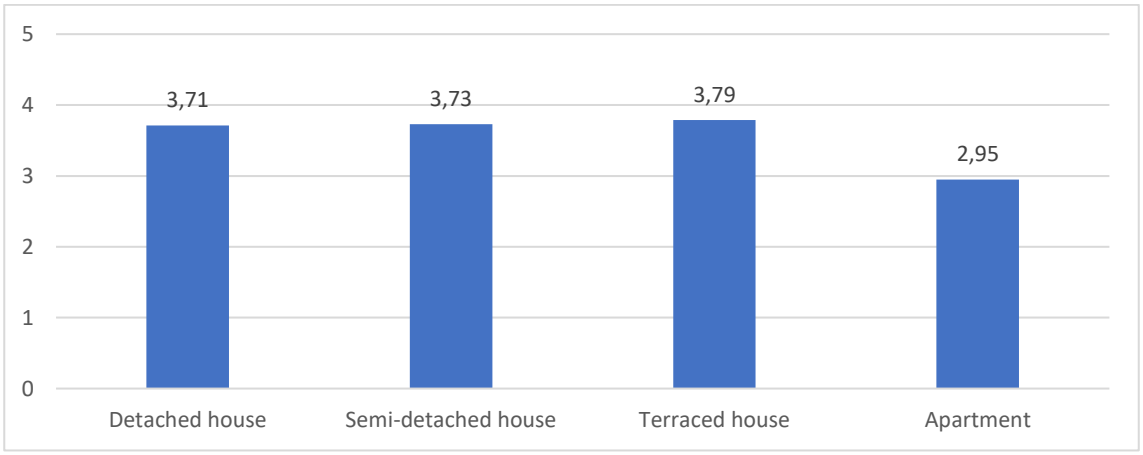


FIGURE 20 ARE YOU PLANNING TO MAKE SOME INVESTMENTS TO SAVE ENERGY IN YOUR HOUSE?

Respondents who have installed an Fluvius digital meter HEMS ($M= 1.86$, $SD= 1.23$) are planning less energy investments, compared to other HEMS ($F(7, 340) = 7.768$, $p < .001$).

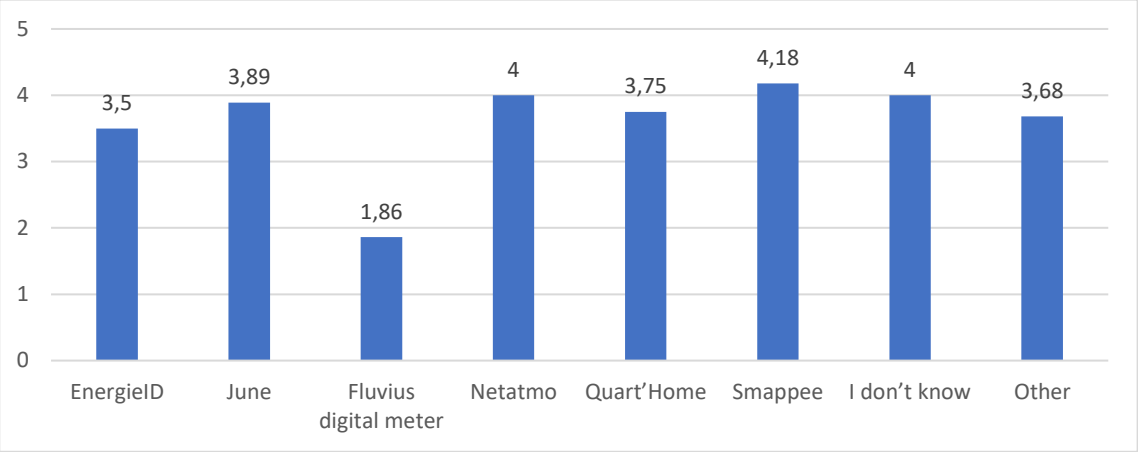


FIGURE 21 ARE YOU PLANNING TO MAKE SOME INVESTMENTS TO SAVE ENERGY IN YOUR HOUSE?

People who have installed an Indirect HEMS (M= 2.82, SD= 1.45) are planning less energy efficient investments than people with a Direct HEMS (M= 3.79, SD= 0.99) (t(343) = -3.82, p= .001). No other significant differences were found between people who have installed an Indirect HEMS or a Direct HEMS. Furthermore, the older the house, the more likely respondents are to make energy efficient investments (r= -.133, p= .013).

4.2.3. Satisfaction with HEMS

77,9% of the participants are happy to very happy with the fact that they now have a new HEMS. 0,6% are not happy at all with the new HEMS.

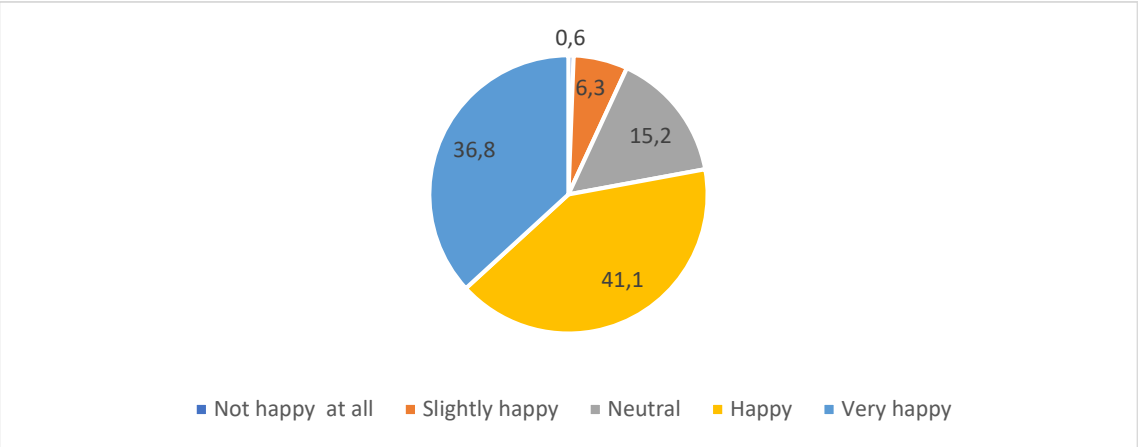


FIGURE 22 ARE YOU SATISFIED WITH THE FACT THAT YOU NOW HAVE A NEW HOME ENERGY MONITORING SYSTEM IN YOUR HOME?

Compared to respondents who have installed a EnergieID HEMS (M= 4.30, SD= 0.66), a June HEMS (M= 4.25, SD= 0.89), a Netatmo HEMS (M= 4.76, SD= 0.44) or a Quart'Home HEMS (M= 3.94, SD= 0.89), respondents with a Fluvius digital meter HEMS are less satisfied (M= 2.86, SD= 0.86). In addition, respondents with a Netatmo HEMS (M= 4.76, SD= 0.44) are more statisfied than respondents with a Quart'Home HEMS (M= 3.94, SD= 0.89)) (F(7, 340) = 9.839, p < .001).

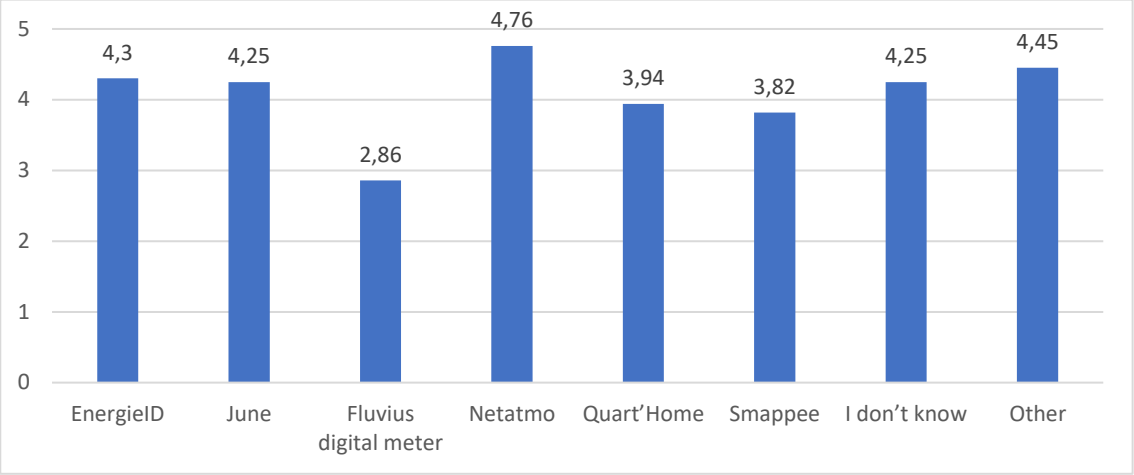


FIGURE 23 ARE YOU SATISFIED WITH THE FACT THAT YOU NOW HAVE A NEW HOME ENERGY MONITORING SYSTEM IN YOUR HOME?

People who have installed an Indirect HEMS are less satisfied (M= 3.71, SD= 1.03) that they have a new HEMS than people with a Direct HEMS (M= 4.11, SD= 0.88) (t(343) = -2.48, p= .013).

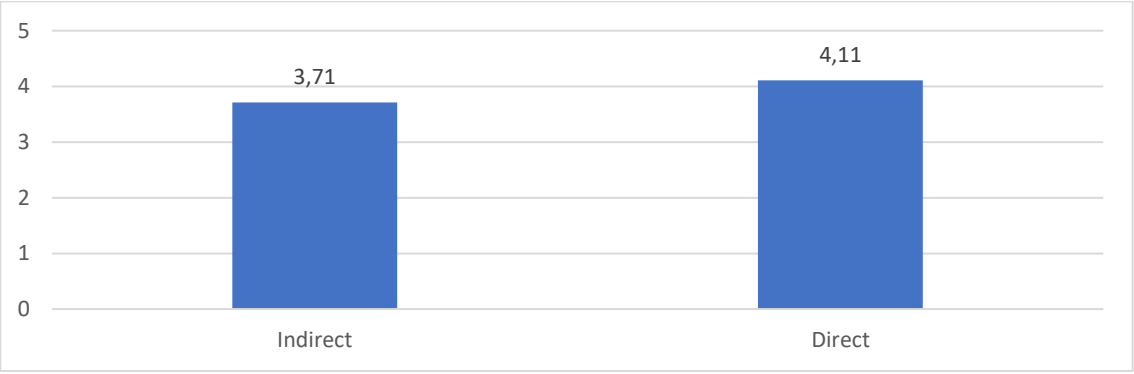


FIGURE 24 ARE YOU SATISFIED WITH THE FACT THAT YOU NOW HAVE A NEW HOME ENERGY MONITORING SYSTEM IN YOUR HOME?

Furthermore, respondents who've installed a Comfort HEMS (M= 4.58, SD= 0.56) are more satisfied than people who've installed an Energy HEMS (M= 3.93, SD= 1.04) or an Energy + Comfort HEMS (M= 3.97, SD= 0.89) (F(2, 341) = 12.861, p<.001). However, the groups do not statistically differ from each other about planning energy efficient investments.

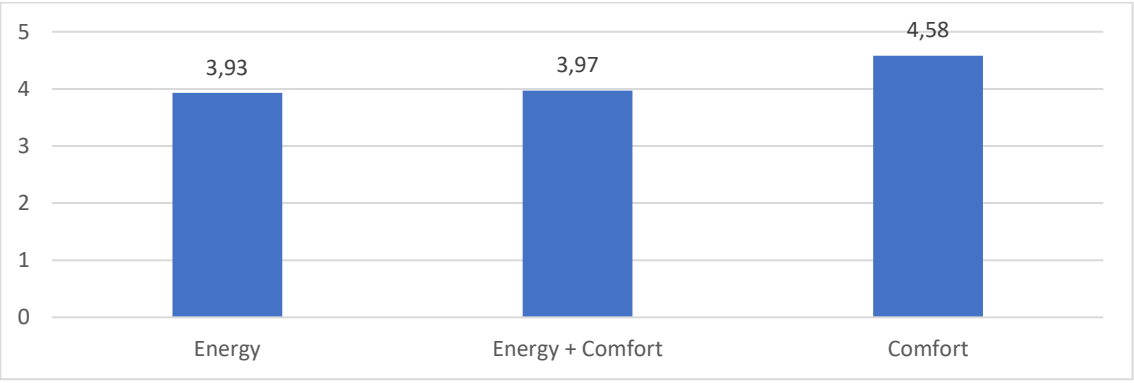


FIGURE 25 ARE YOU SATISFIED WITH THE FACT THAT YOU NOW HAVE A NEW HOME ENERGY MONITORING SYSTEM IN YOUR HOME?

The results showed a (weak) correlation between age and satisfaction: the younger respondents are, the more satisfied they are with the new installed HEMS (r = -.116, p= .030).

4.3. Post-installation survey

The post-installation questionnaire was completed 82 times. 54,9% (45) male and 20,7% (17) female participants filled in the questionnaire. 24,4% (20) of the participants did not report their gender. 42,7% (35) of the participants were residents of Belgium, 51,2% (42) were French citizens and 6,1% (5) of the participants had the British nationality. Participants had an age between 30 and 72 (M= 49.61, SD=10.70). As with the gender, 20 participants did not fill in their age.

41,5% (34) of the respondents have installed the Quart'Home HEMS, 26,8% (22) have installed the Netatmo HEMS, 3,7% (3) have installed Other (Vsmart) HEMS, another 3,7% (3) have the June HEMS installed and 1 person has installed the Fluvius digital meter. For the analysis we have added the respondent with the Fluvius digital meter installed to the Other group.

More demographic statistics of the respondents can be found in the graphs below. As with the pre-questionnaire, the majority of the respondents live in a house build before 1980: 61,1%. As indicated in the pre-questionnaire, also here the minority of respondents lives in an apartment (1,2%). 25,6% of the respondents lives in a detached house, 26,8% in a semi-detached house and 22% in a terraced house.

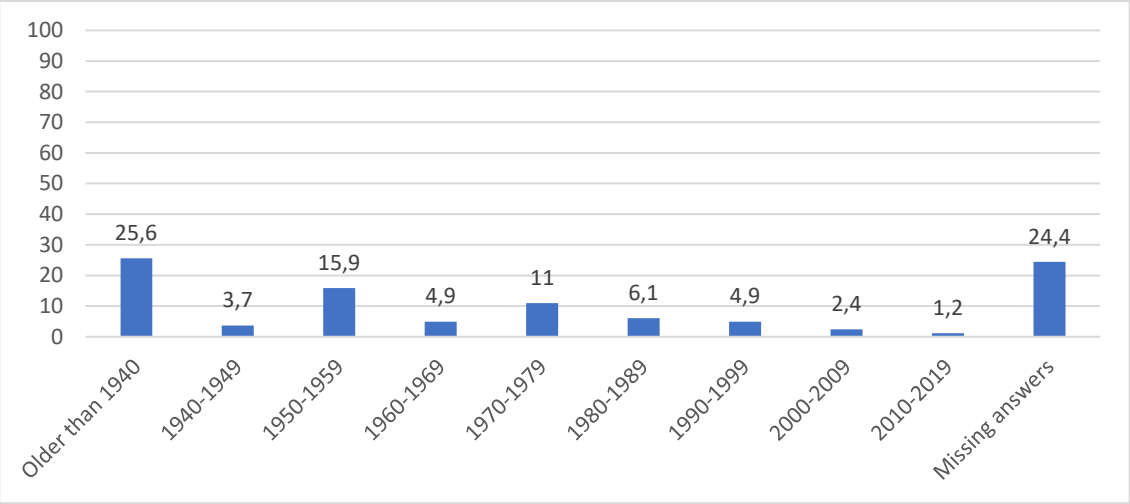


FIGURE 26 WHAT IS THE CONSTRUCTION YEAR OF THE HOUSE?

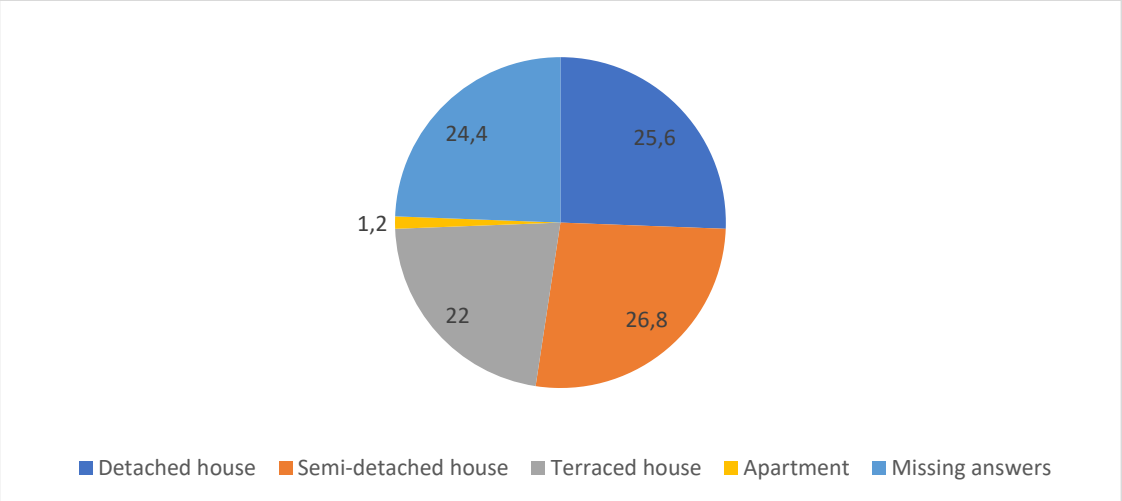


FIGURE 27 IN WHAT KIND OF PROPERTY IS THE HOME ENERGY MANAGEMENT SYSTEM INSTALLED?

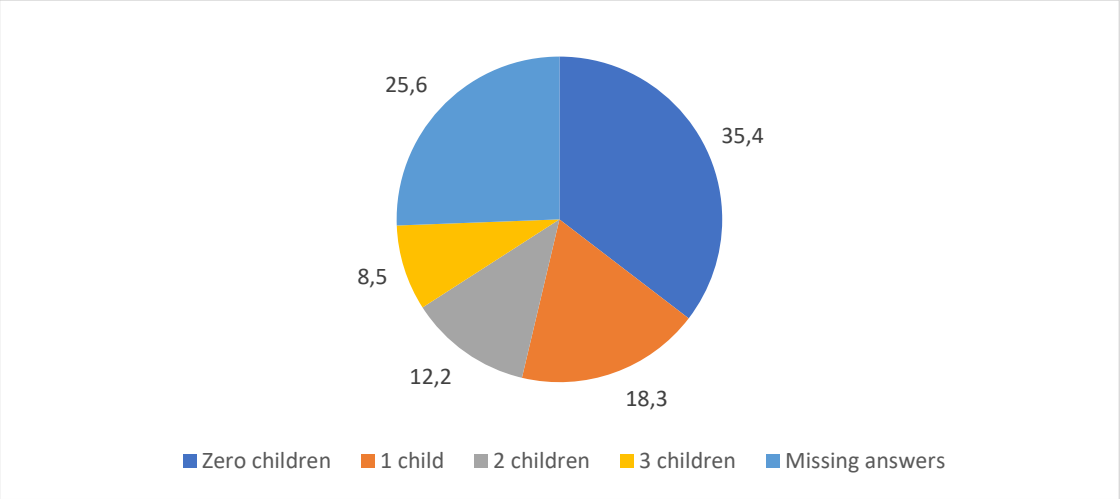


FIGURE 28 NUMBER OF CHILDREN LIVING IN YOUR HOUSE (UNDER 16 YEARS)

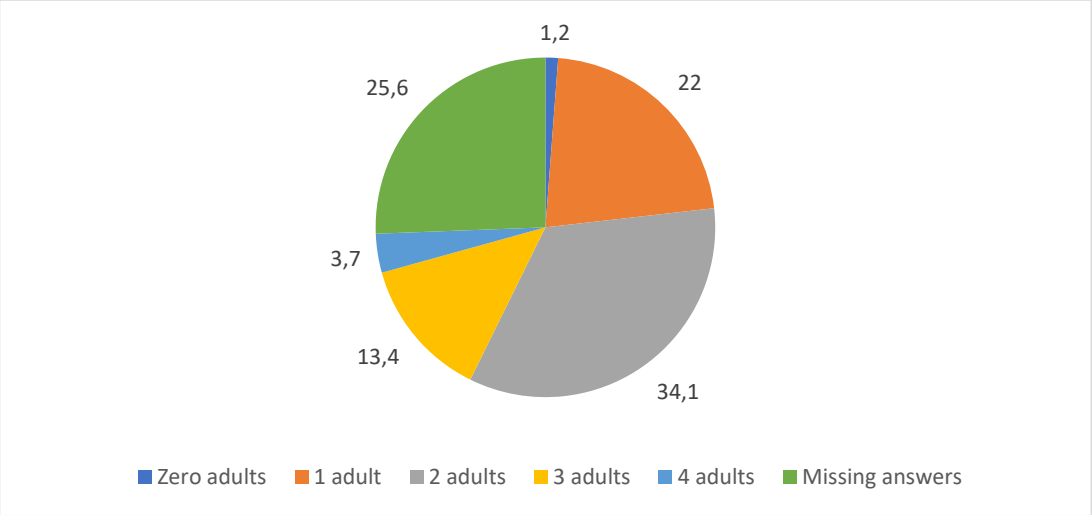


FIGURE 29 NUMBER OF ADULTS LIVING IN YOUR HOUSE (OVER OR EQUAL TO 16 YEARS)

35,4 % has zero children living in their house. 18,3% has 1 child, 12,2% has 2 children and 8,5% has 3 children living in their house. Only 1,2% has zero adults living in their house. 22% has 1 adult, 34,1% has 2 adults, 13,4% has 3 adults and 3,7% has 4 adults living in their house.

4.3.1. Satisfaction with HEMS

More than 50% is satisfied with the new HEMS. Only 4,9% is dissatisfied with his/her newly installed HEMS (figure 27). 37,8% is very satisfied about the overall installation, 31,7% is very satisfied (figure 28). Nearly 50% got found him/herself to have received sufficient information regarding the use of the HEMS. 4,9% has received insufficient information and 8,5% found that he/she had received somewhat insufficient information (figure 29).

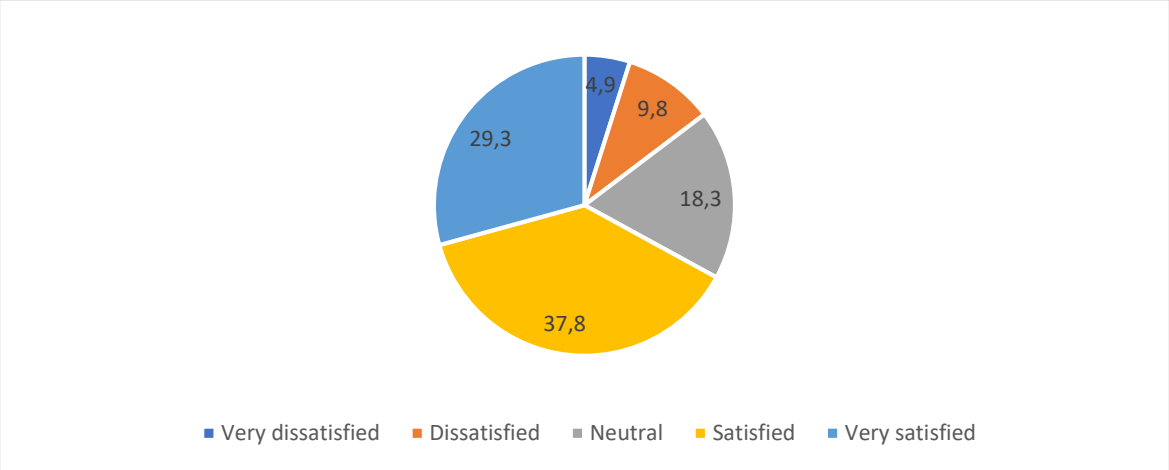


FIGURE 30 SATISFACTION WITH HEMS

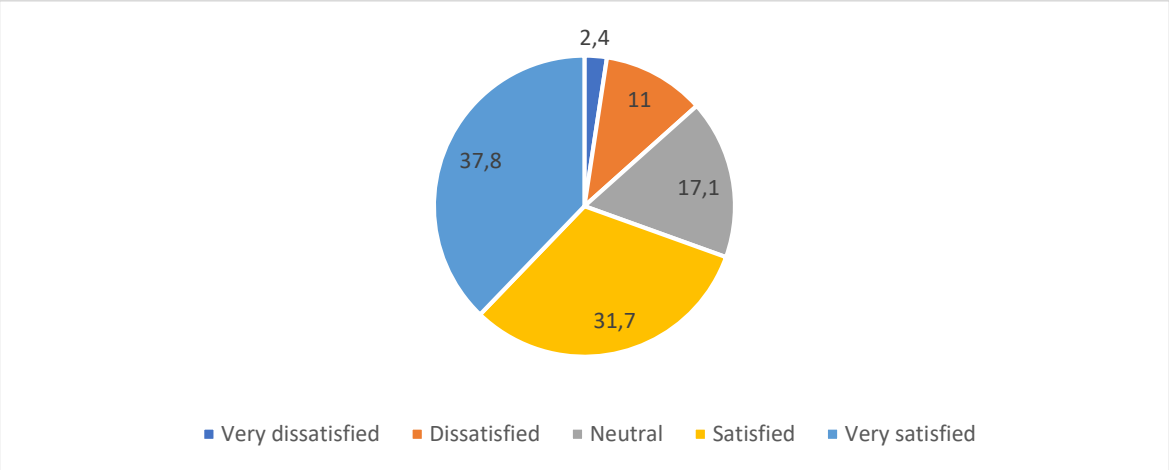


FIGURE 31 SATISFACTION OVERALL INSTALLATION PROCESS

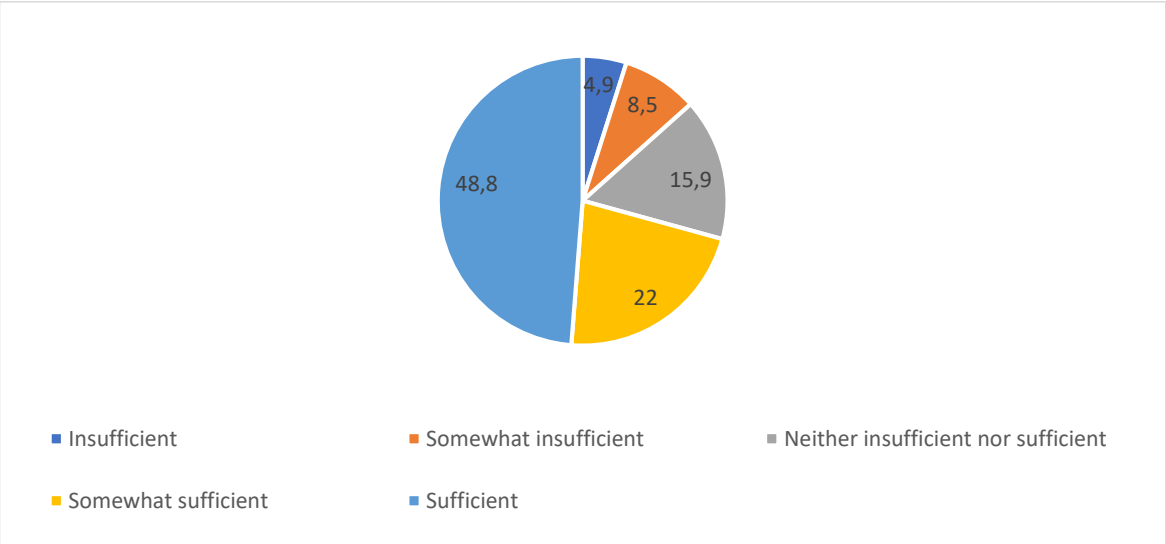


FIGURE 32 SUFFICIENT INFORMATION REGARDING USE

43,9% of the participants say their expectations about the HEMS are fulfilled. 25,6% of the participants indicate that their expectations were not fulfilled. 58,6% of the respondents were willing to recommend their installed HEMS to others. 29,3% would not recommend the HEMS they

installed. 56,1% would install the same HEMS again when they should install a new one. 28,1% would not install the same HEMS.

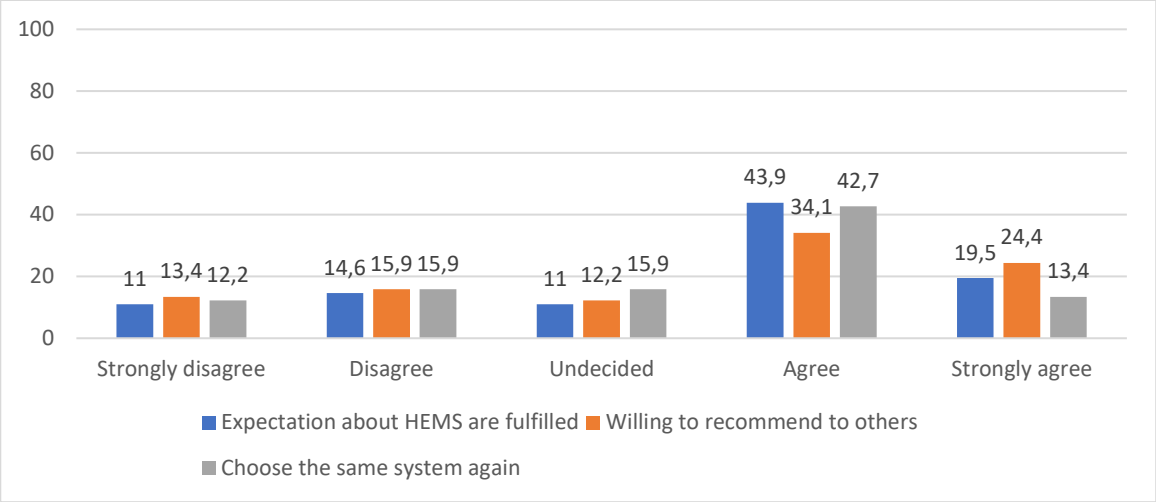


FIGURE 33 FULFILLMENT OF HEMS EXPECTATIONS

Participants who have installed a Netatmo HEMS found themselves to have received sufficient information regarding the use of the HEMS, (M= 4.95, SD= 0.21) more than participants who have installed a Quart'Home HEMS (M= 3.26, SD= 1.29) (Welch's F(3, 5.96) = 15.616, p= .003). Participants who have installed another type of HEMS do not differ significantly from each other.

Participants who have installed a Netatmo HEMS are more satisfied with the overall service they received during the installation/configuration process (M= 4.77, SD= 0.43) than participants who have installed a Quart'Home HEMS (M= 3.26, SD= 1.16) (Welch's F(3, 6.69) = 15.144, p= .002). Participants who have installed another type of HEMS do not differ significantly from each other.

Participants who have installed a Netatmo HEMS are more likely to choose the same HEMS again if they should buy a new one (M= 4.09, SD= 0.53) than participants who have installed a Quart'Home HEMS (M= 2.65, SD= 1.43) (Welch's F(3, 7.07) = 8.615, p= .009). Participants who have installed another type of HEMS do not differ significantly from each other.

Participants who have installed a Netatmo HEMS (M= 4.18, SD= 0.59) or another HEMS (Vsmart or Fluvius) (M= 4.19, SD= 0.60) are more willing to recommend the HEMS they have installed to others than participants who have installed a Quart'Home HEMS (M= 2.62, SD= 1.50) (Welch's F(3, 7.30) = 11.574, p= .004). Participants who have installed another type of HEMS do not differ significantly from each other.

The analysis on the expectations about the HEMS and the satisfaction on the HEMS could not be performed due to a variance of zero in at least one group.

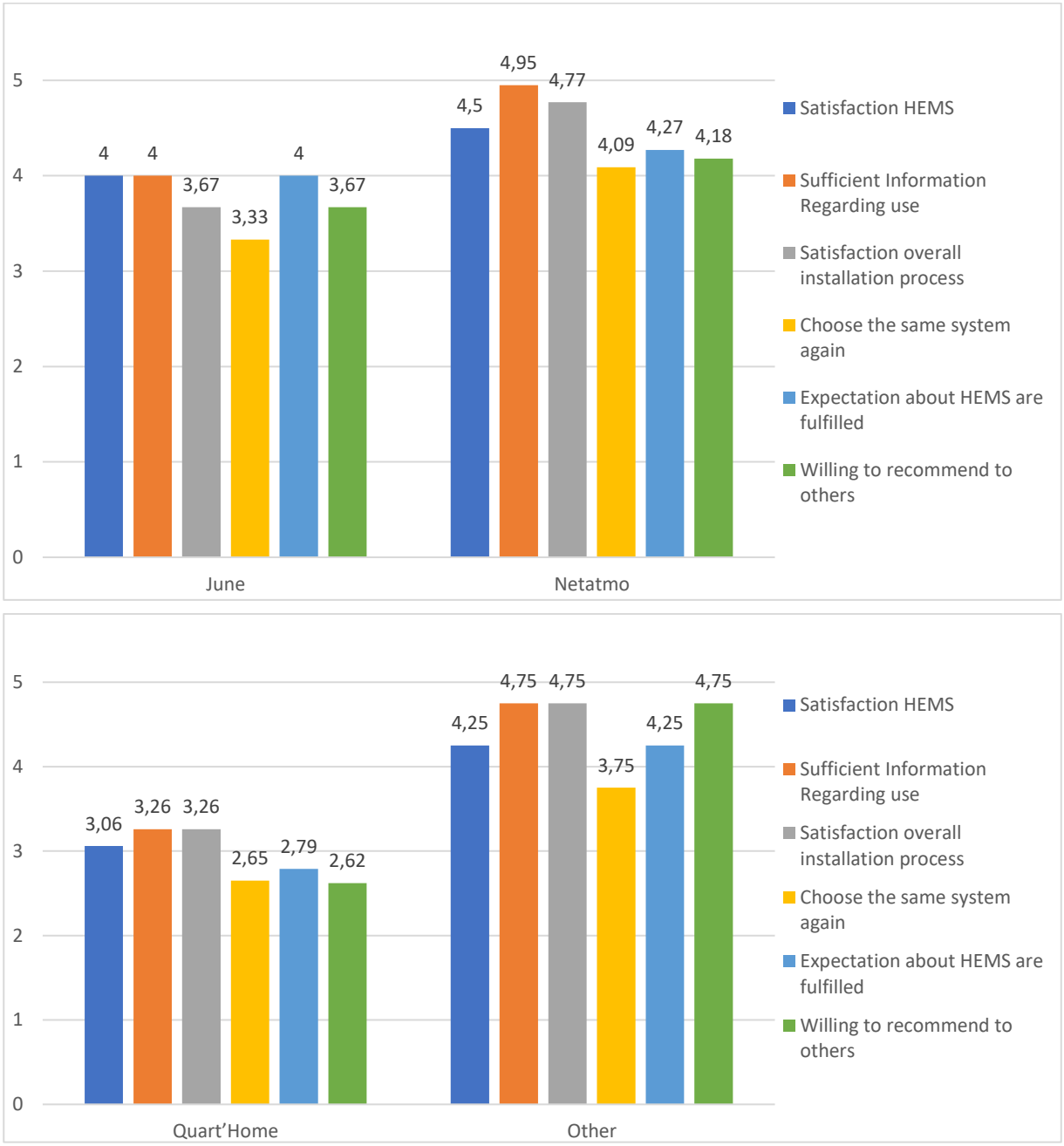


FIGURE 34 SATISFACTION WITH HEMS

4.3.2. Ease of the HEMS use

40,2% of the participants looks monthly to the data of the HEMS. Only 4,9% of the respondents looks daily to the data. 13,4% has not yet looked to the data.

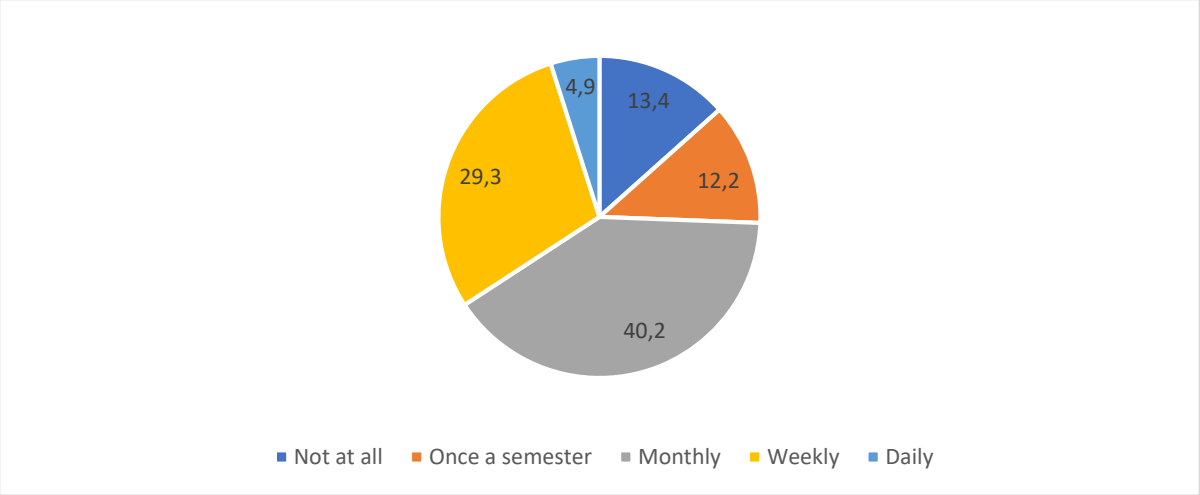


FIGURE 35 TIMES LOOKED AT HEMS DATA

The number of times people have looked at the data of the HEMS since the installation does not differ significantly from one HEMS to another (figure 36), nor from gender ((t(60) = 0.52, p= .604).(figure 33).

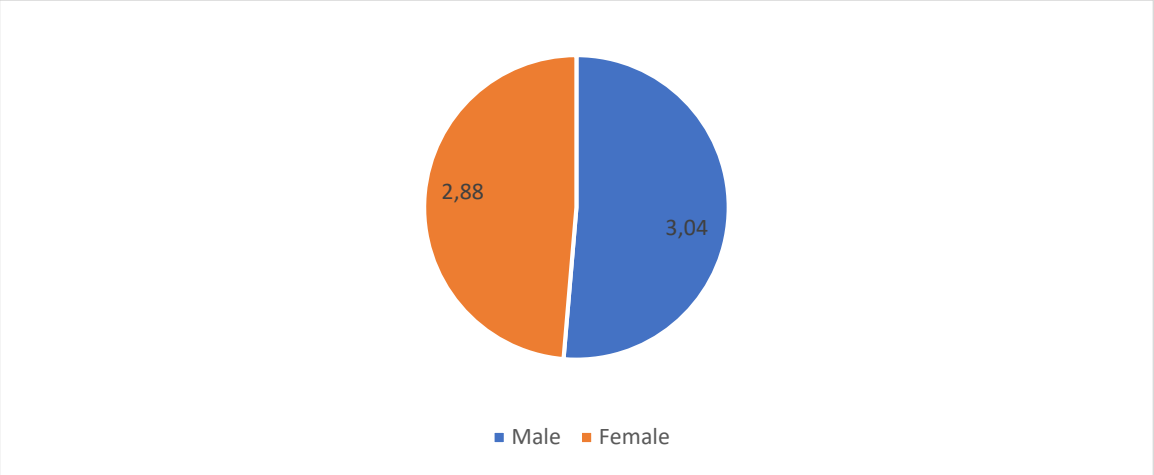


FIGURE 36 TIMES LOOKED AT HEMS DATA BASED ON GENDER

Participants found the HEMS easy to use: 45,1% found it moderately easy and 29,3% found it very easy to use. Only 1,2% found it moderately difficult to use.

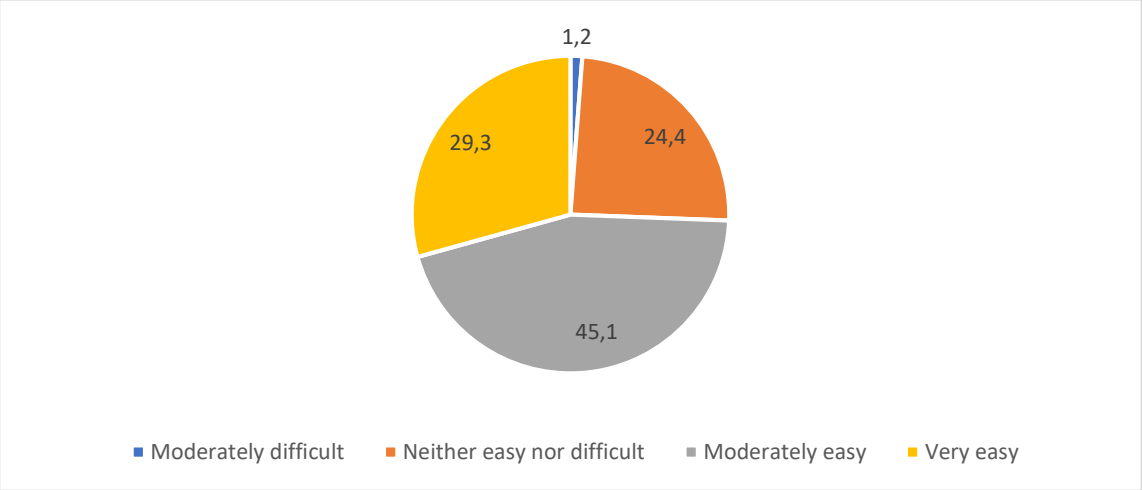


FIGURE 37 PERCEIVED EASE OF USE

The ease of use of the HEMS differed significantly between respondents who have installed a Netatmo HEMS (M= 4.50, SD= 0.67) and a Quart'Home HEMS (M= 3.74, SD= 0.71). The first group found the HEMS easier to use than the latter (Welch's F(3, 6.50) = 6.85, p= .020).

In terms of perceived helpfulness 56,1% of the respondents found that the HEMS helped them to save energy. 19,5% of the participants found that the HEMS did not help them to save energy.

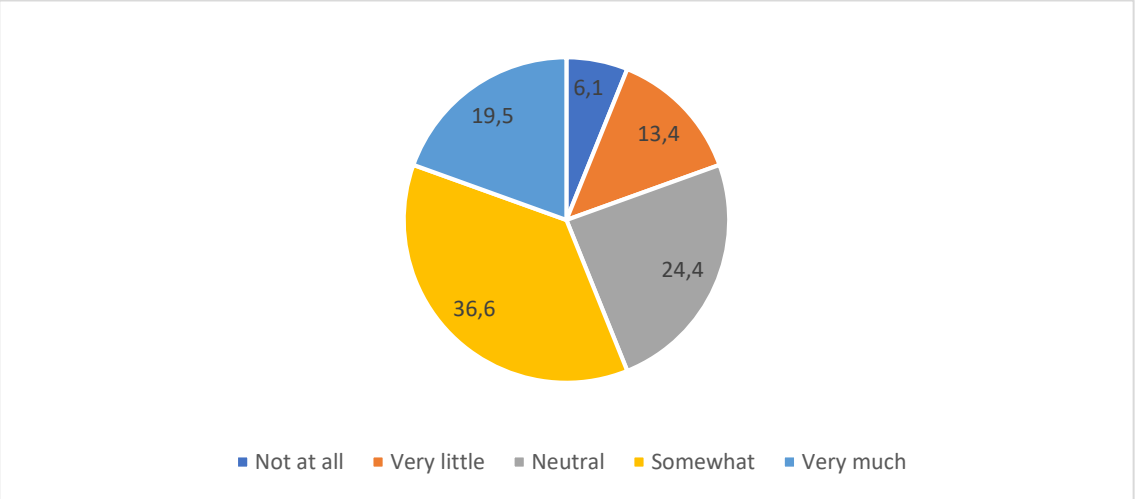


FIGURE 38 PERCEIVED HELPFULNESS

Respondents who had installed Netatmo HEMS felt that the system had helped them more (M= 3.86, SD= 0.71) in saving energy than respondent who had installed a Quart'Home HEMS (M= 3.15, SD= 1.35) (Welch's F(3, 7.02) = 5.012, p= .036).

In addition, respondents who have installed an Other HEMS felt that the system had helped them more (M= 4.50, SD= 1.00) in saving energy than respondent who had installed a Quart'Home HEMS (M= 3.15, SD= 1.35) or a June HEMS (M= 2.67, SD= 0.58) (Welch's F(3, 7.02) = 5.012, p= .036).

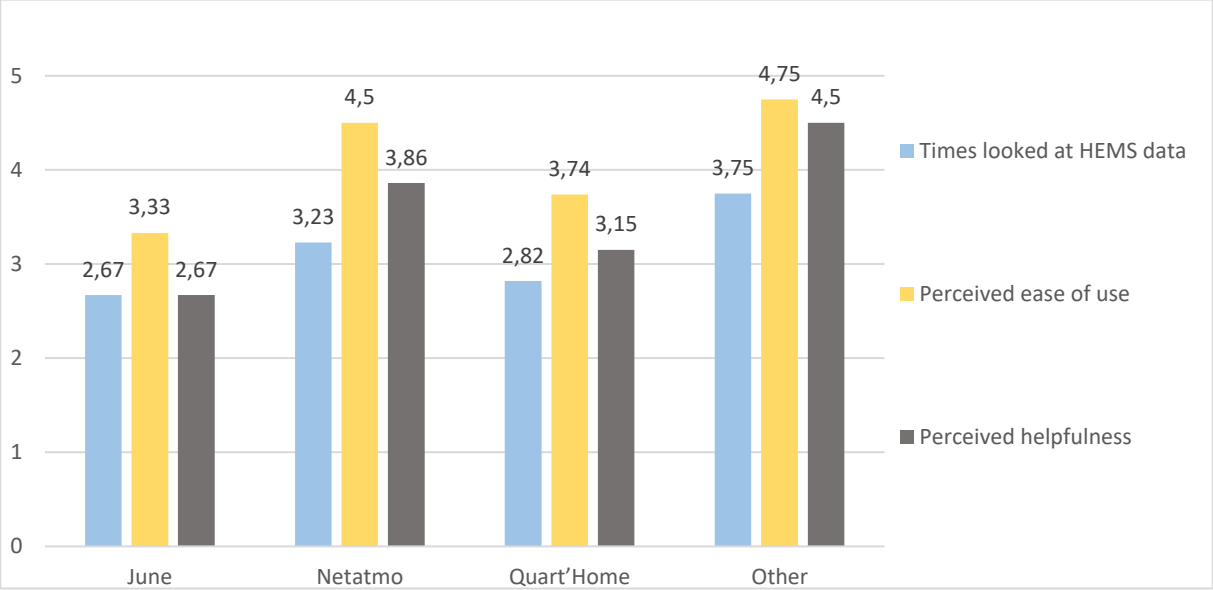


FIGURE 39 EASE OF USE OF THE HEMS

4.3.3. Change in energy efficient behavior

Most of the participants have changed their behaviour around the house as a result of the information they received from the HEMS.

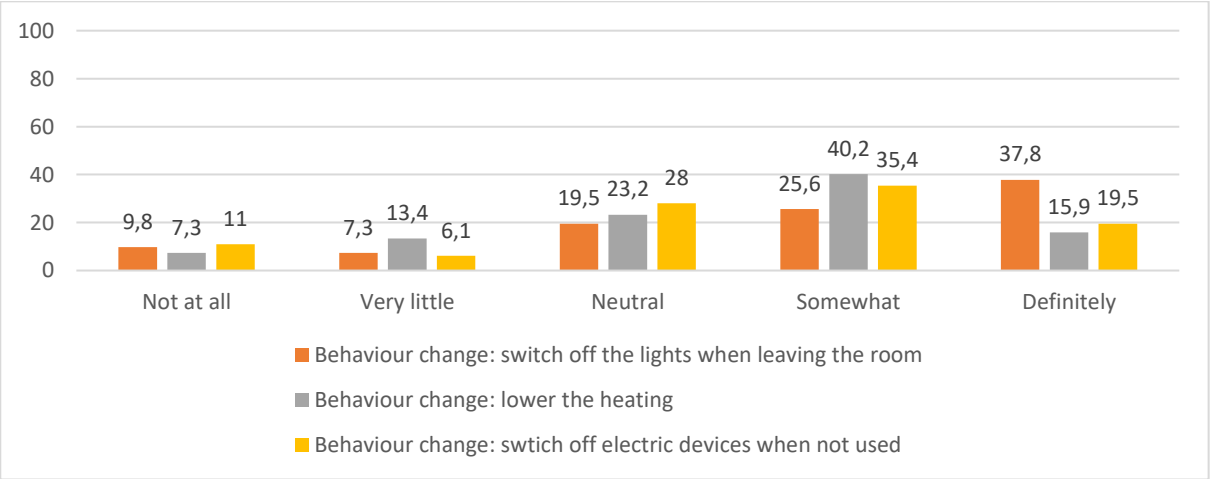


FIGURE 40 BEHAVIOUR CHANGE

Participants who have installed a Quart'Home HEMS (M= 4.24, SD= 1.35) indicate that they have changed their energy efficient behaviour (more specific switching off the lights when leaving the room) as a result of the information received from the HEMS, more than people who have installed a Netatmo HEMS (M= 3.14, SD= 1.13) and a June HEMS (M= 2.00, SD= 1.00) ($F(3, 59) = 5.48$, $p = .002$). Moreover this behaviour change also differed in terms of gender. This change in behaviour was greater with male participants (M= 3.98, SD= 1.32) than with female participants (M= 2.94, SD= 1.30) ($t(60) = 2.767$, $p = .008$).

The other two question regarding energy efficient behaviour could not show any significant difference from one HEMS to another, nor from gender. One test could not be performed due to a variance of zero.

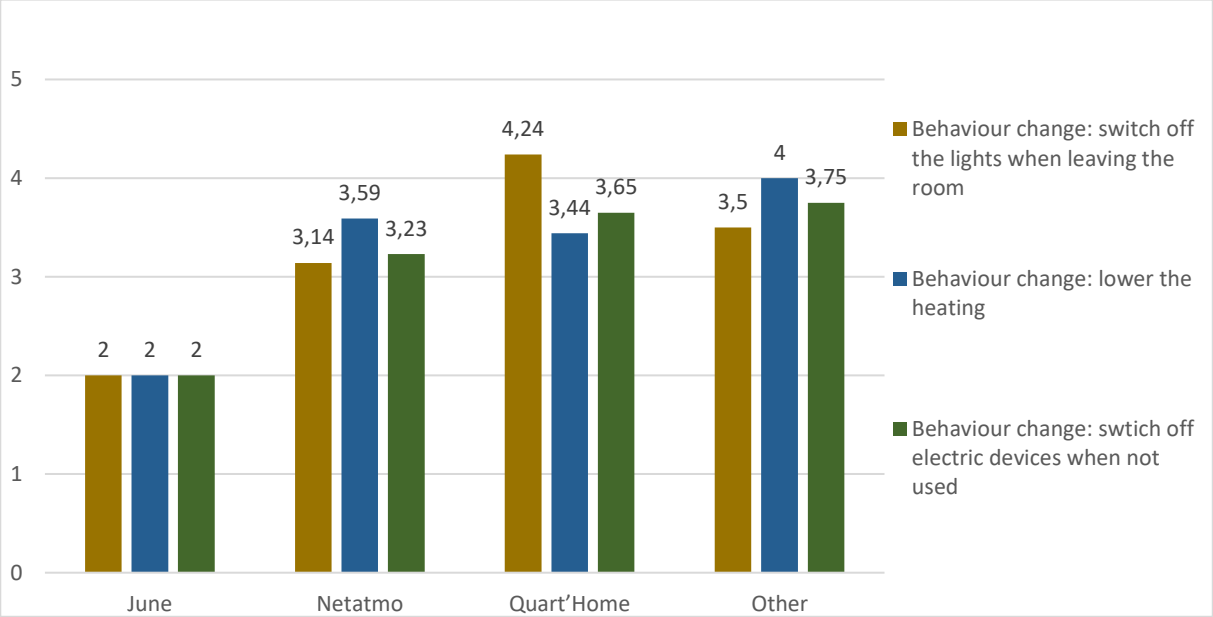


FIGURE 41 CHANGE IN ENERGY EFFICIENT BEHAVIOR

29,3% (24) of the participants has invested in energy-saving measures, 70,7% (58) has not adjusted anything to save more energy after installation of the HEMS. 10 male and 10 female participants have indicated that they have made some investments to save energy compared to 35 male and 7 female participants who indicated that they have not made investments. In addition, people who have installed a Netatmo HEMS (M= 3.45, SD= 0.96) or an Other HEMS (M= 4.5, SD= 0.58) are more willingly to plan energy efficient investments than participants who have installed an Quart'Home HEMS (M= 2.68, SD= 1.53) (Welch's F(3, 7.28) = 6.171, p= .021). This significant difference could not be found in terms of gender.

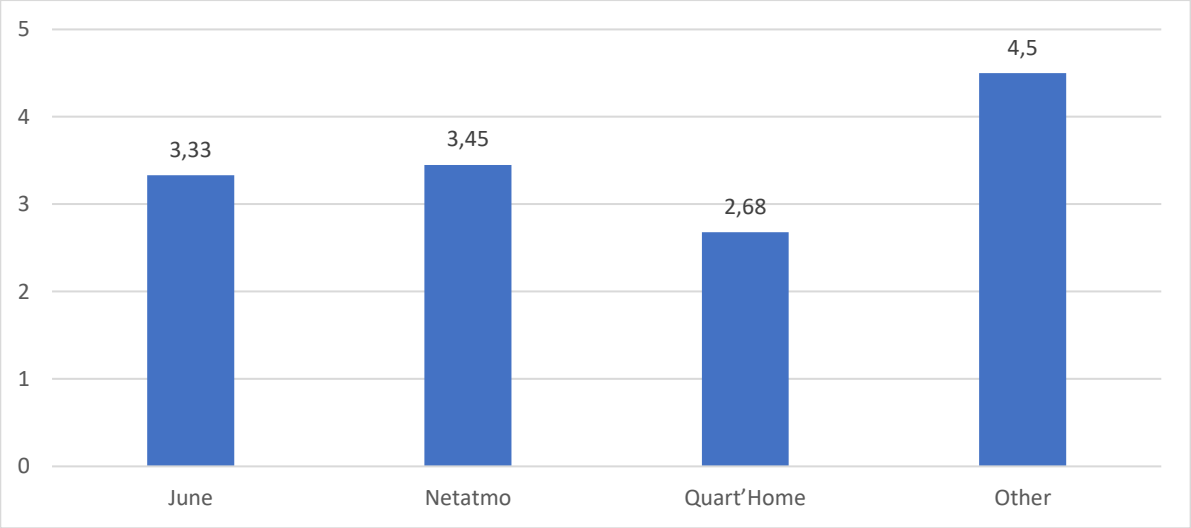


FIGURE 42 ARE YOU PLANNING TO MAKE SOME INVESTMENTS TO SAVE ENERGY IN YOUR HOUSE?

Participants who have installed Comfort HEMS found themselves to have received sufficient information regarding the use of the HEMS (M= 4.95, SD= 0.21) more than participants who have installed an Energy+Comfort HEMS (M= 3.38, SD= 1.30) (Welch's F(2, 5.09) = 23.403, p= .003) (figure 41). Besides, the group of participants who have installed a Comfort HEMS were more satisfied with the overall service during the installation process (M= 4.77, SD= 0.43) compared to the group of participants who have installed an Energy + Comfort HEMS (M= 3.38, SD=1.19) (Welch's F (2, 5.73) = 21.532, p= .002) (figure 41). Moreover, people who have installed a Comfort HEMS(M= 4.09, SD= 0.53) are more willingly to choose the same HEMS than people with an Energy+Comfort HEMS installed (M=2.73, SD=1.41) (Welch's F (2, 6.04) = 13.540, p=.006))

(figure 41). Furthermore, respondents who've installed a Comfort HEMS (M= 4.18, SD= 0.59) would recommend the installed HEMS more than people who have installed an Energy+Comfort HEMS (M= 2.78, SD= 1.55) (Welch's F(2, 6.267) = 11.185, p= .009)) (figure 41).

Respondents who have installed an Comfort HEMS (M= 4.50, SD= 0.67) think it is more easy to use than people with an Energy HEMS (M= 3.33, SD= 1.16) or an Energy+Comfort HEMS (M= 3.81, SD= 0.74) (F(2, 59) = 7.499, p= .001) (figure 42). In addition, the Comfort HEMS group (M= 3.86, SD= 0.71) also think that the HEMS helped them save energy, more than Energy+Comfort HEMS group (M= 3.24, SD= 1.36) (Welch's F (2, 6.571) = 5.986, p= .033).

Participants who have installed an Energy+Comfort HEMS (M= 4.16, SD= 1.34) indicate that they have changed their energy efficient behaviour (more specific switching off the lights when leaving the room) as a result of the information received from the HEMS, more than people who have installed a Energy HEMS (M= 2, SD= 1) and a Comfort HEMS (M= 3.14, SD= 1.13) (F(2, 59) = 3.908, p= .001). In addition, the result show that participants who have installed an Energy+Comfort HEMS (M= 3.68, SD= 1.11) after the installation of the HEMS switch off the electric devices more often when they are not in use than the people who have an Energy HEMS installed (M= 2, SD= 1) (F(2, 59) = 7.424, p= .025).

The type of residence revealed no significant differences. All respondents in the post-installation-questionnaire had an Direct HEMS.

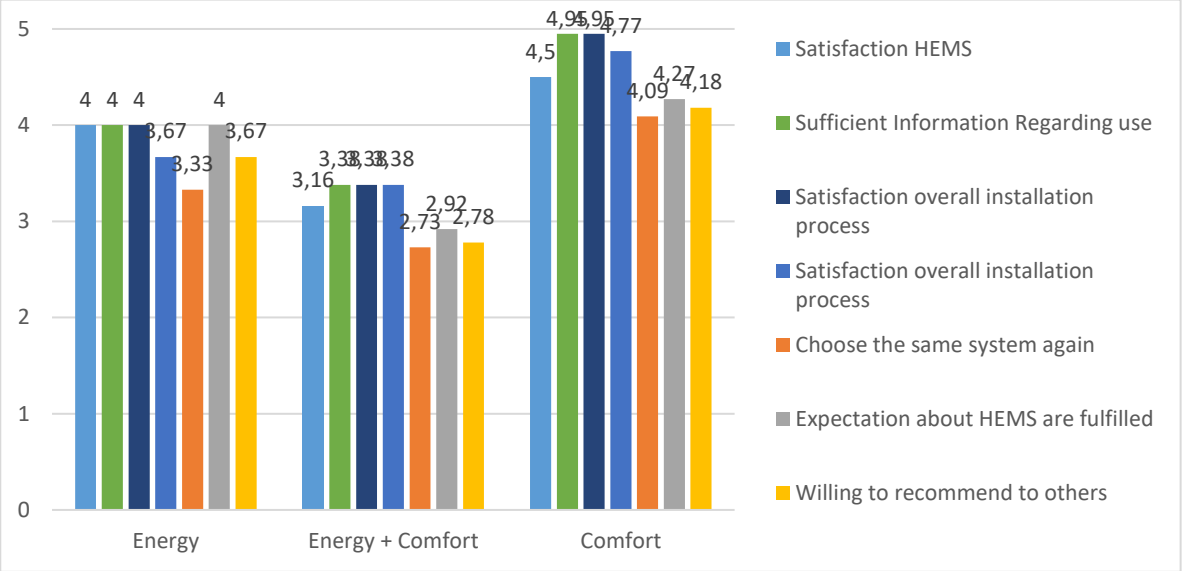


FIGURE 43 SATISFACTION WITH HEMS

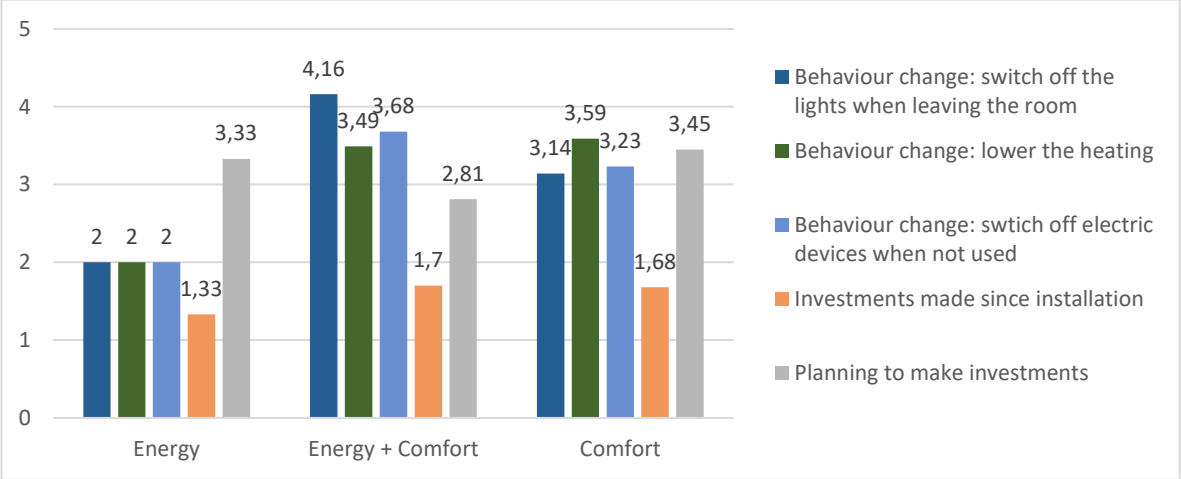


FIGURE 44 CHANGE IN ENERGY EFFICIENT BEHAVIOR

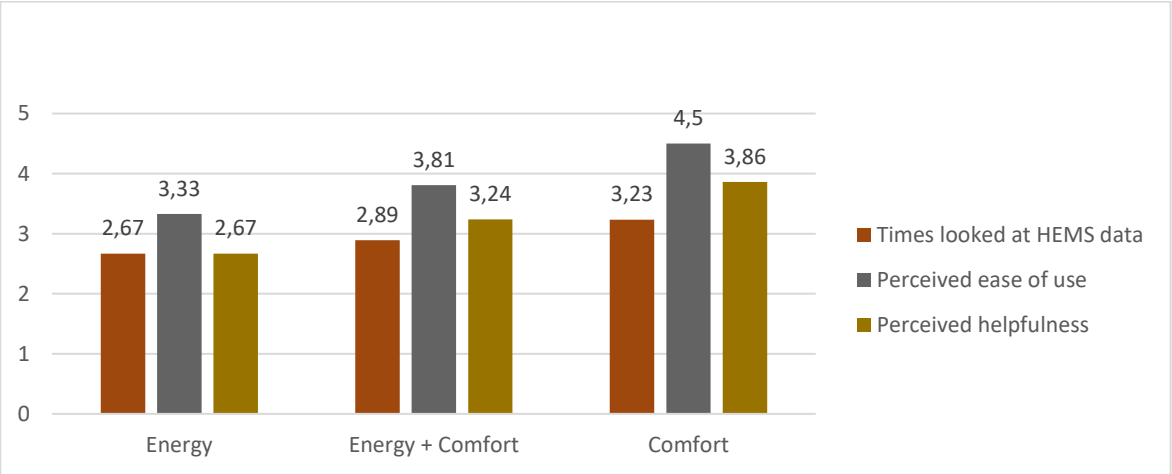


FIGURE 45 EASE OF USE OF THE HEMS

4.4. Conclusion

This survey study aimed to examine homeowners' satisfaction with the HEMS device which has been installed in their house and whether this HEMS assisted them in saving energy. A first survey was sent to homeowners immediately after the installation of the HEMS device and a second survey was sent to them eight months later.

The first survey was completed by 348 homeowners living in Belgium or France. Most people live in an older house that uses a lot of energy. The HEMS were mostly installed in a detached, semi-detached or terraced house and almost half of the participants had no children living in their house. Most individuals who participated in our survey believe it is important to save energy.

The majority of participants were (highly) satisfied with the HEMS installed in their house and convinced that the HEMS will help them to save energy. Two-third of the individuals are planning to make some energy-saving investments. A few gender differences appeared in our study in that women are more likely to make some energy-saving investments and they attach more importance to saving energy compared to the men in our sample. Age is positively related to the fact that participants think that their house uses a lot of energy, a correlation that may be explained by the fact that these individuals also live in older houses.

Few differences appeared between the different types of HEMS with regard to satisfaction. However, the results revealed that people with a FLUVIUS meter are less satisfied with the installation of the meter compared to the others, are least convinced that their meter will help them to save energy and are least planning to make some energy-saving investments. This may be explained by the fact that installation of a FLUVIUS meter was not a free choice for individuals, while it was for the other meters. This may have led to a different profile of participants with a FLUVIUS meter compared to participants with one of the other meters.

The second survey was only completed by 82 individuals of which 62 could be linked to the first survey. Given this limited amount of individuals who completed this post-survey one should be careful with interpreting the research results. It is important to only draw conclusions about Quart'Home (N = 34) and Netatmo (N = 22) meters as there are too few answers for the other meters (< 5 participants).

The results of this post-survey revealed that most participants are still satisfied with their HEMS after eight months of use. They state that they received sufficient information and they were satisfied with the installation process. About 60% of the people would recommend their HEMS to other people and also believe that their expecations are fulfilled. Slightly more than half of the individuals indicate that they would choose the same HEMS again. However, about a quarter of the individuals disagree and believe their expectations were not fulfilled, would not recommend their meter to others or would not choose the same meter again. Although most individuals indicated to look at their meter on a monthly or weekly basis, one out of ten indicated that they have never looked at their meter in the past months. Most people find their HEMS easy to use and can help them to save energy. To conclude, more than half of the individuals reported behavioral change (switch off lights, switch off devices that are not used and lower the heating). About 30% of the individuals had already invested in energy-saving measures, while 70% had not adjusted anything.

When looking at the differences between a Netatmo and Quart'Home meter, the results reveal that people with a netatmo meter were more inclined to choose the same meter again. The Netatmo meter was also perceived as more easy to use compared to the Quart'Home meter and participants with a Netatmo meter more strongly believe that this meter can help them save energy. With regard to behavioral change, people with a Quart'Home meter reported that they are more often switching off the lights compared to people with a Netatmo meter. People with a Quart'Home meter had the least intentions to invest in energy-saving measures. However, one has to be careful with generalizing these conclusions as they are based on a small number of individuals and differences could be attributed to a different profile of individuals rather than to differences in HEMS.

5. Conclusions

The project aimed to assess the experiences of LAs regarding the incorporation of HEMS actions and homeowners' energy use behaviour change and willingness to adopt low-carbon technologies. The HEMS feedback type and monitoring capabilities, the cost efficiency and the ease of installation, the compatibility with the energy management system and legal procedures play a consistent role in the decision-making of LAs regarding the adoption of HEMS. We analysed the adoption parameters from the perspectives of LAs and homeowners. For LAs' HEMS adoption process, relative advantage, trialability, simplicity, compatibility, and visibility were important factors. Particularly, LAs valued the ease of use and access to the data, a user-friendly online platform format to collect data and an easy data analysis process.

The study first categorised HEMS types based on the factors that might affect the adoption of home energy renovation measures and looked at the selected of these types by LAs. The current HEMS can be classified based on type of feedback, data access, and type of information. The most preferred HEMS model by LAs was the one that provided historical data feedback through both hardware and software. The second highest scored model was having real-time feedback combined with hardware and software data access. Moreover, LAs showed preference for the model that provides energy use data and a thermostat function.

Second, the study investigated adoption parameters according to each adoption phase for local authorities. The study finds that HEMS actions can be embedded in other LA actions regarding sustainability awareness raising and housing renovation. LAs particularly value that HEMS can support them with more accurate real-time energy use and comfort data. However, HEMS should be carefully selected and tested based on cost efficiency, ease of installation, compatibility with the energy management and legal system, simplicity of the feedback and supporting administration and data access arrangements. The selection and testing of HEMS required a specific effort from the LAs: assessment tests were done by experts and homeowners. The HEMS were rapidly innovating, so there was also a limitation to procure the latest HEMS models. The most important barriers to upscale LA HEMS actions were data contracting, legal issues regarding privacy and the lower-power positioning of LAs compared to energy providers regarding data access.

Third, the study analysed homeowners experiences through an ex ante and ex post HEMS installation survey. The study concludes that people were satisfied with the selected installed HEMS as well as with the service during the installation process. To some extent, almost every HEMS had contributed to the start of behaviour change, but there was no real outlier. Respondents were aware of the fact that it was valuable to save energy in their home. This might also have been one of the main reasons they installed HEMS. With all types of HEMS homeowners got sufficient information while the installation happened, and the majority of them would recommend the HEMS to others. More than half of the rrespondents reported energy-related behavioral change. About 30% of the individuals invested in energy-saving measures, while 70% had not adjusted anything. Thus within eight months, the HEMS did not have a strong impact yet on how people invested in new energy-saving measures. The willingness to plan new energy-efficient investments was at that time still rather low.

The study thus confirms that local policy actors perceive a need to upscale HEMS adoption to support the adoption of renovation measures and tested a possible role for LAs to help distribute HEMS. LA actions for HEMS distribution towards homeowners are generally well received, but might also result in complex processes within LAs and be confronted with a lack of trust, technical know-how and digital vulnerability of homeowners. While the adoption of HEMS can support homeowners' behavioral change, to date there is no conclusive evidence that this will also lead to adoption of renovation measures by homeowners. LAs therefore think that HEMS actions might not be pursued unless there is more support from national policy, citizen initiatives, energy distribution net managers and market actors. Collaboration will be key for upscaling the adoption of HEMS. This might be an opportunity for further research.

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APPENDIX A.1 EVALUATED QUESTIONS FOR LA ADOPTION

Categories	Questions
Local authority context	Can you briefly explain why you as a local authority engaged in distributing HEMS? E.g. how does it support your local policy development or implementation? How did the HEMS action help you to build a vision, network, learning,..?
Relative advantage	How did you interpret the relative advantage of the chosen HEMS compared to other HEMS? E.g. What did you use as successful arguments to convince homeowners to have a HEMS? How did you take into account the need of the homeowner and/or yourself as a Local Authority for having energy or other data? What did the homeowners or suppliers mention as advantage why the end users would want a HEMS? Please illustrate for multiple HEMS if applicable. If you didn't pay specific attention to relative advantage, please explain why.
Visibility	How did you interpret the need for visibility of the (data from) chosen HEMS for the homeowner? E.g. What barriers did you encounter to make the HEMS visible to the homeowner? How did you solve these barriers? How did the availability of an online or offline feedback system affect your decision to select a certain HEMS for distribution? How did you take into account the placement of the HEMS in the rooms? How are the energy data managed by you or the HEMS to give extra feedback to homeowners? Please illustrate for multiple HEMS if applicable. If you didn't pay specific attention to visibility, please explain why.
Simplicity	How did you consider and/or check if the HEMS or its data are easy to use or to handle by the homeowner and yourself? What barriers did you encounter when collecting or analysing complex data? How did you solve these barriers? Please illustrate for multiple HEMS if applicable. If you didn't pay specific attention to ease of use, please explain why.
Trialability	How did you test the HEMS either with companies or with homeowners? E.g. How did feedback from homeowners affect your decision to select a certain HEMS for distribution? What barriers did you encounter when testing the HEMS? How did you solve these barriers? Please illustrate for multiple HEMS if applicable. If you didn't pay specific attention to testing, please explain why.
Compatibility	How did you consider and check the compatibility of the (data from) chosen HEMS? E.g. How did you investigate if the chosen HEMS is compatible with what the homeowner wants or already has as equipment? How do you perceive that the HEMS action fits with what the local authority wants? How did local GDPR restrictions influence the choice of HEMS or the handling of data? How did you eliminate compatibility barriers?

APPENDIX B.1 PRE-INSTALLATION SURVEY

QID7 What is the brand of the home energy monitoring system that is (being) installed in your home? (select 1 or 2 options)

- ☐ 2-Wire (1)
- ☐ EnergieID (2)
- ☐ iungo (3)
- ☐ June (4)
- ☐ Flukso (5)
- ☐ Fluvius digital meter (6)
- ☐ NEST (7)
- ☐ Netatmo (8)
- ☐ Quart'Home (9)
- ☐ Plugwise Smile P1 (10)
- ☐ Smappee (11)
- ☐ Toon/Eneco (12)
- ☐ Spider (13)
- ☐ Victron (14)
- ☐ Wendy (15)
- ☐ I don't know (16)
- ☐ Other, please specify: (17) _____

QID1 Do you think your home uses a lot of energy?

- ○ Not at all (1)
- ○ I don't think so (2)
- ○ Average (3)
- ○ I think so (4)
- ○ Definitely (5)

QID3 Do you think it is important to save energy in your house?

- ○ Not important at all (1)
- ○ Slightly important (2)
- ○ Fairly important (3)
- ○ Important (4)
- ○ Very important (5)

QID4 Are you satisfied with the fact that you now have a new home energy monitoring system in your home?

- ○ Not happy at all (1)
- ○ Slightly happy (2)
- ○ Neutral (3)
- ○ Happy (4)
- ○ Very happy (5)

QID5 Do you think the new home energy monitoring system will help you to save energy?

- ○ Not at all (1)
- ○ Very little (2)
- ○ Neutral (3)
- ○ Somewhat (4)
- ○ Very much (5)

QID6
Are you planning to make some investments to save energy in your house?

- ○ Not at all (1)
- ○ Very little (2)
- ○ Neutral (3)
- ○ Somewhat (4)
- ○ Very much (5)

QID8 In which year were you born? (Ex. 1965)

_____

QID9 What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ X (3)

QID10 Number of adults living in your house (over or equal to 16 years)

_____

QID12 number of children living in your house (under 16 years)

_____

QID13 What is your highest education level?

- ○ Primary school (1)
- ○ Secondary school (2)
- ○ College/ High school (3)
- ○ University (4)
- ○ PhD (5)

QID14 What is the construction year of the house?

- ○ Older than 1940 (1)
- ○ 1940-1949 (2)
- ○ 1950-1959 (3)
- ○ 1960-1969 (4)
- ○ 1970-1979 (5)
- ○ 1980-1989 (6)
- ○ 1990-1999 (7)
- ○ 2000-2009 (8)
- ○ 2010-2019 (9)

QID15 In what kind of property is the home energy management system installed?

- ○ Detached house (1)
- ○ Semi-detached house (2)
- ○ Terraced house (3)
- ○ Apartment (5)

QID16 Where is the house located?

- ○ Antwerpen (1)
- ○ Breda (2)
- ○ Kent (3)
- ○ Mechelen (4)
- ○ Oostende (5)
- ○ Hauts-de-France (6)
- ○ Rotterdam (7)
- ○ Other, please specify: (8) _____

QID21 Do you have any additional comments, questions, or concerns you would like to share?

_____

_____

_____

_____

Appendix B.2 Post-installation survey

Q39 What is the brand of the home energy monitoring system that is (being) installed in your home? (select 1 or 2 options)

- ☐ 2-Wire (1)
- ☐ EnergieID (2)
- ☐ iungo (3)
- ☐ June (4)
- ☐ Flukso (5)
- ☐ Fluvius digital meter (6)
- ☐ NEST (7)
- ☐ Netatmo (8)
- ☐ Quart'Home (9)
- ☐ Plugwise Smile P1 (10)
- ☐ Smappee (11)
- ☐ Toon/Eneco (12)
- ☐ Spider (13)
- ☐ Victron (14)
- ☐ Wendy (15)
- ☐ I don't know (16)
- ☐ Other, please specify: (17) _____

QID1 How satisfied are you with the new home energy monitoring system?

- ○ Very dissatisfied (1)
- ○ Dissatisfied (2)
- ○ Neutral (3)
- ○ Satisfied (4)
- ○ Very satisfied (5)

QID3 Did you receive sufficient information regarding the use of the new home energy monitoring system?

- ○ Insufficient (1)
- ○ Somewhat insufficient (2)
- ○ Neither insufficient nor sufficient (3)
- ○ Somewhat sufficient (4)
- ○ Sufficient (5)

QID4 How satisfied are you overall with the service you received during the installation/configuration process?

- ○ Very dissatisfied (1)
- ○ Dissatisfied (2)
- ○ Neutral (3)
- ○ Satisfied (4)
- ○ Very satisfied (5)

QID5 Indicate to what extent you agree with the following statements:

	Strongly disagree (1)	Disagree (2)	Undecided (3)	Agree (4)	Strongly agree (5)
If I would buy a new home energy monitoring system, I would choose the same system again. (1)	○	○	○	○	○
My expectations regarding the home energy monitoring system were fulfilled. (2)	○	○	○	○	○
I would recommend the home energy monitoring system to others. (3)	○	○	○	○	○

QID6 How often did you already look at the data of your HEMS since it has been installed?

- ○ Not at all (1)
- ○ Once a semester (2)
- ○ Monthly (3)
- ○ Weekly (4)
- ○ Daily (5)

QID18 How easy do you find it to use the home energy monitoring system?

- ○ Very difficult (1)
- ○ Moderately difficult (2)
- ○ Neither easy nor difficult (3)
- ○ Moderately easy (4)
- ○ Very easy (5)

QID20 Do you think the home energy monitoring system helped you to save energy in your home?

- ○ Not at all (1)
- ○ Very little (2)
- ○ Neutral (3)
- ○ Somewhat (4)
- ○ Very much (5)

QID21 Which information you receive from the home energy monitoring system is most valuable to you?

_____

QID22 Have you changed your behavior around the house as a result of the information you received from the home energy monitoring system? For instance:

	Not at all (1)	Very little (2)	Neutral (3)	Somewhat (4)	Definitely (5)
switch off the lights when leaving the room (1)	○	○	○	○	○
lower the heating (2)	○	○	○	○	○
switch off electric devices when not used (3)	○	○	○	○	○

QID23 Have you made some investments to save energy in your house since the installation of the HEMS?

○ Yes (1)

○ No (2)

QID24 Which investment have you made? (tick the box)

☐ wall insulation (1)

☐ floor insulation (2)

☐ roof insulation (3)

☐ improved glazing (4)

☐ draught strips (5)

☐ reflective panels behind radiators (6)

☐ energy-saving light bulbs (7)

☐ solar panels (8)

☐ solar boiler (9)

☐ heating system or heating control (10)

☐ energy-saving household appliances (11)

☐ other, please specify:.. (12)
_____

QID25 How satisfied are you with the technologies installed?

- ○ Very dissatisfied (1)
- ○ Dissatisfied (2)
- ○ Neutral (3)
- ○ Satisfied (4)
- ○ Very satisfied (5)

QID27 How satisfied are you with the service you received from the installer?

- ○ Very dissatisfied (1)
- ○ Dissatisfied (2)
- ○ Neutral (3)
- ○ Satisfied (4)
- ○ Very satisfied (5)

QID28 Would you recommend to install these technologies to others?

- ○ Recommend it not at all (1)
- ○ Recommend it very little (2)
- ○ Neutral (3)
- ○ Recommend it somewhat (4)
- ○ Definitely recommend it (5)

QID29 Are you planning to make some investments to save energy in your house?

- ○ Not at all (5)
- ○ Very little (6)
- ○ Neutral (7)
- ○ Somewhat (8)
- ○ Definitely (9)

QID30 Which investments are you considering?

_____

QID33 Do you have any additional comments, questions, or concerns you would like to share?

_____

ADDENDUM. RECOMMENDATIONS BY LOCAL AUTHORITIES

Antwerp

1. Think very well if you want to make the homeowners install the HEMS or by the supplier and purchase different types of HEMS for testing. When the installation is complicated, it is better done by the supplier.
2. Maybe it is better to invest in a platform that can monitor the consumption instead of HEMS (e.g., a platform that can upload the meter readings of the digital meter installed by the grid operator)
3. Reserve staff for the follow-up of the HEMS

Breda

1. Finding a contractor was the main barrier.
2. The LAs could not disseminate the HEMS to homeowners.

Kent

1. Procurement is more difficult for smaller numbers of installation, so be prepared for this.
2. Ensure you get an agreement so you can monitor data afterwards as this is incredibly valuable and gives really interesting results
3. Beware public perception of HEMS, and you may need to ensure residents understand them a lot better to get uptake.

Mechelen

1. Think about the **service** you want to offer by using EnergieID.
2. Do not underestimate the time and effort needed to check data quality and to conduct data analyses of your EnergieID group.
3. Do not underestimate the time and effort needed to create and sustain a community on Energie.
4. Think about the service you want to offer with HEMS instead of focusing on the technical device itself
5. Data and privacy is a significant concern for homeowners; it should be clear what's in for them when using HEMS.
6. Make it as easy as possible for citizens to participate in energy monitoring (this might have to include helping them installing or configuring the HEMS)

Hauts-de-France

1. A HEMS easy to install is a HEMS not easy to maintain. So you have to choose the HEMS in terms of the duration of your monitoring.
2. Let the supplier deal with the contract and the data collection because he is more aware of the issues of the DATA protection.
3. As far as possible, let the supplier deal the installations and the maintenance because it is less time consuming for the LA who can focus more on the monitoring phase and the analysis.
4. As far as possible, the LA should only be an advisor in the use of HEMS. To give the maximum of HEMS, several LA employees should install the HEMS in their own house because only someone who knows how to use it can provide proper advice.
5. Ask for the maximum of service in your specification. Do not think that you will have the time to manage a part that can more easily be controlled by the supplier.
6. Do not neglect the testing phase. Do it before the last negotiation with the supplier. You will have the opportunity to adapt the HEMS if possible.

Ostend

1. Select a good contractor who has experience in installing HEMS and is convinced of the added value of the product.
2. When installing, retrieve the historical consumption (possibly via a power of attorney - request consumption from the distribution network operator) and follow up monthly, so we can calculate how much the savings are, and the resident will also receive monthly insight into consumption. Via a digital meter, the resident will be able to log in to his account and monitor consumption.
3. During the installation, also explain the boiler settings (e.g., water pressure, low temperature, heating curve, ...), this will also contribute to savings. Is a small effort while the contractor installs the HEMS. Also, if interested, explain compatible thermostatic radiator valves via radio signal / WIFI that communicate with the HEMS.