Prescient building Operation utilizing Real Time data for Energy Dynamic Optimization

WP8 – HOLISTIC SUSTAINABILITY STRATEGY

D8.4 – Report on prosumer segments and prosuming drivers and barriers

Version 1.0

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PRELUDE CONSORTIUM PARTNERS

	Participant organization name	Country
1	AALBORG UNIVERSITET	DK
2	TAMPEREEN KORKEAKOULUSAATIO SR	FI
3	ASOCIACIÓN DE INVESTIGACIÓN METALÚRGICA DEL NOROESTE	ES
4	POLITECNICO DI TORINO	IT
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EXECUTIVE SUMMARY

This deliverable offers insights to the consumer-to-prosumer transformation. According to the literature, the drivers for using PRELUDE solutions are mainly economic, environmental, and convenience based. The barriers are related to high upfront costs, perception of complexity, lack of knowledge and incompatibility to existing infrastructure.

The three studies done for this deliverable (via interviews and questionnaires) show that these aspects from the previous literature are true but add other complementary elements that customers appreciate in the transformation towards prosumerism, including perspectives on predictive innovations, HEMS business models, and customer co-creation.

This deliverable highlights the role of active participation from lead users in the first phases of commercialization. These users are typically technologically capable, live in single homes they own, and have certain flexible loads, such as electric vehicle chargers and water boilers in their homes. Lead users can help in many ways in HEMS commercialisation, such as by sharing experiences and knowledge and gaining better understanding on what solutions are value by the customers.

The questionnaires conducted also have the same profile for the early adopters. When moving towards more mainstream markets, the solutions should be turnkey services, which should include customization and reliable customer service. Lack of knowledge on HEMS solutions' benefits and features is a barrier. Also, there is a benefit of targeting them with services on monitoring electricity usage and decreasing electricity consumption.

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ABBREVIATIONS

B2B	Business-2-Business
B2C	Business-2-Consumer
BMS	Building Management System
D	Deliverable
DR	Demand Response
EPC	Energy Performance Certification
EV	Electric Vehicle
GA	Grant Agreement
H2020	Horizon 2020 Programme
HEMS	Home Energy Management System
IPR	Intellectual Property Right
KPI	Key performance indicator
MS	Milestone
TPO	Third Party Ownership
WTP	Willingness-to-Pay

1. INTRODUCTION

Technological transitions are often seen as supply-side changes, in which a prevailing technology changes to a new one. Customers are seen as individuals who react to market changes and adopt market offerings when they are mature enough. Not much attention is put on how users shape and enable the transitions to happen. Within the energy sphere, consumers are becoming prosumers, meaning that they engage in the energy system in new ways. Their activities include energy production, selling, storing, demand response and innovation engagement (IEA-RETD, 2014; Kotilainen, 2019). Users also participate in the creation of new services, find new ways of using them, and help in knowledge sharing among users.

This deliverable will look at both sides of the development: individuals' adoption of technologies like solar PV and home energy management solutions (HEMS). It will also look at lead users' role in developing the HEMS market by identifying their motivations, solutions, challenges and communication with other peers and small SMEs and start-ups. The winter of 2022-2023 was an interesting time period from PRELUDE's perspective, as energy prices increased dramatically, and demand response solutions were suddenly years ahead of their predicted demand. The implications of these studies are discussed in the Conclusions.

2. BACKGROUND AND PREVIOUS STUDIES ON SMART ENERGY SERVICE ADOPTION

The PRELUDE solution is positioned at the crossroads of different technologies and solutions, ranging from smart homes to demand response and self-consumption of renewable energy. Central to these functions is often the Home Energy Management System, which is used to control, monitor and optimize the whole building's energy usage. The Figure 1 aims to illustrate the positioning between the different PRELUDE-related technologies.

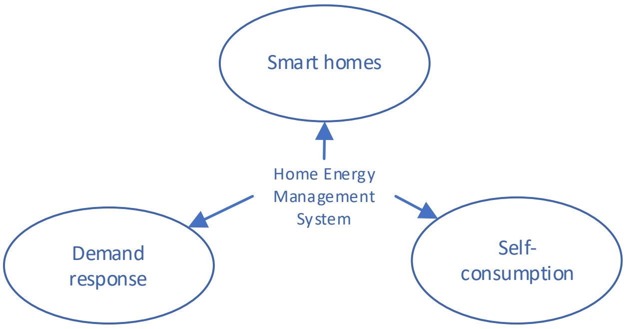

Figure 1. Technologies related to PRELUDE service.

2.1. Barriers

The barriers to using HEMS can therefore be categorized into different technologies, but as we can see later on, there are commonalities between different studies and home energy technologies.

In the microgeneration section, mainly residential solar PV, Palm (2018) has reviewed the barriers over a 10-year period. She concludes over following elements, which can be further divided into systemic, behavioural, technical and financial barriers.

In the section of demand response, smart homes and HEMS, the situation is slightly different, as the solutions are more tailored to the end-customer. Every situation is slightly different, because the home appliances and living conditions are different across different customers. Here, the typical barriers are multiple. In this deliverable, smart homes are seen especially from the energy management point of view. Other functionalities, like entertainment, also exist, and may even be more typical in smart homes, but their customer value is quite different compared to energy monitoring and energy savings, provided by HEMS (Sanguinetti, Karlin, Ford, et al., 2018).

The behavioural barriers are related to distrust of the service provider and technology, one's own capabilities to operate the system (Balta-Ozkan et al., 2014; Li et al., 2021) and the perception that one's own energy consumption is already so low that it cannot be improved more (Nilsson, Lazarevic, et al., 2018). On the contrary, smart homes can also be seen as increasing energy consumption, and in that way producing a rebound effect (Li et al., 2021). Some basic functions like cooking, washing, taking showers are not seen as modifiable, or at least if someone tries to change them, it is seen as producing anxiety and stress (Nilsson, Wester, et al., 2018). Demand response is also seen as unbalancing the family relations (Li et al., 2021). Furthermore, the installation is often seen as a hassle and time-consuming (Li et al., 2021). On the more political level, consumers in Israel were more willing to engage in DR when it was framed as a tool to promote energy independence rather than for economic or environmental reasons (Michaels & Parag, 2016). From this example it can noted that alignment to societal values and norms is in that sense important.

The financial barriers of smart homes are related to the high up-front costs reasons (Michaels & Parag, 2016). People may consider smart homes to be luxury items with high costs over installation, operation and maintenance (Balta-Ozkan et al., 2014). The technology is also sometimes seen as unreliable, becoming easily obsolete, and the lack of standards and interoperability issues do not help the situation (Sovacool & Furszyfer Del Rio, 2020). **In general, the lack of information and knowledge on smart homes and HEMS is a barrier.** Some customer segments, who could otherwise be adopters of the technology, do not know about the availability of HEMS solutions, price levels or places where to buy them (Sanguinetti, Karlin, & Ford, 2018). Although, it must be noted that after this study, the prices of smart home devices have decreased significantly.

Nevertheless, the situation of tenants, landowners and homeowners is different. Renters can be less willing to invest in smart home technologies, especially when they are difficult to transfer to new apartments (Balta-Ozkan et al., 2014). Also the aesthetics in some buildings often prevent or make it more challenging for installations of sensors and other devices (Balta-Ozkan et al., 2014).

The data protection and privacy issues are always present in barriers analysis. Fear of personal data privacy breach, criminal activities, losing control over devices, and possibility of causing physical accidents are listed risks (Balta-Ozkan et al., 2014; Li et al., 2021). In the past, there has also been discussions about the health concerns over smart meters (Michaels & Parag, 2016).

In some studies, the quality of feedback and its intuitiveness is also criticised. The smart home features are seen as complex and the system does not help to draw conclusions from the household activities and appliances (Nilsson, Wester, et al., 2018). Complexity is also related to system interoperability and future usage and including add-ins in the system (Tuomela et al., 2021).

2.2. Drivers

Related to the energy-related matters, **the main drivers of smart homes are economic and environmental.** First, people want to maintain or reduce household's energy consumption and do their part of the energy transition in an affordable way. Self-consumption models are seen as hedging against possible future price increases in the energy markets (Palm, 2018). HEMS also provides transparency on daily energy usage. They also want to reduce environmental impacts by saving CO2 emissions. (Li et al., 2021; Siitonen et al., 2023)

Furthermore, smart homes and HEMS have also an impact on the quality of life and convenience is an important driver in the adoption process. Controllability of devices, comfort and ambiance in home, and adding symbolic value to houses, are all factors that should not be neglected (Li et al., 2021; Siitonen et al., 2023). There is also a peer-effect happening, which means that neighbours have an influence on each other's technology adoption (Palm, 2018). Besides the energy, smart homes have also other benefits like improved security, entertainment and health benefits (Sovacool & Furszyfer Del Rio, 2020).

Table 1 Summary and classification of the barriers and drivers.

Barriers	**Drivers**
Systemic • Lack of organizational and institutional support • Uncertainty around regulations and subsidies • Hard to find objective experts	Environmental • Benefitting the grid with flexibility • Carbon, pollution, waste saving
Behavioural • Uncertainty and mistrust that the system will perform as desired • Lack of knowledge • Aesthetic and impact on residence • Perceived increase in maintenance • Presence of different opinion within a household • Satisfied with existing system • Not willing to change routines	Economic • Saving money • Transparency on appliances' energy usage
Technical • Technological complexity • Technical flaws and lack of warranties make the system obsolete • Poor compatibility with existing infrastructure • Stage of technology readiness	Convenience • Controllability of devices
Economic • Investment cost, long pay-off time • Lack of subsidies and not sufficient rate of return	Social benefits • Symbolic value and peer effect • Networking and shared interest in new technology

2.3. Customer segments in smart energy systems

Different studies have defined user segments in the context of smart energy systems, including smart homes, HEMS and self-consumption. Traditional framework for segmentation is the innovation diffusion framework by (Rogers, 2003) In that framework, innovation adoption happens in a sequence, first by innovators, then by early adopters, early majority, late majority, and finally, laggards (see Figure 2). Later on, this framework was used by Moore (2002), who focused on the difference between the early adopters ("visionaries") and the mainstream markets ("pragmatists"). The main inflection point in that framework is in how to get the early majority or pragmatic segment to jump in the diffusion cycle. They don't see themselves as visionaries and therefore are careful in what technologies they adopt, however, if there is clear benefit that solves some of their problems, they will adopt the technology.

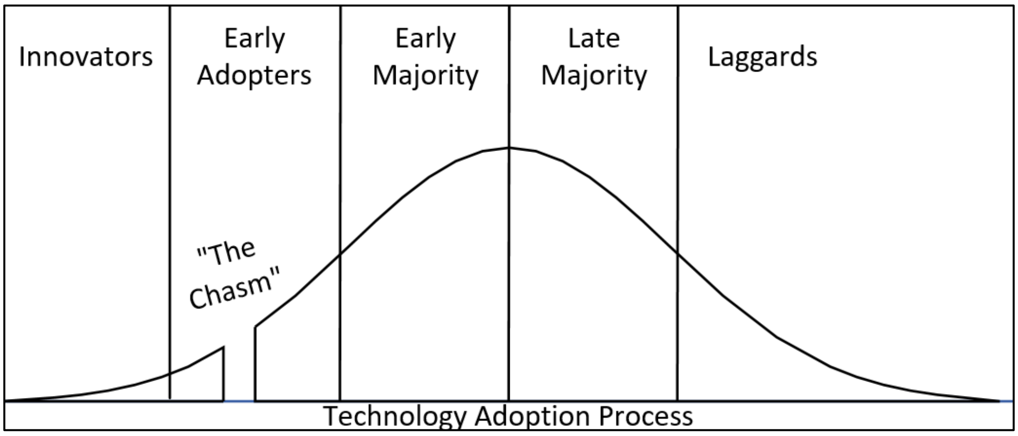

Figure 2. Innovation adoption life cycle (Moore, 2002)

Via interviews, Gonçalves & Patrício (2022) found **three segments in using smart energy management systems.** The most engaged customers used and cocreated advanced home energy management systems and Mobility Energy Management systems. These small, but influential segments were ready to act autonomously in managing consumption and production of energy.

Hall et al. (2021) **divided electricity customers into four different segments, which react differently towards new business models, like ESCOs and peer-to-peer markets.** In the forefront were **"Pragmatic innovators" (16%)** who are engaged and most of them have DERs in home. They have a high trust in suppliers, but a complex view of environment. They think something should be done but not at cost of customer freedom. Pragmatic innovators are the youngest group with few above 55 years, balanced gender, with children, highest education, highest income, highest employment, owner occupiers. Next adopters of innovative business models are **"Engaged but Cautious" (35%),** who have a good understanding of energy matters and trust suppliers. They are price conscious, but not motivated for demand reduction or being first adopters. They tend to be older, female, childless, educated, in employment, average income and owner occupiers. The late majority is described as **"Aspiring Opt-Outs" (27%)** who are not engaged in energy matters, have low trust in big suppliers, but have motivation to save money and are moderately environmentally concerned. They tend to be younger, female, with children, less educated, average employment, low income and high renting. The last segment in there is **"Unconvinced and Unmotivated" (22%),** who are indifferent about their energy use, or climate. They are the oldest group, out of work or retired, male, childless, low education, slightly below average income although high owner occupier.

In another work, Snow et al. (2022) **studied customers' opinions on sharing energy data and participating in demand response program**. They divided customers according to their motivation and ability to join. Motivation was divided into collectivism and trust, and opinions on privacy. Ability was divided into infra compatibility and energy literacy. These scales produced also conflicting segments: ones who were able to participate in DR were not necessarily motivated; and ones who were motivated in DR did not trust the energy companies.

Barjak et al. (2022) segmented electricity users in general in a study combining questionnaires and workshops in Switzerland into "Affluent and quality-oriented" customers, "Ecologically aware", "Technology-savvy", "Regionally rooted", and "Stable and uninterested". Interestingly, in their segmentation, youngest people were the least interested ones, but also ones living on rent, which generally decreases interest in energy matters. The regionality aspect is not generally included in technology adoption scales, but in electricity markets it plays an increasingly important role due to renewable energy diffusion.

3. CROSS COUNTRY SURVEY

3.1. Survey description

The survey was seeking to replicate Chen et al.'s (2020) cross-national study of residents' home energy management system adoption intention and willingness to pay (WTP) in Japan and the United States. Seeking to address the multi-dimensionality of technology adoption and WTP, Chen et al. (2020) incorporated a series of behavioural theories into the survey design. The incorporated theories include Ajzen's (1985) **theory of planned behaviour**, which states that a person's intention to perform a behaviour is determined by their attitude toward the behaviour, subjective norms, and perceived behavioural control. Another theory included is the **Technology Acceptance Model (TAM)** which proposes that an individual's intention to use technology is influenced by perceived usefulness and perceived ease of use. For this construct, we also incorporated **questions from Davis's (1989) original TAM**. Furthermore, Chen et al., (2020) include the **Technology Acceptance Framework (TAF),** which is commonly used to explain sustainable energy technology acceptance. These behavioural theories altogether highlight technology attribute interaction, attitudes, behaviour, social influence, and system and infrastructure expectations.

Other items included in the survey were sociodemographic questions about age, sex, education, annual household income, house characteristics, respondents' location, the current type of electricity contract, as well as the main heating source. Furthermore, we included a series of questions assessing the preventive quality of HEMS seeking to identify whether respondents view HEMS as an innovation that helps prevent or mitigate the effects of electricity price fluctuations, electricity price increases, energy disruptions, and climate change. Finally, our dependent variables assessed willingness to pay (WTP) through the question "How much would you be willing to pay for a HEMS monthly?" and adoption intention through the question "In what timeframe are you likely to acquire a HEMS?". Answer options were in the form of multiple-choice questions and in a 5-point Likert scale where 1 reflected strong disagreement and 5 reflected strong agreement.

Three researchers created, tested, and implemented the survey. The survey was available in nine different languages (English, Finnish, Spanish, Polish, German, French, Danish, Italian, and Greek). Translations were carried out by native speakers of every language to ensure that survey items were accurately and appropriately translated for respondents who spoke each language. These translations were tested once again with native speakers with more of technical knowledge.

3.2. Survey results

Our PRELUDE project partners across Europe helped to distribute the online survey. At this preliminary stage, we have received 155 responses. The respondents were not handpicked from any population, rather, the questionnaire was distributed in social media, and people's own networks. From the sample of 155, we excluded the ones who said they did not understand the concept of HEMS (n=9). This sample size fulfils the minimum sample size for a PLS model where the sample should be ten times the largest number of formative indicators measuring one construct (Hair et al., 2014). This sample size is sufficient for preliminary data analysis and a comparison between southern and northern regions. Table 2 reports participants' sociodemographic information. The sample overrepresents males and young people.

Table 2. Respondents' demographics

Sex	n	Percentage
Male	84	57.5
Female	62	42.5
Prefer not to say	0	0
Age group		
18-25	11	7.5
25-35	60	41
36-45	43	29.5
46-55	20	13.7
56-65	8	5.5
Over 65	4	2.8
Type of household		
Detached house	45	30.8
Semi-detached house	14	9.6
Apartment block	82	56.2
Other	5	3.4
Household income		
Under € 9,999	2	1.3
€ 10,000 - € 19,999	6	4.1
€ 20,000- € 39,999	35	24
€ 40,000 - € 69,999	40	27.4
€ 70,000-99,999	18	12.3
€ 100,000-150,000	18	12.3
More than 150,000 €	8	5.6
Don't want/can't say	19	13
Location		
Northern Europe	62	42.5
Southern Europe	84	57.5
N	146	100

Data analysis in SPSS

To assess the contributions of single variables to the dependent variables (WTP and planned timeframe for adoption), we relied on multiple linear regression, which is useful to identify the effects of individual variables. Our approach was as follows: first, we designed a multiple regression model with all variables to see how much traditional multiple regression could explain the variance of dependent variables. Further on, to explore the dynamics of independent predictors, we selected backward elimination regression. Backward regression eliminates from the original list of predictors first the predictor with the highest p-value and runs the multiple regression again. We removed predictors until all remaining variables had p-values less than or below 0.10. **With this, we were able to identify the best arrangement of predictors explaining WTP and the timeframe to adopt HEMS.**

Once we identified the best arrangement of predictors that contributed to each dependent variable, we interpreted the unstandardized beta (β). In regression analysis, the unstandardized beta is a measure of the strength and direction of the relationship between an independent variable and a dependent variable. A positive unstandardized beta indicates a positive relationship between the independent variable and the dependent variable, meaning that as the value of the independent variable increases, the value of the dependent variable (WTP and timeframe to adopt) also increases. On the other side, a negative unstandardized beta indicates a negative relationship between the independent variable and the dependent variable, meaning that as the value of the independent variable increases, the value of the dependent variable decreases.

Descriptive statistics

With the analysis tool SPSS and Excel, we obtained an overview of relevant descriptive statistics for the data. Descriptive statistics provide insights into the central tendency and distribution of the data and can help interpret patterns in the data. Figures 3-7 depict users' WTP for HEMS monthly, the timeframe in which the respondent is most likely to adopt, WTP for specific services, as well as the preferred forms of financing, interaction, installation, and customization.

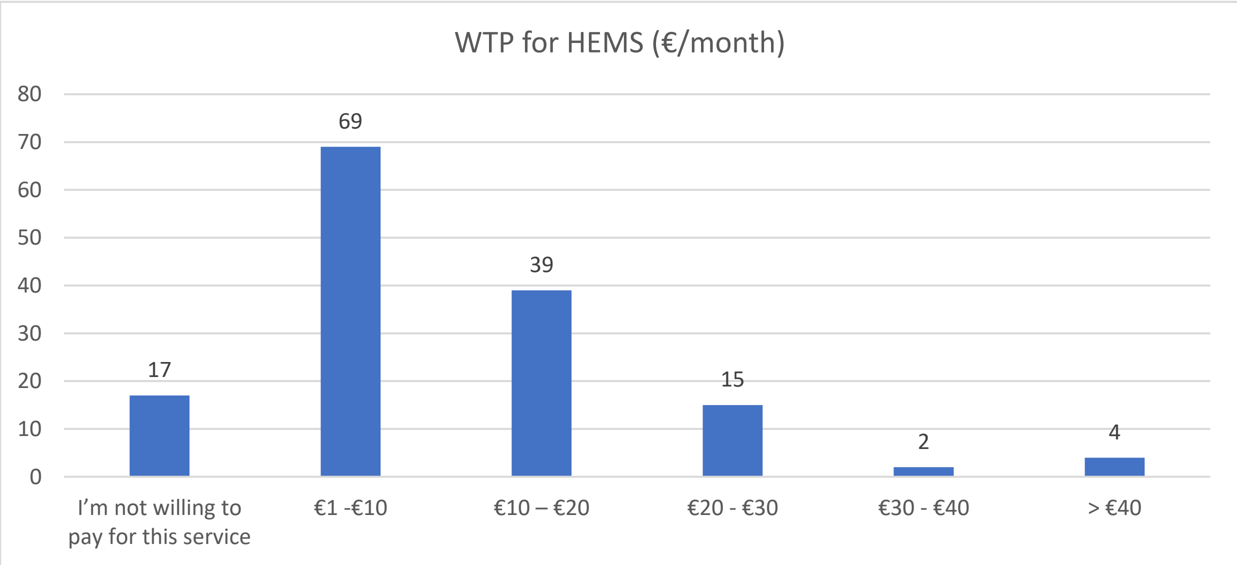

Figure 3. WTP for HEMS service per month.

The WTP for HEMS is generally under 20€ per month. In the edges, there are also some who are willing to pay more or not all for the service. **In the interviews done with HEMS providers in Finland, the general pricing was under 10€/month, so this result is in line with that result.** This result should, of course, be compared to the service level and the initial investment of the HEMS service.

Furthermore, most users are inclined to pay for all specific features of HEMS, **being monitoring electricity usage to save money and decreasing electricity consumption to reduce environmental impact the most popular services users are willing to pay for.** These features are introduced later in the study.

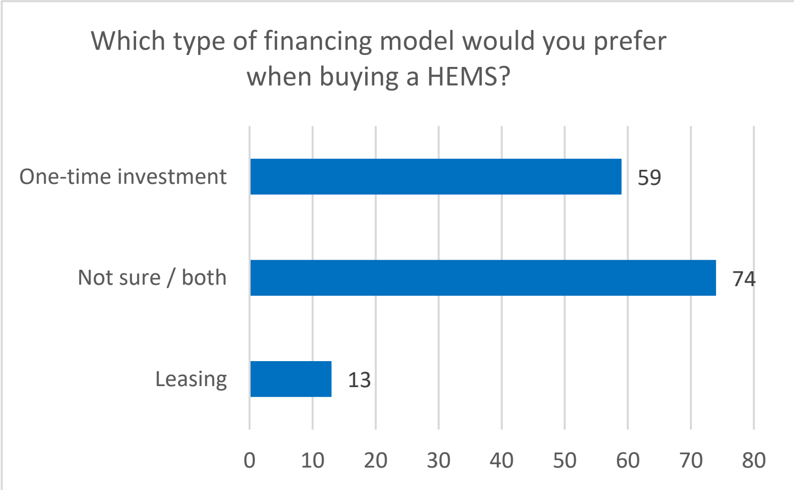

Figure 4. Financing model preferences

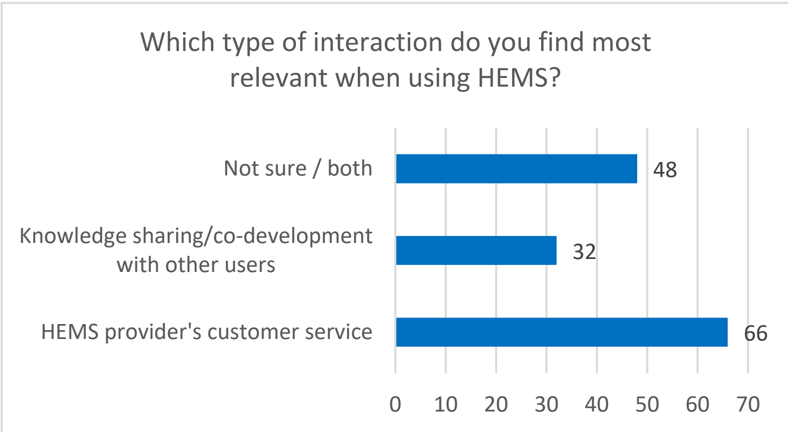

Figure 5. Type of interaction preferences

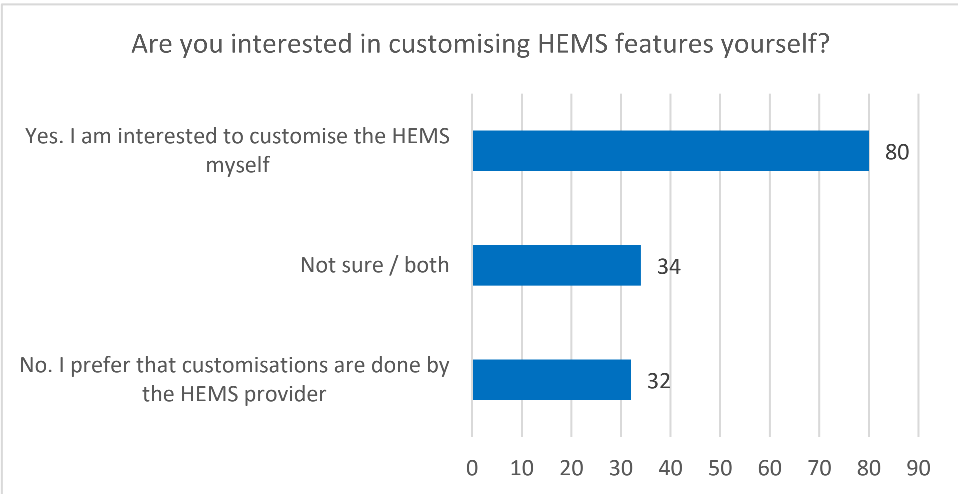

Figure 6. Feature customisation manner preferences

As shown in the business model figures above, users overall prefer the options with least financial commitment (leasing). Furthermore, respondents seem to prefer interacting and allowing the installation to be done by the HEMS provider, which could be the reflection of the previously identified low ease of HEMS use. However, they are more interested in customising the HEMS by themselves, rather than having the HEMS provider to do it.

Willingness to Pay for HEMS: Most significant contributors.

Results from the backward elimination regression model highlight eleven variables as the most significant contributors to willingness to pay for HEMS. A closer look at each variable's unstandardized beta helps identify how each variable contributes to the dependent variable.

Table 3. WTP variables

	Unstandardized B	Std. Error	Sig.	Tolerance	VIF
(Constant)	4.666	.928	<.001		
Heating source	.095	.057	.098	.659	1.517
Perceived usefulness	.169	.087	.053	.888	1.126
Perceived ease of use	-.373	.114	.001	.645	1.551
Anxiety	-.425	.159	.008	.223	4.481
Perceived behavioural control	.365	.130	.006	.656	1.525
Social norms	.162	.077	.037	.856	1.169
Prevention: price fluctuations	-.267	.108	.014	.758	1.319
Prevention: disruptions	.123	.070	.080	.824	1.214
Age	-.228	.070	.001	.904	1.107
Education	-.304	.098	.002	.847	1.181
Region	-.390	.188	.040	.644	1.552

As shown in Table 3, out of the eleven significant variables, there are five variables with a positive unstandardized beta, this means that as the value of the independent variable increases, so does the value of the dependent variable. In this case, the data was coded as a positive unstandardized beta represents a higher willingness to pay. The five significant variables are:

1. Current source of the heating supply, where greater willingness to pay comes from respondents that rely on electricity, wood/pellets, or district heating; these are also the most environmentally friendly energy sources out of the response options included in the survey.
2. Perceived usefulness that identifies HEMS will help respondents accomplish tasks more quickly.
3. Perceived behavioural control identifying that respondents can adopt HEMS.
4. Social norms where the respondent's family thinks they should reduce energy consumption.
5. A prevention variable highlighting the capacity of HEMS to prevent energy disruptions.

The remaining six significant variables have a negative unstandardized beta, this means that as the value of the independent variable increases, the value of the dependent variable decreases. These variables are:

1. Perceived ease of use, identifying learning to use HEMS will not be easy.
2. Technology anxiety highlighting that working with HEMS will make respondents feel nervous.
3. A prevention variable identifying that respondents do not perceive HEMS as a way to prevent electricity price fluctuations.
4. Demographic variables of age, highlighting younger respondents are more willing to pay for HEMS.
5. Demographic variables of education, highlighting respondents with lower levels of education are more willing to pay for HEMS.
6. A demographic variable of region identifying Northern Europe respondents to have lower WTP for HEMS.

Planned timeframe to adopt HEMS: Most significant contributors.

Results from the backward elimination regression model highlight eight variables as the most significant contributors to the planned timeframe for HEMS adoption. A closer look at each variable's unstandardized beta helps identify how each variable contributes to the dependent variable.

Table 4. Contributors of HEMS adoption

	Unstandardized B	Std. Error	Sig.	Tolerance	VIF
(Timeframe)	-2.500	1.036	.017		
Age	.233	.134	.083	.902	1.108
Perceived usefulness	-.302	.170	.077	.675	1.482
Perceived ease of use	-.334	.132	.012	.813	1.230
Attitudes	.884	.170	<.001	.615	1.625
Prevention: severity of price fluctuations	.429	.103	<.001	.803	1.246
Energy saving behaviors	.230	.113	.044	.935	1.069
No. of people in the household	.340	.082	<.001	.944	1.059
Region	.876	.222	<.001	.797	1.254

As shown in Table 4, out of the eight significant variables, there are six variables with a positive unstandardized beta, this means that as the value of the independent variable increases, so does the value of the dependent variable. **In this case, data were coded from 1=Never and 6=within 6 months, so a positive unstandardized beta represents a shorter intended period to adoption**. The six significant variables are:

1. Demographics: Age, highlighting older respondents to have a shorter period for HEMS adoption.
2. Number of people living in the household
3. Attitudes, highlighting that using HEMS will be beneficial for respondents.
4. A prevention variable identifying a high perceived severity of price fluctuations from respondents will result in a lower intended period for adoption.
5. A variable identifying the respondent's energy-efficient behaviours, in this case, the variable representing a small form of energy-efficient behaviour: buying light bulbs.
6. A demographic variable of region identifying Northern Europe respondents to have a shorter intended period for adoption.

The remaining two significant variables have a negative unstandardized beta, this means that as the value of the independent variable increases, the value of the dependent variable decreases. These variables are:

1. Perceived usefulness, highlighting respondents do not view HEMS as useful to control their household energy use.
2. Perceived ease of use, identifying learning to use HEMS will not be easy.

These results illustrate interesting aspects behind the adoption of HEMS. Northern regions (Denmark, Finland, Poland, and Germany) varied from Southern regions in Europe (Spain, Greece, Italy, and France) regarding WTP and timeframe to adopt. Northern regions displayed lower WTP, yet depict a smaller timeframe planned for adoption. Furthermore, there is an overall perception that HEMS is beneficial and can help prevent the consequences of energy price fluctuations, yet HEMS are not perceived as a tool to control household energy use. Interestingly, HEMS have the purpose of helping users monitor and manage their energy consumption; **these results highlight that users may not be aware of the benefits of using HEMS or how they work, which can lead to a lack of perceived value in HEMS as a tool to manage energy consumption.**

When we compare these findings to earlier studies on WTP and the adoption intention of HEMS we find some similarities. First, it seems that WTP is influenced by more factors than the timeframe to adopt, as reported by Chen et al. (2020). Furthermore, the dimensions of attitude, behaviour, and usefulness have the strongest influence over adoption behaviour as reported by Chen et al. (2020) and Hubert et al. (2019). On the other side, the strong effect of risk perception through the variable of 'severity' is also in line with Hubert et al.'s (2019) findings on smart home usage, who identify risk perception as a major inhibitor of use intention. Furthermore, the influence of sociodemographic factors is a common finding across the globe.

Differences among different services

From the different HEMS services, the most popular ones were "monitoring electricity usage to save money" and "decrease electricity consumption to reduce environmental impact". 75% and 79% respectively, said there were likely to invest in these functions in HEMS. The function of predictive maintenance was the least desired function.

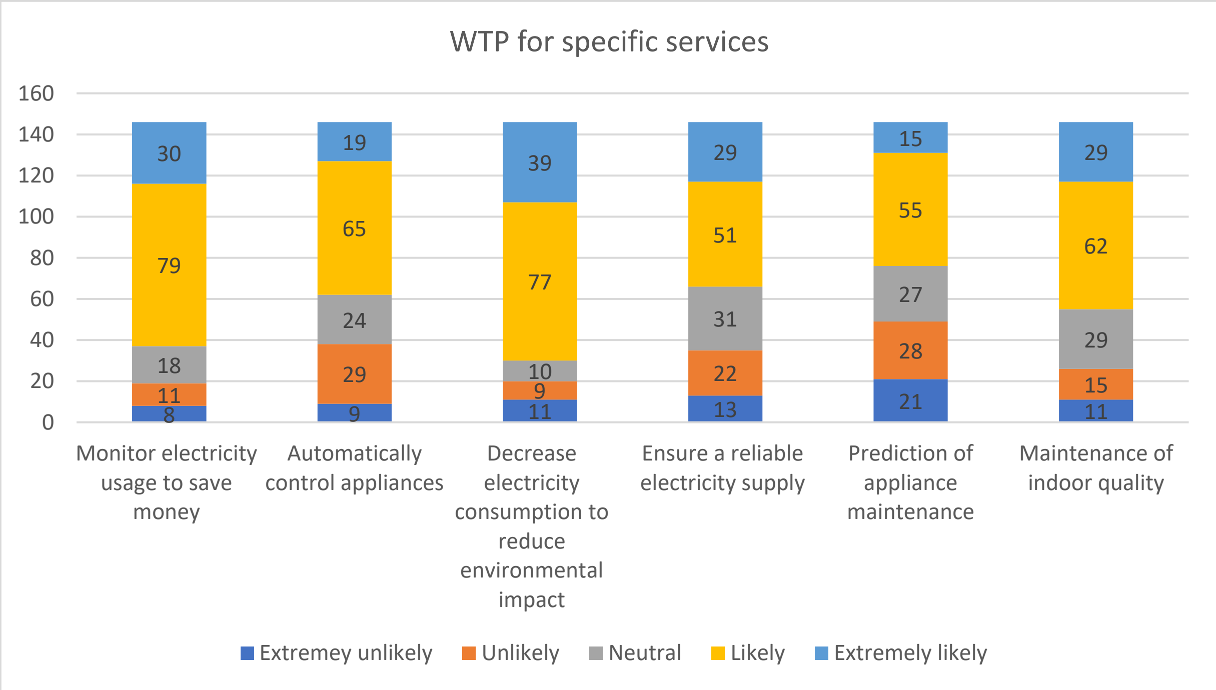

Figure 7. WTP for different HEMS services

For analyzing the different HEMS services, we conducted a cluster analysis on SPSS. This was done by choosing the questions on different service functions and making a two-stage cluster analysis. The first step was to do a hierarchical cluster analysis, which was followed by a K-means cluster analysis. The hierarchical cluster analysis was used applying Ward's method so that the proposed clusters were roughly of same size. The proximity measure used was Euclidean distance. The proposed dendrogram showed that three clusters could be identified. In the K-means clustering, we entered three clusters as a default. The aim was to create more variability amongst the clusters and inside them more homogeneity.

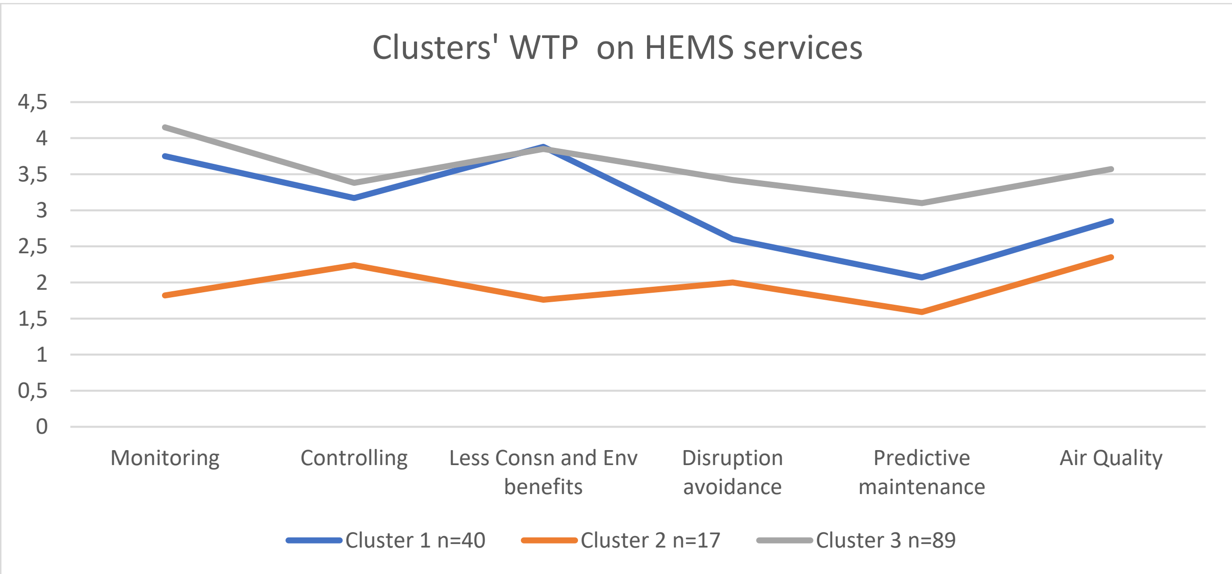

Figure 8. Clusters' WTP on different services

The clusters identified showed that the main cluster of respondents was inclined to have a strong WTP on all six services, yet there was also a significant cluster of people, who were much more willing to pay for monitoring, controlling and lowering their consumption than the other three functions. A rather small minority was disengaged from all the HEMS services.

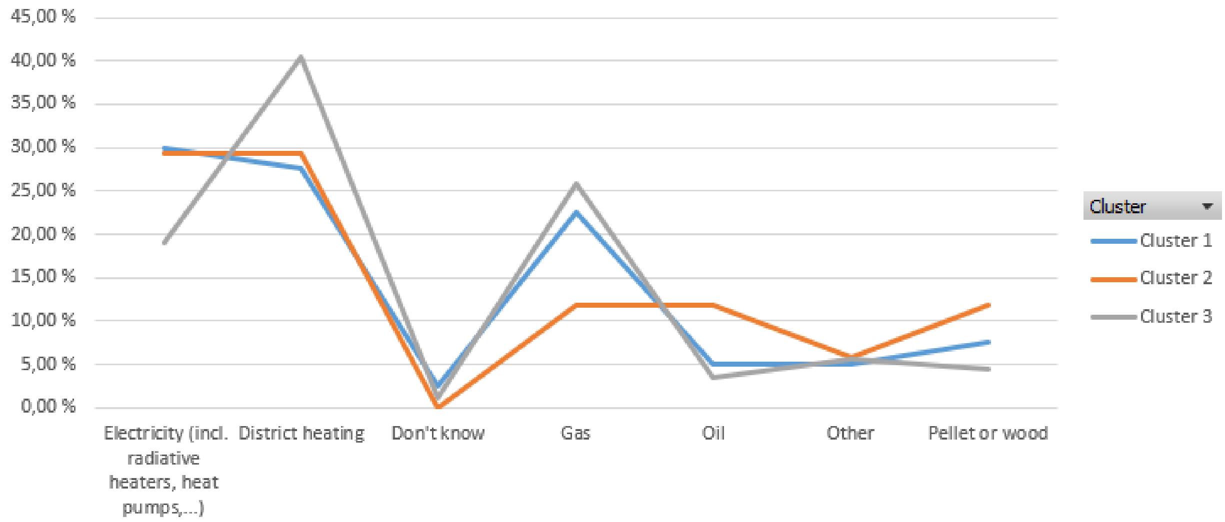

Figure 9. The clusters' heating sources

The cluster 1 differed from the other clusters by having a larger share of district heating as a heating source, and electricity as less. This is somewhat counterintuitive because electricity heating generally adds the manageable load through HEMS. Also, the share of gas-heated homes was slightly more common in clusters 1 and 3.

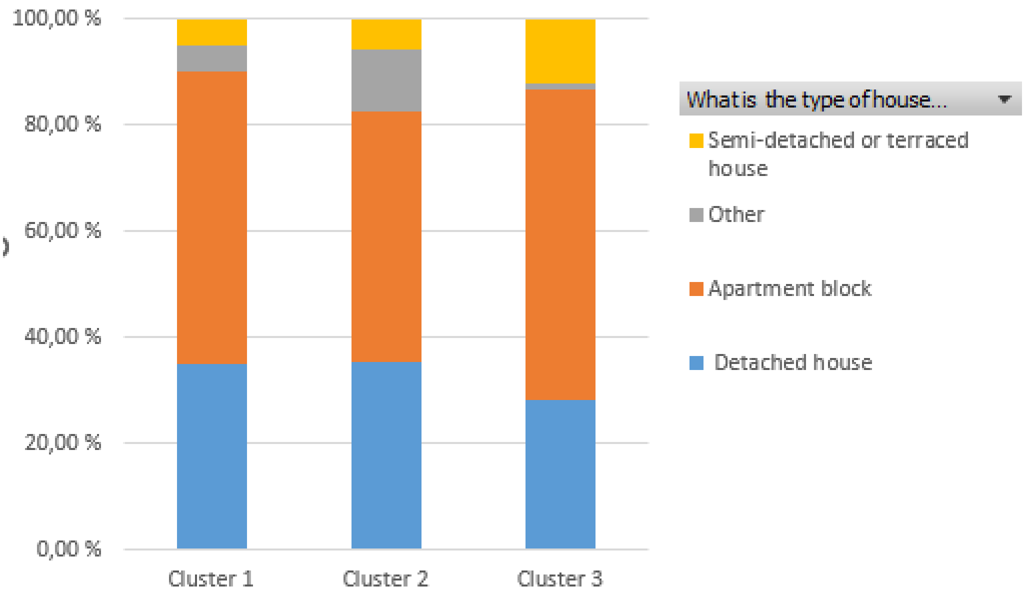

Figure 14. Building type

The building types were surprisingly similar in the clusters, but in cluster 3 there was an increase in semi-detached buildings compared to detached houses.

4. CONSUMER-TO-PROSUMER SOLAR PV SURVEY IN FINLAND

To study the adoption of residential solar PV systems, the researchers worked in collaboration with a local electricity company in central Finland. Residential solar PV systems can be owned either directly by the homeowner or through a third party (Third Party Ownership, TPO). Direct ownership involves the homeowner purchasing and owning the equipment, with or without a government subsidy. Direct ownership used to be the most common choice of ownership. In the past decade, there has been a shift towards TPO (Rai et al., 2016) where commercial companies own and operate the PV systems either on the customer's property or in designated solar parks. Customers have the option to lease the system or enter a power purchase agreement (Rai et al., 2016). TPO can reduce adoption costs, risks, and complexity, and result in cost savings within the first month, unlike direct ownership which can take decades to yield cost savings (Drury et al., 2012).

The electricity company offers two types of TPO and a purchase option. **This study focuses on three options for ownership: purchase of the PV system, rental of a panel from a solar PV park, and selection of a solar electricity contract**. In the case of direct ownership, the consumer orders the photovoltaic system, and the electricity company delivers and installs the system on-site. For the first case of TPO, consumers rent a panel from a solar PV park, and the production of that panel is credited to the electricity bill; the average credit for one panel in central Finland is 1€/month. For the second case of TPO, consumers choose their electricity to be fully solar produced; consumers pay a basic monthly fee (fixed per month) and a consumption fee (fixed rate per kWh).

Survey design

The survey was designed following Wolske et al. (2017), Elmustapha et al. (2018), Bouman et al. (2018), and Korcaj et al. (2015) **to identify intentions regarding target behaviours**. The first part of the survey measured background factors, which included sociodemographic questions about age, sex, education, and annual household income, and the second part of the survey assessed elements measuring adoption intention and adopter values. We selected these factors as they have been identified as significant predictors in previous studies of the adoption of green innovations.

Our dependent variables assessed willingness to pay (WTP) through the question "How much would you be willing to pay for a photovoltaic system?" and adoption intention through the questions "Would you be willing to sign up for a solar contract?" and "In which period would you be willing to take up a solar contract?".

Background factors

Regarding **age**, there is a common belief that young people are more likely to engage in pro-environmental behaviour which has been verified by empirical studies (see e.g., Weber, 2016). However, other settings have found older people to exhibit greater environmental behaviour (Wang et al., 2021).

The impact of **gender** on pro-environmental behaviour has also been examined. Some studies have found that women tend to be more environmentally conscious (Xiao and Hong, 2010; Mertens et al., 2021) while others suggest that gender stereotypes have no significant impact on everyday pro-environmental behaviours (Vicente-Molina et al., 2018).

Furthermore, the relationship between **education** and pro-environmental behaviour has also been explored, with higher education levels often associated with greater environmental knowledge and concern (Xiao & Hong, 2010).

Regarding i**ncome**, research suggests that higher-income groups are more likely to engage in pro-environmental behaviour, particularly when purchasing environmentally friendly products (Khare, 2015). However, individuals with lower incomes tend to avoid waste and preserve more resources (Wang et al., 2021; Melasniemi-Uutela, 1994).

Finally, we assessed **housing characteristics**, as these are relevant when studying technologies that are location dependent. Housing characteristics included in the survey were the size and type of the house the respondent lives in (detached, semi-detached, apartment block) and the type of management of the housing, meaning if it is owner-occupied, or some form of tenancy.

Diffusion of innovations factors

DOI constructs were measured with two to three items, based on previous studies on the adoption of PV systems (Elmustapha et al., 2018; Korcaj et al., 2015; Masukujjaman et al., 2021). Items included in the prevention construct were designed based on the literature on the preventive quality of PV systems about emission reduction and climate change prevention (see e.g., European Commission, 2011). Answer options were in the form of multiple-choice questions (for gathering sociodemographic data) and in a 5-point Likert scale for remaining variables where 1 reflected strong disagreement and 5 reflected strong agreement.

4.1. Survey distribution and responses

The survey was distributed through the website of the electricity company in central Finland from September to November 2021. The final sample size was 284 responses, which fulfils the minimum sample size for a Partial Least Squares model (Hair et al., 2014).

Table 5 reports the sociodemographic information of respondents. When compared to the general Finnish population, the sample represents certain characteristics more than others. For example, sex and household income were close representations of national averages. However, in the case of respondent age, respondents under 25 were overrepresented and respondents over 65 were underrepresented. Additionally, the number of respondents living in an apartment block was overrepresented at 54%, whereas in Finland, approximately 25% of the population lives in rental homes (Tilastokeskus, 2020).

Table 5. Participant information

Sex	n	Percentage
Male	108	38.1
Female	170	59.8
Prefer not to say	6	2.1
Age group		
18-25	68	23.9
25-35	42	14.8
36-45	50	17.6
46-55	62	21.8
56-65	62	21.8
Over 65	0	0
Type of household		
Detached house	81	28.5
Semi-detached house	31	10.9
Apartment block	156	54.9
Other	16	5.7
Household income		
Under € 9,999	7	2.5
€ 10,000 - € 19,999	38	13.4
€ 20,000- € 39,999	82	28.9
€ 40,000 - € 69,999	60	21.1
€ 70,000-99,999	37	13
€ 100,000-150,000	18	6.3
More than 150,000 €	4	1.4
I don't want / can't say	38	13.4
N	284	100

4.2. Data analysis and results

We relied on multiple regression (in SPSS software) and partial least squares structural equation modelling (in SmartPLS4 software) to explain dependent variable behaviour with independent predictors. With multiple regression, we sought to identify respondent willingness to pay for a PV system (direct ownership). For this, we chose backward elimination regression, which allows us to find the best arrangement of predictors. With partial least squares structural equation modelling we designed and tested a series of hypotheses that identified respondent adoption intention of a PV system through Third Party Ownership.

4.2.1. Willingness to Pay for PV Systems

Our final model depicted ten significant variables that contributed to the willingness to pay for solar PV systems. Out of the ten significant variables, five variables corresponded to demographic information, two to attributes of innovations, two to attitudes, and one highlighted the preventive quality of PV systems.

In the case of demographic variables, our findings indicate that age, gender, type of household, house management, and household income play a role in WTP. Specifically, young and female respondents had a higher WTP for the purchase of PV systems. Furthermore, respondents with higher household incomes, who live in detached or semi-detached houses, and who own their household have a higher WTP. The influence of these sociodemographic factors is in line with other studies across the globe (Ebers Broughel, 2019).

Other significant variables highlight that respondents that consider themselves knowledgeable in PV issues have higher WTP; this finding is in line with previous studies on factors for PV system adoption in Finland (Karjalainen & Ahvenniemi, 2019). Furthermore, respondents that think there is too much public discussion of environmental issues have lower WTP. This is in line with earlier findings that people who think more environmental issues should be raised have higher WTP (Schulte et al., 2022). Additionally, one significant variable brings the preventive attitude of respondents as a significant issue for WTP as this shows that respondents think people should do all they can to prevent pollution and climate change. Finally, one variable signals a favourable attitude towards PV technology and favourable attitude results in higher WTP.

4.2.2. Adoption intention of PV systems

Our Partial Least Squares model's constructs were based on innovation attributes as presented in Rogers (2003), and the preventive quality of PV systems about emission reduction and climate change prevention (European Commission, 2011). Based on the results from the PLS-SEM analysis, we found the preventive quality of innovations to be a standalone construct with a significant impact on adoption intention, yielding a greater impact than all other studied constructs. While the relative advantage is traditionally considered the most important predictor of the adoption of innovations (Rogers, 2003), we found the preventive quality of TPO-PV systems to have higher predictive power; this could be explained by the increasing pressure individuals experience regarding sustainability objectives through their actions (IEA, 2021). Green products perform better in materials, energy, and/or pollution in comparison to conventional products for which the preventive quality of innovations is inherently present in all green and sustainable innovations.

4.3. Implications and conclusions

Findings in this study build up an avenue for future research to investigate the adoption process of photovoltaic systems either through direct or third-party ownership. These studies have specifically emphasized the impact of PV systems in preventing and mitigating the effects of climate change. Recognizing the influence of preventive measures on innovations is a valuable discovery for policymakers, as it provides insights on how to encourage the adoption of innovations that enhance the capacity for prevention and contribute to the creation of resilient societies (United Nations, 2020). Particularly, policymakers could promote a favourable evaluation of prevention among potential adopters. An important limitation of this study is the geographic and demographic distribution of our respondents, as they were predominantly in central Finland and other European countries vary drastically regarding yearly sunshine and the utility of PV panels.

5. CUSTOMER CO-CREATION OF DEMAND RESPONSE SOLUTIONS

5.1. Background

Arguably, the transition to zero-carbon societies requires systemic changes in how citizens behave and what routines are followed. Users are not only adopters of technology but also shape how the technology gets developed and used. They create new needs and demands. Transition scholars also talk about second-order learnings, in which technological usage leads to questioning the prevailing assumptions on routines, needs and practices that have been taken for granted previously. Gonçalves & Patrício (2022) divided the activities of such engaged customers into different co-creation categories (see Table 6).

In the typology of user roles in transitions, (Schot et al., 2016) divide user roles to producing, legitimating, intermediation, citizenship, and consumer. User-producer and user-legitimators, who create technological and symbolic variety. They co-develop the solutions by interacting with other users and integrating other's solutions to their own solutions (Gonçalves & Patrício, 2022). Some of them even turn into entrepreneurs. They invent new solutions and channel certain societal expectations into practice.

User-intermediator have contacts with many stakeholders, and they reconfigure the design of new technologies. Users also share information with others, leading to co-learning. This is pronounced in lead customer groups, which use different communication channels to share their experiences and customisation opportunities of technologies. User-citizens are active politically and they aim to promote technologies within societal movements, often against incumbents' opposition. User-consumers are closest to ordinary customer roles, but they clearly connect technology usage to status and symbolic meanings.

Table 6. Customer engagement activities related to smart homes (Gonçalves & Patrício, 2022)

Customer Engagement Behaviours	Activity
Actively Orchestrating (augmenting)	• Monitoring and controlling the EV energy consumption and functionalities • Monitoring and controlling my home • Energy consumption and production through app • Programming home appliance
Learning and Improving (learning)	• Proactive Customization • Problem-solving • Searching for information about new solutions
Knowledge Sharing	• Sharing usage experiences • Sharing analysis and research • Sharing schemas to co-develop
Co-developing	• Co-design solutions with community • Integrate Solutions with community • Developments based on research and forums inputs
Complying (disengagement Behaviour)	• Monitoring energy costs through incomes • Monitoring home comfort levels

Another angle to the user role is the shift from energy citizenship towards energy democracy. There, the decision-making and ownership of energy assets are broadened from utilities and companies to citizens.(Wahlund & Palm, 2022) The uprising of energy communities supports this democratisation movement, often seen as a necessity for local acceptance of many renewable energy projects and achieving legitimacy of a widescale energy transition overall (Genus & Iskandarova, 2020).

In this chapter the implications of a study which was conducted to identify and relate consumer developed home energy management solutions in Finland are presented. The development can be followed in virtual communities formed in platforms such as social media or forums. User innovators are found to interact and share their ideas in these communities. User innovation is much more common than traditionally is thought and Von Hippel et al. (2011) refer to it as a new innovation paradigm. The data for this study was collected with semi-structured interviews with seven consumers and seven solution provider representatives.

5.2. Methods

The methodological choices of this study and the underlying factors are illustrated in Figure 10. The choices were based on the research problem, constraints, and the researcher's philosophical position. The research problem was to find out what the role of user developed solutions is among home energy management, and what kinds of solutions have been developed in Finland. The main constraints set on this study included time and scope. This study was conducted over six months and the data collection and analysis took two months. The time horizon was therefore cross-sectional, focusing only on a particular time. The philosophical assumptions were practical, and the research problem could be solved best with practical methods that produce useful methods. Therefore, the philosophy was established as pragmatism, which allows flexibility in theory development and data collection (Saunders et al., 2019). The theory was developed using abduction.

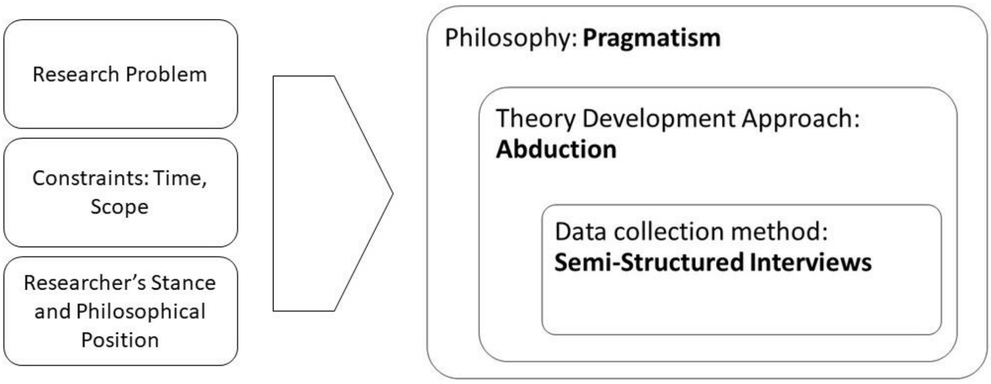

Figure 10. Methodological choices

The data collection method that seemed to best fit this study was semi-structured interviews. They allowed for a more conversational discussion that could dive deep into the interviewees' experiences while staying around the themes of this study. The environments of the interviewees were unique, and the solutions that they had developed were assumed to be unique as well. Therefore it was best to allow them to describe those solutions in detail in their own words while also having the chance to ask clarifying questions or probe for more details (Saunders et al., 2019, p. 444). The disadvantages of semi-structured interviews include the time and effort that designing and conducting the interviews takes. A more structured data collection method would be quicker to arrange, but more likely to result in less detail.

A summary of the characteristics and details about the interviews with the consumers are presented in tables 7 and 8 below. The interviewees were found through Facebook groups, since Facebook was observed to have the largest virtual communities in Finland focusing on electricity consumption. The interviewees had typically shared some of their solutions for the community and seemed enthusiastic about the topic. 18 consumers were invited for an interview, seven accepted the invitation, two refused, and nine did not respond. The interviews were held from late January of 2023 to early February. The interviews were held online using Microsoft Teams. This allowed for long-distance interviews and real-time transcription. Microsoft Teams was also used to record the interviews.

Table 7. Summary of consumers interviewed

Index	Date	Age Group	Gender	Duration
UI1	26.1.2023	26–35	Male	43 min
UI2	2.2.2023	36–45	Male	55 min
UI3	3.2.2023	36–45	Male	59 min
UI4	3.2.2023	46–55	Male	47 min
UI5	6.2.2023	46–55	Male	56 min
UI6	8.2.2023	46–55	Male	58 min
UI7	13.2.2023	36–45	Male	63 min

Table 8. Profession and house type of consumers interviewed

Index	Education level	Professional field	House type	House size
UI1	Master's Degree	Software Engineering	Row house	75 m^2
UI2	Master's Degree	Energy Industry	Semidetached	148 m^2
UI3	Master's Degree	Information Technology	Detached	210 m^2
UI4	Bachelor's Degree	On pension	Flat	27 m^2
UI5	Vocational	Telecommunications	Detached	230 m^2
UI6	General Upper Secondary	Security automation	Semidetached	165 m^2
UI7	Bachelor's Degree	Information Technology	Detached	120 m^2

The interviews were held in Finnish and were only translated in English for some direct quotes. The data analysis was done on the Finnish data. The chosen qualitative data analysis method was a thematic analysis with the assistance of computer aided qualitative data analysis software. The data was coded with mostly codes generated beforehand based on literature. This data was then categorized under themes to see relationships and patterns. The themes were the user's environment as in elements describing the household, lead user characteristics, virtual communities, and solutions.

5.3. Results

User innovation and virtual communities

The consumer interviewees were very interested and knowledgeable in the field of electricity consumption with different areas of expertise. UI4 and UI2 had industrial and market level knowledge which is why they understood the concepts well but it was less beneficial for innovations on a personal level. All the other interviewees had experience from the IT field of engineering and four of those had software engineering experience. Software engineering was found to be an excellent ground for smart home related innovations. The users were innovative and wanted to learn about related concepts.

The most common motivators for user innovators to create consumption optimization solutions were financial benefits, public good, and learning and having fun. Financial benefits are the most concrete result for an individual and can make the investments easily justifiable. It was more surprising that many of the interviewees reported that they want to do their part in balancing the load on the grid and avoid power outages. This can be seen in the comment from UI1 below:

> *"In the name of truth, I must say that price and decreasing the electric bill are like priority number one but then as a second are like those possible power outages like avoiding those, so I do want to do my part there [...] and to keep the balance in the power grid." (UI1)*

Learning was also mentioned as a benefit on multiple occasions. UI6 expected that he could inspire others with his innovations, and discussing those solutions was fun for him. UI7 also wanted to spread the public good around him. Many viewed their innovation processes which most often consisted of personal software development as a hobby. Having a good time was valuable enough to make them care less about the costs. The financial costs were estimated to be low, and the time spent was not viewed as a cost. Part of the fun and enhancing the experience were discussions had in virtual communities.

The Finnish virtual communities that the interviewees were a part of had between 15 000 to 53 000 members. They had grown a lot during early 2023 and the growth was not viewed as a completely positive thing. Growth could reduce the amount of expertise in the group and clutter the feed with posts about the same questions. It was estimated by UI5 that there would be around 100 active members in a group of 10 000 who have knowledge and actively participate. The most common posts to the community were asking for help, looking for knowledge in a specific situation, and sharing own solutions. The active members also looked for close relationships and UI6 had an interesting idea of a smaller group meeting:

> *"What I wish would happen [...] would be some kind of a meet up and it would be quite optimal to find 20 to 30 people from this smart home group who would go explore for example some just built new house with top notch implementations, and we'd meet there and go through the house which would also benefit the builder and give ideas on how to improve but also inspire others to make good solutions." (UI6)*

The community members enjoyed discussing solutions with like-minded people and valued their opinions. The community could make you think about a problem from a different perspective. It was also said that the interaction is reciprocal, and many rewarding relationships can start from reciprocal help.

Solutions developed by consumers

The interviews produced results about a good number of user innovations that were grouped and analysed. The innovations were divided based on whether they relied the most on hardware, software, or behaviour. Hardware and software mostly go together, but if there was software development involved, the innovation was classified as software. Behavioural innovations were interesting and required the least amount of specific skills and were more about creative ideas within the given context and other people around.

The interviews resulted in 21 software-based innovations, 11 behavioural, and 9 hardware. Software innovations were therefore clearly the most common. Most of the innovations were incremental that improved some existing solution slightly or tailored it to fit that user's specific needs. These included solutions where the users created their own configurations for their home automation systems. Many smart devices such as relays have the option for the user to write their own scripts and the interviewees had taken advantage of that. The most radical and large-scale solution creation had been done by UI6 who designed the whole architecture and smart home system for his house. Below is a quote of his comment:

> *"I'd say I have this whole architecture and software solution like self-developed for exactly this need, so I have barely used any complete commercial solution. This is related to the fact that I've been doing this for quite a while longer than these systems have been, these days the standard that is very often used is Home Assistant. I don't need one because I've built equivalent features myself and that's not necessarily a plus that it's self-built but just a fact." (UI6)*

Some of the solutions developed by consumers were later found to have business potential. This was the case for three interviewed solution providers. They had developed variations of software that could optimize consumption of certain devices such as boilers or relays. They obtain the day-ahead price information from Nord Pool and time the consumption for cheapest hours. The solutions vary in scale, and some offer optimization only for certain devices while others target a more comprehensive solution. This goes to show that in some cases the consumer developed solutions do have business potential.

Some of the challenges related to the development of solutions included different software issues, but also obtaining the day-ahead price information which was often essential to optimize consumption. The day-ahead price data is available from ENTSO-E transparency platform, but it seemed unclear whether or not you could use that data in your own software. It seems that the data can be used for personal solutions but for spreading a solution it is safer to acquire the data from Nord Pool. In developing single solutions, the software challenges varied in different error scenarios. When optimizing heating, there were challenges to make sure that the temperature of water for example never reaches temperatures in which bacteria starts to grow. Some automation could also negatively affect the daily life but could typically be fixed easily. An example of this would be a dishwasher not washing properly. The different solutions created by interviewees are summarized in Table 8 below.

Table 9. *Solutions developed by the interviewees*

Index	Solution	Basis	Challenges	Benefits
UI1	Electricity price integrated to home automation, EV charging timed with smart plugs, automated Christmas lights	Software: Home Assistant Hardware: smart plugs	Making sure that the devices work	Monetary, learning
UI2	Manually timed EV charging, dropped room temperature	Behavioural	Remember the tasks	Monetary, balancing the load
UI3	Automated heat pump: warm certain area half an hour before waking up, track and optimize consumption of all devices	Software: Home Assistant + ESPHome Hardware: sensors + relays	Making sure that the devices work	Monetary, comfort
UI4	Computer, refrigerator, and freezer optimized with buying decisions	Behavioural	Thinking of ways to lower already low consumption	Monetary, environmental
UI5	Floor heating off for 5 hours of highest demand, microcontrollers connected to home automation	Software: Home Assistant + ESPHome Hardware: sensors + relays	Getting the configurations right	Monetary, learning
UI6	EV charging optimized, heating optimizations: avoid 16 most expensive hours, designed home automation software and architecture	Software: developed from scratch Hardware: single-board computer + relays	Software errors	Monetary, learning
UI7	Lighting optimized with motion detectors, monitoring device temperatures, using sauna in hobby facilities	Behavioural Software: Home Assistant Hardware: relays + sensors	Getting a perfect solution for your environment, errors in software development	Monetary, learning

The most common solutions included optimizing those consumption sources with the biggest benefits available. These were heating and electrical vehicle (EV) charging. All the interviewees who had an electric vehicle did optimize its charging times. Among common solutions were also those that were the easiest to implement. These included lighting optimization or behavioural ones such as using a fireplace for heating or dropping the room temperature. The home automation system was in most cases based on the open-source project Home Assistant. None of the interviewees had installed small-scale production devices such as photovoltaics.

5.4. Discussion

The theory behind user innovation relied much on Von Hippel's (1986) research and the theory of innovation. Particularly the diffusion of innovations which Rogers (2003) has explored. The two characteristics of an user innovator are being ahead on an important marketplace trend and having high expected benefits (von Hippel, 1986). It was found that both characteristics existed among the interviewed users. They were ahead of the trend by adopting optimization solutions before the majorities. This was mostly driven by their personal interests and often supported by their background of work and education.

In home energy management, the objective is to shift consumption from the time of high demand to the time of low demand resulting in financial benefits for the consumer and a more balanced load on the network (Zhou et al., 2016). Higher flexibility of demand creates less need for non-renewable energy sources. The typical expected benefits for the consumer are therefore financial and they are the higher the more there are shiftable loads. The number of shiftable loads among the interviewees was not significantly higher than it would be for the average consumer, although most of the interviewees lived in detached houses. Instead, the interviewees valued learning and participating for the public good higher. Particularly the learning aspect is one that explains the high expected benefits encouraging the innovations.

One of the most clearly noticed barriers in the diffusion of home energy management solutions from the lead users to the majorities is the lack of information. It was revealed by the results that the typical consumer does not know much about electricity or balancing the load and does not care about it. Therefore, the solutions should be easy to install, operate, and generate visible profits to be attractive. There were also differences in perceived risks of smart devices. Privacy security seemed to be more important to those who had more technological knowledge and understood it. It was expected that owning smart devices would positively impact the attitude towards new smart technology and the interviews supported this (Sovacool et al., 2021). With more knowledge, consumers would have more positive attitudes.

It was expected that the development processes of the solutions would be more iterative with more back and forth discussions about any single solution in the community. Instead, it was found that, typically, the developers post a request for help once when they face difficulties in the development process. Otherwise, the development takes place in private environments. Other posts about the solution were typically made once it was ready for use. These posts were described as inspirational and other members of the community could get further improvement ideas and make these solutions suit their needs.

The interaction of users and solution providers with combined input from literature and the interviews is summarized in Figure 11 below. Within the user category lead users can clearly be separated from the majorities by a chasm which prevents the diffusion of innovations. The main actions of users in virtual communities are centred around knowledge and experience sharing which leads to learning and connecting with others. The virtual community platforms used by the interviewees included open-source development, messaging, social media, and forums. Messaging platforms are used primarily for sending messages to individuals or a closed group while forums and social media are more open. The solution providers had options to either observe the communication and ideas or participate in the co-creation and spreading information. It is also common to use especially social media platforms for marketing to reach wide audiences quickly. The content in virtual communities can be used to collect feedback, gain market knowledge, and even identify commercially attractive innovations.

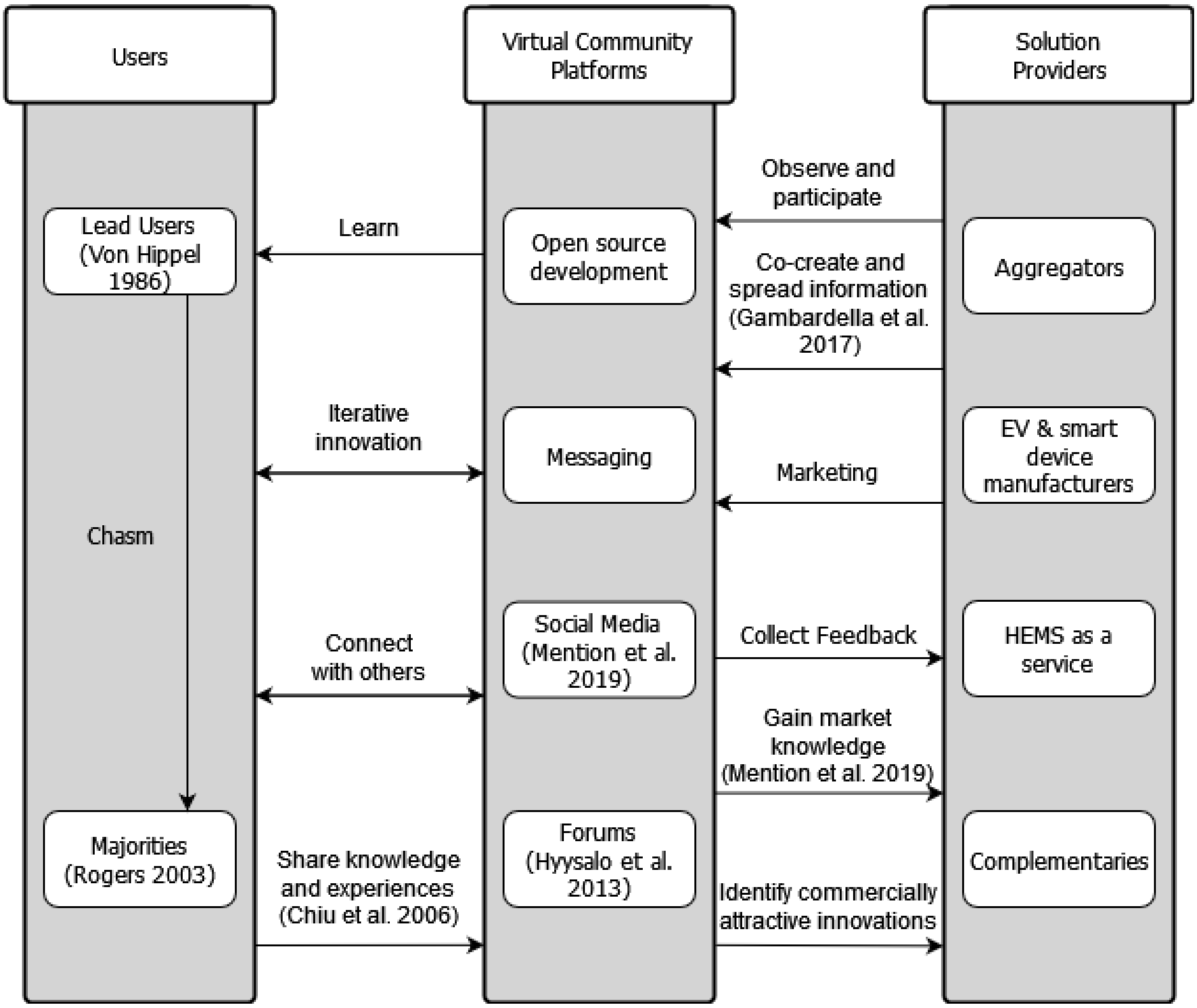

Figure 11. *Framework of user and solution providers' interaction in virtual communities*

An interesting aspect of the development processes was that the consumers enjoyed development in smaller groups. One interviewee had developed a solution together with a friend, one had helped another member of the community more privately, and one had participated in testing groups of solution providers. All these examples were seen as very positive experiences. In a more private and closed environment, you can discuss the topics more deeply and discuss the details at the moment the thought occurs. It could be worth thinking about for the solution providers if they should create smaller pilot groups or testing groups with certain interested consumers. In smaller groups, people get to know each other better and can be more open when the environment feels safe.

The solutions developed by the consumers were often tailored to suit their environment and needs. There was variation between the optimized sources of consumption. Even if the user has optimized the charging of an electric vehicle, there can still be differences between various EV models. These are obstacles to direct commercialization of these solutions. The created solutions still reveal information about what the consumers want which can be important when targeting the majority of consumers. Financial benefits were clearly the biggest factor for a typical consumer. The solutions should not reduce the comfort level of users. The interviewees had found ways to even increase comfort while optimizing consumption.

6. Conclusions

This deliverable includes three different studies related to the consumer to prosumer transformation. The study on different countries showed that northern regions have generally lower WTP but a shorter timeframe for adoption compared to Southern regions. Users perceive HEMS as beneficial but not as tools for controlling energy use. Similar findings are found in earlier HEMS studies on WTP, adoption processes, risk perceptions, and sociodemographic factors.

The second study investigated solar PV adoption in Finland and highlighted the role and concept of a preventive innovation. Prevention of not only climate change, but also price increases and emission reductions. The preventive factor should, according to this study, be added aside the more traditional Diffusion of innovation factors. The preventive side of PRELUDE solution and its different features could be emphasised in marketing.

The third study examined the user's role in co-creating HEMS solutions. Online communities pose an interesting opportunity for PRELUDE commercialisation in the first phase, as users share their experiences, help in developing the solutions, and can promote certain solutions to others.

Overall, the customer segments for PRELUDE have different capabilities and motivations for the service. Whereas the early adopters, "visionaries", can be used when entering to the market, designing the system should also be designed for the majority and laggards (see Figure 12) who are less interested in technology and environmental topics. Yet, as they are more often renters, building owners are able to take initiative and highlight benefits such as convenience and easiness of the solutions.

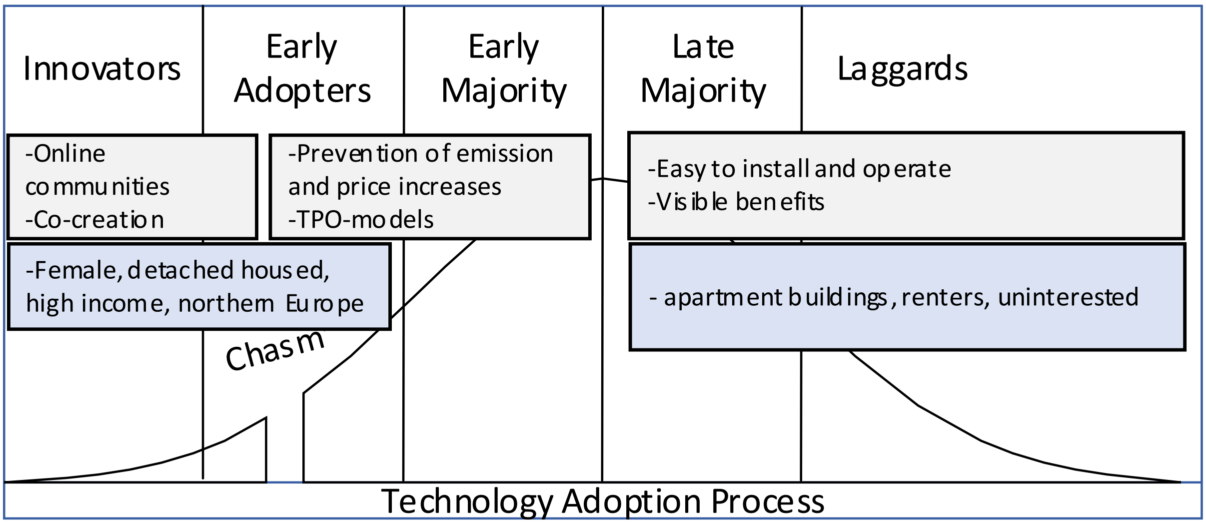

Figure 12. Profiles of innovation adopters related to PRELUDE (blue boxes), and drivers (grey boxes)

This deliverable has focused on the end-user preferences, however the customers for PRELUDE services can also be a building manager, a building owner like a pension fund, or an aggregator. These actors are rather acting in the logics of B2B-markets, which are more "rational" in a sense that they are more professional, financially oriented and require customisation and longer negotiations with the client. Understanding their challenges and possible solutions PRELUDE can offer requires a different approach. This work will be continued in the project. However, the findings of this deliverable are valuable also for them by understanding the customer perception of HEMS and other services. Also, concepts and processes like cocreation in virtual communities and features of preventive innovation have value in commercialising the solution in B2B-markets, too.

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