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Role of Behavioural and Market Failures as Barriers to Energy-Efficiency Investments in Single-Family Housing in Switzerland

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Zusammenfassung

Das Ziel dieses Forschungsprojektes besteht darin, Verhaltensanomalien und Marktversagen zu untersuchen und empirisch zu quantifizieren, die als Hindernisse für energieeffiziente Investitionen im Schweizer Gebäudesektor wirken. In diesem Zusammenhang beziehen sich Verhaltensanomalien auf Abweichungen von Entscheidungsträgern bei der Berücksichtigung der Vorteile und Kosten von Energiespartechnologien infolge verschiedener Befangenheiten, begrenzter Rationalität und Heuristiken. Ergänzend zu diesen Verhaltensfaktoren analysieren wir auch die Rolle der Co-Benefits von Energieinvestitionen. Die in diesem Bericht untersuchten Investitionen konzentrieren sich auf energieeffiziente Sanierungen bestehender Gebäude sowie auf die Minergie-Technologie für Neubauten. Dieser Schlussbericht fasst die Informationen des Projekts zusammen und schliesst es ab.

Résumé

L'objectif de ce projet de recherche consiste à étudier et à quantifier empiriquement les anomalies comportementales et les défaillances du marché qui agissent comme des obstacles à l'investissement dans l'efficacité énergétique dans le secteur du bâtiment en Suisse. Dans ce contexte, les anomalies comportementales se réfèrent aux écarts des décideurs dans leur prise en compte des avantages et des coûts des technologies d'économie d'énergie, résultant de divers biais, d'une rationalité limitée et d'heuristiques. Au-delà des facteurs de comportement, nous analysons également le rôle des co-bénéfices des investissements énergétiques. Les investissements étudiés dans ce rapport comprennent des améliorations de l'efficacité énergétique pour les bâtiments existants et la technologie Minergie pour les nouveaux bâtiments. Ce rapport final synthétise et conclut les informations du projet.

Summary

The goal of this research program is to investigate and empirically quantify behavioural anomalies and market failures that act as barriers to energy-efficient investments in the Swiss building sector. In this context, behavioural anomalies refer to differences among decision makers in fully considering the benefits and costs of energy-saving technologies due to various biases, bounded rationality, and decision heuristics. In addition to these behavioral factors, we also analyze the role of co-benefits of energy investments. The investments studied in this report consist of energy efficient retrofits for existing buildings and the Minergie-technology for new buildings. This final report summarizes and concludes the activities of the project.

Main findings

- Energy-efficient buildings, especially those with Minergie technology, offer not only significant energy savings but also co-benefits, such as improved indoor air quality.
- The Minergie certification is associated with a so-called green premium on the perceived value of single-family home buildings. However, study results seem to suggest not all homeowners are aware of the co-benefits of Minergie-certified houses. Governmental communication campaigns on the advantages of Minergie-certified houses could improve the demand for these types of buildings.
- Energy-efficient retrofits are highly opportunistic investments: many homeowners wait until a building technology is either broken or obsolete before investing in them. Financial motives are major barriers to and determinants for energy-efficiency investments, but these are not systematically the most important ones for all households.
- Co-benefits, such as increased comfort and contributing to a cleaner environment, rank high as determinants of energy-efficient retrofit uptakes.
- Lack of information about the various available subsidies also plays a role in delaying renovation decisions up to the point where broken elements of the house must be replaced.
- Energy audits, such as those offered by Gebäudeenergieausweisder Kantone (GEAK) experts, can provide a solution for this lack of information.
- Homeowners, however, are often unwilling to pay for a GEAK audit. Additional Governments' communication campaigns on the advantages of a GEAK audit or subsidies offered for a GEAK audit could improve the demand for these important audits.

Contents

1 Introduction

1.1 Background information and current situation

The policy and academic debates on the reasons for the too-slow adoption of energy-efficient technologies, a phenomenon known as the Energy Efficiency Gap (Jaffe and Stavins, 1994), has identified several market failures as possible explanations. Additionally, whether the way households make technology-adoption decisions may also play an important role in this debate. Economists have offered the concept of *behavioural anomalies* in reference to the various decision biases and heuristics decision makers may be subject to when they try to fully internalise the benefits and costs of energy-saving technologies.

In this project, we pay particular attention to a broad category of barriers to and determinants of investment decisions including behavioural anomalies that are induced by bounded rationality, lack of financial and energy literacy, and the difficulty associated with collecting and processing all the relevant information pertaining to energy-efficient investments.

Our focus on behavioural anomalies is motivated by three research gaps. First, little is known about their empirical importance in the building sector, even though it is suspected they play an important role as barriers to investments (Gillingham and Palmer, 2014). Second, empirical studies on the determinants of the adoption of energy-efficient technologies in buildings has so far focused on socio-demographics (Achtnicht and Madlener, 2014; Brounen et al., 2013; Kok et al., 2011; Nair et al., 2010), the landlord-tenant relationship (Myers, 2020), and energy codes (Jacobsen and Kotchen, 2013). However, the interaction between behavioural anomalies and market failures, also responsible for the Energy Efficiency Gap, has received little attention, especially in the Swiss context. Finally, the implication that behavioural anomalies exist for policy design still remains an open question.

1.2 Purpose of the project

The overarching goal of this project is to investigate the barriers to and determinants of energy-efficiency investments in the Swiss building sector. We first want to empirically quantify the importance of particular barriers and determinants in the adoption decision of energy-efficient technologies. Second, we aim to analyse the role of behavioural anomalies in shaping Swiss households' perceptions about the co-benefits and hidden costs of energy-efficiency investments. Co-benefits and hidden costs are potential determinants and barriers, respectively, that are particularly likely to be influenced by behavioural anomalies. Third, we will analyse if residents living in Minergie-certified houses consume less energy compared to those living in non-Minergie–certified houses, and we assess the role of behavioural and socioeconomic characteristics in explaining this possible difference.

Overall, our research program will conduct regression analysis on a combination of existing and novel datasets. An important component of our research effort is developing new survey instruments and collecting extensive data. To that end, we have worked in collaboration with EnergieSchweiz, the Canton of Zurich, and Gebäudeenergieausweis der Kantone (GEAK) experts. These collaborations enabled us to collect datasets that provide insights into the role of behavioural anomalies, socio-demographics, attitudes and values, co-benefits, and hidden costs in the adoption of energy-efficient technologies in the Swiss residential building sector. Finally, we also leverage our existing expertise and past data collection effort. Specifically, in addition to the Swiss Household Energy Demand Survey (SHEDS), for which we have contributed, we also use a unique micro-level dataset collected by the Centre for Energy

Policy and Economics (CEPE) that combines households' energy use with detailed household and building information.

1.3 Objectives of the project

Our overall project objectives are (a) to quantify behavioural factors and anomalies that act as barriers for investments in energy efficiency and (b) to show the implication of such barriers to and determinants for the design of policies in the Swiss building sector. To accomplish these objectives, we have identified three interrelated research questions:

(1) What are the behavioural, socio-economic, and policy barriers to and determinants of the adoption of energy-efficient technologies in the Swiss residential building sector?

(2) Do behavioural anomalies create and/or exacerbate information asymmetries related to the co-benefits and hidden costs associated with energy-efficient technologies?

(3) How do the behavioural and socio-economic characteristics of owners living in Minergie-certified houses affect the quantity of energy consumed compared to those living in non-Minergie–certified houses?

To answer these questions, we will use data from various sources. Some datasets have already been collected by our research group. However, an important part of the activity of this grant is developing and implementing new survey instruments, which we describe in section 2.

Our research results will inform the design of certifications for buildings, such as the Minergie and the GEAK programs, and policies that provide financial incentives to promote energy-efficiency investments in buildings. The research will leverage existing and novel datasets collected in collaboration with Minergie Schweiz, EnergieSchweiz, the Canton of Zurich, and GEAK experts.

1.4 Structure of the report

In this report, we summarise the findings of our research in five policy briefs. These policy-briefs are based on this projects' academic research papers, which are available online.

The report is structured as follows:

In Working package 1 (WP1), we analyse the barriers to and determinants for energy-efficient retrofits for existing single-family homes. We summarised the results of WP1 in three policy briefs. The first policy brief analyses the most important barriers to and determinants for energy-efficient retrofits and homeowners' policy preferences based on a household survey from February 2020. In addition, this first policy brief contains the results from an analysis on subsidy programs for energy-efficient retrofits in Switzerland, which is included in this report's appendix. In the second policy brief, we present the results from a follow-up survey from November 2020 to analyse the impact of the COVID-pandemic on retrofit decisions. The third policy brief presents the results from a survey among GEAK experts on the role of energy-efficiency audits and the experts' opinions on homeowners' renovation decisions.

In WP2, we analyse the importance of co-benefits from the Minergie technology, such as improved indoor air quality. The results of this work package are summarised in one policy brief.

In WP3, we show in one policy brief the effect of the Minergie technology on energy consumption.

2 Policy brief – Barriers to and Determinants for Energy-Efficient Retrofits*

Massimo Filippini, Sébastien Houde, Nilkanth Kumar, and Tobias Wekhof

Executive Summary

- Energy-efficient retrofits are highly opportunistic investments: many homeowners wait until a building technology is broken or obsolete before investing in them.
- Financial motives are major barriers to and determinants for these investments, but they are not systematically the most important ones for all households.
- Co-benefits, such as increased comfort and contributing to a cleaner environment, rank highly as determinants of energy-efficient retrofit uptakes.
- Tax deduction policies on retrofits have a small but measurable effect on energy-efficient retrofit uptakes.
- There is strong political support for more generous subsidies.

Outline

In Switzerland, the building sector generates close to one-third of all greenhouse gas emissions (FOEN and SFOE, 2020). As a result, energy-efficient retrofits could be one of the largest reducers of the Swiss carbon footprint. Energy-efficient retrofits are, however, a hard sell for many homeowners because these retrofits are often complex and expensive projects. This policy brief reports on a research program conducted at the Centre for Energy Policy and Economics (CEPE) at ETH; its goal was to identify the behavioural barriers to and determinants of energy-efficiency investments among single-family homeowners living in Switzerland.

The Role of Cantonal Policies

In a first part of the project, we analysed a sample of 8,378 Swiss households using a dataset collected between 2015 and 2016 in collaboration with nine Swiss utilities. The sample covers retrofits for the years 2010 to 2014.[1] The goal was to identify (a) the socio-economic characteristics of the household respondents who performed energy-efficiency renovations in the past and the renovated home's building features and (b) the effects of a tax deduction policy and subsidy policy at the cantonal level.

Our results suggest the building vintage, household income, and education level are all relevant determinants of investment decisions; energy-related attitudes and policy-related variables might also

* This research is financed by the Swiss Federal Office of Energy under contract number SI/501886-01 and has been conducted at the Centre for Energy Policy and Economics at ETH Zurich. This policy brief contributes to Work Package 1 of the project. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of the funding agency.
This policy brief is based on the following research paper:
The Narrative of the Energy Efficiency Gap, Sébastien Houde and Tobias Wekhof
Available at the ETHZ Library under: https://doi.org/10.3929/ethz-b-000495755

[1] Comprehensive details of the survey and the data are provided in Blasch et al. (2018).

play important roles. In particular, a tax deduction policy enacted during that period had a small but positive impact on households' energy-efficient retrofit uptake. The second policy variable, cantonal budget towards energy-saving measures, also had a significant but smaller effect. Altogether, we found the fiscal measures and overall public resources allocated to energy-efficiency investments were one set of relevant determinants.

Barriers and Determinants

To further uncover the barriers to and determinants of energy-efficient retrofits, we conducted a second survey in February 2020 with single-family homeowners (N = 3,471) in the Canton of Zurich. The survey was designed to elicit the determinants that led certain homeowners to perform an energy-efficient retrofit (denoted as the takers, 78% of the sample) and the barriers for homeowners who did not perform such a retrofit (denoted as the non-takers, 22% of the sample).[2] To ensure all buildings in this study could have a high potential for renovation, we selected a sample of homeowners living in single-family homes constructed prior to 1990.

Between takers and non-takers, we found homeowner age is the main significant socio-economic variable that is available to use for policy targeting. In fact, apart from age, we found other socio-economic characteristics, such as income and education, are not robust predictors of past decisions in this most-recent sample. The underlying reason is once the sample consists only of old buildings, income and education have a reduced statistical significance. Moreover, general awareness of energy-efficiency policies is actually lower for takers relative to non-takers, but there are no significant differences in policy preferences between the two groups, which is discussed in the following sections. Overall, our results suggest policy makers need to move beyond building and socio-economic characteristics to target their policies and consider increasing the focus on information campaigns and reducing the bureaucratic burden.

In this survey, we also used a novel method to elicit survey respondents' personal narratives of their energy-efficiency investment decisions. Collecting narratives involves asking people what they think and letting them respond by answering open-ended questions. Recent advances in automated text analysis and artificial intelligence allowed us to turn unstructured text narratives into quantifiable metrics that serve as proxies for household preferences and market barriers.

To collect narratives, we asked survey participants two sets of questions. First, why they decided to renovate (or not). We used this question to extract barriers to and determinants of retrofits. Second, we asked respondents about government policies that should encourage energy-efficient retrofits. We used this question to understand policy preferences.

Barriers

Figure 1 shows a word cloud constructed from the open-ended question about barriers.[3] We clustered the answers into broad topics to identify different household types amenable to policy targeting based on their barriers.

[2] This study's main aim was to analyse the major barriers to and determinants of energy-efficient retrofits. Our sampling strategy was to obtain a final sample of homeowners who have performed an energy-saving retrofit in the past or had planned to do so in the near future. Hence, the share of takers is not representative of the general population in Zurich.

[3] This word cloud is a graphical representation of the words most frequently used to describe the barriers to energy-efficient retrofits non-takers encountered.

For the barriers, two distinct types of homeowners emerged. First, there are owners who do not renovate because they perceive their house as being already energy efficient. They made up 50% of non-takers. Second, there are those who face financial constraints. This group accounts for 23% of all non-takers. Respondents who do not renovate because their building is perceived as being already efficient do not differ in income or age from other non-takers. The only main difference can be found in a higher educational level. Those respondents also have a high awareness of and experience with using energy-efficiency–related policies. However, we found no specific relative differences with respect to preferences for different policy options.

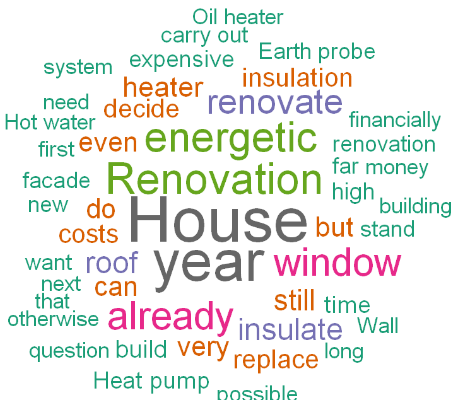

Figure 1: Word cloud with most common words used to describe barriers to energy-efficient retrofits by non-takers

Because homeowners who perceive their building as being already energy efficient do not show notable differences in socio-demographic and building information compared to other non-takers, it is thus difficult to target this group with specific energy-efficiency policies using only building characteristics. In contrast, homeowners who did not renovate due to financial constraints have a lower income; however, they also do not differ in policy awareness or policy preferences, although they have less experience using policies. These findings imply that policy awareness and preferences do not have strong explanatory power related to why particular consumers perform retrofits and others do not. Consequently, improving knowledge of existing policies might not be sufficient to overcome the barriers to energy-efficient retrofits.

Determinants

For the determinants of takers' energy-efficient retrofits, we performed a similar word cloud exercise. Figure 2 shows the main topics found in the narratives elicited with the takers. The determinants can be clustered into three major categories corresponding to different household types of interest for policy targeting: households that invest to replace broken or obsolete building technologies (43% of takers), households that see retrofits as profitable investments (30% of takers), and households that renovate out of ecological concerns (26% of takers).

Homeowners in the first category could be described as opportunistic energy-efficiency investors. They are relatively younger, but they live in older buildings. Even though policy awareness is low for this group, respondents do not favour having more policy information and do prefer less bureaucracy and higher subsidies. In sum, their characteristics are in line with a decision maker who performs energy-efficient retrofits out of necessity (i.e., when it is time to replace broken or obsolete building technologies).

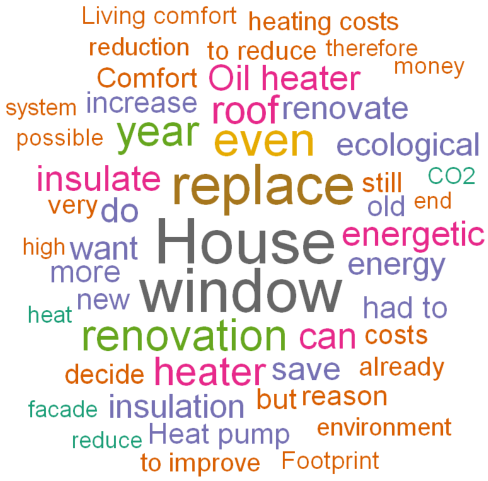

Figure 2: Word cloud with most common words used to describe determinants of energy-efficiency retrofits by takers

The second homeowner group renovates to save money and is characterised by a lower education level and a lower incidence of donating to environmental organisations. Moreover, this group has a weakly higher income level, while controlling for education, compared to others who do not mention financial motives as important determinants. This homeowner group is inclined to use existing policies at a higher rate compared to other groups, but they have no distinguishing policy preferences. Compared to homeowners who renovate out of necessity or opportunity, respondents who renovate to save money do perceive a financial opportunity in energy-efficient investments.

Finally, the last group consists of homeowners who renovated because of environmental concerns. Those respondents have a higher income and have previously donated to environmental organisations. They consult policies more often than other groups and would strongly favour policies promoting information campaigns and environmental standards. For the purpose of policy targeting, this group offers interesting opportunities: policy makers could target this group by providing better and easier access to information related to policies and co-benefits of energy-efficient investments.

Policy Preferences

In a second set of open-ended questions, we asked all respondents (takers and non-takers) about their opinions on how policy makers should encourage energy-efficient retrofits. The most common words from the answers are depicted in the word cloud in Figure 3. These were clustered into topics that describe different policy preferences (Table 1). A wide range of topics emerged from the narratives. When asked how policies could encourage energy-efficient investments for all types of households, the top suggestion was more-generous subsidies. A greater focus on integrating energy-efficiency policies and policy support for solar photovoltaic (PV) technology was the second most-popular suggestion. It is interesting to note in Switzerland, energy-efficiency programs and incentives for solar PV technology are usually not combined. The remaining suggestions referred to providing more information, reducing bureaucracy, and favouring standards. Other topics with smaller response shares also emerged from the narratives. Tax-related measures were discussed, but they were not a popular topic, especially compared to subsidies. Finally, although subsidies was the most popular topic, almost 65% of respondents favoured other policy measures.

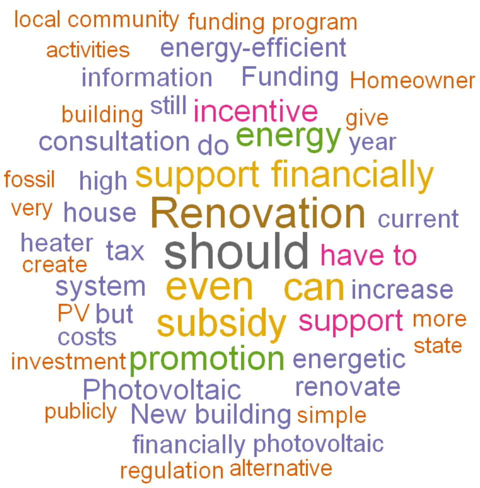

Figure 3: Word cloud with the most common words respondents (takers and non-takers) used to describe their personal policy preferences concerning energy-efficient retrofits. Words in a larger font appear overall more frequently in the answers.

Table 1: Policy preferences from open-ended answers

Policy Preference	All [%]	Retrofit: non-takers [%]	Retrofit: takers [%]
More subsidies	32.5	31.2	36.9
More focus on photovoltaic	16.3	15.8	17.8
More information	16.1	15.7	17.8
Less bureaucracy	15.0	14.3	17.4
Focus heating	12.9	12.8	13.5
Standards	9.3	9.2	9.5
Tax deduction	8.7	8.4	9.7
Pollution tax	6.5	6.3	7.2
Focus on new buildings	4.8	4.9	4.1
Focus insulation	3.6	3.8	2.9
Technology	3.0	3.1	2.9
Property tax	1.5	1.3	2.1
Subsidy threshold	1.1	1.1	1.0
Credit	0.5	0.6	0.2

Note: This table presents policy preferences obtained by classifying an open-ended answer. Keywords unique to each topic and responses that can be part of multiple topics were used in this classification.

Implications and Policy Recommendations

Our results show for most of the respondents, energy-efficient investments are opportunistic endeavours. In particular, several homeowners who invested in energy efficiency did so because a particular building technology was malfunctioning and needed to be replaced. This behaviour may signal myopic attitudes with respect to retrofitting decisions (i.e., homeowners tend not to plan in advance, and this foresight would allow them to optimize their retrofitting plans). However, several non-takers perceived their house as being energy efficient enough and did not believe there was an opportunity to make such investments. For both takers and non-takers, it might, however, be possible that replacing a technology or retrofitting their home might be profitable from a private perspective; they simply do not correctly perceive these financial benefits. Altogether, this suggests information campaigns, targeted audits, and building standards could be important policy measures that influence decisions and the rate at which energy-efficient retrofits are performed.

Financial motives remain important, however. For non-takers, the high cost of investment is the second-most important barrier. Similarly, for takers, the second-most important determinant is that energy-efficiency investments are profitable. When looking at policy preferences, it is also clear financial motives are an important component of this decision. By far, the most popular policy among survey respondents was more generous subsidies. In terms of political support, a significant share of homeowners desired better information, less bureaucratic burden, and improved integration between energy efficiency and residential solar policies. These measures have strong political support, but tax policies, which influence investment decisions and could be used to fund energy-efficiency subsidies, are much less popular.

Finally, whereas householders are very heterogeneous in their motives whether to invest in energy efficiency and support policy preferences, few characteristics that influenced the respondents' decisions are amenable to policy targeting. In particular, homeowners' building and socio-economic characteristics do not differ widely between takers and non-takers. These results show policy makers need to move beyond these characteristics to target their policies. To that end, we propose a more granular approach by focusing on the specific barriers to and determinants for energy-efficient retrofits.

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3 Policy brief – A Tale of Two Crises: COVID-19 and Climate Change*

Nina Boogen, Massimo Filippini, Sébastien Houde, and Tobias Wekhof

Executive Summary

- The COVID-19 crisis did not change Swiss homeowners' intentions related to energy-efficient retrofits.
- During the COVID-19 crisis, concerns for climate change still exceed concerns for COVID-19.
- Respondents concerned with COVID-19 are older compared to those concerned with climate change.
- The important concerns for climate change, even during the COVID-19 crisis, support the idea a green economic stimulus package might have large political support.

Outline

Prior to March 2020 when the COVID-19 crisis engulfed Switzerland and much of the world, the Swiss Energy Strategy 2050, was at the top of the political agenda. Considering the pandemic crisis and the need to stimulate the economy, several political actors proposed directing the government stimuli funds toward environmental projects to accelerate the energy transition (NZZ, 2021). One sector considered particularly promising for such stimuli is the building sector because in Switzerland, the building sector generates close to one-third of all greenhouse gas emissions (FOEN and SFOE, 2020). As a result, energy-efficient retrofits have one of the largest potentials to reduce the Swiss carbon footprint. Energy-efficient retrofits are, however, a hard sell for many homeowners because they are often complex and expensive projects. This lack of attractiveness might have been exacerbated by the COVID-19 crisis, which led to consumers facing uncertain job prospects and consumers of all income groups lowering their expenditures (Konjunkturforschungsstelle ETH Zürich, 2021).

Using a large survey of homeowners living in the Canton of Zurich, we analysed how the COVID-19 crisis affected their decisions related to energy efficiency and their most important health and environmental concerns. We conducted two waves of the survey among a population of more than 3,000 homeowners. The first wave was conducted in January 2020, and the second wave was in December 2020.[4]

* This research is financed by the Swiss Federal Office of Energy under the contract number SI/501886-01 and has been conducted at the Centre for Energy Policy and Economics at ETH Zurich. This policy brief contributes to Work Package 1 of the project. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of the funding agency.

[4] In the second wave, 409 homeowners responded. The sample is representative of the general homeowner population with respect to household size and has a slightly higher average respondent age.

The COVID-19 crisis did not significantly change people's plans for renovating their homes

In the first wave of the survey, weeks before the COVID-19 crisis started, we asked detailed questions about homeowners' plans to renovate their homes and whether they intended to perform energy-efficient retrofits (such as changing the heating system or insulating the roof) or non-energy–related retrofits (e.g. replacing the kitchen cabinets).[5] In December 2020, we followed up with the same households and asked how the health crisis had changed their renovation plans.

For most of the sample, the COVID-19 crisis did not change their plans to renovate their homes. Specifically, 89% of respondents did not change their plans, only 5% of respondents postponed their retrofits due to COVID-19, and the remaining 6% planned additional new projects due to COVID-19. Just prior to the crisis, about one-third of the sample declared they planned an energy-efficient retrofit in the next five years. This proportion thus remained relatively constant over time (see Figure 1).

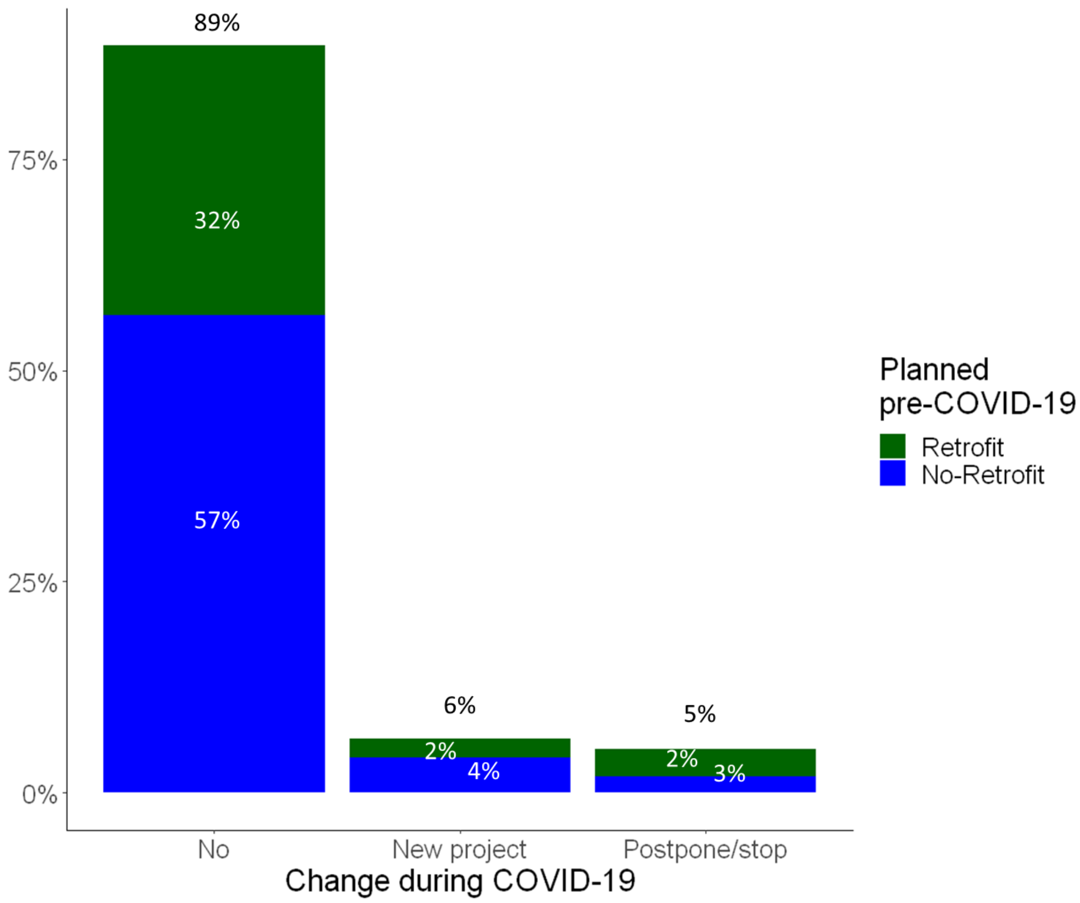

Figure 1: Change in retrofit plans due to COVID-19

[5] Importantly, we selected a sample of homeowners living in buildings constructed prior to 1990. This ensured all buildings could have a high potential for renovations.

Concerns for COVID-19 did not supersede concerns for climate change; both concerns coexist

In the second wave of the survey, we also elicited perceptions and knowledge of different health and environmental risks. Out of the risks related to their homes and comparable general risks, climate change and COVID-19 were the two risks respondents perceived as the most concerning.[6]

The results about the knowledge of the different risk factors showed similar patterns. Respondents stated they know the most about climate change; COVID-19 came as second.[7] The perception and knowledge of different risk factors show the importance of both climate change and COVID-19 to homeowners. However, although the COVID-19 crisis has been a very salient public health and economic issue in the last year, it did not overtake pre-existing concerns for climate change.

Respondents concerned about COVID-19 are not the same as those concerned about climate change

For the two major risk factors, climate change and COVID-19, there are important risk-perception variations across demographic groups. One-third of the respondents have an equal risk perception of COVID-19 and climate change, one-third stated climate change poses the highest risk, and the remaining one-third responded COVID-19 is the highest risk. We analysed the demographic heterogeneity between those groups using a regression analysis. Results indicate COVID-19 is primarily perceived as an important risk for older respondents, and the high concerns about climate change are independent of age. Climate change's risk perception is associated with a higher education. Full-time employed respondents, in contrast to pensioners or part-time employees, have a lower level of concern for climate change. For both risks, household income is not strongly correlated with risk perception. In sum, the most notable difference between those respondents concerned about COVID-19 compared to those concerned about climate change is the respondent's age.

With respect to *risk knowledge*, we also observe differences across demographic groups, but the patterns have some significant differences compared to *risk perception*. For both COVID-19 and climate change, higher household income is associated with more knowledge about the two risk factors. This effect is three times as strong for COVID-19 as for climate change. In both cases, knowledge is positively correlated with perceived risk (more knowledge implies a higher risk perception).

The main difference for risk perception between COVID-19 and climate change is, again, the respondent's age. For both variables, higher knowledge about the risk factor is associated with a higher risk perception. Household income is associated with a higher risk knowledge, but it does not influence the actual perception of the risk.

[6] We asked survey takers about their perception of different risk factors related to their home on a 5-point scale (1: lowest risk to 5: highest risk). Risk factors related to respondents' homes were, for example: radon emissions or indoor air quality. We also asked about general risk factors not directly related to their homes; we used these for a comparison benchmark. These risks were crime, stress, climate change, and COVID-19. Out of all the risk factors, climate change was ranked the highest and COVID-19 the second highest with a score of 2.9/5 and 2.7/5, respectively.
[7] We asked respondents about their knowledge concerning the same risk factors we used to elicit risk perceptions. We also used a 5-point scale (1: lowest level of knowledge to 5: highest level of knowledge). Climate change has a mean knowledge score of 3.8; COVID-19 has a score of 3.7.

Implications and Policy Recommendations

Homeowners' retrofit plans did not change significantly due to COVID-19, and this is an encouraging result. We should expect the current portfolio of energy-efficiency policies and subsidy schemes to have a similar effect as in the pre-COVID era. Even though the COVID-19 crisis's effect was and continues to be very salient, climate change remains the most important concern for our survey respondents. The fact homeowners with a high level of risk perception for climate change are not the same as those who are concerned about COVID-19 suggests we should not prioritise COVID-19–related stimulus at the cost of climate change policies. Persistent support for the climate change issue also reinforces the idea of a green economic stimulus to address the COVID-19 crisis.

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4 Policy Brief – Homeowners’ Valuation of the Minergie Technology*

Nina Boogen, Adan L. Martinez-Cruz, Massimo Filippini, Sébastien Houde, and Tobias Wekhof

Executive Summary

- Homeowners are willing to pay a premium of 6% to 7% of the monthly rental value for the Minergie certification.
- Homeowners who live in Minergie-certified homes value the comfort ventilation system somewhere between 80 and 260 CHF/month; those valuing indoor air quality are in the upper end of this range.
- Homeowners who do not live in Minergie-certified homes fall into two categories: one fraction report no value for the ventilation system, and a second fraction highly value the improved indoor air quality provided by Minergie technology through its ventilation system.
- Homeowners who value indoor air quality, irrespective if they live in a Minergie-certified building or not, are willing to pay for the ventilation system between 160 CHF and 260 CHF per month.

Outline

Swiss government agencies, both at federal and cantonal levels, have issued several measures aiming to generate a substantial reduction in energy consumption in the building sector. For instance, energy-efficient renovations are promoted via subsidies, information programs, and energy-efficiency labels, and construction of new energy-efficient buildings is regulated via strong energy-efficiency building codes, promotion via information campaigns, and subsidies for construction of Minergie-certifiable buildings.

Minergie buildings are characterised by low energy consumption that results from high-quality insulation and an energy-saving and comfort ventilation system (ESV) and from using renewable energy sources. ESV can be characterised as providing three non-energy–related co-benefits: indoor air quality (IAQ), noise reduction, and thermal comfort, which are in addition to energy savings.

In cooperation with the Statistical Office of the Canton of Zurich, we implemented a household survey with which in early 2020, we reached out to 16,700 homeowners living in single-family homes in the Swiss Canton of Zurich. We stratified the sample to have a large enough percentage of homeowners

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* This research is financed by the Swiss Federal Office of Energy under the contract number SI/501886-01 and has been conducted at the Centre for Energy Policy and Economics at ETH Zurich. This policy brief contributes to Work Package 2 of the project. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of the funding agency.
This policy brief is based on the following research papers:

- Value of Co-Benefits from Energy Saving Ventilation Systems–Contingent Valuations on Swiss Homeowners, Nina Boogen, Massimo Filippini, and Adan L. Martinez-Cruz
  Available at the ETHZ Library under: https://doi.org/10.3929/ethz-b-000535197

- Conditional Topic Allocations for Open-Ended Survey Responses, Tobias Wekhof
  Available at SSRN under: https://dx.doi.org/10.2139/ssrn.4190308

who had conducted a renovation recently and a sufficient sample of Minergie owners. Each household received a mailed invitation letter with a lottery entry as an incentive to participate. We obtained a total of 3,471 responses to our survey, of which 524 were Minergie owners (2,947 responses were from conventional building owners).[8]

In this policy brief, we first summarise the results arising from an analysis that estimates the market premium of the Minergie-certification label on housing prices. Second, we outline results from a second study that estimates the value of the comfort ventilation system.

Housing value and energy efficiency

When prospective homeowners are deciding what type of building to invest in, financial considerations and their personal preferences are closely intertwined. To understand the potential for energy-efficient buildings, it is important to know if homeowners are willing to pay a premium to live in a Minergie-certified building. In practice, however, this is a challenge because homeowners could pay a premium for preferences that often occur with Minergie-certified buildings but which are not associated with the technology per se (e.g. architecture or dwelling size).

With the household survey, we analysed the housing value for Minergie-certified and conventional homes with a hedonic regression, using the self-declared rental value as a proxy.[9] On average, Minergie-certified homeowners declared a higher rental value for their home by 494 CHF. However, this can be due to multiple factors, including building characteristics such as location or dwelling size and personal characteristics such as income. Indeed, most of the premium can be explained by Minergie-certified homes' inhabitants' higher incomes.

People buy houses according to preferences such as the location and modern architecture, which can be correlated with Minergie-certified homes; other homeowners may invest in an older building and subsequently remodel it. Individual preferences may also be associated with higher rental values, as in the case of homeowners who place high importance on their buildings' aesthetics and might be willing to pay a premium for these attributes. If, coincidentally, in addition to their energy efficiency, Minergie-certified buildings also have aesthetic benefits, determining if a Minergie-certified homeowner is willing to pay a higher price because of energy efficiency or the aesthetics may be difficult. For this reason, we also inquired into homeowners' preferences with respect to housing and analysed the rental-value premium associated with each preference. To that end, we presented respondents with several attributes, such as noise protection or location, and asked them to rate these attributes on a scale of how much it contributes to their personal satisfaction with their home. We found location, floor space, and noise protection are positively associated with a higher housing value.

In a novel methodological approach, we used open-ended text questions to elicit elements that homeowners positively associate with their homes. Traditional closed-ended questions, with which respondents rate the importance of each attribute on a scale, could suffer from an elicitation bias (i.e. respondents might give a rating to an attribute they would not have thought about prior to the survey). In contrast, the open-ended text questions provide the top-of-mind elements positively associated with the respondent's home. With this approach, we can control for individual preferences and the sentimental value people associate with their homes. Using a machine learning approach, we

[8] Unfortunately, no statistical information on socioeconomic variables for Minergie-owners is available. Therefore, we cannot provide information on the representativeness of the sample.
[9] In Switzerland, homeowners are aware of the rental value of their property for taxation reasons.

incorporated the information contained in the text answer into several model specifications. This gives us the possibility to use two complementary approaches.

The empirical results obtained by estimating several model specifications and using both the classical approach based on closed-ended questions and the novel approach based on open-ended responses suggest a Minergie-certification premium of around 300 CHF. To note that not all specifications yield a statistically significant result. This magnitude represents 6% to 7% of the rental price and is statistically significant.

The value of co-benefits and the ventilation system

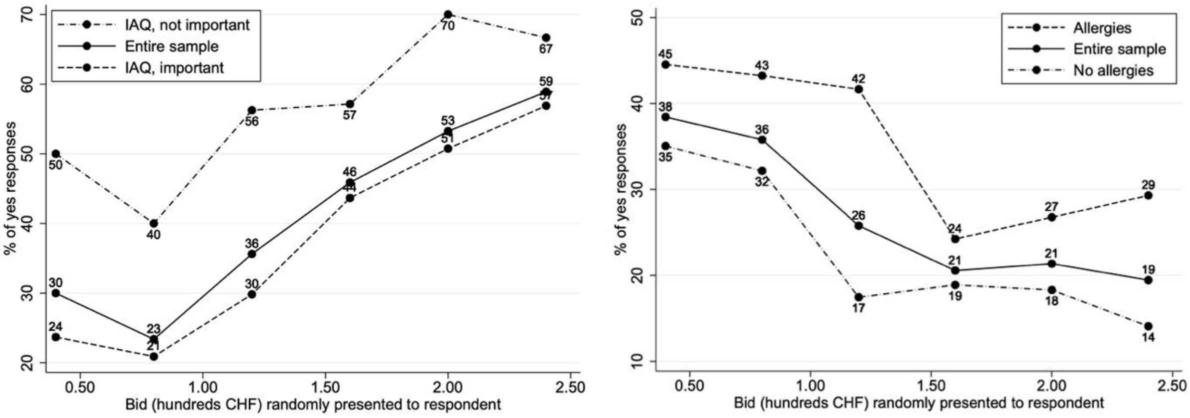
For household decision makers and real estate companies deciding between building a new house equipped with an energy-saving and comfort ventilation system (ESV) or a new conventional house, it is important to consider the costs and benefits of both alternatives. Benefits in this context arise not only as energy savings but also as co-benefits, such as improvement in indoor air quality, noise reduction, and thermal comfort. However, information about the monetary value of such co-benefits is rather rare, and household decision makers and real estate companies thus tend to not consider them in their investment analysis.

To measure the value homeowners place on the comfort ventilation system, we analysed two groups of owners: owners of Minergie-certified homes who have already experienced the ventilation system and conventional homeowners who have not experienced the ventilation system. Both groups first received basic information about the benefits of these ventilation systems with respect to not only energy savings but also co-benefits, such as improved air quality, thermal comfort, and noise reduction. The Minergie-certified homeowner group was presented with a hypothetical scenario in which their ventilation system was broken, and they had to wait three months for the repairs. The scenario included a monthly compensation for the waiting time, which was a random bid between 40 CHF and 240 CHF (the bids were one of the following numbers: 40/80/120/160/200/240 CHF). Minergie-certified homeowners were asked if they deemed their compensation as sufficiently high or not (willingness to accept). Conventional homeowners were asked a similar question with the same random monetary values. However, because they have no experience with the ESV system, the conventional-homeowner respondents were asked a question on their hypothetical willingness to pay a specific monthly amount for a ventilation system for the next 20 years (analogously, a random number between 40 CHF and 240 CHF).

Figure 1 shows the share of respondents who accepted the random bid. In the left panel, the share of owners of Minergie-certified houses who have experience with the ventilation system and were asked to wait for the repairs on their ESV. As expected, these percentages increase as bids increase. Around 30% of respondents answered yes to the lowest bid (CHF 40); and the highest bid (CHF 240) received around 59% of yes responses. The dotted line above the solid line reflects percentages arising from the sub-sample of respondents who consider indoor air quality (IAQ) as important for satisfaction with their home. The dotted line below the solid line reflects percentages arising from the sub-sample of respondents who consider IAQ as not important for their satisfaction. Indeed, Figure 1 visually suggests respondents in the Minergie-certified houses sample who consider IAQ an important element of satisfaction require higher compensation to wait to use ESV.

On the right panel, we show the results from homeowners of conventional homes; they do not have experience with ESV. As expected, these percentages decrease as bids increase. Around 38% of respondents answered yes to the lowest bid (CHF 40); and the highest bid (CHF 240) received around 19% of yes responses. Because the respondents answering the willingness-to-pay (WTP) bids have not experienced the IAQ provided by an ESV, a binary variable reflecting whether there are household members with allergies is used as proxy of relevance of IAQ. Consistently with the visual finding seen in the left panel, it also visually suggests respondents in the conventional house sample who report allergies at home are willing to pay more for ESV. However, note also around 60% of the households receiving the lowest bid did not accept it; this thus shows they were unwilling to pay for the ESV.

The empirical evidence suggests the valuation of the ventilation system varies across types of households. Homeowners who value indoor air quality are willing to pay for the ventilation system between 160 CHF and 260 CHF, independently if they live in a Minergie-certified building or not. Homeowners who do not emphasise the importance of indoor air quality tend to give a lower value to the ventilation system. For Minergie-certified homeowners in that group, the willingness to pay is around 80 CHF for the ventilation system. Whereas homeowners living in conventional buildings and who do not place importance on indoor air quality are not willing to pay any amount for a ventilation system.



Minergie-certified–home owners
Conventional homeowners

Figure 1: Percentage of respondents who accepted a bid for the ventilation system. The left panel consists of Minergie-certified–home owners, the middle graph represents all Minergie-certified–home owners, and the upper and lower graphs consist of a subset of respondents, depending if they put a high or low importance on indoor air quality (IAQ). The right panel consists of conventional homeowners.

Informing a cost-benefit analysis with our valuation estimates of the value of co-benefits (CHF 181 or CHF 163, respectively) yields benefits that are twice as much as costs, thus justifying investment in ESV systems in the residential sector. Estimated costs used in this cost-benefit exercise arise from a back-of-the-envelope calculation yielding a range of values between CHF 88 and CHF 96 for monthly expenses arising from acquiring an ESV system.

Implications and Policy Recommendations

Households and real estate professionals alike are confronted with a complex set of information when it comes to energy-efficient housing. Construction of Minergie-certified buildings is characterised by higher initial costs in the range of 5% to 10% (Salvi et al., 2008). The higher value of energy-efficient housing is closely intertwined with other housing characteristics such as the location, size, and owners' individual preferences. Our results indicate the Minergie-certification premium of about 500 CHF of the monthly rental value accounts for about 50% of other housing characteristics, such as location or aesthetics. This leaves the market premium for Minergie-certified houses at 270 CHF, which corresponds to 6% of the monthly rental value (the average rental value for Minergie-certified buildings in our sample is at 4425 CHF). In a second study, we find the value of co-benefits (such as the indoor air quality) from the Minergie-certified ventilation system is estimated at a monthly value between 80 and 180 CHF, depending on the experience with the Minergie technology and preference for indoor air quality. A fraction of homeowners of conventional homes have reported no WTP for the co-benefits of ESV; however, this zero WTP may become positive if they experience ESV.

Information campaigns and educational programs may be designed to include tools that support decision makers in companies and households. Specifically, our results suggest an opportunity to design perhaps a label not only reflecting houses' energy-saving features (Minergie-label) but also communicating more effectively the presence and value of co-benefits from such energy saving features (e.g. a Comfort and Energy Saving House label). Our results confirm that the existing information on the co-benefits provided by Minergie is important to homeowners.

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5 Policy brief – Experts' Opinions on the Barriers to and Determinants of Energy-Efficient Retrofits*

Massimo Filippini, Sébastien Houde, and Tobias Wekhof[10]

Executive Summary

- Gebäudeenergieausweis der Kantone (GEAK) experts consider energy retrofits' low financial return as the major barrier to investment.
- Experts perceive households who perform energy retrofits do so mainly to replace broken or obsolete technologies, to increase comfort, and/or for ecological concerns.
- Experts believe the existing subsidy programs for retrofits and audits currently offered in Switzerland are important determinants of energy retrofits. Moreover, they believe GEAK energy audits are primarily driven by these subsidy programs.
- Experts also support new policies such as using tax instruments and increases in energy prices to improve the financial attractiveness of energy retrofits.
- The average cost of GEAK audits tends to exceed homeowners' willingness to pay for such a service. The market for energy audits thus requires government support to thrive.

Outline

In Switzerland, the building sector accounts for 40% of all final energy consumption and about one-third of all greenhouse gases emissions (GES) (Swiss Federal Office of Energy, 2022a). Two factors contribute to those high shares. First, Swiss buildings rely predominantly on oil and gas heating systems, which currently represent about 55% of all heating systems (Swiss Federal Office of Energy, 2022a). Second, many buildings would benefit from energy retrofits, but the take-up rate has remained very low. To illustrate, between 2010 and 2020, the main program used by the Swiss Federal Office of Energy and cantons to encourage energy retrofits (Das Gebäudeprogramm/Le Programme Bâtiments) has subsidised close to 135,000 projects and distributed CHF 2.3 billion in subsidies (Swiss Federal Office of Energy, 2022b). However, reaching the objectives stated under Energy Strategy 2050, which focuses on renewable energy and clean technologies, is still far to be guaranteed, and almost a doubling of the current renovation rate is required (Balthasar and Schalcher, 2020).

Several market barriers and failures, however, have slowed the adoption of energy retrofits in the building sector. Consequently, the solution resides not in a single policy instrument but rather in a portfolio of combined measures. But where should we start?

* This research is financed by the Swiss Federal Office of Energy under the contract number SI/501886-01 and has been conducted at the Centre for Energy Policy and Economics at ETH Zurich. This policy brief contributes to Work Package 1 of the project. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of the funding agency.

[10] The analysis and figures presented in this policy brief are based on Mirjam Troxler's Master Thesis, which was conducted at the Centre for Energy Policy and Economics (CEPE) at ETH Zurich and supervised by the present authors. We thank Mirjam Troxler for her excellent work on this project. We take full responsibility regarding the content of this policy brief.

In this policy brief, we report on a research program conducted at the Centre for Energy Policy and Economics (CEPE) at ETH Zurich in our effort to identify the behavioural barriers to and determinants of energy-efficiency investments among owners of single-family homes living in Switzerland. As part of this research program, we interviewed energy audit experts who can assign the GEAK certification, one of the main energy certifications for buildings in Switzerland. Between January and March 2020, we contacted 1,497 GEAK experts all over Switzerland[11] and invited them to participate in an online survey. Of those, 348 experts accepted the invitation and participated (response rate of 23%). In the policy debate, such experts' views are particularly relevant because they have first-hand experience of the market. We report these experts' opinions regarding the important barriers to and determinants of energy retrofits, policy preferences, and their views about the role of energy audits and certification in homeowners' energy-efficient retrofit decisions.

Barriers and Determinants

What do energy-audit experts see as the main barriers to energy retrofits? As shown in Figure 1, experts believe lack of financial attractiveness due to high investment costs and low energy prices are the main two barriers homeowners face. A second type of barrier identified is lack of awareness and information. Finally, the so-called hassle costs of such investments and historical buildings, which might be too complicated or impossible to retrofit, are the third most-prevalent type of barriers experts have identified.

As part of this same research program, we also directly surveyed homeowners about their perceived barriers to and determinants of energy retrofits (Filippini et al. 2022; Houde and Wekhof, 2021). Interestingly, from the homeowners' perspectives, the main barrier they perceive is their building being already energy efficient. But less than 15% of experts believe that this is an important barrier. As discussed in Houde and Wekhof (2021), homeowners might be biased in believing their home is already energy efficient and use this rationale to not invest in retrofits. The large discrepancy between experts' and homeowners' opinions suggests homeowners might be indeed biased with respect to the energy-efficiency potential of their buildings. Better information, notably through energy audits provided by GEAK experts, could help resolve this bias.

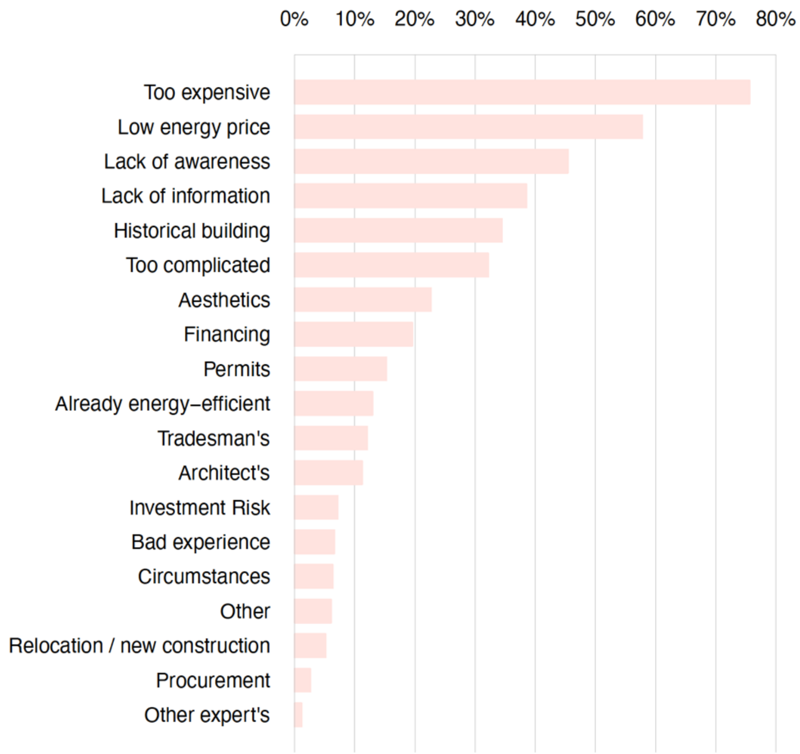
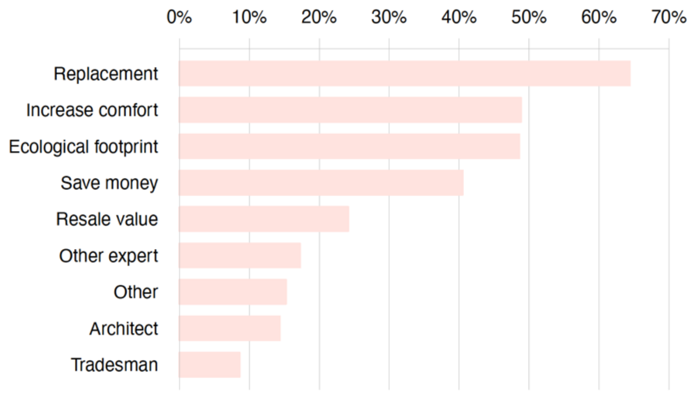


Figure 1: Experts' opinions on homeowners' barriers to energy retrofits

[11] The email invitation and the online survey were written in French for experts located in French-speaking cantons and in German for the rest of Switzerland (i.e., German- and Italian-speaking cantons).

We also asked the energy experts what they perceived as the main determinants of retrofits for homeowners (Figure 2). Unlike for barriers, the monetary dimension was not the primary determinant. Although experts believe it is an important rationale, they rank it behind the need to replace broken or obsolete technologies, the need for comfort, and ecological concerns. These results map very closely to what homeowners themselves stated as the main determinants of their energy-retrofit investment decision (Houde and Wekhof, 2021).



Overall, energy experts' opinions confirm that energy efficiency is an opportunistic investment where co-benefits matter for takers (i.e., homeowners who decide to make the investment). For non-takers (i.e., homeowners who decline to make the investment), the monetary and non-monetary costs together with the lack of awareness and information are the most important barriers.

Figure 2: Experts' opinions on homeowners' determinants of energy retrofits

Policy Preferences

What are the policies energy experts favour to address the barriers they have identified? To answer this question, we first asked the experts to evaluate different types of existing policies promoting energy retrofits. In a follow-up open-ended question, we then asked them to describe what new policies should be put in place to further accelerate the take-up rate of energy retrofits.

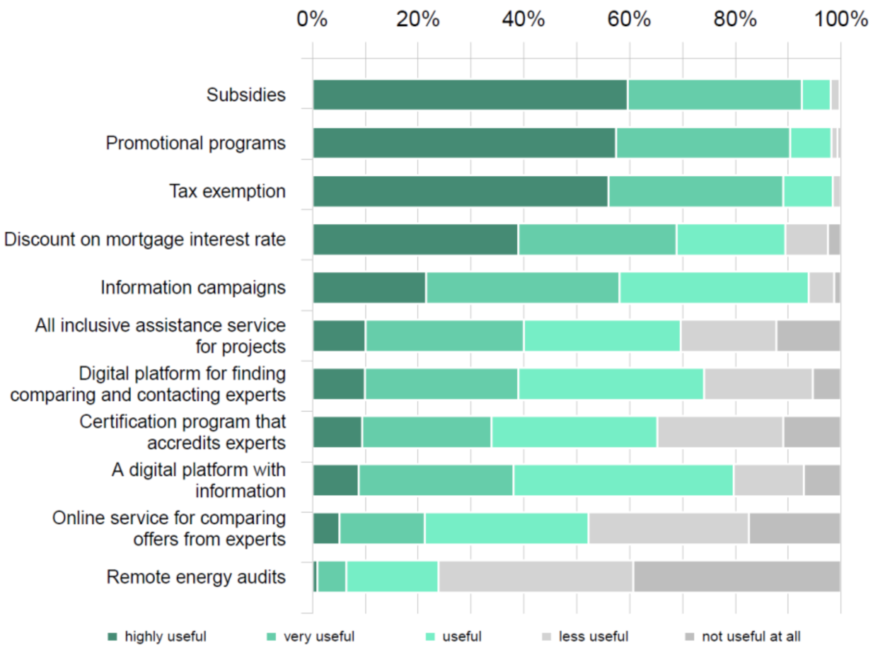


Figure 3: Experts' opinions on usefulness of existing policy instruments

Figure 3 shows the ranking of different existing policies with respect to their degree of usefulness, which experts determined for each policy by using a scale going from *highly useful* to *not useful at all*. GEAK experts almost unanimously consider subsidies as highly or very useful. Promotional programs (i.e. programs explicitly promoting energy retrofits to homeowners) and tax exemptions are also considered highly or very useful. Information programs, which are closely related to promotional programs, are also popular among experts. At the other end of the spectrum, policies that rely on digital solutions are not seen as especially useful. In particular, remote audits, online marketplaces for experts, and online review systems are not considered useful. Note, however, the survey was implemented before the COVID-19 pandemic, which may have changed experts' opinions about the role of digitalisation in this market.

When asked about new or additional policies that should be put in place to increase the take-up rate of energy retrofits, experts' opinions are highly consistent with the barriers they perceived as being important. First, they propose using tax impositions and other instruments that would increase energy prices as a way to increase the return on those investments. Information-related measures then rank second, and subsidies come in third place. Experts thus support the stick over the carrot as additional instruments. It is important to note in Switzerland, energy-efficiency subsidy programs are already in place and can be very generous, which may explain experts' bias toward taxes and higher energy prices. Finally, mandates are also a popular policy, almost as much as subsidies.

The Role of Energy Certification

In Switzerland, several building certification programs related to energy efficiency exist. Minergie, GEAK, and the 2000 Watts are the most well-known certification programs, and each has a special purpose. The GEAK Association is, however, the only one that is entirely public and under the jurisdiction of Swiss cantons. The goal of the GEAK program is to provide energy audits by experts, which yields an A to G letter grade. The GEAK program also offers different types of audit services. The GEAK Plus audit, for instance, offers the letter-grade certification with a detailed menu of three options to retrofit a building together with a financial analysis of each option. The certification is a voluntary option for homeowners. Several cantons, however, have designed policies around the GEAK program, and some offer generous subsidies for GEAK audits and retrofit subsidies conditional on having a GEAK audit performed.

However, some cantons also mandate sellers provide a GEAK certification rating before selling a property.

The GEAK certification resembles other energy certification programs used in other countries. In Europe, for instance, Energy Performance Certificates (EPCs) are the cornerstone of the EU's energy-efficiency directives. EPCs are used to establish minimum standards for buildings, mandates for renovation of highly inefficient buildings, and tax or subsidy eligibility.

In the building sector, an energy certification program is a low-hanging fruit to address informational asymmetries between buyers and sellers. Energy labelling schemes are also designed to increase the focus of the energy dimension in the investment decision. This can induce a so-called green premium that rewards more energy-efficient buildings. Overall, an energy certification can create a virtuous circle in which information and attention related to energy efficiency are disclosed to prospective buyers, which generates more interest for highly efficient properties, which, in turn, induces investors and developers to invest more in energy efficiency. This is an example of a demand-pull policy that aims to move the energy-efficiency frontier into the building sector.

How do GEAK experts perceive the effectiveness of their own certification program? First, we asked the experts why homeowners perform GEAK audits. The existence of promotional programs (i.e., subsidies for retrofits or audits) offered by different levels of governments are a leading source of demand for GEAK audits. Regulations requiring a certification at the time of sale is also an important reason. A much smaller share of experts believes homeowners would voluntarily request GEAK audits, before or during a retrofit, absent subsidy programs or mandates for information disclosure. Therefore, according to GEAK experts, an important driver of the demand for their services comes from other energy-efficiency policies linked to GEAK (Figure 4).

Absent such policies, they believe demand for energy audits could be much smaller. This point becomes clear when we elicit homeowners' willingness to pay for a GEAK audit and compare these values to experts' stated costs for such an audit. We found homeowners are willing to pay CHF 658 for a standard GEAK audit and CHF 1,597 for a GEAK Plus audit. Experts' reported costs for those two types of audits are CHF 959 and CHF 2,208, respectively. There is then a significant price gap, which is consistent with the size of the subsidy for energy audits some cantons offer (in the CHF 500 to 1,000 range). In Switzerland, the market for energy audits thus needs government support to thrive.

Finally, we also asked GEAK experts whether their customers ultimately invest in energy efficiency after completing a GEAK audit. Experts reported about 74% of the customers who commissioned an audit followed up on the recommendations made, which suggests audits do encourage actual investments and are an important part of the investment decision.

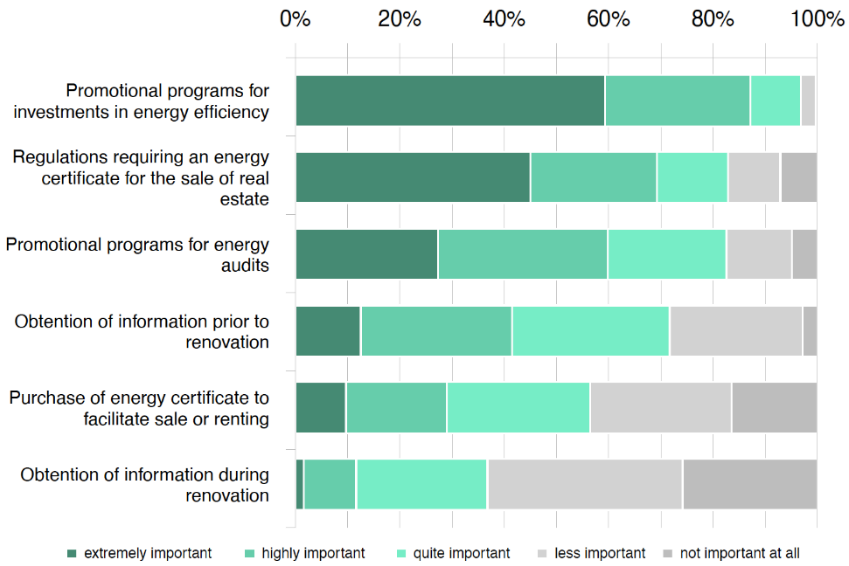


Figure 4: Experts' opinions on homeowners' determinants of GEAK energy audits

Implications and Policy Recommendations

Energy audit experts have a first-hand view of the market for energy retrofits. Their beliefs about homeowners' barriers and determinants suggest that, on the one hand, energy retrofits lack financial attractiveness, which deters several homeowners. On the other hand, for homeowners who do invest, such investment is rather opportunistic and associated with important co-benefits.

Furthermore, energy audits and, in particular, the GEAK program are important starting points for energy retrofits. However, the cost to administer such audits tends to be above what homeowners are willing to pay. This points to an important market barrier towards which the federal and cantonal governments should give additional attention.

The GEAK certification and, more broadly, other energy certification programs should play an important role in Switzerland's long-term energy strategy. A well-designed certification can become a focal point of energy-efficiency policies that enable subsidy programs and mandates and increase the energy efficiency feature in the real estate market. In the future, this policy could be further leveraged in Switzerland notably by allowing renters to perform GEAK audits and having rental properties certified.

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6 Policy brief – Performance Gap Between Energy-Efficient and Non-Energy–Efficient Buildings*

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Executive Summary

- Evidence suggests residents living in Minergie-certified buildings consume between 25% and 50% less total energy.
- The estimated energy-saving potential is lower than predicted ex-ante, which should be considered by policy makers when defining energy-policy scenarios.
- Green building certification systems may help to achieve greenhouse gas reduction targets.

Outline

In Switzerland, the building sector is responsible for approximately 45% of the country's total energy consumption. Most of the energy consumed in buildings comes from fossil fuels (Swiss Federal Office of Energy, 2018). Therefore, to promote sustainable development, adopting energy-efficient technologies in the construction and renovation of buildings is important. As Newell and Siikamäki (2014) demonstrated, information campaigns and energy-efficiency labels, such as Minergie-certification, can facilitate households' decision making by providing information on the energy-cost saving potential. In 1998, the Swiss building sector introduced the Minergie certification scheme, which is characterized by an important thermal insulation and heat recovery ventilation system (from the outgoing stale air) that should consume less energy than households living in non-Minergiecertified buildings. Of course, we should keep in mind not only technological factors determine a household's total energy consumption. Ex-ante engineering calculations predict households living in Minergie-labelled buildings should consume 60% less energy than households living in conventional buildings (Beyeler et al., 2009). This difference is estimated by making some assumptions regarding the characteristics and behaviour of the household members, which may not reflect completely the real situation. In our empirical analysis, we compare the observed energy consumption of Minergie and non-Minergie buildings by estimating an energy-demand function using panel data and econometric methods. In this empirical analysis, we consider different factors like household size or income that can explain the difference in energy consumption. After controlling for several socio-economic factors, our results suggest residents living in certified houses consume around 25% to 50% less energy than those living in conventional buildings.

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Are households living in green-certified buildings consuming less energy? Evidence from Switzerland, Massimo Filippini and Adrian Obrist, Energy Policy 161 (2022)
Available in Energy Policy under: https://doi.org/10.1016/j.enpol.2021.112724

Conventional and Minergie-certified buildings differ in many dimensions

Using bar charts for the group-specific averages and their confidence intervals, Figure 1 and Figure 2 illustrate the average differences regarding energy consumption values between households living in certified dwellings and in their non-labelled counterparts. We observe a significant difference in average total energy consumption between Minergie-certified and non-Minergie–certified houses. As shown in Figure 1, the average annual energy consumption of Minergie-certified buildings is around 14,000 kWh; non-certified houses in our sample demand almost 17,000 kWh or about 20% more energy per year. Non-Minergie–certified buildings differ to their labelled counterparts with respect to living area; therefore, we also computed the average annual energy consumption per square meter in Figure 2. Nevertheless, there is still a significantly lower specific consumption of around 20%. However, both certified and non-certified houses differ significantly in many more dimensions that potentially influence energy demand. Therefore, a simple comparison of the average total energy consumption of Minergie-certified and non-Minergie–certified houses can be misleading. For this reason, it is important to use a regression analysis approach that allows the possibility of considering several factors, such as household size, income, or age, that can explain the level of total energy consumption.

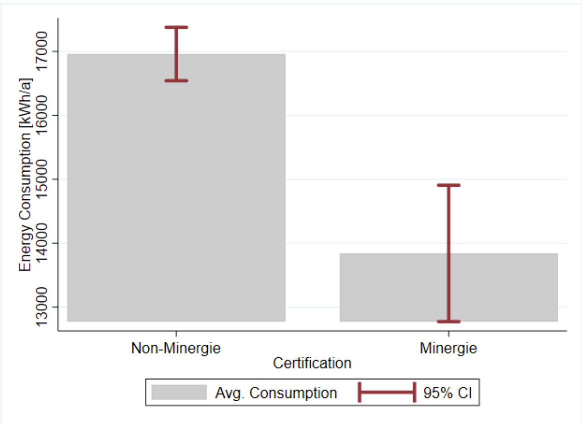

Figure 1: Average annual energy consumption in kilowatt hours: non-Minergie–certified vs. Minergie-certified houses (p-value of t-test: 0.000, N = 6570)

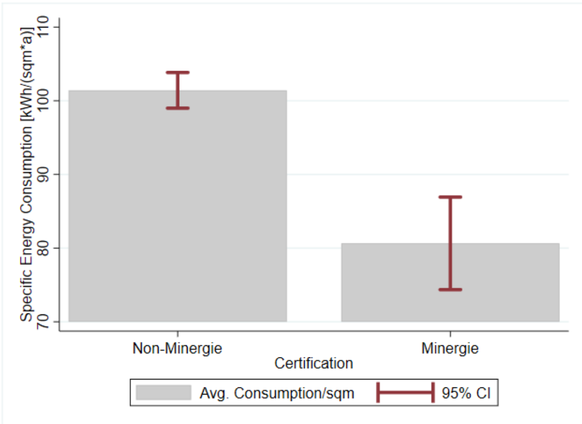

Figure 2: Average annual energy consumption [kWh] per square meter: non-Minergie–certified vs. Minergie-certified houses (p-value of t-test: 0.000, N = 6570)

We specify a residential energy-demand model where energy is assumed to be a function of energy prices, capital price, level of energy services consumed, income, some household and building characteristics, and a binary variable reflecting a building's Minergie certification status. We then estimate the empirical model by using a random effects model and an instrumental variable alternative.

Households living in Minergie-certified buildings consume less energy than households occupying non-labelled houses

The primary goal of our empirical analysis is to estimate the difference in total energy consumption of households living in Minergie-certified dwellings and households occupying non-Minergie–certified buildings. By controlling for several household characteristics, we aim to be able to identify Minergie building certification's effect on total energy consumption. The results show households living in Minergie-certified buildings are associated with lower energy consumption of around 25% to 50% compared to households occupying non-certified houses, ceteris paribus. This effect is highly significant and even larger than the one calculated in the simple comparison of mean consumption previously mentioned.

The observed energy savings are lower than the theoretically predicted ones

Until about 2014, the reduction in energy consumption of a Minergie-labelled house compared to a conventional building was estimated to be around 60% from an engineering point of view (Beyeler et al., 2009). In this study, we have shown, in reality, this saving does not occur completely. Our study indicates an energy consumption saving of about 25% to 50%, which is in line with Li and Carrión-Flores' (2017) findings for Energy Star-certified residences. Possible reasons for the deviation between observed and predicted energy savings include occupants' differential behaviors, erroneous technical assumptions, or non-compliance in the construction phase.

Implications and Policy Recommendations

Even though the theoretical saving potential was not confirmed, our results show the total energy consumption in the building sector can still be substantially reduced by constructing more houses carrying the Minergie label. Additionally, Minergie-certified houses emit much less CO_2 than conventional houses because they are equipped with efficient heating systems based on electricity and, from 2017, rely on renewable energy sources. For this reason, measures that promote the construction and renovation of energy-efficient buildings, such as Minergie certified ones, could contribute to reaching the goals the Swiss Federal Council defined as the Swiss energy strategy and the greenhouse gas emissions target.

The difference between ex-ante predicted and observed energy savings may affect the results obtained in the underlying scenario analysis of the impact of energy policy measures because these scenarios are based on some predefined building-sector energy-consumption levels. In this present case, the scenario based on a reduction of 60% could provide rather optimistic results compared to what we obtain. One way to mitigate the risk of differential target and observed outcomes is to base energy policies such as labels and certificates on observed consumption values instead of theoretical projections.

Conclusion

This study's results are relevant for policy makers looking for energy-policy instruments to promote the construction of energy-saving houses. Traditional building codes remain an important energy policy instrument, but this study's findings confirm the promotion of green building certification systems can also contribute to reduced energy consumption in the building sector, even though the theoretical saving potential was only confirmed partially. These results could be used by policy makers in public information campaigns to reinforce the message that green-certified buildings offer possible energy savings.

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7 Conclusions

In this project, we analysed the behavioural factors and anomalies that act as barriers for investments in energy efficiency and showed the implications of such barriers to and determinants for the design of policies in the Swiss building sector. In WP1, we showed the barriers to and determinants of energy-efficient retrofits from both homeowners' perspectives and GEAK experts' perspectives. WP2 analysed the willingness-to-pay attitude for the Minergie--certified technology and the role of information provision using individual survey data. Finally, WP3 showed the energy performance gap between Minergie-certified and conventional buildings.

Our results from WP1 indicate energy-efficient retrofits are highly opportunistic investments: a large share of homeowners wait until a building technology is broken or obsolete before investing. In this context, financial motives are major barriers to and determinants for such an investment, but they are not systematically the most important ones for all households. Co-benefits, such as comfort and contribution to a cleaner environment, rank high as determinants of energy-efficient retrofit uptakes. Tax deduction policies on retrofits have a small but measurable effect on energy-efficient retrofit uptake. In general, there is strong political support for more generous subsidies. Interestingly, the COVID-19 crisis did not change Swiss homeowners' intentions related to energy-efficient retrofits, and concerns for climate change still exceed concerns for COVID-19.

In contrast to many homeowners, GEAK experts (experts on energy-efficient retrofitting) consider energy retrofits' low financial returns as the major barrier to investment. These experts observed householders who perform energy retrofits do so mainly to replace broken or obsolete technologies, to increase comfort, and/or for ecological concerns. The experts believe the existing subsidy programs for retrofits and audits currently offered in Switzerland are important determinants of energy retrofits. Moreover, they believe demand for GEAK energy audits is primarily driven by these subsidy programs. Because the average cost of a GEAK audit tends to exceed homeowners' willingness to pay for such a service, the market for energy audits thus requires government support to thrive.

Our results for the Minergie certification in WP3 show evidence households in Minergie-certified buildings consume between 25% and 50% less total energy than non-Minergie–certified buildings. These findings complement WP2, where our results suggest homeowners are willing to pay a premium of 6% to 7% of the monthly rental value for the Minergie certification. A fraction of homeowners, regardless of whether they live in a Minergie-certified home or not, value the improved indoor air quality Minergie technology provides through its ventilation system. Homeowners who live in Minergie-certified homes value the ventilation system somewhere between 80 and 260 CHF per month, and those valuing indoor air quality are in the higher end of this range. Homeowners who value indoor air quality are willing to pay for the ventilation system between 160 CHF and 260 CHF, independently if they live in a Minergie-certified building or not. The fraction of homeowners who have not experienced Minergie-certified homes reports no value for the ventilation system.

Overall, our results show energy-efficient buildings, especially those with Minergie technology, offer not only significant energy savings but also co-benefits, such as improved indoor air quality. Some homeowners, however, often do not consider or are not completely aware of these benefits. Energy-efficient retrofits for existing buildings often face financial hurdles, including due to homeowners' lack of information about various available governmental subsidies. This also plays a role in delaying renovation decisions until broken or obsolete technological building elements must be replaced from necessity. Energy audits, such as those offered by GEAK experts, can provide financial information and counsel on energy-efficient options.

8 Outlook and Next Steps

Policy implications: Our results indicate the importance of the co-benefits of both energy-efficient retrofits and the Minergie-technology; therefore, it is key to further develop public awareness about these co-benefits. These results suggest one barrier to energy-efficient retrofits by homeowners is lack of information on both the technical aspects of renovations and available subsidies. For this reason, one major policy implication is the need to promote the audits offered by GEAK experts both financially and through information campaigns. Further, campaigns for energy-saving houses that offer co-benefits, such as Minergie-buildings, should be reinforced.

Further research: To promote energy-saving renovations, several measures can be adopted, such as increasing subsidies, launching information campaigns, and strengthening building standards. A recently emerging complementary instrument directs financial investments toward this sector with an explicitly sustainable objective: green mortgages allow homeowners to finance energy-efficient retrofits. The factors that might influence the demand for Swiss green mortgages as an attractive retail investment product are still unknown; therefore, it could provide an opportunity for further research.

9 National and International Cooperation

Within this project, we collaborated with the following:

– Minergie Schweiz,
– Statistical Office of Canton Zurich,
– EnergieSchweiz, and
– Ticino Energia

Conferences at which authors are active:

– Tobias Wekhof presented ‘The Narrative of the Energy Efficiency Gap’ at EAERE 2021 (June 24, 2021).
– Tobias Wekhof presented ‘The Conditional Topic Allocation for Text Data’ at the Zurich-Monash Text-as-Data Workshop (February 18-19, 2021).
– Tobias Wekhof presented ‘The Conditional Topic Allocation for Text Data’ at the SAEE Student Chapter Workshop (November 11, 2020).
– Adan L. Martinez-Cruz will present ‘Willingness to Pay to Clean Up the Air in Residential Buildings: Insights from a Contingent Valuation on Swiss Homeowners’ at EAERE 2022.

Seminar presentations:

– Tobias Wekhof presented ‘The Narrative of the Energy Efficiency Gap’ at the ETH Seminar in Economics and Data Sciences on April 7, 2021.
– Nina Boogen presented ‘Willingness to Pay to Clean Up the Air In Residential Buildings – Insights from a Contingent Valuation on Swiss Homeowners’ at a Lunch Seminar at Potsdam Institute for Climate Impact Research (PIK) on June 9,2021.
– Tobias Wekhof presented ‘The Conditional Topic Allocation for Text Data’ at the C-SEB Seminar at the University of Cologne (May 24, 2022).

10 Publications

The Narrative of the Energy Efficiency Gap

Sébastien Houde and Tobias Wekhof

Abstract:

For more than forty years analysts have pointed out that society might be too slow in adopting energy efficiency technologies, a phenomenon known as the Energy Efficiency Gap. There are persistent market barriers that impede these efforts. Eliciting these barriers and their heterogeneity is key for policy design. In this paper, we use narratives, a novel approach based on unstructured text answers in surveys, to elicit the barriers to and determinants of energy efficiency investments. Using recent advances in Natural Language Processing (NLP), we turn narratives into quantifiable metrics to rank households' barriers and determinants. We find that financial motives are not the primary barriers or determinants of energy efficiency investments. Instead, we find that such investments are highly opportunistic and co-benefits, such as ecological concerns and comfort, also play an important role. Although there is substantial heterogeneity across the population in the type of barriers and determinants, demographics and building characteristics poorly predict heterogeneity patterns. This has important implications for the targeting of policies. Narratives could be a novel and effective way to implement policy targeting.

Available at the ETHZ Library under: https://doi.org/10.3929/ethz-b-000495755

Value of Co-Benefits from Energy Saving Ventilation Systems–Contingent Valuations on Swiss Homeowners

Nina Boogen, Massimo Filippini, and Adan L. Martinez-Cruz

Abstract:

Previous efforts exploring options to increase residential sector's energy efficiency have overlooked that highlighting co-benefits associated with energy efficiency may represent a promising strategy to draw attention from decision makers. For instance, buildings equipped with energy saving and comfort ventilation (ESV) system provide, in addition to savings in energy costs, co-benefits such as improved indoor air quality (IAQ), thermal comfort, and noise reduction. These co-benefits are difficult to appraise by a person that has not experienced ESV. In Switzerland, Minergie houses are equipped with ESV. Thus, this paper estimates the value of ESV's co-benefits by inquiring willingness to accept (WTA) compensation to hold off on using ESV from owners of Minergie houses. Average monthly WTA is CHF 181 —value dominated by IAQ. WTA protocols may deliver overestimated values. Consequently, this paper estimates willingness to pay (WTP) on a sample of owners of houses that are not equipped with ESV. Average monthly WTP is CHF 163 —value dominated by presence of allergies at home, an approximation to relevance of IAQ among respondents that have not experienced ESV. A back-of-the-envelope cost-benefit analysis informed with our estimates suggests that monthly co-benefits from ESV can be as much as twice the costs.

Available at the ETHZ Library under: https://doi.org/10.3929/ethz-b-000535197

Conditional Topic Allocations for Open-Ended Survey Responses

Tobias Wekhof

Abstract:

This paper develops a novel topic model for text data by conditioning on observables, named the "Conditional Topic Allocation" (CTA). This data-driven method allows identification of latent topics that explain other observable variables. It is particularly suited for small-scale text data, such as open-ended survey responses. First, CTA is used to extract topics from open-ended text answers that explain single observable variables. Then, in empirical models where text is a control variable for unobservable characteristics, CTA's flexible scope of applications allows uncovering latent variables from the text. As a proof-of-concept, this approach is used to analyze the sentimental value homeowners place on their homes and how this relates to energy-efficiency valuation. Specifically, responses from open-ended survey questions are used as control variables in a hedonic regression, and CTA serves to identify latent preferences associated with nearly 50% of the valuation of energy efficiency for single-family houses.

Available at SSRN under: https://dx.doi.org/10.2139/ssrn.4190308

Are households living in green certified buildings consuming less energy? Evidence from Switzerland, *Energy Policy* 161 (2022)

Massimo Filippini and Adrian Obrist

Abstract:

In this paper, we compare the total energy consumption of households living in green certified buildings with households living in conventional buildings based on the example of the Swiss Minergie label. For this purpose, we estimate an econometric total energy demand model using a panel data set comprised of around 1500 households observed over the years 2010–2015. The empirical analysis provides suggestive evidence that households living in green certified buildings save approximately 25% of total energy. The estimated energy savings are lower than predicted by engineering-based bottom-up models that are not considering energy consumption behavioral factors. Nevertheless, our result suggests that savings in energy use and associated emissions of greenhouse gases (and other pollutants) may benefit from energy policy measures such as public information campaigns or subsidies that promote the construction of green certified buildings. Furthermore, since policy scenarios are usually based on ex-ante energy reduction projections, it is important to consider that the energy savings predicted tend, at least for the building sector, to be higher than they actually are. This difference may therefore impact the scenarios and thus the energy policy measures to be implemented.

Available in Energy Policy under: https://doi.org/10.1016/j.enpol.2021.112724

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12. Appendix

Determinants to the adoption of energy-efficient retrofits and buildings: Role of policy and behavioral factors

Date: 19 September 2022

Location: Zurich

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Contents

1 Introduction

In this report, we present several empirical analyses on the determinants of the adoption of energy-efficient retrofits (EER) and the adoption of energy-efficient residential houses by Swiss households. To conduct this analysis, we use two datasets for Switzerland. The focus is to examine the role of behavioral factors, as well as the underlying policy-related measures.

Behind energy-efficiency related investment decisions by households, several factors may play a role. These include crucial attributes like age of the building, income and level of education of the inhabitants, but we also expect other behavioral and cognitive factors like financial literacy, energy-related knowledge, and energy-saving behavior to be important. Finally, policy measures may also have some impact. Especially, we are interested to analyze the impact of the tax credit (i.e., tax deduction for energy-efficiency investments) and expenditure by the cantons for the promotion of energy-saving retrofits, such as by considering the budget under energy-related funding programs and energy-related consulting.

Our main research questions are:
a) What are the determinants to the adoption of energy-efficient retrofits (EER) and do behavioral factors and policy instruments play a role in these energy-saving investment decisions?
b) What are the determinants to the adoption of Minergie-certified residential buildings?

We rely on two existing datasets in order to examine the above research questions. The primary dataset used in the econometric analysis is the CEPE 2015 dataset. In addition, we also attempt to re-estimate similar empirical models using the SHEDS dataset. Both CEPE 2015 and SHEDS are disaggregated datasets at the household level. They capture similar information but with somewhat varying level of details on investments in EER and adoption of Minergie-certified building, in addition to socio-demographic information, dwelling characteristics, literacy and behavioral-related variables.

Empirical literature on the determinants of the adoption of energy-efficient technologies in buildings has focused primarily on socio-demographics (Achtnicht and Madlener, 2014; Brounen, Kok and Quigley, 2013; Kok, McGraw and Quigley, 2011; Nair, Gustavsson and Mahapatra, 2010; Mills and Schleich, 2012), the landlord-tenant relationship (Myers, 2020), and energy codes (Jacobsen and Matthew, 2013). Some studies, e.g., Banfi, Filippini, and Ramseier (2011) and Banfi, Farsi, Filippini and Jakob (2012), examined the role of asymmetric information and transaction costs as potential determinants of the decisions related to investments in energy-efficiency renovations.

A few existing studies have specifically looked into the effectiveness of policies providing incentives for residential energy-efficiency renovations, e.g., tax credits or rebates, but the results have been mixed. Hassett and Metcalf (1995) find that while tax incentive measures for energy efficiency have existed in the US since the 1970s, some of the first empirical studies do not find a positive effect on energy efficiency investments (Walsh, 1989; Dubin and Henson 1988). Hassett and Metcalf (1995) highlights the importance of controlling for unobserved heterogeneity and they exploit panel data in order to measure the impact of tax-based incentive policies for making energy conservation investments by households in the US. They find a positive and significant impact of tax-related policy for such investments.

Alberini, Bigano and Boeri (2014), who examine free-riding behavior on energy efficiency incentives among Italian homeowners, also argue that when it comes to household responsiveness to the incentive amount, “the evidence is mixed and inconclusive”. They point out that incentive programs could disproportionately attract people more competent at identifying and reducing their energy use, some of whom would undertake such renovations anyway. Since incentive programs-based policies are typically voluntary in nature, there may arise some concerns around cost effectiveness of these policies because of such (free riding) behavior (Joskow and Marron, 1992).[12]

This empirical research uses econometric models to study the factors explaining the adoption decision of energy-efficient retrofits and residential single-family houses in Switzerland. Our main contribution is to enrich the (somewhat limited) literature that empirically analyze the role and impact of policy measures, such as tax deduction, for investment decisions in energy-saving renovations. While some studies focus on socioeconomic factors, hardly any studies look into the role of energy-related financial literacy, or on energy saving behavior and attitudes. Our framework relates to Kok et al. (2011) and Banfi et al. (2011), but we use richer data that allows us to shed some light on the role of behavioral and cognitive factors, in addition to socio-demographics and policy factors.

In order to measure and quantify the various behavioral and cognitive factors, our approach borrows from our previous work on the topic, where we define and study the concept of energy literacy and its link with financial literacy and bounded rationality (Blasch et al., 2017a; Blasch et al., 2019) in the adoption and use of electrical appliances. In this report, the focus is particularly on energy-efficient investment decisions related to retrofits and buildings, which is an important distinction as the decision environment and policies for buildings and retrofits maybe different from the appliance market.

Results from our empirical analysis suggests that while the building period, income, and education appear to be relevant determinants; energy-related attitudes as well as the policy-related variables are found to play a very important role for households in our dataset. In particular, there is suggestive evidence that the tax deduction policy has a significant positive impact on households' investment decisions in EER. The other policy variable, i.e. cantonal budget towards energy saving measures, is also found to have a significant but smaller impact. In terms of behavioral factors, coefficients on some energy-related attitudinal variables, such as feeling morally obliged to reduce own energy consumption, are found to be significant. On the other hand, it is unclear whether other factors like financial literacy, energy-related knowledge and energy-saving behavior play any important role, as the results are insignificant and sometimes counter-intuitive.

The rest of the report is organized as follows: Section 2 describes the methodology and the two datasets used. Section 3 reports the results of the empirical analysis and Section 4 provides concluding remarks.

[12] A few studies also look into the role of professional energy-consulting measures, see for example Banfi et al. (2011) and Feser and Runst (2016).

2 Methodology and Data

We consider two types of outcome variables to characterize the adoption decision of energy efficiency investments in the Swiss residential sector: i) number of EER undertaken by a household; and ii) whether a dwelling has a Minergie-certification. To gain some insights into the role of potential determinants, we estimate several cross-sectional and panel data econometric models using data from the CEPE 2015 and SHEDS datasets. For the EER outcome, we estimate ordered probit models using both cross-sectional and panel data. For the second outcome, we estimate probit models using cross-sectional data.

2.1 Number of EER as outcome

The primary outcome variable in our analysis considers a household's decision to undertake an EER. This outcome variable is a count of the total number of EER undertaken by a household in a given period (one year or five years depending on the dataset used) and has been constructed by adding up different types of EER (windows, roof, façade, heating system etc.). We are interested in studying the determinants of household's decision to undertake the number of EER, and as hinted earlier, we put a particular focus on behavioral factors and policy instruments in this part of the empirical analysis. The empirical model that we use is:

EER = f (SEC, DW, LIT, BEH, POL)

where,
EER = number of energy-efficient retrofits undertaken by a household.
SEC = socio-economic attributes, e.g., household income, household size.
DW = dwelling characteristics, e.g., building period, living area, location.
LIT = energy-related literacy and financial literacy of survey respondents.
BEH = an indicator of the energy-saving behavior of survey respondents.
POL = variables related to energy-efficiency related policies in place in the canton.

First, we analyze a cross-sectional ordered probit model where the outcome variable, an ordered numeric variable, is the total number of EER undertaken by households over the last five years. For the CEPE 2015 dataset, this resembles to the 2010 – 2014 period whereas, for the SHEDS data, this refers to the 2015 – 2019 period.

In analysis of the EER decision, we restrict the sample to singled-family houses (SFH) that are owned (not rented). We use the CEPE 2015 data as the main dataset and complement the analysis using the SHEDS dataset – which has a wider geographical coverage but has somewhat limited information for our analysis of interest, for instance policy variables are not included in the estimation. Furthermore, the cross-sectional sample in SHEDS has been prepared by pooling together unique households across separate waves of the SHEDS survey. Although this does not pose any problem with fixed dwelling related attributes like building period or size of the living area, socio-economic characteristics like income and behavioral factors might still change from one year to the next. For simplicity, the attributes collected from the latest available wave are assumed applicable over the previous five years.

Given the surveys underlying the two datasets, we were also able to prepare a panel data for a subsample of the households regarding the total number of EER in a year for the last five years. Hence, we also estimate a panel data ordered probit random effects (RE) model. With the CEPE 2015 data, we estimate another variation of this setup where we also include Mundlak's adjustment terms to account for the unobserved heterogeneity using group means for the time-varying controls (Mundlak, 1978). The panel estimation models also control for the year fixed effects using times dummies for the years in the sample.

In our estimation, we also wanted to examine whether government policies to promote energy-efficiency investments also played a role in the adoption. Unfortunately, neither of the datasets had much useful information related to any policy-related measures. While exploring external data sources, we also noticed that in general there appears to be a lack of a systematic collection, storage and availability of such policy measures, both current as well as historical data, across different regions and cantons. Hence, collecting energy policy related information across different regions turned to be rather complicated and time-consuming. In this regard, it is worth mentioning that our research group also organized and supervised research work as part of a student semester paper with the primary goal of collecting comparable energy-policy related information at the cantonal level using external data sources.

We briefly summarize the policy information and the data sources collected as part of this exercise. The following types of policy information was collected:

- Cantonal budgets, e.g., for energy subsidy programs (Förderprogramme) and energy-related audit and consulting (Fachstelle), as well as availability of tax deductions for energy-efficiency investments. This information was collected from the annual report published by the SFOE on the state of cantonal energy and climate policy.

- An aggregate cantonal ranking based on the overall rating of cantonal building energy politics has been published by WWF in 2014 and again in 2019 (Müller et al., 2014, 2019). In this ranking, each canton is ranked in one of the three groups from best to worst in terms of their relative performance according to several criteria.

- Information related to several local and cantonal subsidy programs are available at the postcode level on the Energie-Franken portal of www.energie-experten.ch. Although the data appears to have quite elaborate information on different types of policies, e.g., related to energy-efficiency investments, Minergie, GEAK etc. it relies on self-reporting by several institutions. There is also no common reporting structure or categorization which makes it difficult to create comparable policy variables across different regions.

Given these policy-related measures, and after evaluating the constraints underlying the data as well as existing findings in the literature (Banfi, Filippini and Ramseier, 2011; Müller et al., 2014), we make use of two policy-variables at the canton level. The first variable is dichotomous and represents whether or not a tax deduction for energy-efficiency investments is available. The second variable captures the total budget for energy funding programs and energy-related consulting per capita.[13] We use these two policy

[13] This information was collected from annual reports "Stand der Klima- und Energiepolitik der Kantone" published by the BFE for the years 2010 – 2018. This exercise was part of a semester paperwork undertaken by Björn Lalin at CEPE, ETH Zurich.

variables as explanatory variables in the main model using the CEPE 2015 dataset.[14] Table A.1 in the Appendix presents an overview of the two policy variables across all the cantons from 2010 to 2014.

From an econometric point of view, the identification of the impact of a policy measure such as a tax credit, or a subsidy, should ideally be performed using a difference-in-difference estimation strategy because the presence of a policy in some regions and not in others resembles a natural experiment framework. Unfortunately, we do not have the necessary data to apply a difference-in-difference method. However, following the footsteps of Hassett and Metcalf (1995), we tried to minimize some of the econometric issues related to unobserved heterogeneity in our dataset by specifying a rich model and by using a random effects model with the Mundlak adjustment. Of course, we are aware that we cannot claim that our analysis estimates the causal impact of the two policies considered. Nevertheless, we think that we can provide at least suggestive evidence of the impacts of these policies on the investment decisions in energy-saving retrofits by owned single-family households in our dataset.

2.2 Minergie-certified dwelling as outcome

As a secondary analysis, another outcome variable related to dwellings captures whether the building is Minergie-certified. We examine this binary outcome to gain insights on the determinants of living in Minergie-certified housing for a sample of households in Switzerland. The empirical model is:

MINERGIE = f (SEC, DW, LIT, BEH)

where, the binary outcome is equal to one if a dwelling has any type of Minergie-certification and zero otherwise. The rest of the variables capture attributes as mentioned in Section 2.1. Given the binary outcome, we use a simple probit methodology for this analysis using the two datasets. Note that in general we have a small sample of Minergie-certified buildings within our datasets, hence for the purpose of this analysis, we consider both single-family (SFH) and multi-family households (MFH) that are owned (not rented).

It is to be noted that the existing datasets did not collect detailed information regarding the Minergie-certification of dwellings. We tried to find the type of Minergie-certification (Eco/P/A) using external data sources at the building level, but we could not achieve a satisfactory result because of very limited building-level information in our existing datasets. We only know whether a household lives in a Minergie-certified building and do not know any further details related to the certification (for instance the year of certification) or policy-related information. Hence, the results reported here should only be considered indicative.

In addition, we used the newly collected data from the Canton of Zurich in 2020 to estimate the same model as above, but with the new data. In the new survey, we collected detailed information about household- and building characteristics[15]. We had a strong focus to capture household preferences with respect to their house and with respect to policy makers. Preferences for specific policies were obtained using a novel model with open ended questions. Respondents were asked to write four sentences on what they would like policy makers to engage in. A detailed analysis on the methodology on how to extract topics out of the open text answers can be found in Houde and Wekhof, (2021).

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[14] Note that the empirical estimation model for the total number of EER using cross-sectional data from CEPE 2015 uses the policy information of the year 2014.
[15] We collected information about the detailed Minergie certification, however due to the sample size and different temporal introduction of the labels we choose not to analyze the exact Minergie label choice.

2.3 Data

We used three datasets that were gathered from three different surveys from three independent research projects over the span of last few years. As mentioned, the primary dataset used in the empirical analysis is the CEPE 2015 dataset that was collected during 2015-2016 in collaboration with nine Swiss utilities and consists of 8,378 Swiss households. Comprehensive details of the survey and the data are provided in Blasch et al. (2018).

The SHEDS dataset, on the other hand, is part of a large SCCER-CREST collaborative project with annual survey waves in 2016, 2017, 2018 and 2019. The data consists of around 5000 respondents per wave and has a larger geographical coverage (25 cantons). Detailed information on SHEDS can be found in Weber et al. (2017) and Burger et al. (2018).[16] The SHEDS surveys are extensive and have been continuously adapted from one wave to another with new and returning respondents across the waves.[17] Considering all the four waves from 2016 – 2019 together, there are 10,019 unique respondents. In our analysis, we use the data from the last three waves, which resembles to 8,551 unique households, as we have limited information on several variables from the first wave in 2016.

Both CEPE 2015 and SHEDS have disaggregated household level information on investments in EER and adoption of Minergie-certified building in addition to socio-demographic information, dwelling characteristics, literacy and behavioral attributes. Subsets of the two datasets have been used in several research articles published in recent years (Blasch et al. 2017a, 2017b, 2019; Hess et al., 2018; Hille et al., 2019). For brevity, Table 1 and Table 2 provide an overall summary of the two datasets and information on the underlying variables used in this empirical analysis. Note that in the empirical estimations involving categorical variables like building period, household income, region and living area, the first category (as shown in these descriptive statistics table) are usually the reference category.

It is to be noted that since the underlying surveys were independent, most of the variables across the two datasets were also captured differently, and this is noticeable in the two tables, e.g., in the categories for the building period and in the range of the literacy-related variables. The CEPE dataset comprises of 28% SFH whereas 40% of all the dwellings were owned. The SHEDS on the other hand has 35% SFH and 36% of all dwellings are owned. Statistics on some other comparable variables like household size and size of the dwelling (in square meters, or sqm) are similar across the two datasets.

For the third dataset we use the survey that was collected for this project in the Canton of Zurich in February 2020. The survey data contains a total of 2755 households, out of which 524 (19%) live in a Minergie certified dwelling. The remaining households were sampled with the condition that all non-Minergie houses were built prior to 1990. More information on that survey, together with more detailed summary statistics, can be found in Houde and Wekhof (2021). The advantage of using this survey data is the availability of numerous variables that measure household preferences with regard to housing and policies.

[16] Official SHEDS website: https://www.sccer-crest.ch/research/swiss-household-energy-demand-survey-sheds/

[17] As can be expected, this has practical implications in constructing a coherent dataset for the same set of variables. At the same time, SHEDS allowed for more flexibility and adaptability in the information researchers were able to collect in the newer survey waves.

Table 2: Overview of the CEPE 2015 dataset and underlying variables.

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Number of EER (over last 5 years)	0.2	0.73	0	6	8378
Dwelling is minergie certified	0.08	0.28	0	1	8378
Owned dwelling	0.4	0.49	0	1	8378
SFH dwelling	0.28	0.45	0	1	8378
Living room temperature	20.91	1.45	16	24	7977
Household size	2.26	1.17	1	6	8180
Size of dwelling (in sqm)	115.18	58.03	20	400	8218
Number of rooms	3.71	1.34	0	6	8378
Building built before 1940	0.25	0.43	0	1	8378
Building built in 1940-1970	0.3	0.46	0	1	8378
Building built in 1970-2000	0.29	0.45	0	1	8378
Building built in 2000-2015	0.16	0.37	0	1	8378
Household has kids/teens	0.24	0.42	0	1	8378
Household has elderly	0.25	0.43	0	1	8378
Respondent's age $<$ 40 years	0.28	0.45	0	1	8378
Respondent's age between 40-60 years	0.38	0.49	0	1	8378
Respondent's age $>$ 60 years	0.34	0.47	0	1	8378
Household Income $<$ 6k	0.34	0.47	0	1	8378
Household Income in 6k-12k	0.48	0.5	0	1	8378
Household Income $>$ 12k	0.18	0.38	0	1	8378
Respondent has university degree	0.42	0.49	0	1	8378
Respondent's partner has university degree	0.19	0.4	0	1	8378
Respondent's investment literacy	0.53	0.5	0	1	8378
Respondent's energy literacy	3.46	3.09	0	11	8378
Respondent's energy-saving behavior	2.26	1.07	0	4	8378
Feels morally obliged to reduce consumption	0.70	0.46	0	1	8378
Is concerned about free-riding by others	0.09	0.28	0	1	8378

Notes: This table reports the summary statistics for Swiss households in the CEPE dataset.

Table 3: Overview of the SHEDS dataset and underlying variables.

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Number of EER (over last 5 years)	0.08	0.36	0	6	8551
Dwelling is minergie certified	0.2	0.4	0	1	6921
Owned dwelling	0.36	0.48	0	1	8551
SFH dwelling	0.35	0.48	0	1	8551
Living room temperature	20.73	1.02	18	23	8063
Household size	2.32	1.33	1	29	8551
Size of dwelling (in sqm)	115.84	69.57	0	999	8551
Building built before 1960	0.24	0.43	0	1	8225
Building built in 1960-1969	0.1	0.3	0	1	8225
Building built in 1970-1979	0.13	0.34	0	1	8225
Building built in 1980-1989	0.13	0.34	0	1	8225
Building built in 1990-1999	0.12	0.32	0	1	8225
Building built in 2000-2009	0.13	0.33	0	1	8225
Building built after 2010	0.16	0.36	0	1	8225
Household income: Upto 4,499	0.16	0.36	0	1	7271
Household income: 4,500-5,999	0.15	0.36	0	1	7271
Household income: 6,000-8,999	0.29	0.45	0	1	7271
Household income: 9,000-12,000	0.23	0.42	0	1	7271
Household income: 12,000 or more	0.18	0.38	0	1	7271
Respondent has a second residence	0.1	0.3	0	1	8551
Respondent has university degree	0.46	0.5	0	1	8551
Respondent's investment literacy	1.55	0.64	0	2	8213
Respondent's energy literacy	5.21	1.9	0	9	8551
Respondent's energy-saving behavior	2.07	0.86	0	3	8551
Region = Alpen und Voralpen	0.21	0.41	0	1	8551
Region = Ostmittelland	0.29	0.45	0	1	8551
Region = Suisse romande	0.26	0.44	0	1	8551
Region = Westmittelland	0.24	0.43	0	1	8551
Living area = Agglomeration	0.28	0.45	0	1	8538
Living area = City	0.50	0.50	0	1	8538
Living area = Countryside	0.22	0.42	0	1	8538

Notes: This table reports the summary statistics for Swiss households in the SHEDS dataset.

3 Empirical results

We report the results of the estimated models for the two outcomes using the two datasets in this section. First, we report the result of the ordered probit models on the CEPE 2015 dataset and the SHEDS dataset. Afterwards, we present the results for the probit models with the binary Minergie-certification outcome.

3.1 Estimation results for number of EER

As mentioned earlier, we estimated three models on the sample from the CEPE 2015 dataset – Model (1): Cross-sectional ordered probit where the outcome variable is the total number of EER over the last five years (POOL); Model (2): Panel ordered probit random effects (RE); and Model (3): Panel ordered probit random effects with Mundlak adjustment terms (REM). Table 3 reports the estimated coefficients for the three models, and Table 4 reports the average marginal effects.[18]

For the SHEDS dataset, we estimate a similar Model (1) and Model (2) but without any policy related variable due to data limitations. As there are no other time-varying covariates, an REM specification would give the same result as the RE in Model (2), and hence, has not been reported. Table 4 presents the estimated coefficients, and Table 5 reports the average marginal effects.

For the analysis of the number of EER, we restrict the sample to singled-family houses (SFH) that are owned as these are likely to be the relevant sample with more autonomy in undertaking an EER. The final estimation sample has 1663 households in the CEPE 2015 dataset and 1613 households in the SHEDS dataset.

For the CEPE 2015 dataset results (Tables 3 and 4), while most variables appear to be insignificant, we observe some expected findings. Compared to the buildings built before 1940 (reference category), those built in 1940 -1970 are associated with a higher likelihood to undergo more EERs whereas newly constructed buildings (after 2000) are naturally associated with a much lower likelihood. Both policy related variables, the tax deduction for energy-efficiency investments, also appear to be positively associated with households undertaking more EER decisions.[19] Interestingly, level of education of the survey respondent's partner living in the same household appears to show an important association to the number of EER. The coefficients on the literacy and energy-saving behavior are insignificant. However, the two energy-related attitudinal variables have positive and significant coefficients. Respondents who feel morally obliged to reduce their energy consumption appear to be more likely to undertake more EER. Interestingly, the same is also true for respondents who are concerned about potential free-riding behavior by others.[20]

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[18] For all ordered probits, the average marginal effects (AME) have been calculated using the *margins* command in *Stata v13.1* and represent probability of a specified outcome level (number of EER = 1). For RE and REM specifications (*xtoprobit*), the AME calculation assumes that the random effect is zero. For brevity, we report the variables with statistically significant estimates in at least one of the models.

[19] We also performed robustness checks on the role of policy related variables at the cantonal level and estimated additional models based upon matching based methodologies, such as propensity score matching. These models are based on a sub-sample by design, e.g., they compare similar households across two different regions – one with tax deduction policy and other without. The findings seemed to be suggestive of a positive role of the cantonal tax deduction policy towards EER investments by households in the CEPE 2015 sample. Results are available upon request.

[20] The dichotomous variables related to moral obligation and concern for free riding are equal to one for respondents who agreed, or strongly agreed, to the two statements: "I feel morally obliged to reduce my energy consumption." and "I am not willing to reduce my energy consumption if others don't do the same."

Table 4: Ordered probit models for EER using the CEPE 2015 dataset.

	POOL (1)	RE (2)	REM (3)
Tax deduction policy	0.248**	0.126*	0.128*
	(0.101)	(0.066)	(0.066)
Energy policy expenses per capita	0.013**	0.006**	0.006*
	(0.005)	(0.002)	(0.004)
Household size	0.109***	0.033	-0.029
	(0.036)	(0.022)	(0.057)
Size of dwelling (in sqm)	0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.000)
Number of rooms	-0.003	0.021	0.019
	(0.036)	(0.024)	(0.024)
Building built in 1940-1970	0.244***	0.151***	0.151***
	(0.080)	(0.052)	(0.052)
Building built in 1970-2000	-0.165**	-0.060	-0.060
	(0.076)	(0.051)	(0.051)
Building built in 2000-2015	-1.287***	-0.870***	-0.870***
	(0.136)	(0.103)	(0.104)
Household has kids/teens	-0.216**	-0.069	-0.082
	(0.096)	(0.060)	(0.061)
Household has elderly	-0.128	-0.066	-0.064
	(0.084)	(0.055)	(0.055)
Respondent's age $<$ 40 years	0.235*	0.136	0.143*
	(0.125)	(0.084)	(0.085)
Respondent's age $>$ 60 years	-0.112	-0.086	-0.084
	(0.089)	(0.058)	(0.058)
Household Income in 6k-12k	0.058	0.002	0.002
	(0.088)	(0.058)	(0.058)
Household Income $>$ 12k	0.070	0.031	0.031
	(0.107)	(0.070)	(0.070)
Respondent has university degree	-0.033	-0.010	-0.009
	(0.071)	(0.047)	(0.047)
Respondent's partner has university degree	0.237***	0.107**	0.105**
	(0.079)	(0.052)	(0.053)
Std(investment literacy)	-0.012	-0.008	-0.008
	(0.035)	(0.023)	(0.023)
Std(energy literacy)	0.031	0.019	0.019
	(0.031)	(0.021)	(0.021)
Std(energy-saving behavior)	0.038	0.025	0.026
	(0.032)	(0.021)	(0.021)
Feels morally obliged to reduce consumption	0.245***	0.160***	0.158***
	(0.071)	(0.047)	(0.048)
Is concerned about free-riding by others	0.207*	0.157**	0.158**
	(0.107)	(0.071)	(0.071)
Observations	1663	7799	7799

Notes: This table reports the coefficients of a cross-sectional ordered probit model (POOL), a panel ordered probit random effects model (RE), and a panel ordered probit random effects model with Mundlak adjustment terms (REM) estimated on the CEPE 2015 dataset. The outcome variable refers to the total number of EER. The year fixed effects, constants, ordered probit cut points, and coefficients on the Mundlak terms (in REM) have not been reported. The literacy and behavior variables were used in a standardized format. Robust standard errors in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

Table 5: Marginal effects (CEPE 2015 dataset).

	AME (POOL)	AME (RE)	AME (REM)
Tax deduction policy	0.0162**	0.0101*	0.0103*
	(0.0067)	(0.0053)	(0.0054)
Energy policy expenses per capita	0.0008**	0.0005**	0.0005*
	(0.0004)	(0.0002)	(0.0003)
Household size	0.0072***	0.0027	-0.0023
	(0.0024)	(0.0018)	(0.0046)
Building built in 1940-1970	0.0160***	0.0121***	0.0122***
	(0.0054)	(0.0042)	(0.0042)
Building built in 1970-2000	-0.0108**	-0.0049	-0.0048
	(0.0050)	(0.0041)	(0.0041)
Building built in 2000-2015	-0.0843***	-0.0701***	-0.0700***
	(0.0093)	(0.0086)	(0.0086)
Household has kids/teens	-0.0142**	-0.0056	-0.0066
	(0.0064)	(0.0048)	(0.0049)
Respondent's age $<$ 40 years	0.0154*	0.0110	0.0115*
	(0.0082)	(0.0068)	(0.0068)
Respondent's partner has university degree	0.0155***	0.0086**	0.0085**
	(0.0053)	(0.0042)	(0.0042)
Feels morally obliged to reduce consumption	0.0161***	0.0129***	0.0127***
	(0.0047)	(0.0038)	(0.0039)
Is concerned about free-riding by others	0.0136*	0.0127**	0.0127**
	(0.0071)	(0.0057)	(0.0057)
Observations	1663	7799	7799

Notes: This table reports the average marginal effects (AME) obtained for the three ordered probit models estimated on the CEPE 2015 dataset. The outcome variable is an ordered variable that refers to the total number of EER. The AME have been calculated using `margins` in `Stata v13.1` and represent probability of a specified outcome level (number of EER = 1). For brevity, the table reports the variables with statistically significant coefficients in at least one of the models. Robust standard errors in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

For the SHEDS dataset results (Tables 5 and 6), we observe somewhat similar findings for recently built dwellings and some income categories appear to play a role too. The level of education of the respondent has a positive and significant coefficient (we do not have information on partner's level of education) but the coefficient on the standardized financial literacy variable is counter intuitive. Coefficients on the variables related to energy literacy and energy-saving behavior are insignificant. Most of the other coefficients are also insignificant.

Table 6: Ordered probit models for EER using the SHEDS dataset.

	POOL (1)	RE (2)
Region = Ostmittelland	-0.0004	-0.013
	(0.121)	(0.095)
Region = Suisse romande	0.114	0.075
	(0.122)	(0.095)
Region = Westmittelland	-0.156	-0.145
	(0.125)	(0.099)
Living area = City	0.015	-0.013
	(0.113)	(0.091)
Living area = Countryside	0.096	0.077
	(0.099)	(0.078)
Preferred living room temperature	-0.062	-0.062*
	(0.045)	(0.035)
Household size	0.041	0.032
	(0.030)	(0.023)
Size of dwelling (in sqm)	-0.0001	-0.00001
	(0.001)	(0.0004)
Building built in 1960-1969	0.017	-0.0002
	(0.169)	(0.133)
Building built in 1970-1979	0.049	0.046
	(0.138)	(0.108)
Building built in 1980-1989	0.149	0.133
	(0.121)	(0.093)
Building built in 1990-1999	-0.338**	-0.270**
	(0.134)	(0.108)
Building built in 2000-2009	-0.854***	-0.685***
	(0.168)	(0.141)
Building built after 2010	-1.124***	-0.938***
	(0.229)	(0.199)
Household income: 4,500-5,999	0.230	0.185
	(0.216)	(0.172)
Household income: 6,000-8,999	0.400**	0.313**
	(0.188)	(0.150)
Household income: 9,000-12,000	0.119	0.071
	(0.195)	(0.157)
Household income: 12,000 or more	0.453**	0.341**
	(0.197)	(0.158)
Respondent has a second residence	0.071	0.044
	(0.114)	(0.090)
Respondent has university degree	0.173*	0.133*
	(0.090)	(0.071)
Std(investment literacy)	-0.095*	-0.077**
	(0.049)	(0.038)
Std(energy literacy)	-0.037	-0.021
	(0.047)	(0.037)
Std(energy-saving behavior)	0.050	0.042
	(0.051)	(0.040)
Observations	1613	8065

Notes: This table reports the coefficients of a cross-sectional ordered probit model (POOL) and a panel ordered probit random effects model (RE) estimated on the SHEDS dataset. The outcome variable refers to the total number of EER. The year fixed effects, constants, ordered probit cut points have not been reported. Robust standard errors in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

Table 7: Marginal effects (SHEDS dataset).

	AME (POOL)	AME (RE)
Living room temperature	-0.0080	-0.0026*
	(0.0058)	(0.0015)
Building built in 1990-1999	-0.0436**	-0.0114**
	(0.0173)	(0.0047)
Building built in 2000-2009	-0.1103***	-0.0290***
	(0.0219)	(0.0063)
Building built after 2010	-0.1451***	-0.0397***
	(0.0297)	(0.0089)
Household income: 6,000-8,999	0.0486**	0.0120**
	(0.0204)	(0.0050)
Household income: 12,000 or more	0.0561**	0.0134**
	(0.0220)	(0.0055)
Respondent has university degree	0.0224*	0.0056*
	(0.0117)	(0.0030)
Std(investment literacy)	-0.0123*	-0.0033**
	(0.0063)	(0.0016)
Observations	1613	8065

Notes: This table reports the average marginal effects (AME) obtained for the two ordered probit models estimated on the SHEDS dataset. The outcome variable is an ordered variable that refers to the total number of EER. The AME have been calculated using `margins` in `Stata v13.1` and represent probability of a specified outcome level (number of EER = 1). For brevity, the table reports the variables with statistically significant coefficients in at least one of the models. Robust standard errors in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

3.2 Estimation results for Minergie-certified dwellings

For the analysis of the adoption of Minergie-certified building, we consider both SFH and MFH that are owned. We estimated simple probit model on a cross-sectional sample for the two datasets. The final estimation sample has 3131 households in the CEPE 2015 dataset, 2105 households in the SHEDS dataset and 2755 households in the household survey from 2020.

Table 7 reports the average marginal effects obtained by estimating the probit models using the CEPE2015 and the SHEDS datasets (Table A.2 in the Appendix presents the probit coefficients). In terms of the building period, since the Minergie certification came into effect in late 1990s, we observe a very strong and positive coefficient on the most recent building period category. A few other attributes appear to be significant too, such as the dwelling size, but we do not observe much consistent findings across the two samples. While the variables preferred living room temperature and household income appears to be important determinants in the CEPE 2015 dataset, they are insignificant in the SHEDS data. Education of the respondent's partner and energy-saving behavior exhibited by respondents appear to have a positive role in the CEPE dataset. The two attitudinal variables related to moral obligation and concern towards free-riding attitude are positive but insignificant. At the same time, the coefficients on the financial literacy and the energy literacy variables in SHEDS are negative and counter intuitive. Lastly, compared to the Alpen and Voralpen region, households in Suisse Romande region appear to have a lower likelihood of adopting a Minergie-certified dwelling.

In Table 8, we present the marginal effects of a probit model, like the one in Table7 but with the survey data from the 2020 household survey. All three columns report regression coefficients from the same model. Minergie homeowners tend to be younger compared to the rest of the sample, this effect however might be due to the sampling. Non-Minergie houses were sampled such that the buildings were built before 1990. For this reason, Minergie buildings in the sample are newer and have a larger floor size. Interestingly, neither income nor the reported rental value of the house differs between Minergie and non-Minergie. Minergie owners show different results for behavioral variables: they have a higher energy related financial literacy[21] but are less likely to having donated money to an environmental organization. For the housing preferences, we also observe significant differences between the two groups. Minergie owners place less importance on floor space and on the carbon footprint of their house. This effect is likely due to the fact that Minergie owners already have a larger floor space and a lower carbon footprint and hence do not have to be concerned about these issues for their own building. On the other hand, Minergie owners have a high priority on the Minergie certification and on indoor air quality. Policy preferences also show important heterogeneities: Minergie owners have made more use of existing policies compared to other homeowners. When asked about what policy makers should focus on, Minergie owners put less emphasis on subsidies, information campaigns and promoting insulating homes and slightly more emphasis on supporting solar PV.

[21] Energy related financial literacy extends the standard concept of financial literacy with questions that measure respondent's knowledge on energy consumption and energy prices. More Information on how that variable was constructed can be found in Houde and Wekhof (2021).

Table 8: Marginal effects: Probit models for Minergie-certified building.

(a) Estimation on CEPE 2015 dataset

	AME (Probit)
SFH dwelling	0.0058
	(0.0127)
Household size	0.0119*
	(0.0063)
Size of dwelling (in sqm)	0.0003**
	(0.0001)
Number of rooms	-0.0115**
	(0.0056)
Building built in 1970-2000	0.0007
	(0.0139)
Building built in 2000-2015	0.1804***
	(0.0128)
Household has kids/teens	-0.0353**
	(0.0161)
Household has elderly	-0.0077
	(0.0120)
Living room temperature	0.0112***
	(0.0041)
Household Income in 6k-12k	-0.0460***
	(0.0132)
Household Income > 12k	-0.0420**
	(0.0169)
Respondent has university degree	-0.0155
	(0.0114)
Respondent's partner has university degree	0.0238*
	(0.0133)
Std(investment literacy)	-0.0011
	(0.0058)
Std(energy literacy)	0.0061
	(0.0056)
Std(energy-saving behavior)	0.0102**
	(0.0052)
Feels morally obliged to reduce consumption	0.0006
	(0.0115)
Is concerned about free-riding by others	0.0088
	(0.0175)
Observations	3131

(b) Estimation on SHEDS dataset

	Probit
SFH dwelling	0.0120
	(0.0184)
Household size	-0.0079
	(0.0059)
Size of dwelling (in sqm)	0.0002**
	(0.0001)
Building built in 1990-1999	0.0296
	(0.0249)
Building built in 2000-2009	0.1939***
	(0.0188)
Building built after 2010	0.4188***
	(0.0156)
Living room temperature	0.0085
	(0.0083)
Household income: 4,500-5,999	0.0061
	(0.0374)
Household income: 6,000-8,999	0.0042
	(0.0316)
Household income: 9,000-12,000	-0.0165
	(0.0320)
Household income: 12,000 or more	-0.0064
	(0.0331)
Respondent has a second residence	-0.0119
	(0.0207)
Respondent has university degree	-0.0146
	(0.0160)
Std(investment literacy)	-0.0161*
	(0.0087)
Std(energy literacy)	-0.0151*
	(0.0082)
Std(energy-saving behavior)	-0.0066
	(0.0081)
Region = Ostmittelland	0.0322
	(0.0600)
Region = Suisse romande	-0.0797*
	(0.0425)
Region = Westmittelland	-0.0100
	(0.0408)
Living area = City	0.0112
	(0.0194)
Living area = Countryside	0.0032
	(0.0184)
Observations	2105

Notes: This table reports the average marginal effects (AME) obtained for the cross-sectional probit models estimated on the CEPE dataset and the SHEDS dataset. The binary outcome variable is one if the dwelling had a Minergie certification. Robust standard errors are reported in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

Table 8: Marginal effects: Probit model for Minergie-certified buildings with BFE survey 2020

Dependent variable: Minergie adoption					
Socioeconomics		*Housing Preferences*		*Policy Preferences*	
Log Income	0.005 (0.009)	Aesthetics	0.001 (0.002)	Policy awareness	−0.002 (0.003)
Age	−0.001*** (0.0004)	Location	0.001 (0.003)	Policy use	0.009*** (0.003)
Male	0.003 (0.006)	Floor space (importance)	−0.007** (0.003)	Policy: less bureaucracy	−0.001 (0.007)
Children	0.012 (0.007)	Garden	−0.001 (0.002)	Policy: more subsidy	−0.014** (0.006)
University Degree	0.001 (0.006)	Parking	−0.003 (0.002)	Policy: more info	−0.012** (0.005)
Allergies	0.004 (0.007)	Monetary value house	−0.002 (0.002)	Policy: more standards	−0.005 (0.006)
Building Characteristics		Maintenance	0.004 (0.003)	Policy: more PV	0.015 (0.010)
Building Age	−0.001*** (0.0004)	Carbon-Footprint	−0.007** (0.003)	Policy: more insulation	−0.013** (0.005)
Floor Size	0.0002*** (0.0001)	Energy Costs	−0.001 (0.003)		
Log Rental Value	−0.001 (0.006)	Minergie (importance)	0.021*** (0.006)		
Behavioral Characteristics		Indoor Air Quality	0.017*** (0.005)		
Energy Literacy	0.011* (0.006)	Thermal-Comfort	−0.006 (0.004)		
Took Econ	0.004 (0.006)	Noise-Protection	−0.0005 (0.003)		
Math Proficient	0.003 (0.006)				
Energy Saving Score	−0.002 (0.003)				
Donated	−0.012* (0.007)				
Happiness Score	−0.0005 (0.002)				
Observations		1,360			

Note: *p<0.1; **p<0.05; ***p<0.01
This table reports the average marginal effects (AME) obtained from a cross-sectional probit regression model. The data was obtained with a household survey in the Canton of Zurich in February 2020. Minergie adoption is a binary outcome variable that takes the value of one if a respondent lives in a Minergie certified building. All three columns report results from the same regresson.

4 Concluding remarks

In this study, our main objective is to examine the determinants for the adoption of energy-efficient retrofits and adoption of Minergie buildings, together with the role of behavioral factors and policy instruments in these decisions. We use the CEPE 2015 data as the main dataset and complement the analysis using the SHEDS dataset.

Results from the empirical analysis suggests that while the building vintage, income, and education appear to be relevant determinants; energy-related attitudes as well as the policy-related variables might also play a very important role. There is suggestive evidence that the tax deduction policy has a significant positive impact on households' investment decisions in EER. The other policy variable, i.e., cantonal budget towards energy saving measures, is also found to have a significant but smaller impact. In terms of behavioral attributes, coefficients on some energy-saving attitudinal variables, such as feeling morally obliged to reduce own energy consumption as well as energy related financial literacy, are found to be significant. Moreover, policy preferences for Minergie owners suggest that those respondents are more inclined to make use of existing policies and are less interested in subsidies or information campaigns but rather favor more emphasis on solar PV.

The reported results capture correlations and readers should consider this only as suggestive evidence at best. Moreover, the datasets used here are limited in terms of details on the Minergie-certification of buildings, e.g., the level of certification (Eco/P/A) is not precisely identified. A finer measure of the Minergie certification status could help shed light on the determinants of preferences across different levels of certification. The lack of availability of systematic and comprehensive policy data at the household level is also a challenge, although the use of external data sources could be helpful. We expect the new survey underlying this research project to overcome some of these issues.

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Appendix

Table A.1: Overview of the policy variables across all cantons from 2010 to 2014.

Kanton	Year	Tax deduction available	Energy budget per capita	Kanton	Year	Tax deduction available	Energy budget per capita
AG	2010	1	22.55	NW	2010	1	12.75
	2011	1	17.82		2011	1	13.89
	2012	1	11.70		2012	1	24.84
	2013	1	9.32		2013	1	7.62
	2014	1	9.43		2014	1	14.58
AI	2010	1	15.31	OW	2010	1	17.64
	2011	1	15.30		2011	1	19.11
	2012	1	24.77		2012	1	10.59
	2013	1	22.18		2013	1	17.73
	2014	1	13.75		2014	1	18.29
AR	2010	1	13.57	SG	2010	1	7.52
	2011	1	13.58		2011	1	9.96
	2012	1	16.71		2012	1	17.15
	2013	1	39.80		2013	1	9.23
	2014	1	39.72		2014	1	11.31
BE	2010	1	25.96	SH	2010	1	42.28
	2011	1	26.17		2011	1	43.50
	2012	1	37.54		2012	1	59.73
	2013	1	18.41		2013	1	96.82
	2014	1	19.04		2014	1	58.70
BL	2010	1	17.41	SO	2010	1	10.97
	2011	1	21.68		2011	1	12.38
	2012	1	33.64		2012	1	20.00
	2013	1	27.42		2013	1	26.68
	2014	1	35.32		2014	1	18.35
BS	2010	1	23.68	SZ	2010	1	5.67
	2011	1	41.63		2011	1	3.54
	2012	1	30.60		2012	1	11.63
	2013	1	82.20		2013	1	7.71
	2014	1	44.26		2014	1	7.69
FR	2010	1	12.81	TG	2010	1	53.72
	2011	1	21.54		2011	1	54.06
	2012	1	74.47		2012	1	51.84
	2013	1	16.28		2013	1	91.07
	2014	1	19.40		2014	1	71.81
GE	2010	1	18.31	TI	2010	1	8.58
	2011	1	20.64		2011	1	14.41
	2012	1	14.85		2012	1	10.24
	2013	1	24.25		2013	1	11.92
	2014	1	16.87		2014	1	17.52
GL	2010	1	10.53	UR	2010	1	30.00
	2011	1	22.53		2011	1	30.49
	2012	1	18.61		2012	1	45.61
	2013	1	17.50		2013	1	37.82
	2014	1	25.13		2014	1	36.66
GR	2010	1	26.06	VD	2010	1	16.71
	2011	1	28.55		2011	1	16.12
	2012	1	34.31		2012	1	27.50
	2013	1	27.17		2013	1	11.14
	2014	1	23.13		2014	1	11.18
JU	2010	1	11.41	VS	2010	1	12.52
	2011	1	14.64		2011	1	15.49
	2012	1	24.10		2012	1	14.17
	2013	1	26.04		2013	1	17.54
	2014	1	25.98		2014	1	19.44
LU	2010	0	12.84	ZG	2010	1	5.77
	2011	0	10.26		2011	1	23.43
	2012	0	28.34		2012	1	14.33
	2013	0	17.60		2013	1	21.95
	2014	0	18.03		2014	1	20.27
NE	2010	1	20.82	ZH	2010	1	9.47
	2011	1	11.84		2011	1	6.55
	2012	1	9.24		2012	1	19.66
	2013	1	9.80		2013	1	9.71
	2014	1	14.36		2014	1	8.51

Notes: Information was collected from annual reports "Stand der Klima- und Energiepolitik der Kantone" published by the BFE for the years 2010 – 2018. Tax deduction availability is denoted by either 1 (Yes) or 0 (No). Energy budget per capita is in CHF and is calculated at the cantonal level as the sum of the budget for energy funding programs and energy-related consulting per capita.

Table A.2: Probit models for Minergie-certified building.

(a) Estimation on CEPE dataset

	Probit
SFH dwelling	0.042
	(0.091)
Household size	0.085*
	(0.045)
Size of dwelling (in sqm)	0.002**
	(0.001)
Number of rooms	-0.082**
	(0.040)
Building built in 1970-2000	0.005
	(0.099)
Building built in 2000-2015	1.292***
	(0.093)
Household has kids/teens	-0.253**
	(0.115)
Household has elderly	-0.055
	(0.086)
Living room temperature	0.080***
	(0.029)
Household Income in 6k-12k	-0.329***
	(0.094)
Household Income > 12k	-0.300**
	(0.121)
Respondent has university degree	-0.111
	(0.082)
Respondent's partner has university degree	0.170*
	(0.096)
Std(investment literacy)	-0.008
	(0.042)
Std(energy literacy)	0.044
	(0.040)
Std(energy-saving behavior)	0.073*
	(0.037)
Feels morally obliged to reduce consumption	0.004
	(0.082)
Is concerned about free-riding by others	0.063
	(0.125)
Observations	3131

(b) Estimation on SHEDS dataset

	Probit
SFH dwelling	0.059
	(0.090)
Household size	-0.038
	(0.029)
Size of dwelling (in sqm)	0.001**
	(0.001)
Building built in 1990-1999	0.144
	(0.122)
Building built in 2000-2009	0.947***
	(0.095)
Building built after 2010	2.045***
	(0.103)
Living room temperature	0.042
	(0.041)
Household income: 4,500-5,999	0.029
	(0.179)
Household income: 6,000-8,999	0.020
	(0.152)
Household income: 9,000-12,000	-0.082
	(0.156)
Household income: 12,000 or more	-0.031
	(0.160)
Respondent has a second residence	-0.058
	(0.101)
Respondent has university degree	-0.071
	(0.078)
Std(investment literacy)	-0.079*
	(0.043)
Std(energy literacy)	-0.074*
	(0.040)
Std(energy-saving behavior)	-0.032
	(0.040)
Region = Ostmittelland	0.145
	(0.268)
Region = Suisse romande	-0.429*
	(0.233)
Region = Westmittelland	-0.047
	(0.194)
Living area = City	0.055
	(0.094)
Living area = Countryside	0.016
	(0.091)
Observations	2105

Notes: This table reports the coefficients of a cross-sectional probit model estimated on the CEPE dataset and the SHEDS dataset. The binary outcome variable is one if the dwelling had a Minergie certification. The constants, the utility fixed effects (in CEPE), and cantonal fixed effects (in SHEDS) have not been reported. The literacy and behavior variables were used in a standardized format. Robust standard errors are reported in parentheses. *,** and *** respectively denote significance at 10%, 5% and 1% levels.