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Impact of complexity and experience on energy investment decisions for residential buildings

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Abstract

Complexity within the decision-making process can inhibit energy investment for residential buildings. In this paper, we explore effects of complexity on investment behaviour, as well as the impact of experience with similar investments and of subsidies as a promoting policy tool. To shed light on these issues, we conduct a discrete choice experiment (DCE) among homeowners. Furthermore, we investigate appreciation of a simplifying one-stop-shop concept and calculate the willingness to invest. Our results show that homeowners are interested in energy investments and have a positive but decreasing marginal willingness to invest. Subsidies matter for investment choices, and their effect more than offsets the negative impact of costs. Experience with similar investments plays a role for single homeowners and especially those who are familiar with subsidies seem to be interested in the one-stop-shop concept.

JEL Classification: D12, L94, Q41.

Keywords: Energy efficiency, Renewable energy, Discrete choice experiment, Conditional logit models

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1 Introduction

Investing in more sustainable energy usage to fight climate change has become an increasingly important topic in recent years. Energy-efficiency and renewable energy investments can be beneficial for residents and the environment. Such measures can help to reduce the substantial share of CO_2 emissions caused by residential buildings (Gerarden et al., 2017). Even despite availability of promoting policies like subsidies which can promote investment decisions (Mundaca and Samahita, 2020), there seem to be barriers that prevent households from investing. Lack of experience and complexity, which can even arise through the subsidy application process, can be such barriers (Bagaini et al., 2022; Bauner and Crago, 2015). Lowering transaction costs resulting from bureaucratic hurdles can foster energy investments (Inderberg et al., 2018). A "one-stop shop" (OSS) taking care of complex tasks can be a convenient solution by taking the burden off homeowners' shoulders. Yet, findings regarding appreciation of the OSS are not unambiguous (Pardalis et al., 2021).

However, there is still a lack of evidence in how far complexity (Buser and Carlsson, 2017), also in the subsidy application process, experience with such investments and an OSS affect energy investment decisions. In this paper, we investigate how households perceive subsidies for energy investments, which role complexity plays and if experience as well as an OSS concept can help to foster investment decisions. Therefore, we use a discrete choice experiment (DCE) and analyse data from a sample of 4'122 Swiss homeowners with conditional logit models. Furthermore, we calculate their willingness-to-invest (WTI)[1] based on the estimation results.

Our results show that homeowners value energy investments, especially those to produce renewable energy. Subsidies prove crucial as their impact outweighs equivalent cost reductions. This shows an even irrationally high appreciation of subsidies. Although the application process is not perceived as too complicated by most respondents, some

[1]We talk about WTI because we only consider investments in our experiment. Anyhow, in the literature, it is usually talked about WTP, which is often equivalent to what we refer to.

groups show an appreciation of the OSS concept. Whether experience positively influences investment decisions depends on the investment. In general, we find distinct differences between owner types, also when it comes to their WTI, which has also policy implications, as those groups may have to be addressed with different measures.

This paper is structured as follows. Section 2 reviews briefly the related literature. Section 3 describes the methodology and our experiment. Section 5 presents the results and the corresponding discussion, and Section 6 concludes and discusses policy implications.

2 Literature review

Different energy efficiency (EE) and renewable energy (RE) investments are of interest for residential buildings (see e.g., Sachs et al., 2019; Gerarden et al., 2017). Choice experiments in the residential energy investment context are conducted by a variety of researchers. Banfi et al. (2008) carry out a choice experiment and analyse stated preferences from 305 Swiss household and find that they have a positive but decreasing WTP when it comes to energy efficiency investments. Achtnicht (2010) conducts a choice experiment and finds that German homeowners' choices are affected by environmental benefits, even though this is not the case for all investment options like insulation. He also identifies uncertainty as an obstacle to such investments. Scarpa and Willis (2010) conduct a choice experiment on attitudes towards microgeneration of renewable energy. They find a positive but potentially insufficient WTP for investments like PV.

A range of potential barriers has been discussed in the literature (see e.g., Achtnicht and Madlener, 2014). Complexity can affect investment decisions as they depend on various factors and many details need to be considered (Buser and Carlsson, 2017; Golove and Eto, 1996). Information has to be gathered, technical know-how can be required and requirement must be fulfilled (Baumhof et al., 2018; Blasch et al., 2018). Furthermore, organisation and financing, possibly with the help of loans, as well as monitoring and re-assessment add tasks on hand (Biere-Arenas et al., 2021; Wilson et al., 2015). Resulting stress, required time and effort can become barriers (Bagaini et al., 2022). Resulting transaction costs and the feeling of being overwhelmed can hinder investments (Ebrahimigharehbaghi et al., 2020).

Uncertainty about performance, reliability and returns can act as barriers to energy investments (Fawcett, 2014; Zahedi, 2011; Caird and Roy, 2010). But uncertainty can be diminished by means of learning coming with experience (Bjørneboe et al., 2017; Haavik et al., 2010). Experience with energy investments affects investment decisions, as it can reduce the barriers resulting from complexity and uncertainty (Hrovatin and Zorić, 2018). There is evidence that familiarity with renewable energy installations favours similar investment (Nair, 2012). However, how experience affects future investment depends on the nature of the experience gained. Negative experience can lower incentives to invest again (Ebrahimigharehbaghi et al., 2019). In some cases, there is only interest in specific energy investments so that repeated investment is less likely (Pardalis et al., 2019). The aforementioned difficulties can also cause people to give up early in the investment process, which in turn interrupts the learning process that would otherwise accompany it (Bertoldi et al., 2021).

Because the potentially high costs of energy investments can act as a barrier (Achtnicht and Madlener, 2014), subsidies are often available to promote energy investments by lowering these costs (Mundaca and Samahita, 2020; Gillingham et al., 2009). Yet, the subsidy application process can be a hassle and as a result add to the complexity and impair their effectiveness (de Vries et al., 2020).

Innovative business models can therefore be required to solve existing problems (Boza-Kiss et al., 2021; Mahapatra et al., 2013; Mokhlesian and Holmén, 2012). A one-stop shop (OSS) may be a solution. It can be a physical or virtual contact point which acts as an intermediary between all parties involved and strives for the most efficient implementation. The service can go so far that the OSS takes care of everything necessary to identify, implement and monitor the appropriate investment opportunity. Thereby, knowledge and expertise, often crucial for successful investment, are pooled (Hunkin and Krell, 2019).[2] Thereby, the investment process is optimised, which reduces the burden on the owner and promotes successful investment Biere-Arenas et al. (2021); Bertoldi et al. (2021).

Energy investments and attitude towards OSSs are examined, for instance, by Mahapatra et al. (2019) based on an online survey. Their results show that especially younger people are interested in building-related investments, with optical improvements being given priority over energy measures. When it comes to OSSs, there is the need for services that ensure high quality work, although the enthusiasm for such services remains within bounds. Pardalis et al. (2019) also identify residents' interest in OSSs for energy investment, even though the majority of their Swedish respondents did not indicate an urge for such a solution.

Yet, although research has been conducted in this context, it lacks a comprehensive analysis of factors affecting the relevant range of potential energy investments. It is not only important to find out which characteristics and investment-specific aspects have an influence. As pointed out by Buser and Carlsson (2017) amongst others, there are issues like complexity in the investment decision process, which have not been extensively studied yet. Thus, we want to analyse what role subsidies, complexity and experience play in the investment process and whether an OSS can help to overcome existing problems. By doing this, our approach exceeds existing research and breaks new grounds.

3 Research methodology

We conduct a discrete choice experiment (DCE) to gather data for our analysis. The decisive advantage of the choice experiment approach is that not only specific energy investments in their entirety but also corresponding attributes and levels can be considered to gain a better understanding, as all these factors may play decisive roles for investment

[2] For a detailed explanation of the concept of an OSS and examples see Biere-Arenas et al. (2021); Reid and Wettenhall (2015)

decisions (Bessette and Arvai, 2018; Bidwell, 2013). The stated preference approach makes it possible to obtain information not only from owners who have already invested, but also from those who have not yet invested. The latter group is of particular interest to policymakers because involvement of those homeowners would be important to reach climate goals.

3.1 Discrete choice experiment

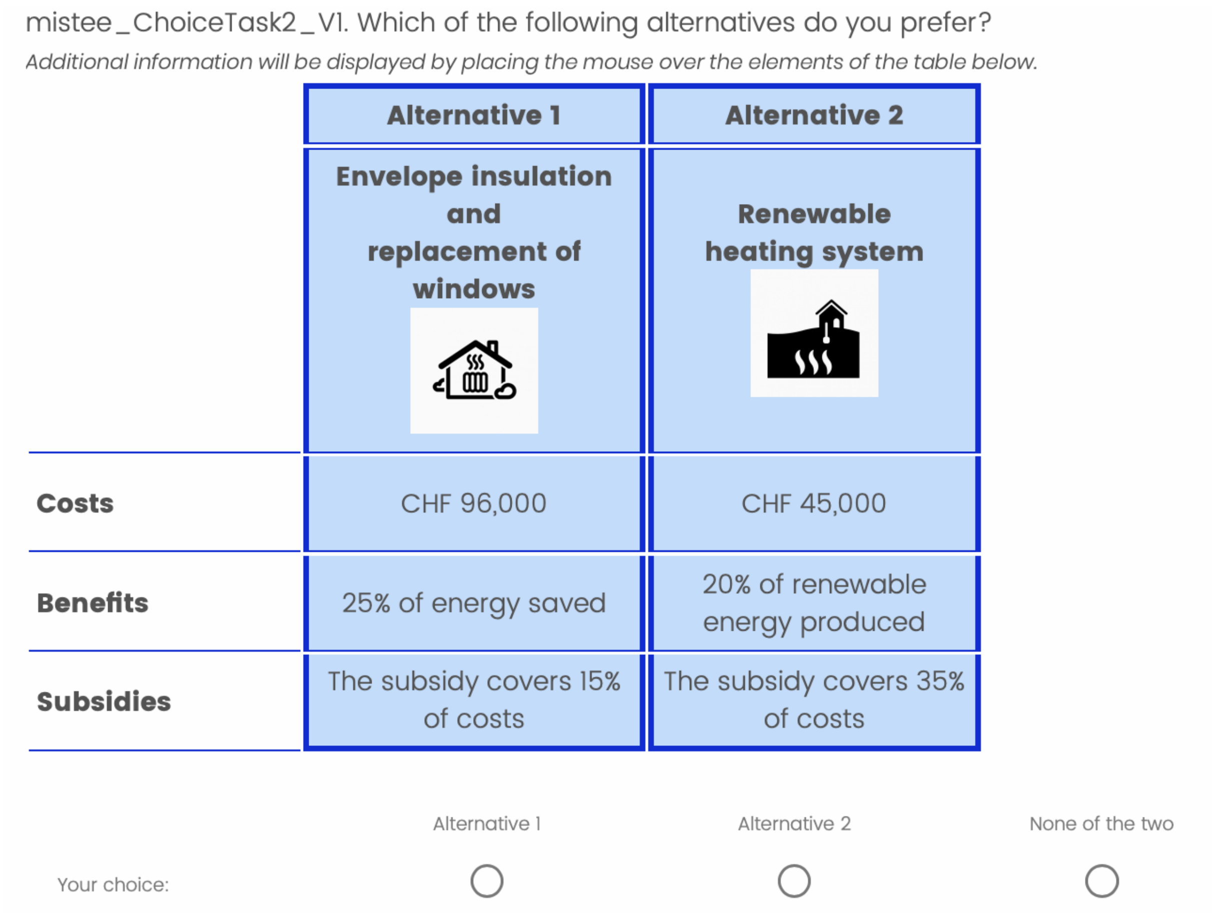
An example of an actual choice task is presented in Figure 1. All choice tasks looked identical. Each of them consisted of two energy-related investment options and a non-energy-related spending or saving option (referred to as status quo or short SQ in the remainder of this paper).

Our experiment consists of four choice tasks in total. Respondents are asked to choose according to their preferences, taking their financial restrictions and living situation into account. Energy investments come with three attributes: costs, corresponding benefits of the investment in form of energy savings or renewable energy production, as well as subsidies available for this specific investment, as it also can be seen in Figure 1. The offered energy investment options represent all depths, from low impact overhauls up to major improvements like building insulation (Esser et al., 2019).

Attributes and levels attributed to each investment option correspond to realistic values. They are displayed in Table 1. Our experiment includes numerous relevant energy investments: overhaul of the façade or running fossil fuel operated heating system, insulation, renewable heating, for instance by means of a heat pump, PV as well as combinations of different investments that can be feasible, as it can also be seen in Table 1. Because we also want to analyse the role subsidies play for investment decisions, we include different

[2]For a more detailed discussion of pros and cons of stated and revealed preference approaches see also Newell and Siikamäki (2014); Vossler et al. (2012); Verhoef and Franses (2003); Louviere et al. (2000) and for a precise description of our approach see Paper 1 Section 3

Figure 1: Sample choice task



mistee_ChoiceTask2_V1. Which of the following alternatives do you prefer?

Additional information will be displayed by placing the mouse over the elements of the table below.

	Alternative 1	Alternative 2
	Envelope insulation and replacement of windows	Renewable heating system
Costs	CHF 96,000	CHF 45,000
Benefits	25% of energy saved	20% of renewable energy produced
Subsidies	The subsidy covers 15% of costs	The subsidy covers 35% of costs

	Alternative 1	Alternative 2	None of the two
Your choice:	○	○	○

realistic levels of subsidies for certain investments whenever feasible. The respective levels can be seen in the last column of Table 1.

Furthermore, we introduce a treatment to half of the sample. They receive an information page ahead of the actual choice experiment, which contains information about the current state of the subsidy application process. Additionally, it is pointing out related difficulties. Thereafter, the OSS concept is explained. In our experiment, this OSS simplifies the subsidy application process by taking care of all important tasks. This implies a significant reduction of effort and uncertainty. This should decrease the main barriers, increase the effectiveness and thus promote a positive attitude towards subsidies and, as a result, also energy investments.

Table 1: Investments, corresponding attributes and levels

Investment	Costs in CHF	Benefits as % of energy saved or produced	Subsidies in % of total costs
Status quo	–	–	–
Overhaul and energy efficiency investments			
Envelope reinstatement	7000−32000	0−5	0
Insulation	40000−96000	15−60	8−35
Heating system overhaul	700−20000	5−25	0
Insulation and heating overhaul	41000−116000	15−60	8−35
Renewable energy investments			
Renewable heating	7000−60000	20−100	8−35
PV	11000−23000	11−60	8−35
PV and renewable heating	18000−85000	20−100	8−35
Energy efficiency and renewable energy investment			
Insulation and renewable heating	47000−156000	20−100	8−35

Similar to Allcott and Kessler (2019), our treatment comes with both verbal information and a figure to promote information transmission. Besides an explanation of the situation and concept, the simple figure of a shopping cart with a check sign within is chosen to visualise the convenience of the procedure by drawing parallels to online shopping.[3]

3.2 Implementation

The choice experiment is published within the Swiss Household Energy Demand Survey (SHEDS).[4] Our survey was also conducted in the canton of Zürich and was sent to the subscriber pool of Pronovo, which manages subsidies for PV investments in Switzerland. The total sample consists of 4'122 homeowners.

Almost all respondents from Pronovo have experience with certain energy investments and subsidies, which distinguishes them from most respondents of the other surveys.

[3]The treatment page can be found in Appendix A.4

[4]See also (Weber et al., 2017) for further information. The respondents stem partially from a pool of subjects managed by the private survey company Intervista (see also https://www.intervista.ch).

Therefore, the proportion of respondents familiar with such investments and corresponding subsidies is naturally higher in this sample compared to the entire population. They are of particular interest to policymakers, as their revealed preferences and perception of the process can provide information on the functioning and potential for improvement of existing measures. For the sake of simplicity, the respondents from SHEDS and the survey in Zurich are referred to below as "Sample 1" and those from Pronovo as "Sample 2". [5] The sample composition is detailed in Table 2.

Table 2: Composition of the sample

	Sample 1	Sample 2	Total
Flat owner	489	31	520
	(27.46)	(1.32)	(12.62)
MFH owner	93	138	231
	(5.22)	(5.89)	(5.60)
SFH owner	1199	2172	3371
	(67.32)	(92.78)	(81.78)
Total	1781	2341	4122
	(100.00)	(100.00)	(100.00)

Shares in parentheses (in %).

Most of the respondents (3'371 individuals) are single-family house (SFH) owners, with flat owners being the second-largest group (520 individuals). Multifamily house (MFH) owners are less represented in our sample (231 individuals) because we focus on private owners and do not consider institutional owner groups, which are common in Switzerland.

These owner groups differ fundamentally. MFH owners, for example, do not benefit from investments to the same extent as SFH owners, as they do not necessarily live in the same building. Flat owners on the other hand are not in a position to make investment decisions on their own building on their own, as coordination with other residents is necessary. This makes decision-making more difficult for them, also due to the resulting

[5] Unless stated differently, the pooled sample (sample 1 and 2 together) is used as the basis for statements, graphs and tables. For some of the descriptive statistics, we look at sample 1 and sample 2 separately. This is feasible due to the previously mentioned differences and helps to identify potentially different attitude towards energy investments and subsidies.

transaction costs (Matschoss et al., 2013; Williamson and Masten, 1999). Because of these differences, it makes sense to carry out the analysis separately for the different groups.

4 Econometric analysis

The econometric approach is based on the random utility theory of McFadden (1974), according to which individuals receive utility not only from a product itself, but also from its attributes like costs and resulting benefits. As a result, specific attribute levels can be estimated that facilitate utility maximisation.

Formally speaking, our sample consists of $N = 4122$ individuals. Those choose their preferred option out of $J = 3$ alternatives in each of the $T = 4$ choice tasks to maximise their own utility. Trade-offs between available energy investments and corresponding attributes are revealed by repeated choices. In the random utility framework, individual n acquires the utility U_{njt} from choosing alternative j in choice task t. This can formally be expressed by the equation:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \quad \text{with} \quad n = 1, ..., N, \quad j = 1, 2, 3, \quad t = 1, ..., 6 \tag{1}$$

Therein, V_{njt} is the representative utility, which is assumed to be a linear utility function. For the conditional logit model, the random term ε_{njt}, which is assumed to be independently and identically distributed.

V_{njt} is a linear function of the observable explanatory variables:

$$V_{njt} = \beta_n' x_{njt} \tag{2}$$

Attributes of alternative j and characteristics of the respective respondent n are contained in Vector x_{njt}. This model is estimated with a conditional logit model, which means that the parameters of interest are constant ($\beta_n = \beta \; \forall \; n$). For conditional logit models, the independence of irrelevant alternatives is assumed. That implies that cross-effects are equal. The independence of irrelevant alternatives property derives from the assumption of an independent and identical distribution in the V_{njt}, which means independence of utility across alternatives and contexts.

We also use the estimation results to calculate respondents' WTI for the investment options. The WTI for attribute k is calculated as the ratio of the attribute coefficient to the cost coefficient, as it can be seen in Equation 3.

$$WTI_k = \frac{-\beta_k}{\beta_{cost}} \tag{3}$$

The estimate show how much money an individual is ready to invest to get a specific energy improvement or installation. More specifically, the willingness to invest to benefit from either energy savings or renewable energy production.

5 Experimental Results

In the upcoming parts, both descriptive statistics and empirical results are presented to identify personal perception, attitude and preferences.

5.1 Descriptive statistics

To evaluate the importance of subsidies, we identify how many homeowners in our sample invested with or without having received subsidies. We consider experience with PV, renewable heating (RH) and insulation (EI). Most respondents from Sample 2 have already invested in PV. Due to the differences between the samples, the following figures are partly presented separately to avoid blurring.[6] Table 3 gives a general indication of how many

[6]Whenever no separate Figures are presented, then results do not significantly differ from each other

respondents in Sample 1 and 2 are experienced by having invested in energy measures before.[7]

Table 3: Energy investment experience

	Sample 1	Sample 2	Total
No experience PV	1531	31	1562
	(85.96)	(1.32)	(37.89)
Experience PV	250	2310	2560
	(14.04)	(98.68)	(62.11)
No experience RH	1149	705	1854
	(64.51)	(30.12)	(44.98)
Experience RH	632	1636	2268
	(35.49)	(69.88)	(55.02)
No experience EI	970	998	1968
	(54.46)	(42.63)	(47.74)
Experience EI	811	1343	2154
	(45.54)	(57.37)	(52.26)
Total	1781	2341	4122
	(100.00)	(100.00)	(100.00)

Shares in parentheses (in %)

Shares of respondents who have already carried out energy investments for their building, with or without having received subsidies are detailed in Table 4. PV investments are often supported by subsidies. On the contrary, envelope insulation (EI) and renewable heating (RH) investments are regularly carried out without subsidies. Hence, subsidies seem to be especially crucial for PV investments. The main reason for not having received subsidies for any of these investments is the lack of availability of such subsidies, followed by unawareness and other reasons like the feeling that it is not worth the effort.[8]

To find out more about the perceived complexity of the subsidy application process, respondents are asked how they experienced it. Through this, we seek to get a better idea of whether the complexity of the subsidy process can be a significant barrier to energy

[7] In this case, "experienced" means that the person personally has already invested in an energy measure on their own building. The possible investments are PV, renewable heating or insulation of the building. Some have even invested in multiple energy measures.

[8] Detailed figures about respondents' answers to the question of why they did not receive subsidies can be found in Appendix A.1.

Table 4: Experience with and without subsidies

	Sample 1	Sample 2	Total
PV without subsidies	34	106	140
	(13.60)	(4.59)	(5.47)
PV with subsidies	216	2204	2420
	(86.40)	(95.41)	(94.53)
Total	250	2310	2560
	(100.00)	(100.00)	(100.00)
RH without subsidies	458	1075	1533
	(72.47)	(65.71)	(67.59)
RH with subsidies	174	561	735
	(27.53)	(34.29)	(32.41)
Total	632	1636	2268
	(100.00)	(100.00)	(100.00)
EI without subsidies	688	1027	1715
	(84.83)	(76.47)	(79.62)
EI with subsidies	123	316	439
	(15.17)	(23.53)	(20.38)
Total	811	1343	2154
	(100.00)	(100.00)	(100.00)

Shares in parentheses (in %)

investment. As data in Figures 2 suggest, most respondents do not consider the subsidy application process as overly complicated.

Inspection of Figure 3 indicates that respondents would like a simplified subsidy application process. They show valuation of an OSS idea, even though a substantial share of respondents indicate their understanding of the current system. Thus, the effect of an OSS may be limited, and it comes with the danger of promoting free-riding behaviour, especially if the current procedure is not perceived as a barrier.

When asked if they think that simplified procedures could promote the effectiveness of subsidy programs, the majority of respondents agree, as illustrated in Figure 4. Given the previously discussed personal perceptions, this may not be crucial, even though simplifications are appreciated.

Figure 5 shows that many respondents think that complexity can deter people from investing. Others chose that especially those who are less financially strong cannot afford

Figure 2: Perception of the subsidy application

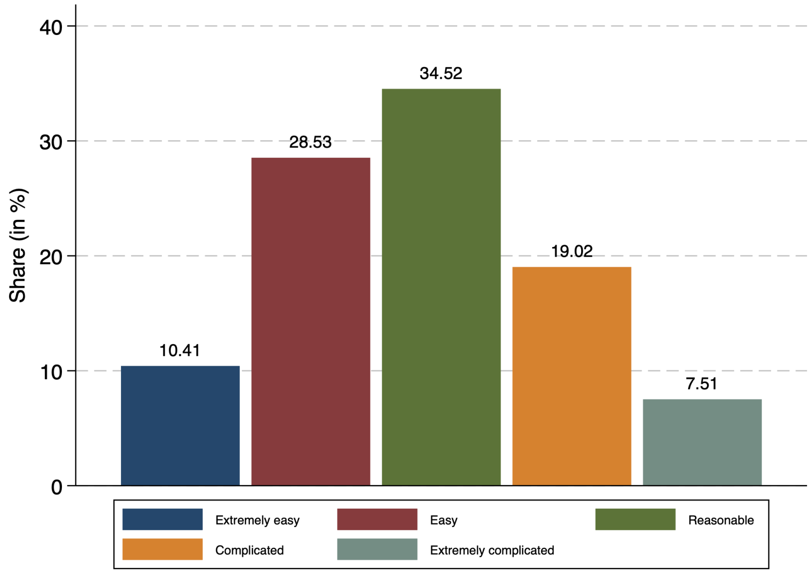
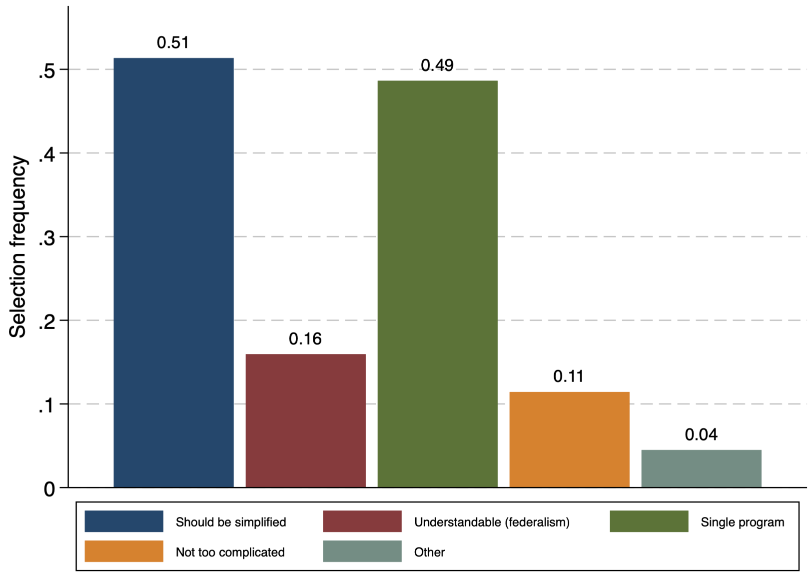


Figure 3: Views on subsidy programs



consultation necessary to find the optimal solution. Also, they answer that energy investment decisions are already complex and adding another layer of complexity can have negative effects.[9]

[9]The exact wording of the question was: In your opinion, what are the main problems complexity can create? and the respective answer options: (1) People would not apply because it is too much hassle for

Figure 4: Expectations about increased effectiveness due to simplifications

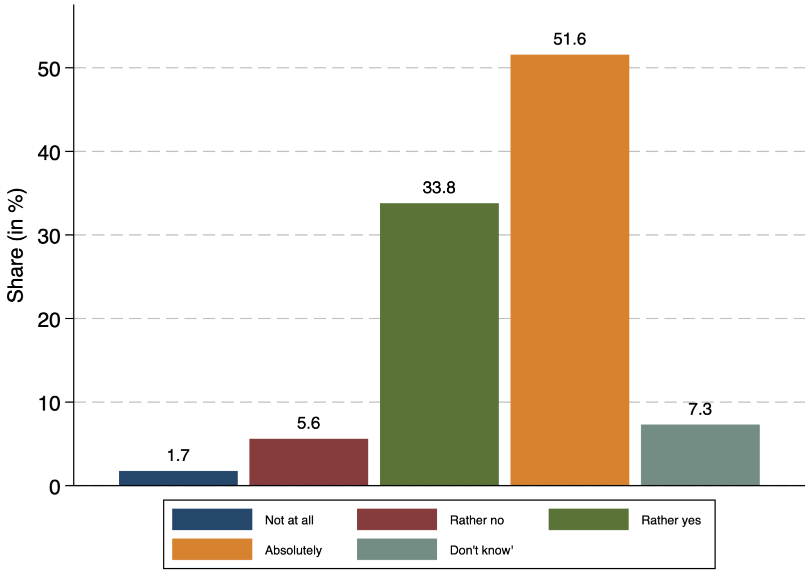
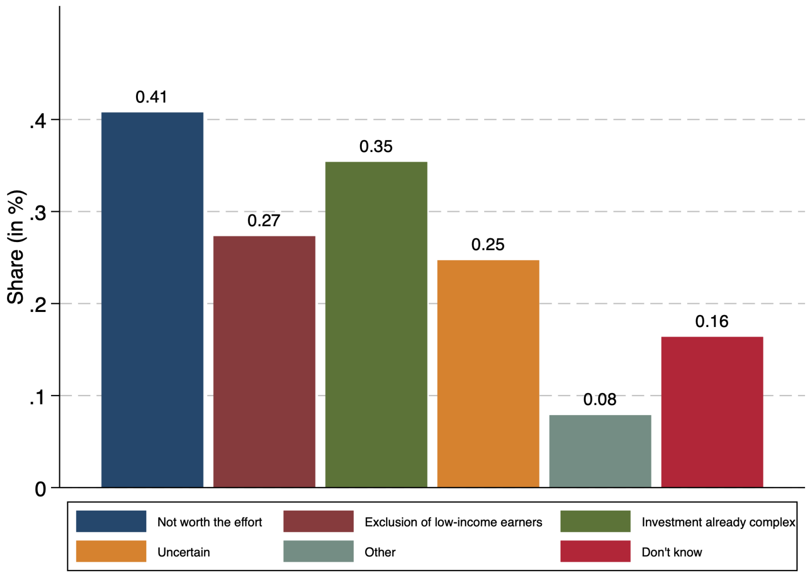


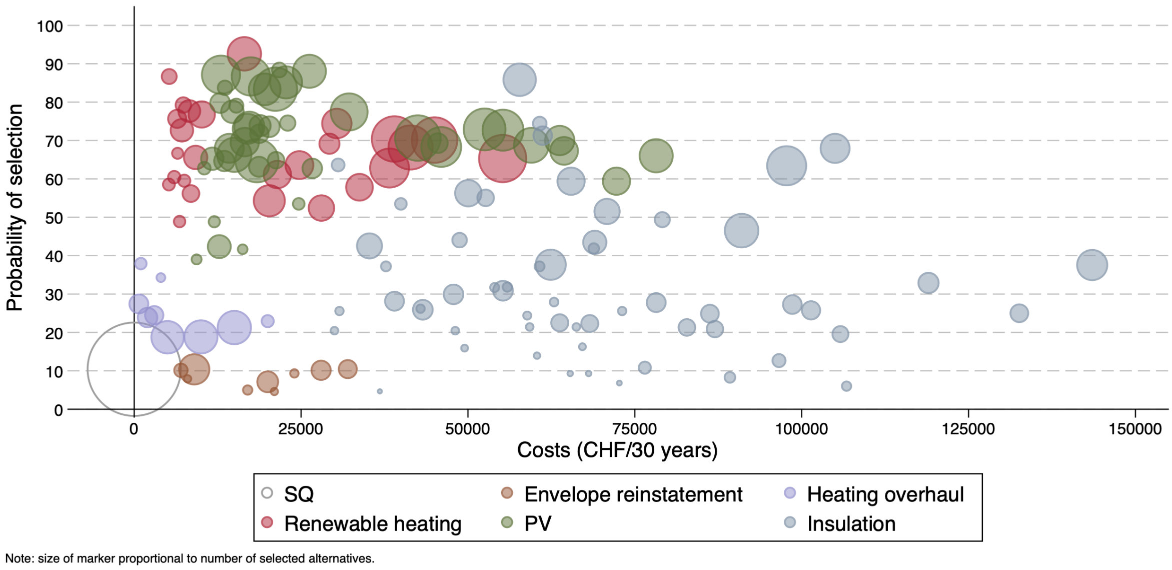
Figure 5: Perceived problems due to complexity of the subsidy application



When looking at the general choice behaviour, Figure 6 illustrates that respondents choose renewable heating and PV most of the time when it is available, indicating a pro-

amount (2) Low-income homeowners do not benefit since they cannot afford a consultant to help them to find all relevant subsidies (3) The investment decision is already complex. Adding another level of complexity dissuades homeowners from any investment (4) Too much uncertainty about the acceptance conditions (5) Other (please specify) (6) I do not know sumer preference. EE investments are less frequently chosen. What is also noticeable is that especially cheaper options are chosen more often. This is in line with findings by Gillingham et al. (2009), for example, who identify costs as an obstacle to such investments.

Figure 6: Selection probability of energy investments by costs



5.2 Empirical results and discussion

Estimation results for the pooled sample are reported in Table 5.[10] The estimation shows how selection is affected by the investment types and respective attributes, as well as some personal characteristics. Therewith, these estimation results answer the research questions regarding the importance of subsidies, valuation of the OSS concept and effect of experience.

In line with the previously discussed descriptive statistics, the estimation results reveal interest in energy investment options. Especially renewable energy measures show a comparably strong effect, which underlines the previously mentioned prosumer preference.

[10] Estimation results by sample can be found in Appendix A.2

Table 5: Estimation results: Pooled sample

	Pooled sample	
Observations	49,464	
Investments (base category: SQ):		
Envelope reinstatement	-0.1692^{**}	(0.0665)
Heating overhaul	0.4827^{***}	(0.0615)
Ren. Heating	1.5701^{***}	(0.0681)
PV	1.5760^{***}	(0.0787)
Insulation	1.2704^{***}	(0.0998)
Costs (in 1000 CHF after subtracting subsidies):		
Costs	-0.0111^{***}	(0.0008)
Benefits (in %):		
Benefits	0.0155^{***}	(0.0021)
Benefits × Benefits	-0.0001^{***}	(0.0000)
Subsidies (in 1000 CHF):		
Subsidies	0.0170^{***}	(0.0020)
OSS Treatment effect (interacted with subsidies):		
Treated	-0.0061^{*}	(0.0037)
Treated × Experience (PV) with subsidies	0.0068^{*}	(0.0040)
Treated × Experience (EI) with subsidies	0.0302^{***}	(0.0057)
Experience effects:		
Experience (PV) × PV	0.5116^{***}	(0.0662)
Experience (EI) × Insulation	0.1025	(0.0689)
Characteristics:		
University degree × Benefits	0.0037^{***}	(0.0010)
Retirement age × Ren. Heating	-0.4629^{***}	(0.1190)
Retirement age × PV	-0.3768^{***}	(0.1183)
Retirement age × Insulation	-0.5377^{***}	(0.1250)

Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Standard errors in parentheses

Insulation is also valued, whereas simple envelope reinstatement is the only investment option that is clearly disliked.

Because one of the main objectives of this paper is to reveal homeowners' valuation of subsidies, it is interesting to see that subsidies have a significant and positive effect. This effect is even comparably stronger than the negative cost effect, which indicates that respondents value subsidies more than a comparable reduction of investment costs.

Therewith, they deviate from rational behaviour, but it attests the importance of subsidies for investment behaviour. This is in line with the fact that almost all PV investments were undertaken with support of subsidies, as it is shown in Table 4. Thus, subsidies can be effective in encouraging energy investment and help to facilitate CO_2 reduction targets. On the other hand, this irrationally high valuation can also lead to a distortion of decisions and, as a result, to distortions in the market. For example, producers can benefit in an asymmetric way from it.[11]

As the results have revealed, subsidies are very important for investment decisions. They can even become a prerequisite for therefore. If the steps to obtain subsidies are too complicated, this can negatively affect investment opportunities or even completely prevent investments in energy improvements. Thus, effectiveness of such policies may be even increased if barriers as complexity in the subsidy process are further decreased. The estimation results show that for those who are familiar with energy investments and subsidies, the OSS treatment increases appreciation of subsidies even more. Thus, simplifications seem to be esteemed by those who are familiar with such procedures and the corresponding hassle. Interestingly, the treatment effect for those who received subsidies for previous PV investments is not very severe. In contrast, the effect is more pronounced for those who invested in insulation and received subsidies for it. Putting this in perspective and comparing it with the descriptive statistics in Table 4, insulation investments were often made without subsidy support. This means that those who received subsidies for their insulation investments would have an even higher appreciation for subsidies if the process of obtaining them were simplified by means of an OSS. Conversely, taking the whole picture into account, it also means that subsidies do not really seem to be a prerequisite for insulation and that simplification would significantly increase the value of such subsidies. As the descriptive statistics show, subsidies are rather essential for PV,

[11]The exact magnitude of the subsidy effect depends on the model specification used for the econometric analysis. In Appendix A.3 we used a differently specified model with total costs instead of net costs and subsidies in percentage, as they were displayed to respondents, instead of the respective monetary value in CHF. For this model, there are hardly any differences when it comes to the subsidy coefficients between different owners. Yet, the overall effect is the same. It shows that respondents really seem to be irrational in a way that they value subsidies more than the same amount of cost reduction.

and although they can also be valued for insulation work, there is a risk of creating free-rider problems through further simplification, because it becomes very easy for owners to collect the subsidies. On the other hand, the general treatment effect does not support these findings. Inexperienced respondents do not seem to perceive the subsidy application process as being problematic as it is. Taking into account that complexity does not seem to be a major hurdle as the descriptive statistics in Section 5.1 reveal, the results can be an indication that the OSS concept is not fundamental to promote energy investments. Even though they stated their valuation for further simplifications, this does not seem to be necessary given the other results. Furthermore, such simplifications, also in the form of an OSS could promote free-riding behaviour because it would lower barriers. This can support subsidy seeking efforts even for those owners who would otherwise have invested without subsidies, which increases the inefficiency of such measures. Thus, such trade-offs have to be carefully considered (Studer and Rieder, 2019). This may argue against a simplification of the current process, especially in view of the fact that it is largely not considered too complicated.

Respondents who already invested in PV are more likely to choose PV again in the choice experiment. Thus, such experience and the corresponding learning effect enhances the chances of selecting similar investments, probably also due to the decreased uncertainty and satisfaction of the PV installation. In contrast, familiarity with insulation work shows no significant effect on the re-selection of such investments. This may be due, for example, to the inconvenience involved and the dirt that often results, which primarily affects those who are less into such energy investments in the first place (Stieß et al., 2010; Weiss and Dunkelberg, 2010).

When it comes to personal characteristics, higher education has a significant effect on the importance of benefits. Thus, homeowners with higher education may be willing to invest more to reduce their CO_2 emissions. This can also be explained by the fact that people with higher education usually also earn more (OECD, 2019). Because of this greater financial freedom, their scope of action for such measures can be higher, so that more effective options can be chosen. People in the retirement age are significant less likely to select costly energy investments such as insulation or switching to a renewable heating system. This may be motivated by the fact that their planning horizon is shorter, as they do not know how long they will continue to live in the building and what will happen to it afterwards, which some of them also stated in the experiment. Furthermore, it is also not surprising, as such energy investments need several years to be economically viable (Weiss and Dunkelberg, 2010).

We conduct the same analysis for the different owner types separately to compare them and identify differences in their preferences and attitudes. This makes sense because they vary in terms of their autonomy of decision, the way they benefit from a potential investment and other factors. Differences would imply that policies had to be fitted in order to target the different types effectively.

The estimation results in Table 6 show a similar general picture as seen in Section 5.2. Envelope reinstatement is still the only energy investment which is obviously disliked by all owner groups, especially MFH owners. Yet, some differences between the groups are visible. Heating related investments show comparably stronger effects for MFH owners, which can be explained by the fact that such investments in either overhaul or switch to renewable heating are inevitable from time to time. Costs are most crucial for flat owners, and for them subsidies have also a stronger effect than for SFH owners. Subsidies play an even more important role for MFH owners. They show a very high valuation of subsidies. Thus, such policies may have a large effect and can for instance help to overcome the split incentive problem, which leads to under-investment of MFH in their rental buildings (Ástmarsson et al., 2013).

For flat owners, there is no treatment effect observable. For MFH and SFH owners who invested in insulation before, the OSS treatment increases their valuation of subsidies even more. Thus, getting subsidies easily for such investments may increase investment behaviour, but can bear previously discussed problems. Interestingly, the OSS treatment shows a negative effect for MFH owners who have already invested in PV. Yet, the results for MFH have to be cautiously interpreted because the sample is very small.

There are no effects of experience observable for flat owners. MFH and SFH who invested in PV before are more likely to choose PV in the experiment again. This indicates their satisfaction with the previous investment. Experience with insulation does not foster selection of similar investments, which is the same for all owner types.

Benefits have a positive but marginally decreasing effect, which shows that benefits are valued, but the valuation of additional energy savings is diminishing. This again indicates that despite their general interest in energy investments, homeowners are not necessarily interested to facilitate the full CO_2 emission reduction potential. Benefits do not have a significant effect for MFH owners. This is not surprising because they do not benefit themselves through their investment (Melvin, 2018).

Buildings with a number of co-owners are presented with the problem of collective decision-making when it comes to investing in energy improvements (Fleischhacker et al., 2018). This can cause interaction problems and difficulties to agree on certain actions. This results in transaction costs. These can ultimately prevent energy investments on residential buildings, which can explain the lack of significant results for flat owners (Heiskanen et al., 2012; Hüttler et al., 2006). Also, in this case, stricter rules can be more efficient than solely supportive policies (Matschoss et al., 2013).

Personal characteristics seem to be especially influential for SFH owners, as they show hardly any meaningful effects for flat and MFH owners.

Table 6: Estimation results by owner group

	Flat owners	MFH owners	SFH owners
Observations	6,240	2,772	40,452
Investments (base category: SQ):			
Envelope reinstatement	-0.3436	-0.5728^{*}	-0.1065
	(0.2104)	(0.3369)	(0.0720)
Heating overhaul	0.6919^{***}	0.8730^{***}	0.4093^{***}
	(0.1571)	(0.2781)	(0.0691)
Ren. Heating	1.4394^{***}	1.7810^{***}	1.5819^{***}
	(0.1884)	(0.2822)	(0.0754)
PV	1.5209^{***}	1.3911^{***}	1.6021^{***}
	(0.1826)	(0.3738)	(0.0921)
Insulation	1.0808^{***}	1.2310^{***}	1.3093^{***}
	(0.3892)	(0.4771)	(0.1064)
Costs (in 1000 CHF after subtracting subsidies):			
Costs	-0.0143^{***}	-0.0131^{**}	-0.0111^{***}
	(0.0054)	(0.0065)	(0.0008)
Benefits (in %):			
Benefits	0.0172^{***}	0.0100	0.0155^{***}
	(0.0061)	(0.0083)	(0.0023)
Benefits × Benefits	-0.0001^{*}	-0.0000	-0.0001^{***}
	(0.0001)	(0.0001)	(0.0000)
Subsidies (in 1000 CHF):			
Subsidies	0.0280^{**}	0.0528^{***}	0.0157^{***}
	(0.0112)	(0.0132)	(0.0020)
Treatment effects (interacted with subsidies):			
Treated	-0.0166	-0.0253	-0.0047
	(0.0141)	(0.0205)	(0.0039)
Treated × Experience with subsidies (PV)	0.0253	-0.0442^{*}	0.0067
	(0.0267)	(0.0228)	(0.0042)
Treated × Experience with subsidies (EI)	0.0327	0.0793^{***}	0.0289^{***}
	(0.0266)	(0.0254)	(0.0059)
Experience effects:			
Experience (PV) × PV	0.3377	0.5165^{*}	0.5153^{***}
	(0.2639)	(0.3080)	(0.0769)
Experience (EI) × Insulation	0.1784	-0.1025	0.1019
	(0.2142)	(0.2686)	(0.0754)
Characteristics:			
University degree × Benefits	0.0052^{*}	0.0058	0.0036^{***}
	(0.0030)	(0.0044)	(0.0011)
Retirement age × Ren. Heating	-0.1486	0.2386	-0.6167^{***}
	(0.2639)	(0.5722)	(0.1411)
Retirement age × PV	0.1425	-0.7280	-0.5319^{***}
	(0.2438)	(0.4623)	(0.1438)
Retirement age × Insulation	0.1195	-0.7533^{*}	-0.6945^{***}
	(0.2889)	(0.4498)	(0.1485)

Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Standard errors in parentheses

5.3 Willingness to invest

Table 7 presents the WTI for 15% of benefits in the form of energy savings or renewable energy production, which are based on the previously discussed estimation results. For both SFH and flat owners the WTI decreases as the starting level of benefits increases, whereas results for MFH owners are not significant, even though they show a similar general pattern.[12] Flat owners are willing to invest CHF 18,000 for the first 15% of benefits, which decreases to CHF 8,500 for a 15 percentage-point increase at the level of 45% of benefits. The situation is similar for house owners. They are initially willing to invest CHF 21,000. However, this WTI decreases by CHF 10,000 and amounts to only CHF 11,000 at 45%.[13]

Table 7: WTI for 15 pp. of benefits (in CHF)

	0-15%	15-30%	30-45%	45-60%
Flat owners	18,019**	14,808**	11,596**	8,384**
	(8,335)	(6,589)	(4,942)	(3,535)
Multi-family house owners	11,449	10,522	9,595	8,668
	(10,367)	(8,350)	(6,587)	(5,335)
Single-family house owners	20,965***	17,546***	14,128***	10,709***
	(3,402)	(2,619)	(1,878)	(1,256)

Standard errors in parentheses.
Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The estimation results show that all types of owners value energy investments, with only very few who chose the non-energy options. The strong effects when it comes to renewable energy production by means of PV or, for instance, heat-pumps can be interpreted as being a sign for a prosumer tendency. This means that owners are more into renewable energy and less into energy efficiency measures.

Benefits seem to play a subordinate and diminishing role and do only partially affect decision-making, which is also reflected in the decreasing WTI. This may indicate that it is

[12]The relatively small sample of MFH owners can be the reason for the lack of significance.
[13]Investment specific benefit effects show no significant effect.

rather the warm glow of having done something environmental friendly (Ma and Burton, 2016) than the actual benefits resulting from the investment that affects choice behaviour. Such findings can speak in favour of stricter rules instead of monetary incentives, if the resulting benefits are deemed insufficiently low.

6 Conclusion

In this paper we analyse the attitude of different owner groups towards a wide range of energy investments on their residential buildings and, primarily, which role subsidies, complexity and experience play for decision-making. Furthermore, we investigate the effect of a potential OSS solution on their energy investment decisions.

Therefore, we conduct a DCE and gather a sample consisting of 49,464 observations from 4,122 Swiss homeowners. Generally speaking, the results of the analysis indicate that importance of corresponding factors and attributes differ between owner types. Subsidies play an important role for all of them, especially for investments in PV. They are even perceived more important than an equally high cost reduction, which underlines the importance of such policies for energy investments. Complexity is deemed a barrier for energy investments, but the current process appears to be not too complex, which offers an explanation for the limited effect of the OSS treatment. This has important policy implications. On the one hand, policies like subsidies seem to be important for energy investments and consequently achieving the climate goals. Yet, due to existing differences between owner types, specific policy measures may be required to target them effectively. Furthermore, it confirms the policymakers in their implementation, as further simplifications would be perceived positively, but do not really seem to be necessary and at the same time risk increasing free-rider problems and the inefficiency that goes with them.

Experience with PV investments proves to be influential for energy investment decisions by SFH and partially also MFH owners, as it positively affected choices in our experiment. This shows that the learning effect associated with such experiences can indeed be crucial for future investments, which is in line with other findings in the literature. The lack of significant results for flat owners can be due to the smaller share of experienced owners in this group and their decision-making requires cooperation, which makes investment decisions more difficult. Interestingly, experience with insulation does not foster selection of insulation in the experiment. This may be due to the familiarity with the hassle and negative externalities coming with such improvements.

Finally, respondents show a positive but decreasing willingness-to-invest. This can be an indication that it is rather a warm glow of having done something environmental friendly and socially valued than the goal of cutting CO_2 emissions as much as possible that is driving investment decisions. If resulting investment levels are deemed insufficiently high to achieve climate goals, policymakers may have to consider implementing stricter requirements such as CO_2 caps or the obligation to install a renewable energy production system when constructing a new building.

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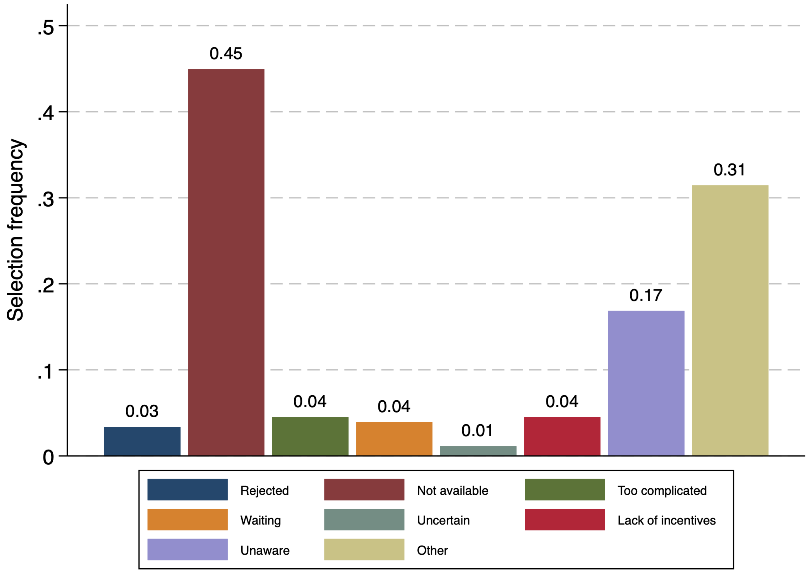
A Appendix

A.1 Reasons for not having received subsidies

Those who have invested without receiving subsidies are asked about the reasons for this. Figures 7, 8 and 9 detail their answers. No availability of subsidies is the main reason.[14]

Figure 7: Reasons for not receiving subsidies for PV investment
(140 respondents)



[14]"not available" and "unaware" may partially overlap because some respondents may have been not aware of availability of subsidies, and they assumed a lack of availability and vice versa.

Figure 8: Reasons for not receiving subsidies for RH investment (1533 respondents)

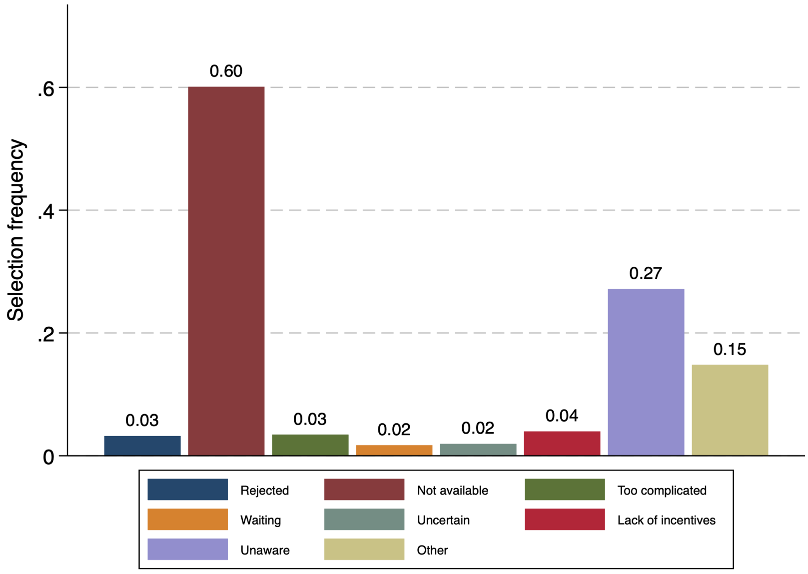
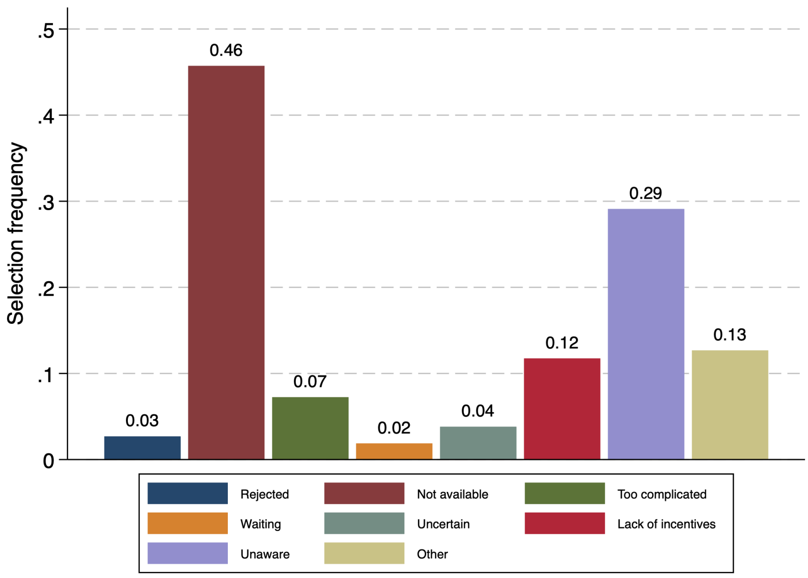


Figure 9: Reasons for not receiving subsidies for EI investment (1715 respondents)



A.2 Sample comparison

When looking at the two sub-samples separately, the picture is similar to that of the pooled sample, although there are some differences. Generally speaking, we see that choice behaviour from respondents of both samples was positively affected by most energy options, with envelope reinstatement being the only exemption. In sample 1, the effect of heating overhaul is stronger, whereas in sample 2 the effects of both renewable energy options is comparably higher. Costs play a more important role in sample 1, so do benefits. Subsides are more decisive for respondents of sample 2. One explanation for this can be that respondents in sample 2 are familiar with subsidies, and some of them waiting to receive their subsidies.Therefore, they may have an even higher valuation of subsidies than those who do not necessarily have practical experience and a resulting relationship with subsidies. Yet, as already seen for the pooled sample, subsidies have a stronger effect than costs for both samples. This indicates a higher valuation of subsidies in comparison to costs. Experience also has slightly different effects in the samples. In sample 1, the OSS treatment is rather enhancing selection possibilities for those who already invested in PV before, whereas the same holds for those who invested in insulation before in sample 2. A similar picture can be seen when looking at the experience effects. Higher education shows significant positive effects in both samples, whereas older respondents were less likely to choose major renovations or renewable energy investments, even though these results are partially insignificant for sample 1 and more severe for sample 2. Overall, results are similar, but differences may exist between the different owner types.

Table 8: Estimation results: Pooled sample and sub-samples

	Pooled sample	Sample 1	Sample 2
Observations	49,464	21,372	28,092
Investments (base category: SQ):			
Envelope reinstatement	-0.1692^{**}	-0.0252	-0.3103^{***}
	(0.0665)	(0.0931)	(0.0960)
Heating overhaul	0.4827^{***}	0.6993^{***}	0.2470^{***}
	(0.0615)	(0.0864)	(0.0894)
Ren. Heating	1.5701^{***}	1.3818^{***}	1.6805^{***}
	(0.0681)	(0.1016)	(0.0926)
PV	1.5760^{***}	1.5680^{***}	1.9010^{***}
	(0.0787)	(0.1010)	(0.3663)
Insulation	1.2704^{***}	1.2646^{***}	1.3032^{***}
	(0.0998)	(0.1475)	(0.1365)
Costs (in 1000 CHF after subtracting subsidies):			
Costs	-0.0111^{***}	-0.0136^{***}	-0.0100^{***}
	(0.0008)	(0.0013)	(0.0011)
Benefits (in %):			
Benefits	0.0155^{***}	0.0160^{***}	0.0146^{***}
	(0.0021)	(0.0031)	(0.0029)
Benefits × Benefits	-0.0001^{***}	-0.0001^{***}	-0.0001^{***}
	(0.0000)	(0.0000)	(0.0000)
Subsidies (in 1000 CHF):			
Subsidies	0.0170^{***}	0.0155^{***}	0.0179^{***}
	(0.0020)	(0.0031)	(0.0026)
Treatment effects (interacted with subsidies):			
Treated	-0.0061^{*}	0.0005	-0.0075
	(0.0037)	(0.0044)	(0.0119)
Treated × Experience (PV) with subsidies	0.0068^{*}	0.0198^{**}	0.0014
	(0.0040)	(0.0092)	(0.0120)
Treated × Subsidies (EI)	0.0302^{***}	0.0262^{**}	0.0329^{***}
	(0.0057)	(0.0105)	(0.0068)
Experience effects:			
Experience (PV) × PV	0.5116^{***}	0.3770^{***}	0.2070
	(0.0662)	(0.1281)	(0.3634)
Experience (EI) × Insulation	0.1025	0.0343	0.1200
	(0.0689)	(0.0997)	(0.0970)
Characteristics:			
University degree × Benefits	0.0037^{***}	0.0044^{***}	0.0041^{***}
	(0.0010)	(0.0014)	(0.0014)
Retirement age × Ren. Heating	-0.4629^{***}	-0.1519	-1.1095^{***}
	(0.1190)	(0.1364)	(0.3325)
Retirement age × PV	-0.3768^{***}	-0.1908	-1.2673^{***}
	(0.1183)	(0.1292)	(0.3113)
Retirement age × Insulation	-0.5377^{***}	-0.2559^{*}	-1.7745^{***}
	(0.1250)	(0.1416)	(0.5115)

Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Standard errors in parentheses

A.3 Regression: Spec 2

To check the validity of the above presented results, we also tried different specifications to estimate the results. The following Table 9 shows regression results for all owner types but with gross costs (not net as before) and subsidies in percentage, as they were displayed to the respondents.

Compared to the previously in Section 5.2 discussed results, here subsidy effects are on a comparable level for all owner types.

Table 9: Regression results with gross costs and subsidies in %

	Flat	MFH	SFH
Investments (base category: no energy investment):			
Envelope reinstatement	-0.4649**	-0.7277**	-0.2171***
	(0.2072)	(0.3364)	(0.0714)
Heating overhaul	0.6915***	0.9514***	0.4065***
	(0.1574)	(0.2803)	(0.0688)
Ren. Heating	1.2845***	1.4788***	1.1930***
	(0.2042)	(0.3007)	(0.0785)
PV	1.3608***	1.0360***	1.2324***
	(0.1943)	(0.3731)	(0.0932)
Insulation	0.8792**	0.7535	0.9000***
	(0.3861)	(0.4686)	(0.1062)
Costs (gross in CHF):			
Costs	-0.0061	-0.0017	-0.0056***
	(0.0047)	(0.0057)	(0.0007)
Benefits (in %):			
Benefits	0.0167***	0.0036	0.0125***
	(0.0061)	(0.0086)	(0.0023)
Benefits × Benefits	-0.0001*	0.0000	-0.0001***
	(0.0001)	(0.0001)	(0.0000)
Subsidies (in %):			
Subsidies	0.8656	2.3088***	2.2731***
	(0.5695)	(0.8645)	(0.2104)
Treatment effects (base: untreated; interacted with subsidies):			
Treated	-0.2758	-0.7085	-0.3309
	(0.7680)	(1.3457)	(0.3937)
Treated × Experience (EI) with subsidies	0.9612	4.7806**	1.8813***
	(2.2882)	(2.0935)	(0.6163)
Treated × Experience (PV) with subsidies	2.2167	-0.6891	0.6932
	(2.0371)	(1.4445)	(0.4239)
Experience effects (base: no experience):			
Experience (EI) with subsidies × Insulation	0.3537	0.6768**	0.7322***
	(0.4491)	(0.3345)	(0.1058)
Experience (EI) without subsidies × Insulation	0.1558	-0.3105	-0.0509
	(0.2188)	(0.2921)	(0.0792)
Experience (PV) with subsidies × PV	0.3524	0.5841**	0.5211***
	(0.2616)	(0.2977)	(0.0770)
Experience (PV) without subsidies × PV	-0.4175	0.9459*	0.2669
	(0.4566)	(0.5429)	(0.1972)
Characteristics:			
University degree × Benefits	0.0053*	0.0057	0.0036***
	(0.0030)	(0.0044)	(0.0011)
Retirement age × Ren. Heating	-0.1392	0.2192	-0.6183***
	(0.2640)	(0.5709)	(0.1436)
Retirement age × PV	0.1426	-0.7220	-0.5320***
	(0.2429)	(0.4579)	(0.1436)
Retirement age × Insulation	0.0685	-0.5549	-0.6800***
	(0.2884)	(0.4455)	(0.1484)

Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

A.4 Treatment

Figure 10: OSS treatment

mistee_treatment. The current situation regarding subsides is quite complicated. Assume that a considerable simplification is implemented: like in a **"one-stop shop"** you can settle all subsidy requests at once.

For you as a homeowner, this means:

- All subsidies are organized within a single program.
- There will be one simplified request form for all types of investments (building and energy-related renovations and heating and PV systems). This means that the administrative burden is noticeably reduced ("less paper work").
- Tax deductions are still attributed at the cantonal level (as they are now).

You will now be asked **four questions where you can choose between two energy investment alternatives or none of the two**.

If you have already implemented some of the offered investments, please still select your preference assuming that you could go back in time and decide again. Your experience is important for us. **Please select your preference keeping in mind the above simplification of the subsidy landscape ("one-stop shop")**.