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Value of co-benefits from energy saving ventilation systems —Contingent valuations on Swiss home owners*

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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, in addition to savings in energy costs, buildings equipped with energy saving and comfort ventilation (ESV) system provide co-benefits such as improved indoor air quality (IAQ), thermal comfort, and noise reduction. These co-benefits are attributes of an *experience goods* as their value is difficult to appraise unless they have been experienced. This paper estimates the value of these co-benefits by inquiring willingness to accept (WTA) compensation to hold off on using ESV from Swiss owners of *Minergie* houses, which are equipped with ESV. Average monthly WTA is CHF 181 —value dominated by IAQ. WTA protocols may deliver overestimated values. Thus this paper estimates willingness to pay (WTP) on a sample of owners of conventional houses —i.e. respondents that have not experienced an 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 benefits from ESV can be as much as twice the costs.

Keywords: Co-benefits of energy efficiency; residential investment decisions; willingness to accept; willingness to pay; Swiss home owners.
JEL Classification Codes: D12, Q40, R21.

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1. Introduction

The European Union and other countries such as Switzerland aim to be climate-neutral by 2050, and thus are working towards an economy with net-zero greenhouse gas (GHG) emissions (Federal Council, 2021). The building sector's contribution to GHG emissions is around 36% in EU, and 25% in Switzerland.[1] Therefore, a rapid and widespread increase in energy efficiency of the building sector is regarded as essential to reach climate neutrality. For instance, CO_2 emissions from buildings in Switzerland should be reduced by 65% (compared to the 1990 levels) by 2030 (Federal Council, 2021).

Swiss government agencies —both at federal and cantonal levels— have issued several measures aiming to 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, whereas construction of new energy efficient buildings is regulated via strong energy efficiency building codes, promotion via information campaigns, and subsidies to construction of *Minergie* buildings.

Minergie buildings are characterised by a low energy consumption that results from high quality insulation, an energy saving and comfort ventilation system (ESV), and by the use of renewable energy sources. ESV can be characterised as providing three non-energy related co-benefits —indoor air quality (IAQ), noise reduction, and thermal comfort— in addition to energy savings. This characterisation results from the way that ESV works. ESV recovers heat from air leaving a building and adds this recovered heat to the air entering the building. By making opening of windows unnecessary, this ESV system improves indoor air quality, reduces noise, and increases thermal comfort —all three services simultaneously.[2]

From an investment analysis point of view, an individual deciding between constructing a conventional house or a Minergie house should consider costs and benefits arising not only in the form of energy savings but also from indoor air quality, noise reduction, and thermal comfort. Incorporating these co-benefits in cost-benefit calculations has become even more relevant in recent years as the introduction of more stringent energy consumption standards in the Swiss building sector has reduced the difference in energy efficiency between Minergie houses and conventional (non-Minergie) houses (Filippini and Obrist, 2022), which leaves co-benefits of ESV as the main difference between residing in Minergie houses and residing in conventional new houses.[3]

Monetising energy savings over a building's lifetime is fairly straightforward —for instance, compared to conventional new buildings, construction of Minergie buildings is characterised by higher initial costs in the range of 5% to 10% (Salvi et al., 2008). However, estimates of value of indoor air quality, noise reduction, and thermal comfort are more difficult to calculate because these co-benefits are not traded individually in a market —instead, they are delivered by ESV in the form of a bundled good.

Thus this paper's main goal is to estimate the value of co-benefits provided by ESV. One challenge to this task —and, in general, a challenge to estimating the value of co-benefits of energy saving investments— is that most people *have not experienced* those co-benefits —for instance, Minergie-certified buildings in Switzerland represent

[1]EU: https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-feb-17_en, Switzerland: https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/buildings.html

[2]The ventilation system substitutes polluted indoor air with fresh air from outside and, therefore, offers an advanced and energy saving alternative to classic window ventilation. Thus, even with closed windows, the exhaled air is removed as needed and replaced by fresh outside air filtered from fine dust and preheated via a heat exchanger. This ensures good air quality, thermal comfort and reduced noise pollution. In addition, the supplied air is filtered from pollen, thus relieving allergy sufferers.

[3]The more stringent energy consumption standards in Switzerland are the "Mustervorschriften der Kantone im Energiebereich 2014" (MuKen 2014). Note that the "MuKen2014" includes an energy consumption maximum of 35 kWh/m^2 for newly constructed single family houses. Minergie adopted this same threshold for the two sublabels "Minergie" and "Minergie A" but sets it at only 70% of this value for "Minergie P" buildings in its latest product definition sheet.

only 2.7% of housing stock, which includes multi-family houses and single-family homes.[4]

In the economic literature, an *experience good* is a good difficult to appraise prior to its usage —i.e. such appraisal is feasible only after it has been experienced. Kahneman and Thaler (2006) describes this condition as a disparity between ''decision utility" and ''experience utility". An instance of an experience good is rear visibility while driving (Sunstein, 2019). A person can better appraise rear visibility once rear cameras have been experienced —i.e. once a car driver has become used to how rear cameras are operated. By interacting with an experience good, consumers learn the good's attributes —which include co-benefits— only after buying and consuming (Sunstein, 2019). This description holds for an ESV system. As co-benefits from an ESV are not a component of everyone's daily life, their appraisal is difficult. For instance, an individual that has experienced poor air quality most of his/her life would find difficult to ponder the value of an improvement in indoor air quality unless he/she experiences such an improvement (Kahn et al., 2022).

Therefore, an appraisal of ESV's co-benefits must rely on preferences reported by people that have experienced such co-benefits. Consequently, we have estimated the value of ESV's co-benefits by analysing answers that owners of Minergie houses —which are equipped with ESV— have provided to a contingent valuation protocol. Via a single-bounded dichotomous choice question, we have gathered monthly willingness to accept (WTA) compensation to hold off on using ESV. WTA protocols have been documented to yield substantially larger welfare estimates than willingness to pay (WTP) protocols.[5] To explore whether overestimation holds in this case, we have also implemented a single-bounded dichotomous choice WTP protocol on owners of conventional (non-Minergie) houses. Our empirical strategy is similar to that of a couple of studies previously exploring whether experience drives differences in stated values (Chau et al., 2010; Golbazi et al., 2020). While we calculate WTA and WTP estimates utilising contingent valuation protocols, Chau et al. (2010) and Golbazi et al. (2020) have estimated WTP estimates relying on discrete choice experiments. In particular, they implement an identical discrete choice experiment exploring WTP for green buildings' attributes on both occupants of conventional buildings and occupants of green buildings.

With this paper we want to contribute to the nascent literature on the value of co-benefits of energy efficient investments in the residential sector. To the best of our knowledge, co-benefits analysed in this paper have been the focus of five previous studies —Spetic et al. (2005); Banfi et al. (2008); Chau et al. (2010); He et al. (2019); Golbazi et al. (2020). From those studies, only Chau et al. (2010) and Golbazi et al. (2020) have considered that these co-benefits are attributes of experience goods, exploring preferences of, respectively, apartment residents in Hong Kong and students in USA. Indeed, there is space for research when it comes to exploring values of co-benefits from energy efficiency investments once a resident has experienced such co-benefits. The lack of research documenting experience values of residents in Europe, and in particular in Switzerland, is a relevant gap given both the ambitious goals that the European Union has set in terms of climate-neutrality, and the potential contribution of the European residential sector to such goals.

The rest of the paper is organised as follows: Section 2 describes two strands of literature —studies estimating value of co-benefits under study here, and studies that have highlighted the experience good inherent nature of those co-benefits. Section 3 describes our analytical framework. Section 4 describes design and implementations of our contingent valuation protocols, and presents descriptive statistics of gathered data. Section 5 reports econometric specifications and welfare estimates. Section 6 puts in context our main findings and concludes.

[4]As of January 2022 there are 48'547 houses that are Minergie-certified (https://www.minergie.ch/de/gebaeude/gebaeudeliste/) and the housing stock in Switzerland comprised 1.8 million residential buildings as of end 2020 (https://www.bfs.admin.ch/bfs/en/home/statistics/construction-housing/buildings.html

[5]This empirical regularity is particularly sharp when it comes to public goods, and holds to a lesser extent in the case of private goods. The literature documenting relative WTA/WTP magnitudes is longstanding —by early 2000s, three decades had already passed since it was first discussed (see Haab and McConnell, 2002, p. 8). The reader interested in further details is referred to these papers reporting on a meta-analysis each: Horowitz and McConnell (2002, 2003); Tunçel and Hammitt (2014).

2. Previous studies

The literature on the estimation of co-benefits of energy saving residential houses is limited. We have identified three studies that estimate the value of (co-)benefits of energy-efficient buildings or green building attributes using a sample of households without a living experience in these type of buildings (Spetic et al., 2005; Banfi et al., 2008; He et al., 2019), and two recent studies that have highlighted the experience good nature of these co-benefits and have analysed data provided by households with and without a living experience in energy efficient buildings. All these studies use a willingness to pay (WTP) approach.

In Canada, Spetic et al. (2005) measure preferences for healthy home attributes using a nationwide survey with 3,592 participants. Individuals taking the survey were asked a dichotomous question on whether they would be willing to pay extra —but not how much— if a guarantee could be made to them that their new houses would have i) better indoor air quality, ii) better lighting systems, and iii) better acoustics. Knowledge of the concept of ''healthy homes", along with age, income, gender, level of physical activity, and level of satisfaction with and importance placed on indoor air quality, were significant predictors of willingness to pay for better indoor air quality at home.

In Switzerland, Banfi et al. (2008) estimate the marginal WTP of 142 homeowners (and 163 households in rented apartments) for energy-saving characteristics such as window, facade, and ventilation system. They use a discrete choice experiment where the respondents could choose between the actual current situation and a hypothetical housing with different energy-saving characteristics and a different price (ceteris paribus). The resulting WTP for the ventilation system was estimated at 4% of existing houses' price, 12% of new buildings' price, and 8% of apartments' rental price.[6] The authors did not find heterogeneous effects of households characteristics and socio-economic variables on estimated WTP.

In Wuhan, China, He et al. (2019) estimate heterogeneous WTP for attributes of Green housing using a discrete choice experiment on a sample of 313 households. They find indoor air quality to be high among the attributes people were ready to pay for. Moreover, they conducted a post-estimation clustering analysis yielding findings suggesting that households can be classified according to socio-demographic characteristics and knowledge of Green housing, whereas the environmental concern could not be used to classify them.

A second strand of studies that intersect our interests are those that include the ''experience" factor in their analysis. Chau et al. (2010) have implemented a discrete choice experiment to infer whether residents with experience in living in a green residency have different WTP values for building enhancements than residents in conventional buildings. Generally, both green and conventional residents were willing to pay more for improving various aspects of environmental performance in green residential developments. They are found to be willing to pay more for energy conservation, than indoor air quality improvement and noise level reduction. However, no significant differences are found in the preferences between green and conventional residents for energy conservation, indoor air quality improvement or indoor noise reduction.

Golbazi et al. (2020) have studied answers provided by around 1,000 student residency occupants in conventional and green building residencies in the US. Participants were asked a multiple choice contingent valuation question on how much they were willing to pay extra for living in a green building as compared to a non-green building. Students in green residencies report higher satisfaction on thermal, lighting, and overall comfort levels, and report higher positive impact of their living environment on the quality of their studying. However, they find that the willingness to pay of students to reside in a green building upon graduation are comparable in both the study and the control population with 35% to 40% indicating no willingness to pay extra.

[6] Banfi et al. (2008) assume a house price of 650,000 CHF for new houses and and 686,000 CHF for existing single family houses. This corresponds to a WTP of 27,440 CHF and 78,000 CHF. Households in rented apartments expressed a WTP of 8% of the monthly rent. Assuming a rent of 1330 CHF/month for flats in existing buildings and 2030 CHF/month for flats in new buildings, Banfi et al. (2008) estimate a monthly WTP of 106–162 CHF/month.

Summarising, there are just two studies that have empirically estimated the value of (co-)benefits of energy efficient housing by gathering preferences of individuals that have a living experience in this type of buildings. As already mentioned previously, we think that the "experience dimension" is essential for the empirical valuation of co-benefits from energy efficient dwellings. The present study contributes to this nascent literature by providing estimates of values assigned to co-benefits from energy efficient houses by residents in Switzerland —which is particularly relevant given that European residents have been overlooked by this literature despite their potential contribution to tackle climate change via adoption of energy efficient dwellings.

3. Analytical framework

This study estimates the value of co-benefits from energy saving and comfort ventilation systems (ESV) —indoor air quality, noise reduction, and thermal comfort. As these co-benefits are bundled with energy savings —i.e. they all are delivered together simultaneously—, no market data are available that may allow for variation in co-benefits that could be associated with variation in prices, and thus revealed preferences methods are not useful in this context. Consequently, we resort to a stated preferences method to approximate the value of those co-benefits. These methods estimate measures of economic value through analysis of responses to survey questions. These questions are most commonly formulated either in a close-ended format to which only a yes- or a no-answer can be provided —a strategy called contingent valuation (CV)— or in a discrete choice experiment (DCE) format to which respondents react by expressing their preference among two or more multi-attribute alternatives (Johnston et al., 2017).

Both CV and DCE are feasible alternatives in our context. A DCE, for instance, may represent hypothetical variations in each co-benefit and corresponding changes in prices of ESV. However, this variation may be perceived as extremely unrealistic —recall, all four co-benefits are delivered as a bundle. Thus, we have decided to implement a CV protocol that simulates a scenario in which a home owner holds off on using their ESV. This scenario implies a change in all co-benefits at once, and we deem it more realistic.

Value of co-benefits of ESV can be approximated either from a willingness to accept (WTA) perspective or from a willingness to pay (WTP) approach —and both approaches are equivalent theoretically (Haab and McConnell, 2002). We have highlighted that co-benefits from ESV can be thought as attributes of an experience good —i.e. a good that cannot be appraised accurately unless it is experienced. Thus, we use a WTA approach to gather stated preferences from home owners that have experience with co-benefits under study. Consequently, this section describes our analytical framework in terms of WTA compensation.

According to canonical definition and referring to the decision of holding off on using ESV embedded in Minergie homes, we refer to WTA as the change in income that a home owner requests to be indifferent between the status quo (i.e. using ESV) and holding off on using ESV. Formally, WTA is defined implicitly in the following equality:

$$V(\mathbf{p}, q_1(e, a, t, n), y + WTA) = V(\mathbf{p}, q_0(e, a, t, n), y) \quad (1)$$

where

$$V(\mathbf{p}, q, y) = \max_{\mathbf{x}} \{U(\mathbf{x}, q) | \mathbf{p} \cdot \mathbf{x} \leq y\}$$

In equation (1), V stands for home owner's indirect utility, and results from maximizing utility function U subject to home owner's budget restriction ($\mathbf{p} \cdot \mathbf{x} \leq y$). V is a function of income (y) and prices ($\mathbf{p}$) of private goods ($\mathbf{x}$) —one of which is the energy saving ventilation system (q).[7] The energy saving ventilation system is decomposed

[7] As WTA and WTP applications are usually implemented in contexts dealing with changes in quality of public goods, q is usually described as a vector of public goods. As our application deals with a private good, we take the approach of using q to denote characteristics (co-benefits) of the private good of interest here (see Haab and McConnell, 2002, p.5).

in its four co-benefits $q(e, a, t, n)$: savings in energy costs (e), indoor air quality (a), thermal comfort (t), and noise reduction (n). Subscripts 0 and 1 in q_j denote, respectively, the status quo scenario in which a home owner uses their energy saving and comfort ventilation system, and the scenario in which a home owner holds off on using their energy saving and comfort ventilation system.

Keeping in mind that our WTA protocol has presented home owners to a single-bounded dichotomous choice question, the random utility model (RUM) is the theoretical model providing the elements to translate equation (1) into an empirically estimable model on answers to dichotomous WTA questions (Hanemann, 1984).[8] RUM's departure point is that home owners know exactly the factors determining their indirect utility functions and, consequently, their answers to a WTA question. However, researchers cannot observe a number of such factors and, therefore, they can only observe home owners' indirect utilities in an imprecise way —which ultimately implies that while indirect utilities are not random by nature, they behave as random variables from the researcher' point of view. Consequently, researchers can only make probabilistic statements about observed indirect utility functions (u):

$$Pr(yes_i) = Pr(u_1(y_i + bid_i, q_{1i}, \mathbf{z}_i, \epsilon_{1i}) > u_0(y_i, q_{0i}, \mathbf{z}_i, \epsilon_{0i})) \tag{2}$$

Granted a single-bounded dichotomous choice CV protocol presents each home owner with a randomly selected compensation or bid, $Pr(yes_i)$ in equation (2) stands for the probability that home owner i answers yes to the presented bid. This probability is equal to the probability that home owner's observed indirect utility is higher when holding off on using their energy saving ventilation system and receiving compensation —$u_1(y_i + bid_i, q_{1i}, \mathbf{z}_i, \epsilon_{1i})$— in comparison to observed indirect utility when remaining in status quo conditions —$u_0(y_i, q_{0i}, \mathbf{z}_i, \epsilon_{0i})$. In addition to depending on income (y), bid and benefits from energy saving and comfort ventilation (q_{ji}), observed indirect utilities (u_j) are functions of home owner's characteristics ($\mathbf{z}_i$) and an indicator of researcher's uncertainty (ϵ_{ji}).

Empirical estimation of equation (2) is feasible once two modelling decisions have been taken —form of utility functions u_j, and distribution of error terms ϵ_{ji}. Assume linear utility functions —i.e. that u_j are linear in income and covariates—:

$$u_{0i} = \gamma y_i + \beta q_{0i} + \boldsymbol{\alpha}_0 \mathbf{z}_i + \epsilon_{0i}$$

and

$$u_{1i} = \gamma(y_i + bid_i) + \beta q_{1i} + \boldsymbol{\alpha}_1 \mathbf{z}_i + \epsilon_{1i}$$

where γ stands for income's marginal utility, β stands for marginal utility provided by energy saving and comfort ventilation, and $\boldsymbol{\alpha_j}$ is a vector of parameters reflecting how utility under scenario j is influenced by home owner's characteristics. Accordingly, equation (2) can be expressed as

$$Pr(yes_i) = Pr(\gamma bid_i + \beta \Delta q_i + \boldsymbol{\alpha} \mathbf{z}_i + \epsilon_i > 0) \tag{3}$$

where $\epsilon_i \equiv \epsilon_{1i} - \epsilon_{0i}$; $\Delta q_i \equiv q_{1i} - q_{0i}$; and $\boldsymbol{\alpha} \equiv \boldsymbol{\alpha}_1 - \boldsymbol{\alpha}_0$.

Recall that the energy saving ventilation system provides four co-benefits —i.e. $q_i \equiv q_i(e, a, t, n)$. Subscript i attached to q denotes that the energy saving ventilation system provides a private service that is not uniform across home owners. This variation in service is direct consequence of variation in home owners' own experience with the energy saving ventilation system. This experience depends both on whether a home owner perceives or experiences co-benefits from energy saving ventilation and on the number of experienced co-benefits. Assume availability of home owner-level information that allows for statistical variation in perceived co-benefits—that we denote e_i, a_i, t_i, and n_i. Then, the change in private service provided by the energy saving ventilation system can be decomposed as $\Delta q_i = \Delta e_i + \Delta a_i + \Delta t_i + \Delta n_i$, where any or all four of the specific changes can take value zero depending on whether

[8] We have also considered the design of a double-bounded dichotomous question so that welfare measures are estimated with lower standard errors (Hanemann et al., 1991). The main reason for which we have chosen a single-bounded format is that our contingent valuation protocol has been part of a relatively lengthy survey gathering energy-related decisions of respondents.

home owner i perceives or experiences the corresponding co-benefit. Thus, equation (3) can be re-expressed as

$$Pr(yes_i) = Pr(\gamma bid_i + \beta_e \Delta e_i + \beta_a \Delta a_i + \beta_t \Delta t_i + \beta_n \Delta n_i + \boldsymbol{\alpha} \mathbf{z}_i + \epsilon_i > 0) \quad (4)$$

In this study, parameters γ, β_e, β_a, β_t, β_n, and $\boldsymbol{\alpha}$ are estimated via a logit specification which assumes that ϵ_i are independently and identically distributed, following a mean-zero logistic distribution —which results from assuming that ϵ_{0i} and ϵ_{1i} follow a extreme value distribution each.[9] With estimated parameters at hand, conditional average WTA for holding off on using the energy saving and comfort ventilation system can be calculated as (see Haab and McConnell, 2002; Hanemann, 1984, for details):

$$E_\epsilon(WTA_i|\hat{\gamma}, \hat{\boldsymbol{\beta}}, \hat{\boldsymbol{\alpha}}) = \frac{\hat{\beta}_e \Delta e_i + \hat{\beta}_a \Delta a_i + \hat{\beta}_t \Delta t_i + \hat{\beta}_n \Delta n_i + \hat{\boldsymbol{\alpha}} \mathbf{z}_i}{\hat{\gamma}}. \quad (5)$$

4. Contingent valuation protocols

4.1 Elicitation questions and bids

We have implemented two contingent valuation (CV) protocols —one of them gathers willingness to accept (WTA) compensation, and the other one gathers willingness to pay (WTP). As co-benefits from energy saving and comfort ventilation can be appraised once those co-benefits have been experienced, main findings in this study rely on answers by owners of Minergie houses to the WTA question. However, there is a potential for overestimation when analyzing answers to WTA questions —an empirical regularity that holds when studying public goods but only to a lesser extent when it comes to private goods (see Horowitz and McConnell, 2002, 2003; Tunçel and Hammitt, 2014). Thus, the WTP protocol has been designed to explore the magnitude of this potential overestimation.

All respondents to our CV protocols were presented to the following information:

> *We spend plenty of time in our house, particularly at night. Good indoor air quality therefore contributes significantly to our well-being and health. A so-called comfort ventilation system offers an advanced alternative to classic window ventilation: even with closed windows, the exhaled air is removed as needed and replaced by fresh outside air filtered from fine dust and preheated via a heat exchanger. This ensures* **good air quality, thermal comfort** *and* **reduced noise pollution**. *In addition, the supplied air is filtered from pollen, thus relieving allergy sufferers. The ventilation is also* **energy-saving**. *Waste heat is recovered from the polluted air, which would otherwise escape unused through the window.*

Owners of Minergie homes have experienced the ventilation system described above as it is embedded in their homes, and thus they have provided dichotomous answers (yes/no) to the following WTA question —numbers listed in brackets are the six bids randomly presented to respondents—:

> *Please, assume that the ventilation system in your dwelling has a defect at the beginning of a winter season. The ventilation system company informs you that it is a problem that they can fix but there is a shortage of staff at the moment. Therefore you would have to wait about 3 months before the ventilation system can be repaired.*
>
> *Do you find that CHF [40/80/120/160/200/240] per month is a reasonable compensation for the waiting time?*

[9] A probit specification is also feasible if we assume that ϵ_{0i} and ϵ_{1i} follow a normal distribution. Welfare measures arising from both specifications are, in practice, identical unless the implicit distribution present large tails —for which situation, a logit specification is preferred.

Owners of conventional (non-Minergie) homes have not experienced energy saving and comfort ventilation as described in the introductory paragraph, and thus they have responded to the following WTP question:

> Would you be willing to pay CHF [40/80/120/160/200/240] on a monthly basis during 20 years for a comfort ventilation as described above?

A first feature we highlight is that duration of the change implied by our CV question is different depending on whether we explore WTA or WTP. On one hand, the WTP question implies a *permanent* change from not owning to owning an energy saving and comfort ventilation system. On the other hand, the WTA question implies a change that would last three months. This difference in duration arises from the impracticability in simulating WTA scenarios implying an identical duration than WTP scenarios.

A WTA scenario implying a permanent change —from using/owning to not using/not owning an energy saving and comfort ventilation system— is not a realistic scenario. As energy saving and comfort ventilation is embedded in Minergie homes, simulating a permanent change in use/ownership of ventilation would imply a disutility due to changes beyond those associated with co-benefits of ventilation. Instead, presenting a temporary malfunction due to a repairable flaw is more realistic in this context.

A WTP scenario implying a temporary change —from not owning/not using to owning/using an energy saving and comfort ventilation system— is not realistic. For instance, an alternative to simulate a temporary change is to explore WTP to leasing a ventilation system. However, installation of an energy saving and comfort ventilation system for renting purposes becomes impractical due to installation costs —these costs represent a good portion of initial costs and they become sunk costs once they have been afforded. Another possibility to simulate a temporary change is to explore WTP for renting a house with an energy saving and comfort ventilation system. However, as our respondents are owners of their dwellings, simulating a rental market may be particularly unrealistic to them. A more realistic scenario in this context is to request that respondents consider the possibility of buying an energy saving and comfort ventilation system.

To assure comparability of welfare measures arising from both CV protocols, we have presented respondents to bids expressed on a monthly basis. Not only these bids are *standardised* in terms of periodicity but the range and set of values covered are identical across WTA and WTP questions —CHF 40, CHF 80, CHF 120, CHF 160, CHF 200, and CHF 240.

In pondering whether the range of monthly values covered by those bids is reasonable, keep in mind two back-of-the-envelop calculations. On the one hand, we have estimated that acquiring an energy saving and comfort ventilation system would represent monthly expenses within CHF 88 and CHF 96.[10] On the other hand, we have estimated that average premium for Minergie certification ranges somewhere between CHF 108 to CHF 218.[11] These numbers reflect approximations to the value of all four co-benefits either as revealed in the energy saving and comfort ventilation market —CHF 88 to CHF 96— or as revealed in the rental market —CHF 108 to CHF 218. Bids in our CV protocols closely cover the range of values delivered by those two back-of-the-envelop calculations. We have added CHF 40 at the lower tail of our estimated range so that we allow for lower stated WTP than our lower estimates in the revealed preferences space; similarly, we have added CHF 240 at the upper tail so that we

[10]In arising to these numbers, we have considered that a ventilation system as the one described in this study can be purchased for something between CHF 18,000 to CHF 20,000. We have assumed a lifespan of 20 years, and maintenance costs of CHF 150 on an annual basis. Leaving aside discount rate, a simple calculation on a monthly basis yields at least CHF 88 —$[18000/(20*12)+(150/12)]$—, and at most CHF 96 —$[20000/(20*12)+(150/12)]$.

[11]These numbers arise from OLS regressions on 21 observations reflecting monthly rental prices of apartments with 2.5 to 3.5 rooms in Zurich —zip codes 8008, 8004, 8041, and 8048. Regressions on rental prices and logarithm of rental prices have controlled for zip code fixed effects and a binary variable capturing whether an apartment is Minergie certified. While those regressions yield coefficients reflecting positive point estimates, standard errors do not allow rejection of the null hypothesis that premium is zero. Considering that we have analysed only 21 observations —10 of which correspond to Minergie apartments—, we deem these coefficients appropriate back-of-the-envelop calculations. Information was gathered manually from `https://en.comparis.ch/`.

allow for higher stated WTA than our upper estimates in the revealed preferences space.

4.2 Administration

Data have been collected via a survey implemented in 2020 in the Canton of Zurich, Switzerland. This survey was implemented in cooperation with the Statistical Office of the Canton of Zurich. We sent out personalised invitation letters by postal mail directly to a random sample of households. The invitation included a link to an online survey which was created using the software "Surveymonkey". Respondents answered the online survey in the period between 05.02.2020 and 13.03.2020.[12] In total, the Canton of Zurich sent out 16,700 letters on Feb. 3, 2020 on our behalf. The response rate was relatively high: 2,846 respondents out of 16,700 invitations, which implies a response rate of 17%.

More precisely, we divided the invitation sample into two groups: *1)* 14,629 letters were sent to a stratified sample of single family homes and *2) 2,071 letters were sent to all Minergie certified single-family homes in the Canton of Zurich*. The stratification for the first sample was implemented according to the following rules: only single-family homes, year of construction prior to 1990, 50% with renovation permits during the last 5 years; large buckets for age and household size. In the Canton of Zurich, there is a total of 127,950 single family homes, 10,737 out of which applied for a renovation permit during the past 5 years. Out of this first sample, 2,322 households responded to our survey. We refer to this sample as *conventional houses sample*. Out of the second sample where the letters were sent to Minergie homes, 524 households responded to our survey. We refer to this sample as *Minergie houses sample*.

Although our sampling strategy targeted a population of homeowners of single-family houses, a small number of respondents did not fall into this category. We had 161 tenants and also a small number of respondents (n=23) living in an apartment. Those observations are excluded for our analysis. Once missing values have been excluded, our working samples include 485 (Minergie houses sample) and 2,042 (conventional houses sample) observations, respectively.

4.3 Descriptive statistics

4.3.1 Respondents

Table 1 describes both samples under analysis —the Minergie houses sample (n=485), and the conventional houses sample (n=2,042). Respondents are not expected to be similar across samples. To begin with, owners of Minergie houses are expected to differ from owners of regular (non-Minergie homes) across dimensions such as income, ages and composition of the households because Minergie houses are more expensive and has been built with some frequency only in the last 20 years. Further, as most Minergie houses have been built in recent times, dwelling characteristics are expected to differ as well. Nevertheless, Table 1 reports t-tests from comparison of means to gain insights on the dimensions across which respondents differ.

The first row in Table 1 reports average bid presented to respondents. This variable, by design, is expected to be similar across both samples —the same set of bids has been presented randomly to respondents in both samples. Accordingly, respondents in Minergie houses sample faced an average bid of CHF 135 and respondents in conventional houses sample faced an average bid of CHF 139 —and a t-test statistic of 1.05 suggest that we cannot reject the null hypothesis that the difference between these means is zero.

[12] Note that the Swiss government declared an "extraordinary situation" (putting the nation into a semi-lockdown) only on March 16, 2020.

Next, Table 1 describes variables reflecting how important is each service provided by ESV —savings in energy costs, indoor air quality, thermal comfort, and noise reduction— for respondent's satisfaction with their home. In particular, while around 70.5% of respondents in the Minergie houses sample consider energy costs as an important feature for satisfaction with their home, only 46.9% of respondents in the conventional houses sample consider so. The corresponding percentages for, respectively, indoor air quality, thermal comfort, and noise are 81.6% versus 33.1%, 80.6% versus 56.0%, and 78.1% versus 61.0%. Thus, a general comparative characterisation is that a larger proportion of respondents in the Minergie houses sample considers that each service provided by ESV is important in comparison to respondents in the conventional houses sample —t-test statistics for all four services suggest that we can reject the null hypothesis that the differences across samples are zero. This characterisation is intuitive as we would expect that respondents that have already experienced ESV are aware of its services.

As the premise of this study is that respondents in the Minergie houses sample have experienced the services provided by ESV but respondents in conventional houses sample have not, we request respondents in the conventional houses sample to report whether household members suffer allergies, and use this variable as a proxy of relevance of indoor air quality had these respondents experienced ESV. Thus, Table 1 reports proportion of respondents at households with members suffering respiratory allergies at home. In particular, while 49.7% of respondents in the Minergie houses sample report respiratory allergies, 34.3% of respondents in the conventional sample report so. That is, a larger proportion of respondents in the Minergie houses sample report allergies at home in comparison to respondents in the conventional houses sample. This characterization is intuitive as we would expect that, ceteris paribus, households suffering allergies more likely own a home equipped with ESV that delivers services such as indoor air quality.

Respondent's socioeconomic and demographic characteristics is the next category of variables described in Table 1. The percentage of female respondents in, respectively, Minergie and conventional houses samples is 22.5% and 21.7%. Average respondent's age in Minergie houses sample is 52.5; and 58.9 in the conventional houses sample. Around 71.3% of respondents in Minergie houses sample are college educated; and around 60.4% in conventional houses sample. While 85.8% of respondents in Minergie houses sample are employed or self-employed, only 62.6% are employed in conventional houses sample.

In terms of households' monthly gross income, Table 1 reports proportion of respondents for six categories of income. These categories are i) below CHF 8,000; ii) between CHF 8,000 and CHF 12,000; iii) between CHF 12,000 and CHF 16,000; iv) between CHF 16,000 and CHF 20,000; v) over CHF 20,000; and vi) not reported/missing. The percentages for each of these categories, following the same order as listed above, are i) 6.4% (Minergie houses sample) versus 17.6% (conventional houses sample); ii) 24.3% (Minergie houses sample) versus 33.2% (conventional houses sample); iii) 23.3% (Minergie houses sample) versus 19.1% (conventional houses sample); iv) 19.4% (Minergie houses sample) versus 9.6% (conventional houses sample); v) 16.9% (Minergie houses sample) versus 9.9% (conventional houses sample); and vi) 9.7% (Minergie houses sample) versus 10.6% (conventional houses sample). Based on those income ranges and corresponding percentages, average monthly gross income for the Minergie houses sample is calculated at CHF 13,665, and at CHF 10,901 for the conventional houses sample.[13]

As part of socioeconomic and demographic characteristics of respondents, we have gathered information to create binary variables denoting that a respondent scores highest in terms of i) energy-related financial literacy, and ii) environmentally friendly behaviours.[14] Energy-related financial literacy is defined as "*the combination of energy cost-specific knowledge, financial literacy and cognitive abilities that are needed in order to take decisions with respect to the investment for the production of energy services and their consumption*" (Blasch et al., 2021).

[13]We have left the missing category out of this calculation.

[14]The motivation to focus on binary variables identifying respondents scoring the highest in each dimension is the relatively high lineal correlation between both dimensions —around 44%. By creating two binary variables, we argue, the potential collinearity is taken care of —around 5% of respondents have scored high in both dimensions, and a chi-squared test on the corresponding contingency table cannot reject the null hypothesis that the two binary variables are independent, with a p-value of 0.25.

Similar as in Blasch et al. (2021), we have approximated our respondents' energy-related financial literacy through five questions involving i) compound interest;[15] ii) inflation;[16] iii) risk diversification;[17] iv) calculation of lifetime energy costs;[18] and v) energy cost knowledge.[19] We have built an index that assigns one unit to respondents for each correct answer which implies that a respondent can score as high as 5 and as low as zero. Then, we have created a binary variable identifying respondents scoring the highest in terms of energy-related financial literacy.

Following Blasch et al. (2017), we extend their approximation of energy-saving behaviours to incorporate a wider range of environmentally-friendly behaviours through four questions involving i) frequency with which respondents perform energy-saving behaviours such as running only fully load washing machines, turning off lights when leaving a room, and completely shutting down electronic devices;[20] and ii) whether respondents have recently donated to an environmental NGO.[21] A respondent that engages in one energy-saving behaviour —either always or often— is assigned one unit; and if he/she has made a donation, she/he also gets a unit. Thus our index can reach a maximum of 4 and a minimum of zero. With this index at hand, we have created a binary variable that identifies respondents scoring the highest in terms of environmentally-friendly behaviour. According to Table 1, around 24.3% and 21.8% of respondents in, respectively, Minergie houses and conventional houses samples score highest in terms of energy-related financial literacy. For environmentally friendly behaviours, the corresponding numbers are 26.2% and 25.3% of respondents in, respectively, Minergie houses and conventional houses samples.

We have also gathered information about household composition. Around 68% of respondents in Minergie houses sample belong to a household composed by a couple with children; and 45.4% is the corresponding number in conventional houses sample. Couple without children represent around 21.2% of respondents in Minergie houses sample, and 42.6% in conventional houses sample. The rest of respondents are classified in categories that reflect a single person with or without children, other type of household, and those that did not answer the question.

Keeping in mind t-test statistics, a first component of a general description in terms of socioeconomic and demographic characteristics focuses on similarities across samples. Respondents to both samples include similar percentages of i) female respondents, ii) respondents scoring highest in energy-related financial literacy; and iii) respondents scoring highest in environmentally friendly behaviours. A second component of a general description in terms of socioeconomic and demographic characteristics focuses on differences across samples. Respondents in the Minergie houses sample are younger, and a larger percentage are college educated, employed or self-employed, wealthier, and in households composed by a couple with children. Differences across these dimensions are also intuitive because, due to only recent availability of Minergie houses, we would expect people owning these houses to be younger, better educated, wealthier, and in more stable conditions —as reflected by employment status and raising of children— than people who live in conventional houses.

Table 1 also describes dwelling's characteristics such as size in square meters, and decade in which the dwelling was built. As Minergie homes are of recent development, it does not come as a surprise that while 39.6% and 38.1% of respondents in Minergie houses sample own dwellings built, respectively, between 2000 and 2010 and 2010 or later, the corresponding numbers for the conventional houses sample are 0.5% and 1.2%, respectively. On the other hand, while most respondents in the conventional houses sample (98.3%) own dwellings built prior

[15] *Suppose you have CHF 100 in a savings account and you will receive 2% interest per year on this savings account. You will not make any further deposits or withdrawals on this account. What would be the balance after 5 years?*

[16] *Now suppose that instead you receive 1% of interest per year and that inflation in the same period is 2%. How much could you afford with the money in your account after one year?*

[17] *Is this statement true or false? "The purchase of shares of a single company usually offers a safer return than buying shares of several companies."*

[18] *Suppose that two heating systems are available on the market. Heating system A costs CHF 24,000 (lifetime: 20 years) and is expected to yield an annual heating bill of CHF 1,800. Heating System B costs CHF 18,000 (lifetime: 20 years) and is expected to yield an annual heating bill of CHF 2,300. Which heating system minimises the total cost over the lifetime?*

[19] *What do you think is the price of electricity that you are currently paying (low tariff), in cents/kWh?*

[20] *How regularly do you engage in the following activities in your daily life? a) Let washing machine or dishwasher only run with a full load; b) turning off the light when leaving a room for short period; c) complete shutdown of electronic devices.*

[21] *have you made a donation to an environmental organisation within the last 12 months?*

Table 1: Descriptive statistics of, respectively, Minergie houses sample (n=485) and conventional houses sample (n=2,042), and comparison of means

Variable	Minergie houses sample[a]	Conventional houses sample[b]	Diff.	Std. Errors	t-test
Bid (hundreds CHF)[c]	1.349	1.386	0.037	0.035	1.046
Factors that are important for respondent's satisfaction with his/her home					
1 if energy costs	0.705	0.469	-0.236	0.023	-10.070
1 if indoor air quality	0.816	0.331	-0.485	0.020	-23.742
1 if thermal comfort	0.806	0.560	-0.246	0.021	-11.678
1 if noise/acoustic factors	0.781	0.610	-0.172	0.022	-7.927
Whether allergies are suffered by household members					
1 if respiratory allergies	0.497	0.343	-0.154	0.025	-6.135
Respondent's socioeconomic and demographic characteristics					
1 if female	0.225	0.217	-0.008	0.021	-0.370
Respondent's age	52.505	58.952	6.447	0.502	12.834
1 if college-educated	0.713	0.604	-0.109	0.023	-4.696
1 if employed or self-employed	0.858	0.626	-0.231	0.019	-12.082
1 if hh monthly gross income is below 08K	0.064	0.176	0.112	0.014	8.052
1 if hh monthly gross income is 08K to 12K	0.243	0.332	0.089	0.022	4.012
1 if hh monthly gross income is 12K to 16K	0.233	0.191	-0.042	0.021	-1.991
1 if hh monthly gross income is 16K to 20K	0.194	0.096	-0.098	0.019	-5.118
1 if hh monthly gross income is over 20K	0.169	0.099	-0.070	0.018	-3.839
1 if hh monthly gross income is missing	0.097	0.106	0.009	0.015	0.589
1 max score in energy-related financial literacy[d]	0.243	0.218	-0.025	0.022	-1.178
1 max score in environmentally-friendly behaviours[d]	0.262	0.253	-0.009	0.022	-0.413
1 if couple with children	0.680	0.454	-0.226	0.024	-9.458
1 if couple without children	0.212	0.426	0.213	0.022	9.883
1 if single with children	0.058	0.029	-0.028	0.011	-2.522
1 if single without children	0.025	0.058	0.034	0.009	3.828
1 if no answer or other type	0.025	0.032	0.008	0.008	0.939
Dwelling's characteristics					
Decade in which dwelling was built					
1 if 1940 or earlier	0.064	0.255	0.191	0.015	12.959
1 if between 1941 and 1950	0.025	0.076	0.052	0.009	5.622
1 if between 1951 and 1960	0.023	0.112	0.089	0.010	9.158
1 if between 1961 and 1970	0.035	0.109	0.074	0.011	6.840
1 if between 1971 and 1980	0.037	0.207	0.170	0.012	13.655
1 if between 1981 and 1990	0.014	0.212	0.198	0.011	18.735
1 if between 1991 and 2000	0.025	0.012	-0.013	0.007	-1.743
1 if between 2000 and 2010	0.396	0.005	-0.390	0.022	-17.520
1 if 2010 or later	0.381	0.012	-0.369	0.022	-16.621
Size of dwelling (m^2)					
1 if 80 or less	0.006	0.017	0.010	0.005	2.299
1 if between 80 and 100	0.008	0.067	0.059	0.007	8.532
1 if between 100 and 120	0.041	0.165	0.123	0.012	10.100
1 if between 120 and 140	0.087	0.161	0.074	0.015	4.887
1 if between 140 and 160	0.148	0.169	0.020	0.018	1.128
1 if between 160 and 180	0.157	0.123	-0.033	0.018	-1.844
1 if between 180 and 200	0.177	0.092	-0.085	0.019	-4.608
1 if between 200 and 220	0.118	0.055	-0.063	0.015	-4.048
1 if between 220 and 240	0.095	0.046	-0.049	0.014	-3.498
1 if between 240 and 260	0.037	0.028	-0.009	0.009	-0.932
1 if between 260 and 280	0.025	0.022	-0.003	0.008	-0.412
1 if 300 or more	0.078	0.036	-0.042	0.013	-3.265
1 if not reported	0.023	0.020	-0.003	0.007	-0.349
Outdoor characteristics					
1 if urban area	0.501	0.619	0.118	0.025	4.712
PM 10 annual median	127.377	128.508	1.131	0.465	2.434

[a] Respondents in the Minergie houses sample have been presented to a willingness to accept (WTA) question, as described in section 4.1.

[b] Respondents in the conventional houses sample have been presented to a willingness to pay (WTP) question, as described in section 4.1.

[c] Respondents to both WTA- and WTP protocols have been randomly faced to the same six bids —CHF 40, CHF 80, CHF 120, CHF 160, CHF 200, CHF 240.

[d] In approximating energy-related financial literacy and environmentally-friendly behaviours, we have closely followed Blasch et al. (2017). Section 4.3.1 reports the battery of questions that we have implemented and provides details on our calculations.

2000, the corresponding number for respondents in Minergie houses sample is 22.3%. In terms of size, dwellings of Minergie houses respondents are bigger in average —as reflected by the smaller percentage among Minergie houses respondents of dwellings size 140 m^2 or less, and larger percentage of dwellings sizes between 180 m^2 and 240 m^2, and 300m^2 or more.

The last two rows in Table 1 describe variables capturing outdoor characteristics that may be relevant to infer values assigned to co-benefits of ESV. The first variable captures whether respondent resides in a urban area —50.1% of Minergie houses respondents and 61.9% of conventional houses respondents reside in urban areas. The second variable refers to PM10 annual median, measured as $\mu g/m^3$ —average value for Minergie houses respondents is 127.3, and 128.5 for conventional houses respondents.[22] Together, and keeping in mind the t-test statistics, these numbers suggest that Minergie houses respondents less likely reside in a urban location and they face less outdoor pollution on an annual basis.

To gain insights into whether respondents to our CV protocols are similar to the overall population in the canton of Zurich, we compare sample averages to Census statistics. For example, while the average age of the population over 20 years is 49.57 in the canton of Zurich, the average age in the Minergie houses sample is 52.5, and 58.9 in the conventional houses sample (Federal Statistical Office, 2020) —i.e. respondents to our CV protocols are older than residents over 20 years old. The average monthly gross income among households in the canton of Zurich is CHF 8,268 according to the national household budget survey (Federal Statistical Office, 2019a). As our estimates of average gross income are CHF 13,665 (Minergie houses sample) and CHF 10,901 (conventional houses sample), it seems that respondents to our CV protocols are wealthier than average households in Zurich. That our respondents are older and wealthier than average residents do not come as a surprise because our respondents are home owners and the average numbers for residents in Zurich include tenants —which tend to be less wealthy and younger.

In terms of dwelling characteristics, the national census median category of owner-occupied dwellings is 120-159m^2 (Federal Statistical Office, 2019b). This number is similar to the median in the conventional houses sample (140–160m^2), but smaller than the median the Minergie houses sample (180–200m^2). This pattern is also not surprising: as Minergie houses are owned by wealthier residents (as our own samples illustrate), they are likely bigger than conventional houses and median dwellings. Summarising, respondents to both of our samples are on older, earn a higher income, and occupy larger dwellings than the average residents in the canton of Zurich. And this pattern is not unexpected as our respondents are owners of single-houses.

4.3.2 Unconditional WTA and WTP

An initial check-up for consistency of responses to CV protocols consists in drawing a line illustrating the pattern that percentage of yes-responses follows as initial bid increases. Percentage of yes-responses to WTA bids is expected to monotonically increase; and monotonically decrease, for the case of yes-responses to WTP bids. Figures 1 and 2 support consistency of responses to, respectively, WTA bids and WTP bids. In addition, these figures motivate econometric findings reported in Section 5.

Figure 1 illustrates the percentage of yes-responses to WTA bids. The solid line reflects percentages arising from the entire Minergie houses sample (N=485). As expected, these percentages increase as bids increase —with exception of yes-responses to CHF 80. Around 30% of respondents answered yes to the lowest bid (CHF 40); and the highest bid (CHF 240) received around 59% of yes-responses. Figure 1 also illustrates the percentage of yes-responses by whether indoor air quality (IAQ) is important for respondent's satisfaction with their home. The dotted line lying above the solid line reflects percentages arising from the sub-sample of respondents that consider IAQ as important for satisfaction with their home. The dotted line lying below the solid line reflects percentages

[22] PM10 emissions data on ZIP code level were kindly provided from the Canton of Zurich, Building Department, Office for Waste, Water, Energy and Air, for a map see Figure 6 in the Appendix.

arising from the sub-sample of respondents that consider IAQ as not important for their satisfaction. Indeed, Figure 1 visually suggests that respondents in the Minergie houses sample that consider IAQ an important element of satisfaction require higher compensation to hold off using ESV.

Figure 2 reports the percentage of yes-responses to WTP bids. The solid line reflects percentages arising from the entire conventional houses sample (N=2,042). As expected, these percentages decrease as bids increase —in contrast to patterns in Figure 1, this decreasing pattern is monotonic. Around 38% of respondents answered yes to the lowest bid (CHF 40); and the highest bid (CHF 240) received around 19% of yes-responses. As respondents to WTP bids have not experienced IAQ provided by ESV, a binary variable reflecting whether there are household members with allergies is used as proxy of relevance of IAQ. Thus, Figure 2 also illustrates the percentage of yes-responses by whether household members suffer allergies. The dotted line lying above the solid line reflects percentages arising from the sub-sample of respondents with allergies at home. The dotted line lying below the solid line reflects percentages arising from the sub-sample without allergies at home. Consistently with the visual finding in Figure 1, Figure 2 visually suggests that respondents in the conventional houses sample that report allergies at home are willing to pay more for ESV.

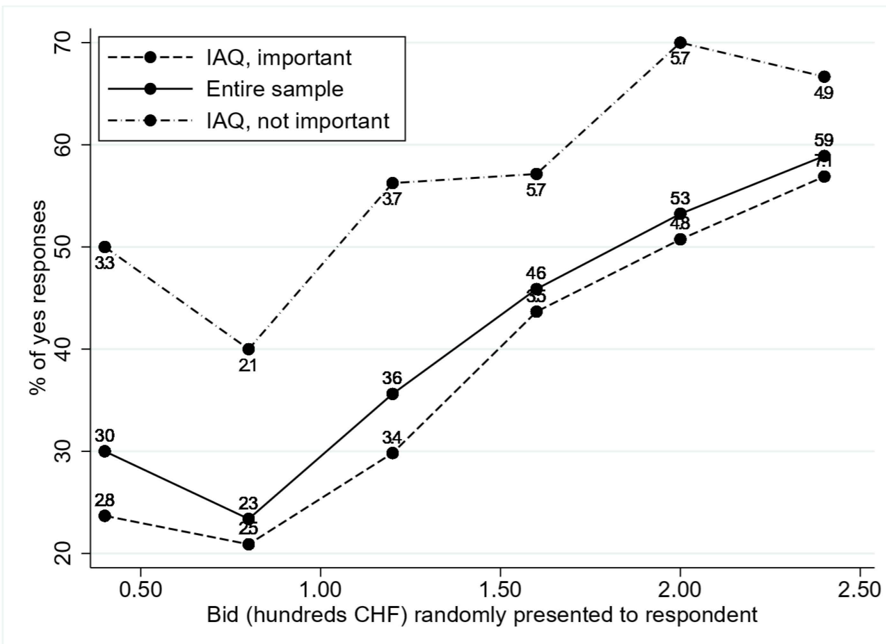

Figure 1: Percentage of yes-responses to WTA bids by whether indoor air quality (IAQ) is important for respondent's satisfaction with his/her home —WTA question was asked to respondents in Minergie houses sample (n=485).

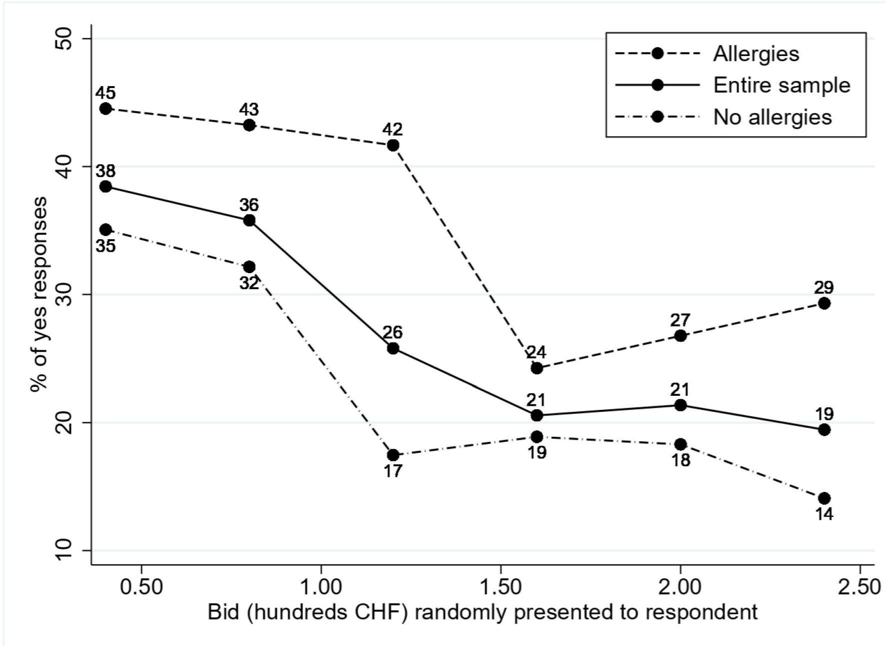

Figure 2: Percentage of yes-responses to WTP bids by allergies at respondent's home —WTP was asked to respondents in conventional houses sample (n=2,042).

5. Results

We deem willingness to accept (WTA) estimates as more informative than willingness to pay (WTP) estimates when it comes to the value assigned to co-benefits of energy saving and comfort ventilation systems because these co-benefits can be thought as attributes of an experience good. Indeed, due to the potential of overestimation embedded in WTA estimates, we also report WTP estimates. WTA estimates arise from responses provided by owners of Minergie houses, and WTP estimates arise from responses by owners of conventional houses. When comparing estimates arising from both samples, we keep in mind that respondents differ across samples in socioeconomic and demographic characteristics —as documented in section 4.3.1, respondents in the Minergie houses sample are younger, wealthier, and better educated.

5.1 Econometric specifications and welfare measures

Table 2 reports three logit specifications. The first two specifications —(WTA I) and (WTA II)— are estimated on binary answers (yes/no) to the WTA question, which has been answered by respondents in the Minergie houses sample. The third specification —(WTP I)— is estimated on answers to the WTP question, which has been answered by respondents in the conventional houses sample. In addition to including the bid (in hundreds CHF), all four specifications include four binary variables reflecting factors —i.e. energy costs, indoor air quality, thermal comfort, or noise— that respondents consider important for the satisfaction with their home. Specification (WTA I) is estimated on the entire working sample of Minergie home owners (n=485). Specification (WTA II) is estimated on a sample that excludes protest zeros from Minergie home owners (n=444).[23] Specification (WTP I) is estimated on the entire working sample of regular (non-Minergie) home owners (n=2,042) —this sample already excludes protest zeros. As coefficients from logit specifications are not interpretable as marginal effects, we direct our description of Table 2 towards the direction of the associations, and go into the discussion of magnitudes when

[23] We have classified as protest zeros those who reported that they *did not understand the scenario* (n=2); and those who responded that *it is the duty of the company to repair the ventilation* (n=39).

reporting implied welfare measures.

A first feature that we highlight in Table 2 is the home owners' responsiveness to the range of bids. As economic theory suggests, a higher bid increases the probability that Minergie home owners are willing to receive compensation to hold off using their energy saving and comfort ventilation system (ESV); and a higher bid decreases the probability that owners of conventional houses are willing to pay for ESV. These associations are statistically significant at a p-value lower than 0.001.

A second feature in Table 2 that we highlight is that respondents considering energy costs an important feature for the satisfaction with their home are more likely to answer yes to both WTA and WTP questions. The positive association for the WTP case is intuitive —a respondent is more willing to acquire an ESV when he/she cares about energy costs as these costs are expected to decrease once an ESV is installed. The positive association for the WTA case is less intuitive but insightful. It suggests that Minergie home owners that *only* care about energy costs can be more easily convinced to hold off using their ESV.

A third feature in Table 2 worth highlighting is that, from among all three co-benefits under study, indoor air quality is the only one with a statistically significant, negative association with the probability of accepting compensation to hold off using ESV. This implies that Minergie home owners that care about indoor air quality are less likely to be convinced to hold off using ESV. Putting together the energy costs and indoor air quality associations, it implies that a Minergie home owner that does not care about energy costs but cares about indoor quality would be less interested in accepting compensation to hold off using ESV in comparison to a respondent that cares about both co-benefits.

While the negative association between indoor air quality and probability of answering yes holds for the WTP case, it is not statistically significant. This result does not come as a surprise, as we have posed that co-benefits of ESV are valued once they are experienced. Instead, we would expect that presence of respiratory allergies at home is relevant among respondents in the conventional houses sample, and this is a finding that we want to highlight next. According to specification (WTP I), the willingness to buy an ESV increases with the presence of allergies at home. Mirroring the finding with respect to lack of statistical association between indoor air quality and WTP, allergies are not statistically associated with WTA.

Figure 3 reports estimates of WTA and their 95% confidence interval that arise from specification (WTA I) —which is estimated on the entire working sample of Minergie house owners (n=485). The first value (CHF 98) refers to the conditional WTA for holding off using ESV —this parameter is calculated by including only the intercept of specification (WTA I) in the numerator of equation (5). The second value (CHF 7) refers to the WTA for holding off using ESV of respondents that consider energy costs as important for home satisfaction —this value is calculated by including the intercept of specification (WTA I) and the coefficient reflecting the effect from energy costs in the numerator of equation (5). The third value (CHF 205) refers to the WTA for holding off using ESV of respondents that consider indoor air quality as important for home satisfaction —it is calculated according to equation (5) in a similar fashion as the the previous welfare measures. The fourth value (CHF 161) refers to the WTA for holding off using ESV of respondents that consider thermal comfort as important for home satisfaction. The fifth value (CHF 118) refers to the WTA for holding off using ESV of respondents that consider noise reduction as important for home satisfaction. The sixth value (CHF 197) refers to the WTA for holding off using ESV of respondents that consider energy costs and all three other services (indoor air quality, thermal comfort, and noise reduction) as important for home satisfaction. The seventh value (CHF 288) refers to the WTA for holding off using ESV of respondents that consider all services but energy costs as important for home satisfaction.

The last value (CHF 190) in Figure 3 reflects the WTA for all three co-benefits under study —indoor air quality, thermal comfort, and noise reduction. It is calculated as the difference between seventh and and first values (CHF 288 - CHF98 = CHF 190) reported in Figure 3. The 95% confidence interval takes on values from CHF 95 to CHF 300.

Table 2: Logit specifications on answers to single-bounded dichotomous questions —willingness to accept (WTA) question has been answered by respondents in Minergie houses sample; and willingness to pay (WTP) question, by respondents in conventional houses sample.

	(WTA I) Minergie houses (entire working sample)	(WTA II) Minergie houses (excluding protest zeros)	(WTP I) Conventional houses (excluding protest zeros)
Bid (hundreds CHF)	0.744***	0.761***	-0.550***
	(0.145)	(0.150)	(0.0761)
Factors that are important for respondent's satisfaction with his/her home			
1 if energy cost	0.676**	0.680**	0.225**
	(0.239)	(0.246)	(0.108)
1 if indoor air quality	-0.800**	-0.977**	-0.0334
	(0.289)	(0.308)	(0.121)
1 if thermal comfort	-0.466	-0.414	0.182
	(0.301)	(0.309)	(0.124)
1 if noise/acoustic factors	-0.149	0.0121	0.0744
	(0.267)	(0.275)	(0.119)
1 if respiratory allergies	-0.0481	-0.0687	0.644***
	(0.196)	(0.205)	(0.105)
Intercept	-0.728**	-0.608*	-0.747***
	(0.338)	(0.352)	(0.139)
Observations	485	444	2042
Pseudo R^2	0.0776	0.0841	0.0419
Loglikelihood	-302.2	-279.1	-1142.7
AIC	618.4	572.2	2299.4
BIC	647.7	600.8	2338.8

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

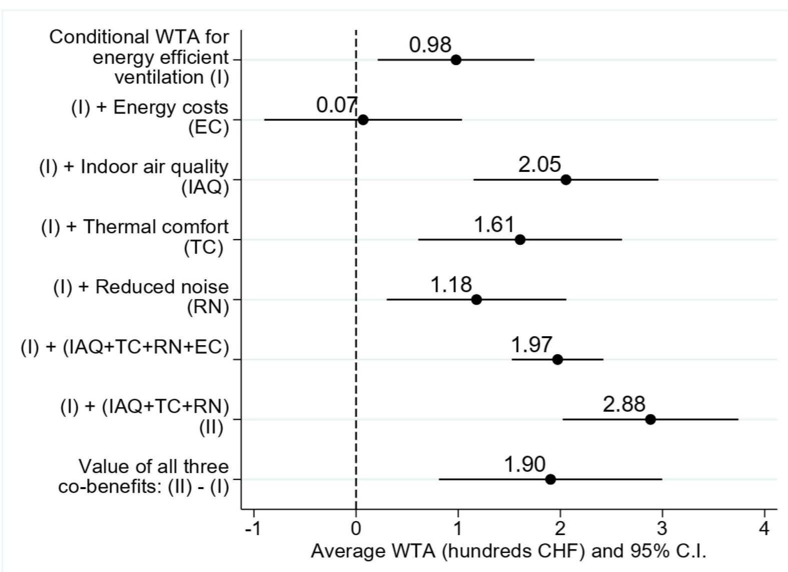

Figure 3: Willingness to accept (WTA) estimates on Minergie home owners (n= 485).

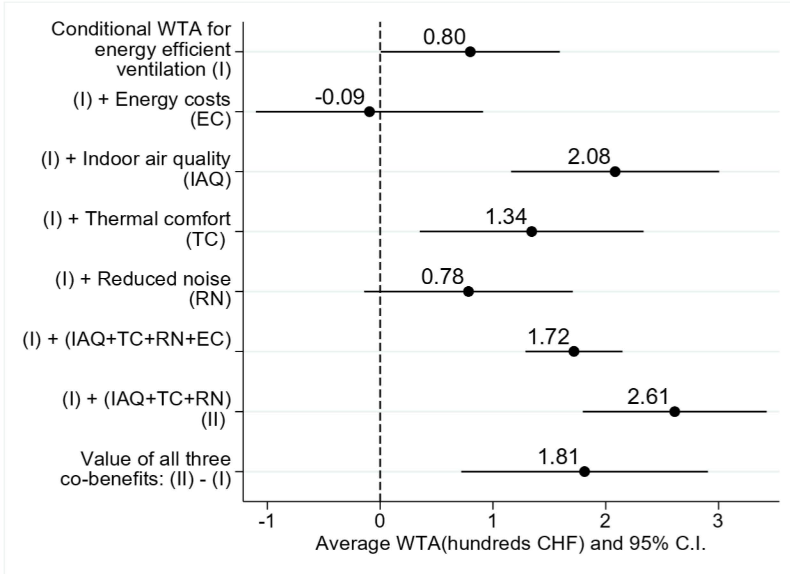

Figure 4: Willingness to accept (WTA) estimates on Minergie home owners, excluding protest zeros (n=444).

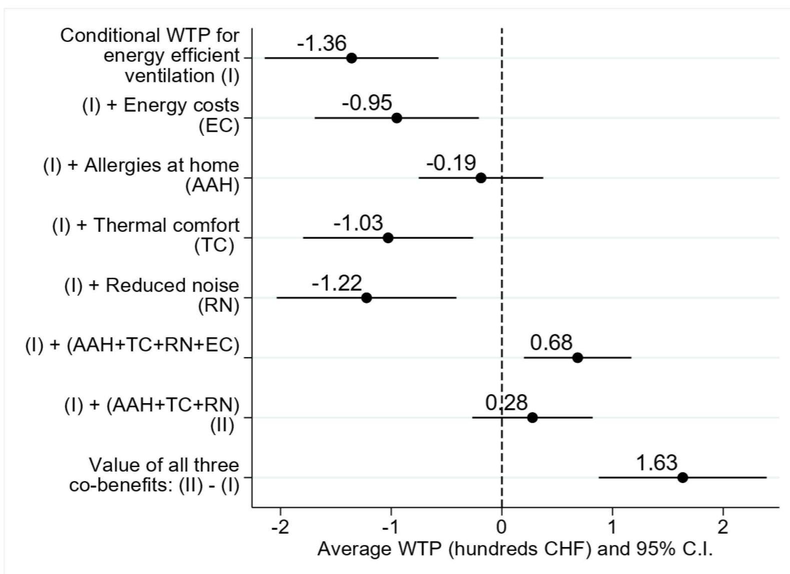

Figure 5: Willingness to pay (WTP) estimates on regular (non-Minergie) home owners (n=2,042)

Figure 4 illustrates that WTA estimates are robust to exclusion of protest zeros. Values reported in this figure follow the same structure as in Figure 3, and arise from specification (WTA II). Thus, the value at the bottom of Figure 4 reflects the WTA for all three co-benefits under study —indoor air quality, thermal comfort, and noise reduction. This number (CHF 181) is not only similar in terms of point value but its confidence interval amply overlaps with the confidence interval in Figure 3. Thus we conclude that WTA estimates are robust to protest zeros.

Figure 5 reports estimates of WTP and their 95% confidence interval that arise from specification (WTP I). Values reported in this figures follow the same structure as in Figure 3. Thus, the value at the bottom of Figure 5 reflects the WTP for all three co-benefits under study. The point estimate is CHF 163, with a confidence interval that takes on a range of values from 0.95 to 2.35. Indeed, the entire confidence interval of the WTP estimate is included in the confidence interval of the WTA estimate —both when including and when excluding protest zeros.

Thus the amply intersection of confidence intervals of both WTA and WTP estimates imply that a null hypothesis that the difference between these numbers (CHF 181 and CHF 163) is zero cannot be rejected.

The similarity in point estimates is striking if we bring into the conversation the differences in age, income, and education across our samples —respondents in the Minergie houses sample are younger, wealthier, and more educated. We would expect that these differences would translate into substantially higher WTA estimates in comparison to WTP —not only respondents in the Minergie houses sample are the ones that have experienced co-benefits of ESV but they are also wealthier. Indeed, it is reassuring that WTA and WTP are similar even when they arise from samples that differ in terms of income, education, and age. At this point, it is also worth pointing out that this similarity in WTA and WTP estimates is consistent with previous empirical studies concluding that WTA estimates tend to be closer to WTP when a private good is under study, in contrast to the case where a public good is studied (Horowitz and McConnell, 2002, 2003; Tunçel and Hammitt, 2014).

5.2 Econometric specifications controlling for additional factors, and robustness checks

We have performed a number of specifications that control for all variables described in Table 1 —sequentially and all together. Findings from these specifications are reported in Appendix A —Table A1 (WTA question) and Table A2 (WTP question). In comparison to specifications reported in Table 2, specifications controlling for additional factors provide only marginal improvement in statistical fit —as expressed by likelihood criteria such as AIC and BIC. This lack of improvement in statistical fit is rooted in the lack of statistical significance of most of the control variables. A number of specifications yield statistically significant coefficients for age, income, and employment status, but it does not substantially improve statistical performance of the model. In general, findings arising from specifications in Table 2 hold —both in direction and magnitude– under specifications reported in Tables A1 and A2.

Indeed, concerns may arise about whether our main finding —i.e. a striking similarity between WTA and WTP estimates— would hold in a case in which the conventional houses sample were similar in socioeconomic and demographic characteristics to the Minergie houses sample. Thus, as a way to check for the robustness of our main finding, we have carried out additional specifications on a sub-sample of conventional houses respondents. This sub-sample arises from a propensity matching score specification that has *paired* 315 conventional houses respondents (out of 2,042 respondents in our working sample) to 485 respondents in the Minergie houses sample. Table A3 reports a comparison of weighted means of variables used in the propensity score matching —weights reflect the number of Minergie houses to which a conventional house has been paired to. The main message in Table A3 is that the *paired* sub-sample of conventional houses owners may be considered a *statistical twin* of the Minergie houses sample in terms of socioeconomic and demographic characteristics considered in the propensity matching score.[24] We have estimated logit specifications on the conventional houses sub-sample, and have calculated WTP estimates of the value of co-benefits under study. Figure 7 reports a WTP of CHF 269 for all three co-benefits. This robustness check suggests that the more similar conventional houses owners are to Minergie houses owners, the higher WTP estimates become —to the point where point WTP estimates may be substantially higher than WTA estimates.

Considering our findings and robustness checks all together, we conclude that WTA estimates are backed up by WTP estimates in that CHF 181 is a reasonable estimate of the value of all three co-benefits of ESV —which is mostly dominated by the valuation of indoor air quality.

[24] Indeed, we have considered dwelling characteristics in our pairing strategy. However, matching becomes more difficult under these stricter requirements. We acknowledge that this is a limitation in this robustness check. However, keep in mind that the study has not been designed to yield *statistical twins* across samples.

6. Conclusions

For household decision makers and real estate companies that have to decide between building a new house equipped with an energy saving and comfort ventilation or a new conventional house, it is important to consider costs and benefits of both alternatives. In particular, benefits in this context arise not only in the form of 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 as well as real estate companies thus tend to not consider them in their investment analysis.

This study provides insights into the value assigned to co-benefits of an energy saving and comfort ventilation system by Swiss home owners that *have experienced* such co-benefits —respondents to our willingness to accept protocol own a house with an embedded energy saving and comfort ventilation system. Based on a willingness to accept (WTA) protocol, average monthly value of those co-benefits is estimated at CHF 181 —a value dominated mostly by indoor air quality. A general downside of WTA estimates is the potential for overestimation. For this reason, we have also estimated willingness to pay (WTP) for those co-benefits on a sample of owners of conventional houses. Average monthly WTP is CHF 163 —a value dominated mostly by presence of allergies at home, which is our approximation to relevance of indoor air quality for respondents that have not experienced an energy saving and comfort ventilation system yet.

Informing a cost-benefit analysis with our WTA estimates of the value of co-benefits (CHF 181) yields benefits that are twice as much as costs —thus justifying investment in energy savings and comfort ventilation 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 energy saving and comfort ventilation system.[25]

We can also compare our estimates to values reported in previous studies. For instance, Banfi et al. (2008) estimate the marginal willingness to pay of Swiss homeowners and households living in rented flats for energy saving and comfort ventilation systems. The resulting WTP for the ventilation system was estimated between 4% and 12% of the house price. Assuming a rent of 1330 CHF/month for flats in existing buildings and 2030 CHF/month for flats in new buildings, Banfi et al. (2008)'s percentages are equivalent to a monthly WTP between CHF 106 and CHF 162 —notice that the upper bound of this range is close to our WTP estimates (CHF 163).

Our findings have implications for real estate companies as well as policy makers. Real estate companies may use estimates reported in this study to inform their investment decisions when it comes to construction of new buildings or renovation of old ones. From an energy and climate policy point of view, our findings suggest that adoption of energy saving houses may be boosted if government agencies underline the presence and value of non-energy related co-benefits —in particular, indoor air quality. Public campaigns and educational programs for house construction companies, architects, and household decision makers are two options to communicate co-benefits of energy saving houses.

In the light of recent evidence, both information campaigns and educational programs may be designed to include tools that support decisions makers in companies and households. For instance, Blasch et al. (2022) have documented that an online lifetime calculator can boost Swiss residents' ability to identify energy efficient appliances. A similar calculator can be designed to support a residents' ability to identify energy efficient homes. This calculator can provide a fuller picture of benefits and costs of energy saving investments by informing it with our estimates of value of co-benefits .

In addition, government agencies may want to consider the designing of a label reflecting not only energy saving features of houses but also communicating the presence and value of co-benefits from such energy saving features —e.g. a "Comfort and Energy Saving House" label. Current labels aiming to inform decision makers in Switzerland

[25] We have reported the details of this calculation in section 4.1.

—e.g. Minergie houses— and elsewhere mainly focus on the energy savings component.

As the value of co-benefits from energy efficient ventilation system is dominated by indoor air quality, we want to highlight that three million residents in Switzerland are currently affected by some form of respiratory allergy —e.g. around 20% of the population suffer from a pollen allergy.[26] These people can directly benefit from living in a house with an energy saving and comfort ventilation system. Further, these individuals represent the *low-hanging fruit* for public policies that may include information campaigns, educational programs, and decision support tools. As COVID-19 has made it clear, improvement of indoor air quality has become a matter of public health because residents in urban contexts spend more than 90% of their time in indoor environments, most of which have poor air quality (The Economist, 2021).

[26] https://www.aha.ch/swiss-allergy-centre

References

Banfi, S., Farsi, M., Filippini, M., and Jakob, M. (2008). Willingness to pay for energy-saving measures in residential buildings. *Energy economics*, 30(2):503–516.

Blasch, J., Boogen, N., Daminato, C., and Filippini, M. (2021). Empower the consumer! energy-related financial literacy and its implications for economic decision making. *Economics of Energy & Environmental Policy*, 10(2).

Blasch, J., Boogen, N., Filippini, M., and Kumar, N. (2017). Explaining electricity demand and the role of energy and investment literacy on end-use efficiency of Swiss households. *Energy Economics*, 68 (Suppl. 1):89–102.

Blasch, J. E., Filippini, M., Kumar, N., and Martinez-Cruz, A. L. (2022). Boosting the choice of energy-efficient home appliances: the effectiveness of two types of decision support. *Applied Economics*, pages 1–23.

Chau, C.-K., Tse, M., and Chung, K. (2010). A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes. *Building and Environment*, 45(11):2553–2561.

Federal Council (2021). Switzerland's Long-Term Climate Strategy. https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/emission-reduction/reduction-targets/2050-target/climate-strategy-2050.html.

Federal Statistical Office (2019a). Household Budget Survey, Haushaltseinkommen und -ausgaben nach Kanton. https://www.bfs.admin.ch/bfs/en/home/statistics/economic-social-situation-population/income-consumption-wealth/household-budget.html.

Federal Statistical Office (2019b). Verteilung der Wohnfläche der bewohnten Wohnungen nach Bewohnertyp. https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/wohnverhaeltnisse/mieter-eigentuemer.assetdetail.7346284.html.

Federal Statistical Office (2020). Demographic balance by age and canton. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung.assetdetail.14087717.html.

Filippini, M. and Obrist, A. (2022). Are households living in green certified buildings consuming less energy? Evidence from Switzerland. *Energy Policy*, 161:112724.

Golbazi, M., El Danaf, A., and Aktas, C. B. (2020). Willingness to pay for green buildings: A survey on students' perception in higher education. *Energy and Buildings*, 216:109956.

Haab, T. C. and McConnell, K. E. (2002). *Valuing environmental and natural resources: the econometrics of non-market valuation*. Edward Elgar Publishing.

Hanemann, M., Loomis, J., and Kanninen, B. (1991). Statistical efficiency of double-bounded dichotomous choice contingent valuation. *American journal of agricultural economics*, 73(4):1255–1263.

Hanemann, W. M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. *American journal of agricultural economics*, 66(3):332–341.

He, C., Yu, S., Han, Q., and de Vries, B. (2019). How to attract customers to buy green housing? their heterogeneous willingness to pay for different attributes. *Journal of Cleaner Production*, 230:709–719.

Horowitz, J. K. and McConnell, K. E. (2002). A review of wta/wtp studies. *Journal of environmental economics and Management*, 44(3):426–447.

Horowitz, J. K. and McConnell, K. E. (2003). Willingness to accept, willingness to pay and the income effect. *Journal of economic behavior & organization*, 51(4):537–545.

Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., Hanemann, W. M., Hanley, N., Ryan, M., Scarpa, R., et al. (2017). Contemporary guidance for stated preference studies. *Journal of the Association of Environmental and Resource Economists*, 4(2):319–405.

Kahn, M. E., Sun, W., and Zheng, S. (2022). Clean air as an experience good in urban china. *Ecological Economics*, 192:107254.

Kahneman, D. and Thaler, R. H. (2006). Anomalies: Utility maximization and experienced utility. *Journal of Economic Perspectives*, 20(1):221–234.

Salvi, M., Horehájová, A., and Müri, R. (2008). Der Nachhaltigkeit von Immobilien einen finanziellen Wert geben – Minergie macht sich bezahlt. Technical report, Center for Corporate Responsibility and Sustainability, University of Zurich.

Spetic, W., Kozak, R., and Cohen, D. (2005). Willingness to pay and preferences for healthy home attributes in canada. *Forest Products Journal*, 55(10):19.

Sunstein, C. R. (2019). Rear visibility and some unresolved problems for economic analysis (with notes on experience goods). *Journal of Benefit-Cost Analysis*, 10(3):317–350.

The Economist (2021). It is time to clean up the air in buildings. `https://www.economist.com/leaders/2021/05/29/it-is-time-to-clean-up-the-air-in-buildings`.

Tunçel, T. and Hammitt, J. K. (2014). A new meta-analysis on the wtp/wta disparity. *Journal of Environmental Economics and Management*, 68(1):175–187.

A. Tables

Table A1: Logit specifications on answers to single-bounded willingness to accept (WTA) question answered by respondents in Minergie houses sample —protest zeros have been excluded (n=444).

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
Bid (hundreds CHF)	0.742***	0.761***	0.780***	0.802***	0.814***	0.812***	0.813***	0.818***	0.813***	0.813***
	(0.145)	(0.150)	(0.153)	(0.154)	(0.155)	(0.157)	(0.157)	(0.158)	(0.157)	(0.157)
1 if energy cost		0.680**	0.694**	0.679**	0.674**	0.665**	0.665**	0.686**	0.667**	0.668**
		(0.246)	(0.255)	(0.256)	(0.257)	(0.259)	(0.259)	(0.261)	(0.259)	(0.260)
1 if indoor air quality		-0.977**	-1.066***	-1.149***	-1.176***	-1.179***	-1.179***	-1.180***	-1.181***	-1.178***
		(0.308)	(0.319)	(0.325)	(0.326)	(0.328)	(0.328)	(0.328)	(0.328)	(0.328)
1 if thermal comfort		-0.414	-0.391	-0.337	-0.304	-0.288	-0.286	-0.288	-0.290	-0.290
		(0.309)	(0.314)	(0.318)	(0.320)	(0.322)	(0.323)	(0.323)	(0.323)	(0.323)
1 if noise/acoustic factors		0.0121	0.0721	0.108	0.0982	0.0899	0.0890	0.0779	0.0837	0.0903
		(0.275)	(0.280)	(0.283)	(0.283)	(0.283)	(0.284)	(0.284)	(0.284)	(0.284)
1 if respiratory allergies		-0.0687	-0.0418	-0.0330	-0.0295	-0.0244	-0.0242	-0.0134	-0.0200	-0.0218
		(0.205)	(0.208)	(0.209)	(0.211)	(0.212)	(0.212)	(0.213)	(0.212)	(0.212)
1 if female			-0.187	-0.238	-0.286	-0.311	-0.310	-0.304	-0.307	-0.311
			(0.264)	(0.266)	(0.271)	(0.274)	(0.275)	(0.275)	(0.275)	(0.275)
Respondent's age			-0.0255*	-0.0284**	-0.0312**	-0.0317**	-0.0316**	-0.0311**	-0.0316**	-0.0316**
			(0.0135)	(0.0136)	(0.0145)	(0.0150)	(0.0151)	(0.0151)	(0.0151)	(0.0151)
1 if college-educated			0.0257	0.0467	0.0582	0.0532	0.0550	0.0430	0.0551	0.0494
			(0.249)	(0.251)	(0.252)	(0.253)	(0.255)	(0.256)	(0.255)	(0.256)
1 if employed or self-employed			-1.187**	-1.227***	-1.245**	-1.260**	-1.260**	-1.250**	-1.256**	-1.260**
			(0.371)	(0.372)	(0.382)	(0.386)	(0.386)	(0.387)	(0.386)	(0.386)
1 if hh monthly gross income is missing			-0.223	-0.248	-0.225	-0.235	-0.233	-0.229	-0.229	-0.231
			(0.399)	(0.406)	(0.408)	(0.414)	(0.415)	(0.415)	(0.415)	(0.415)
1 if hh monthly gross income is over 12K			0.0419	0.0405	0.0670	0.0852	0.0863	0.0973	0.0881	0.0895
			(0.249)	(0.251)	(0.253)	(0.257)	(0.257)	(0.258)	(0.257)	(0.258)
1 max score in energy-related financial literacy				-0.456*	-0.457*	-0.455*	-0.454*	-0.452*	-0.453*	-0.454*
				(0.247)	(0.247)	(0.248)	(0.248)	(0.249)	(0.249)	(0.248)
1 max score in environmentally-friendly behaviors				0.169	0.181	0.182	0.182	0.200	0.190	0.185
				(0.242)	(0.243)	(0.245)	(0.245)	(0.246)	(0.247)	(0.246)
1 if couple with children					-0.336	-0.329	-0.329	-0.313	-0.328	-0.325

Continued on next page

Table A1: Logit specifications on answers to single-bounded willingness to accept (WTA) question answered by respondents in Minergie houses sample —protest zeros have been excluded (n=444).

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
					(0.353)	(0.354)	(0.354)	(0.354)	(0.354)	(0.354)
1 if couple without children					-0.273	-0.283	-0.283	-0.266	-0.278	-0.277
					(0.397)	(0.403)	(0.403)	(0.403)	(0.403)	(0.403)
1 if 2010 or later						-0.00402	-0.00484	-0.00958	-0.00883	-0.00706
						(0.226)	(0.226)	(0.227)	(0.227)	(0.227)
1 if 160 or less						0.0748	0.0754	0.0419	0.0675	0.0698
						(0.241)	(0.241)	(0.244)	(0.243)	(0.242)
1 if not reported						0.443	0.443	0.390	0.427	0.441
						(0.703)	(0.703)	(0.703)	(0.706)	(0.702)
1 if urban area							-0.0128	-0.0922	-0.0401	-0.0391
							(0.215)	(0.235)	(0.236)	(0.236)
PM 10 annual maximum								0.00224		
								(0.00263)		
PM 10 annual median									0.00367	
									(0.0130)	
PM 10 annual standard deviation										0.00798
										(0.0294)
Constant	-1.253***	-0.608*	1.718*	1.944*	2.356**	2.364**	2.361**	1.937	1.904	2.311**
	(0.224)	(0.352)	(0.998)	(1.010)	(1.102)	(1.139)	(1.140)	(1.243)	(1.981)	(1.154)
Observations	444	444	444	444	444	444	444	444	444	444
Pseudo-R^2	0.0456	0.0841	0.103	0.109	0.111	0.111	0.111	0.113	0.111	0.111
Loglikelihood	-290.8	-279.1	-273.4	-271.5	-271.0	-270.8	-270.8	-270.4	-270.7	-270.7
AIC	585.6	572.2	572.9	572.9	576.0	581.6	583.6	584.8	585.5	585.5
AIC	593.8	600.8	626.1	634.4	645.7	663.5	669.6	674.9	675.6	675.6

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table A2: Logit specifications on answers to single-bounded willingness to pay (WTP) question answered by respondents in conventional houses sample —protest zeros have been excluded (n=2,042).

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
Bid (hundreds CHF)	-0.532***	-0.550***	-0.554***	-0.555***	-0.553***	-0.554***	-0.558***	-0.558***	-0.558***	-0.557***
	(0.0750)	(0.0761)	(0.0765)	(0.0765)	(0.0766)	(0.0767)	(0.0768)	(0.0769)	(0.0768)	(0.0769)
1 if energy cost		0.225**	0.247**	0.251**	0.252**	0.255**	0.264**	0.263**	0.264**	0.263**
		(0.108)	(0.109)	(0.109)	(0.109)	(0.109)	(0.110)	(0.110)	(0.110)	(0.110)
1 if indoor air quality		-0.0334	-0.0453	-0.0455	-0.0392	-0.0410	-0.0348	-0.0367	-0.0331	-0.0371
		(0.121)	(0.121)	(0.122)	(0.122)	(0.122)	(0.122)	(0.122)	(0.122)	(0.122)
1 if thermal comfort		0.182	0.200	0.196	0.185	0.180	0.185	0.186	0.187	0.185
		(0.124)	(0.125)	(0.125)	(0.126)	(0.126)	(0.126)	(0.126)	(0.126)	(0.126)
1 if noise/acoustic factors		0.0744	0.0678	0.0709	0.0789	0.0720	0.0686	0.0687	0.0659	0.0691
		(0.119)	(0.120)	(0.120)	(0.120)	(0.121)	(0.121)	(0.121)	(0.121)	(0.121)
1 if respiratory allergies		0.644***	0.609***	0.609***	0.591***	0.599***	0.587***	0.586***	0.587***	0.586***
		(0.105)	(0.108)	(0.108)	(0.109)	(0.109)	(0.110)	(0.110)	(0.110)	(0.110)
1 if female			-0.0695	-0.0571	-0.0162	-0.0160	-0.0383	-0.0371	-0.0407	-0.0369
			(0.130)	(0.131)	(0.134)	(0.135)	(0.135)	(0.135)	(0.135)	(0.135)
Respondent's age			0.00431	0.00466	0.00720	0.00623	0.00537	0.00540	0.00529	0.00539
			(0.00617)	(0.00619)	(0.00682)	(0.00686)	(0.00688)	(0.00688)	(0.00688)	(0.00688)
1 if college-educated			-0.0232	-0.0244	-0.0220	-0.0426	-0.0562	-0.0558	-0.0591	-0.0553
			(0.115)	(0.115)	(0.116)	(0.117)	(0.117)	(0.117)	(0.117)	(0.117)
1 if employed or self-employed			0.137	0.139	0.144	0.144	0.123	0.124	0.123	0.123
			(0.162)	(0.162)	(0.163)	(0.163)	(0.164)	(0.164)	(0.164)	(0.164)
1 if hh monthly gross income is missing			-0.230	-0.231	-0.240	-0.261	-0.282	-0.282	-0.285	-0.282
			(0.187)	(0.187)	(0.187)	(0.188)	(0.189)	(0.189)	(0.189)	(0.189)
1 if hh monthly gross income is over 12K			0.293**	0.289**	0.264**	0.232*	0.221*	0.222*	0.217*	0.222*
			(0.118)	(0.118)	(0.119)	(0.121)	(0.122)	(0.122)	(0.122)	(0.122)
1 max score in energy-related financial literacy				0.0778	0.0781	0.0882	0.0929	0.0935	0.0886	0.0929
				(0.124)	(0.124)	(0.125)	(0.125)	(0.125)	(0.125)	(0.125)
1 max score in environmentally-friendly behaviors				-0.0452	-0.0424	-0.0422	-0.0382	-0.0388	-0.0390	-0.0383
				(0.120)	(0.121)	(0.121)	(0.121)	(0.121)	(0.121)	(0.121)
1 if couple with children					0.308	0.287	0.290	0.289	0.291	0.288

Continued on next page

Table A2: Logit specifications on answers to single-bounded willingness to pay (WTP) question answered by respondents in conventional houses sample —protest zeros have been excluded (n=2,042).

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
					(0.197)	(0.198)	(0.198)	(0.198)	(0.198)	(0.198)
1 if couple without children					0.222	0.227	0.240	0.240	0.241	0.239
					(0.188)	(0.189)	(0.190)	(0.190)	(0.190)	(0.190)
1 if 2010 or later						-0.242	-0.255	-0.253	-0.250	-0.255
						(0.486)	(0.488)	(0.488)	(0.489)	(0.488)
1 if 160 or less						-0.155	-0.171	-0.170	-0.173	-0.169
						(0.110)	(0.111)	(0.111)	(0.111)	(0.111)
1 if not reported						-0.124	-0.138	-0.138	-0.143	-0.141
						(0.389)	(0.390)	(0.390)	(0.390)	(0.390)
1 if urban area							0.214*	0.227*	0.184	0.233*
							(0.109)	(0.121)	(0.124)	(0.122)
PM 10 annual maximum								-0.000322		
								(0.00125)		
PM 10 annual median									0.00309	
									(0.00602)	
PM 10 annual standard deviation										-0.00533
										(0.0148)
Constant	-0.284**	-0.747***	-1.151**	-1.180**	-1.567**	-1.380**	-1.428**	-1.379**	-1.796**	-1.399**
	(0.108)	(0.139)	(0.473)	(0.474)	(0.540)	(0.555)	(0.556)	(0.587)	(0.907)	(0.562)
Observations	2042	2042	2042	2042	2042	2042	2042	2042	2042	2042
Pseudo-R^2	0.0218	0.0419	0.0476	0.0478	0.0489	0.0498	0.0514	0.0515	0.0516	0.0515
Loglikelihood	-1166.7	-1142.7	-1135.9	-1135.6	-1134.3	-1133.2	-1131.3	-1131.3	-1131.2	-1131.2
AIC	2337.4	2299.4	2297.7	2301.2	2302.7	2306.5	2304.6	2306.5	2306.3	2306.5
BIC	2348.6	2338.8	2370.8	2385.5	2398.2	2418.9	2422.7	2430.2	2430.0	2430.2

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table A3: Comparison of weighted means of variables used in propensity matching score —Minergie houses sample contains 485 observations and conventional houses sub-sample contains 118 observations, which have been weighted based on the number of Minergie households that have been *paired* to.

Variable	**Minergie houses sample**[a]	**Conventional houses sample**[b]	**Diff.**	**Std. Errors**	**t-test**
Bid (hundreds CHF)	1.349	1.359	-0.01	0.044	-0.226
1 if energy cost	0.705	0.724	-0.019	0.029	-0.639
1 if indoor air quality	0.816	0.798	0.019	0.025	0.732
1 if thermal comfort	0.806	0.825	-0.019	0.025	-0.744
1 if noise/acoustic factors	0.781	0.761	0.021	0.027	0.764
1 if respiratory allergies	0.497	0.522	-0.025	0.032	-0.77
1 if female	0.225	0.216	0.008	0.027	0.309
Respondent's age	52.505	52.237	0.268	0.626	0.428
1 if college-educated	0.713	0.713	0.000	0.029	0.000
1 if employed or self-employed	0.858	0.866	-0.008	0.022	-0.372
1 if hh monthly gross income is below 08K	0.064	0.06	0.004	0.015	0.266
1 if hh monthly gross income is 08K to 12K	0.243	0.252	-0.008	0.028	-0.297
1 if hh monthly gross income is 12K to 16K	0.233	0.247	-0.014	0.027	-0.526
1 if hh monthly gross income is 16K to 20K	0.194	0.175	0.019	0.025	0.744
1 if hh monthly gross income is over 20K	0.169	0.165	0.004	0.024	0.172
1 if hh monthly gross income is missing	0.097	0.101	-0.004	0.019	-0.215
1 max score in energy-related financial literacy	0.243	0.256	-0.012	0.028	-0.445
1 max score in environmentally-friendly behaviors	0.262	0.276	-0.014	0.029	-0.506
1 if couple with children	0.68	0.722	-0.041	0.029	-1.403
1 if couple without children	0.212	0.194	0.019	0.026	0.718
1 if single with children	0.058	0.047	0.01	0.014	0.719
1 if single without children	0.025	0.014	0.01	0.009	1.158
1 if no answer or other type	0.025	0.023	0.002	0.01	0.211
1 if urban area	0.501	0.489	0.012	0.032	0.385
PM 10 annual median	127.377	126.695	0.682	0.591	1.155

B. Figures

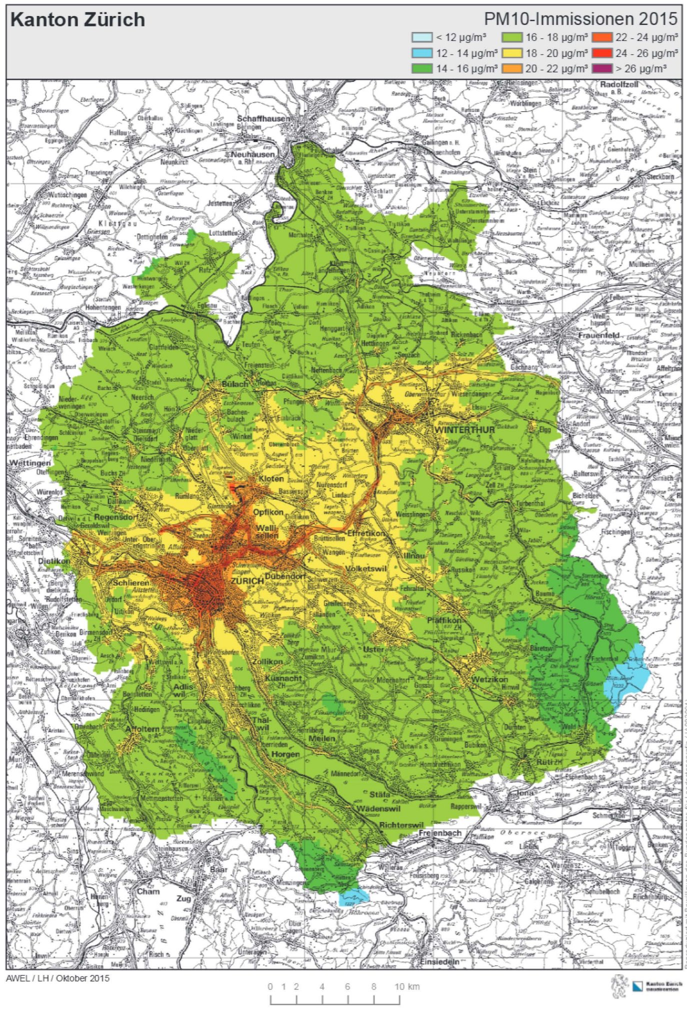

Figure 6: PM10 imissions in the canton of Zurich, 2015. Source: Canton of Zurich, Building Department, Office for Waste, Water, Energy and Air (German: Amt für Abfall, Wasser, Energie und Luft (AWEL)

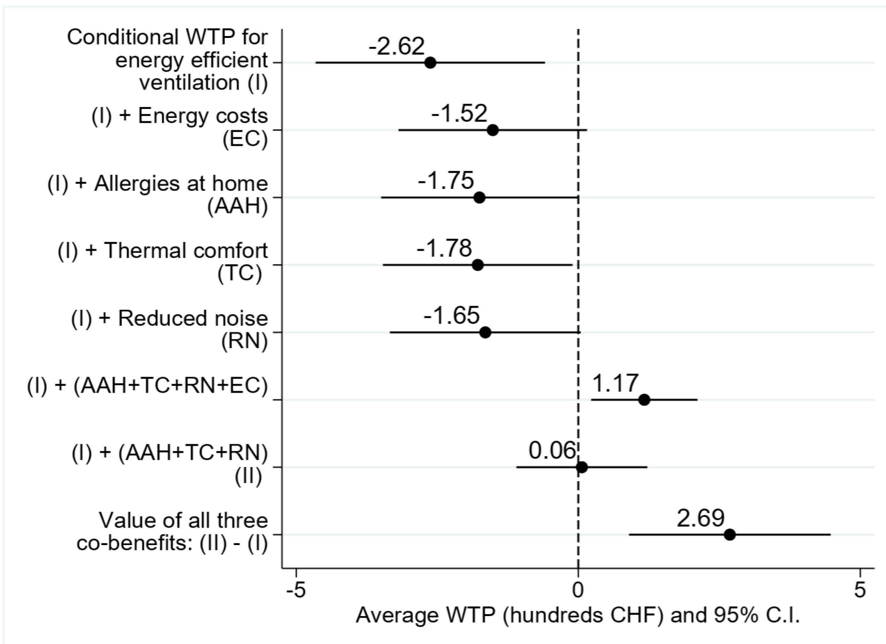

Figure 7: Willingness to pay (WTP) estimates on sub-sample (n=315) conventional houses owners *paired* to Minergie houses owners.

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