

## Willingness to pay for energy-saving measures in residential buildings <sup>☆</sup>

Silvia Banfi <sup>a</sup>, Mehdi Farsi <sup>a</sup>, Massimo Filippini <sup>a,b</sup>, Martin Jakob <sup>a,\*</sup>

<sup>a</sup> *Centre for Energy Policy and Economics, Department of Management Technology and Economics, ETH Zurich, Zürichbergstr. 18, CH-8032 Zürich, Switzerland*

<sup>b</sup> *Department of Economics, University of Lugano, Lugano, Switzerland*

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### Abstract

This paper uses a choice experiment to evaluate the consumers' willingness to pay for energy-saving measures in Switzerland's residential buildings. These measures include air renewal (ventilation) systems and insulation of windows and facades. Two groups of respondents consisting respectively of 163 apartment tenants and 142 house owners were asked to choose between their housing status quo and each one of the several hypothetical situations with different attributes and prices. The estimation method is based on a fixed-effects logit model. The results suggest that the benefits of the energy-saving attributes are significantly valued by the consumers. These benefits include both individual energy savings and environmental benefits as well as comfort benefits namely, thermal comfort, air quality and noise protection.

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\* Corresponding author. Tel.: +41 44 632 06 53; fax: +41 44 632 16 22.

*E-mail address:* [mjakob@ethz.ch](mailto:mjakob@ethz.ch) (M. Jakob).

## 1. Introduction

As is the case in most industrialized countries in temperate zones, residential buildings in Switzerland incur an important share of the end use energy consumption. Thus, improvements of energy efficiency in the building sector could have an important impact on the country's total energy consumption and a considerable contribution in attaining the CO<sub>2</sub>-emissions objectives for a sustainable development. The overall energy efficiency of a building is identified mainly by the insulation characteristics of the building envelope and the presence of an air renewal system.<sup>1</sup> Provided with an energy-efficient implementation, these measures yield two kinds of benefits: First, they reduce the energy consumption of the buildings hence costs, and secondly they generate comfort benefits namely, improved indoor air quality, thermal comfort and enhanced protection against external noise.

With a relatively long cycle of energy-relevant renovations in buildings (usually about 20 to 40 years), the Swiss building sector has still a very low usage of energy-saving measures. Every year only 1 to 2% of the existing building envelopes undergo maintenance or renovation. In only 30 to 50% of these cases the renovation measures include insulation with a reduction of the energy consumption by 50% to 70% and only a very small fraction opts for enhanced energy-efficiency measures that exploit the energy-saving potential completely (see Jakob and Jochem, 2003). Houses with the latter measures satisfy the conditions set by *Minergie* label<sup>2</sup> reducing energy consumption by 70% to 85% for old buildings (constructed prior to the 1970s) or by 50% for today's new buildings.

The Swiss federal and cantonal governments support the renovation or new investments in houses satisfying the *Minergie* requirements through subsidies and/or reduced interest rates. Yet a relatively small number of houses are constructed (5 to 10% of new single-family houses and less than 5% of new apartment buildings) and hardly any are renovated according to *Minergie* guidelines.

In a recent study, Ott et al. (2005) have identified legal and social factors as well as market structural barriers and lack of consciousness as the possible explanations of low usage of energy-saving systems for the case of the Swiss residential building sector. Moreover, as shown by Jakob (2006) depending on the adopted assumptions and especially for ventilation systems, the discounted value of long-term savings in energy costs could be insufficient to justify such investments.

In order to identify effective policy measures to induce more investment in buildings' energy efficiency, it is important to have detailed information on the factors that influence the homeowners' investment decision and on their willingness to pay for the resulting improvements. Similarly in rental buildings it is important to know how consumers value apartments in energy-efficient buildings. However, there are only a few studies that addressed the consumer's valuation of energy-saving measures in buildings. One of the first studies is Cameron (1985) that analyzed the demand for energy-efficiency retrofits such as insulation and storm windows using the actual data collected by a national survey on energy consumption. Using a nested logit model that study shows a considerable sensitivity of demand to changes in investment costs, energy prices and income. In more recent literature, conjoint analysis was used in order to elicit the choice behavior of households

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<sup>1</sup> Air renewal or ventilation systems have a controlled air exchange and provide the indoor spaces with fresh and filtered air (pre-heated by a heat-exchanger) without great heat losses through windows or traditional aeration systems. Not to confuse these systems, also known as "housing ventilation" or "comfort ventilation", with conventional air conditioning used for cooling or moisturizing.

<sup>2</sup> *Minergie* is a quality label that combines high comfort of living and low energy consumption with a limited cost surplus of at most 10% of the construction price. Controlled air exchange requirement, is mostly met with a ventilation system. More information is available at [www.minergie.com](http://www.minergie.com).

for energy-saving measures. For instance, [Poortinga et al. \(2003\)](#) have focused on the characteristics of 23 energy-savings measures including insulation and energy-efficient heating systems in the Netherlands. The conjoint analysis was judged to be a useful method to examine the acceptability of these measures and identify the characteristics influencing the choices. A choice experiment was also carried out in Canada aiming at understanding the preferences of residential consumers when making investment decisions regarding heating system or a renovation that impacts the efficiency of home energy consumption ([Sadler, 2003](#)). The renovation choice was estimated using a binomial logit model and the heating system choice using a multinomial logit model. The results of that study suggest a high preference for the energy-efficient renovations and highlight the effect of comfort in addition to the capital costs, the annual heating expenses and the subsidy regime.

This paper adopts a choice-experiment approach to analyze the willingness to pay (WTP) for energy-saving measures in residential buildings. The results provide the first WTP estimates based on choice experiments in the context of the Swiss housing sector. The analysis includes both renovation cases and new buildings. The decisions are related to purchasing single-family houses as well as renting apartments. The estimation methodology is based on a binomial logit model with individual fixed effects. The results suggest that energy-saving measures are significantly valued by the consumers, which in some cases can counter the implementation and operation costs.

The rest of the paper is organized as follows: Section 2 describes the experiment design; Section 3 presents the theoretical framework and the econometric methodology. A description of the data and the regression sample is provided in Section 4. The estimation results are presented in Section 5. A summary of the main results and the conclusions are given in Section 6.

## 2. Experiment design

The data needed for the econometric estimation of the choice behavior can basically be collected with two different methods: the revealed and the stated preference method. The first method is based on the observation of the actual choice decisions of households from a set of alternatives that are known to the econometrician whereas the second method is based on information extracted from interviews or choice experiments. [Verhoef and Franses \(2002\)](#) and [Louviere et al. \(2000\)](#) provide overviews of the advantages and drawbacks of the two methods.

The aim of this study is to estimate the marginal willingness to pay (WTP) for different energy-saving characteristics. In principle, both revealed and stated preference methods could be used for this purpose. However, the small share of buildings with enhanced energy-efficiency standards makes the use of a revealed preference method difficult.<sup>3</sup> Moreover, it is generally difficult to obtain data on the available choice set from which the alternative has been chosen. For the above reasons we use a stated preference method with choice experiment, initially developed by [Louviere and Hensher \(1982\)](#). This approach has been used in other energy-related topics, for example in [Bergmann et al. \(2006\)](#).

Two samples of households respectively consisting of residents of single-family houses and rental apartments have been presented with several choice sets and asked to choose the alternative they prefer the most. In our case, respondents were asked to choose between their actual situation and a hypothetical housing with different energy-efficiency attributes and a different price, with all other characteristics remaining the same. The price is defined as the purchase price for houses and the monthly rent for apartments. The following attributes are included in the experiment: windows with

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<sup>3</sup> The valuation of different housing attributes can be estimated by applying the hedonic pricing approach to market data.

Table 1

Categories of different attributes (within attributes in descending order) and price levels considered in the choice experiment

Attribute	Categories
Window	1. Enhanced insulation (triple glazing, double coated pane, rubber seal) <sup>a</sup> 2. Standard insulation (coated, rubber seal) 3. Medium old (low insulation, not coated, no rubber seal) <sup>b</sup> 4. Very old (single glazing, not coated, no rubber seal) <sup>b</sup>
Facade	1. Enhanced insulation <sup>a</sup> 2. Standard insulation 3. No insulation, but newly repainted <sup>b</sup> 4. Old (not repainted) <sup>b</sup>
Ventilation	1. With air renewal system (housing ventilation) 2. Without air renewal system
Price	In 5 levels: approximately –100, –50, 0, 50 and 100 CHF per month for rented apartments and –90,000, –45,000, 0 +45,000, +90,000 CHF per house, in addition to the actual price

<sup>a</sup> Applied only to new buildings.

<sup>b</sup> Applied only to existing buildings.

different energy-efficiency standards; facade with different levels of insulation and esthetics; presence of a ventilation system; and price. These attributes and the related categories are listed in Table 1.

The respondents were asked to imagine that their actual housing situation would be improved (downgraded) in terms of the mentioned attributes, with all other characteristics such as number and size of rooms, location etc. being constant. The respondents' actual housing situation was chosen as a reference to reduce the hypothetical character of the survey (as compared to two hypothetical situations to choose from). The respondents already living in housing situations with a high energy-efficiency standard were asked to imagine a decline in one or several of these features.<sup>4</sup> The price levels were related to the actual residence of the respondents and were chosen within a reasonable range. Each respondent was asked to do several choice tasks.

Each choice task consisted of reading a card listing the characteristics of the actual situation and those of one alternative and choosing the one of the two that was preferred. The respondents were provided with descriptive information about the attributes, in particular the relatively new and not widely installed housing ventilation system. This description included information about the characteristics of the attributes and about their positive impacts on the energy efficiency of the building and the comfort benefits such as thermal comfort, air quality and noise protection (see Ott et al., 2006 for more details). The respondents were also informed of the energy cost-savings as well as the entailed environmental improvements. However, we have not provided quantitative information about the extent of these benefits particularly on the potential cost-savings at the individual level. In fact, in most real cases when buying or renting a residence, individuals do not have such quantitative information. Moreover, these benefits particularly the savings in energy costs vary across offered alternatives and strongly depend on the actual situation, hence many unobserved factors which were difficult to assess. It is assumed that the respondents assess the trade-off between prices and the overall benefits from different housing attributes. Thus, the willingness to pay estimates includes comfort benefits and cost-savings as well as the respondents' potential valuation for environmental benefits.

<sup>4</sup> To make the choice tasks as realistic as possible, the set of categories of the hypothetical housing situations was adapted to the present situation of respondents. For respondents living in new buildings only categories 1 and 2 of both window and facade were included in the choice set.

To reflect the real-world choice situations (and to prevent strategic behavior) each of hypothetical alternative consisted of an upgrade in some attributes and/or a downgrade in some other attributes. This design was chosen to enrich the structure of the sample and was based on the assumption the respondents could answer differently depending on their personal experience about different energy-efficiency attributes. In particular, we intentionally included respondents living in situations equipped with ventilation.<sup>5</sup>

### 3. Model specification

With reference to the utility theory, the paper models the choice of respondents (apartment tenants, house buyers) for energy-relevant characteristics of apartments and houses respectively. The underlying assumption is that households evaluate the characteristics of different housing alternatives and then choose the one which leads to the highest utility.<sup>6</sup> We assume that the utility of living in energy-efficient apartments or houses is a function of the price, the housing's energy-efficiency characteristics (for instance the characteristics of windows and facade and the presence of a ventilation system), the building location, household characteristics, and a random component that captures the influence of unobserved factors. The household characteristics can include income, education, environmental consciousness, as well as site-specific characteristics of the household's actual residence. Indeed, according to the random utility theory, the utility of goods or services is considered to depend on observable (deterministic) components, including a vector of attributes ( $X$ ) and individual characteristics ( $Z$ ), and a stochastic element  $e$  (cf. [Louviere et al., 2000](#)). Thus, the utility function of a bundle of characteristics  $i$  for individual  $q$  at choice task  $j$  can be represented as:

$$U_{qij} = V(X_{qij}, Z_q) + e_{qij} \quad (1)$$

where  $V$  is the deterministic part and  $e_{qij}$  the stochastic element. The deterministic variables that will be used in an empirical model are the housing attributes ( $X_{qij}$ ) and the respondent's characteristics ( $Z_q$ ). Assuming an extreme value distribution for the stochastic term  $e_{qij}$  in model (1), the probability of choosing alternative  $i$  out of a set of available alternatives  $A = \{1, 2, \dots, K\}$  can be written in a logistic form as:

$$P_{qij} = \exp(V_{qij}) / \sum_{k=1}^K \exp(V_{qkj}) \quad (2)$$

Expression (2) is the basic equation of a multinomial logit (cf. [Greene, 2003](#) and [Thomas, 2000](#)). Utility function  $V$  is generally assumed to be linear in parameters. In our case, the number of alternatives in each choice task is limited to two possibilities. Thus, the choice set for a given choice task  $j$  can be written as  $A = \{0, j\}$  with 0 indicating the status quo and  $j$  representing the offered alternative. The random utilities of the resulting binary logit model can be written as:

$$U_{qj} = \beta X_{qj} + \alpha Z_q + e_{qj}; U_{q0} = 0 \quad (3)$$

where  $Z_q$  represent the household characteristics that do not vary across choice tasks, and  $X_{qj}$  is the characteristics of the alternative situation of choice task  $j$  for individual  $q$ .  $\alpha$  and  $\beta$  are the vectors of

<sup>5</sup> Further details of the experiment are documented in [Ott et al. \(2006\)](#).

<sup>6</sup> In other words it is assumed that households maximize their utility function of hedonic commodities that they produce from the housing services and goods ([Thompson, 2002](#)).

model parameters. In a multinomial logit framework, the parameters associated with one of the outcomes are normalized to zero namely,  $U_{q0}=0$ . Therefore,  $U_{qj}$  is the random utility of choosing the alternative situation over the status quo.

If all the relevant respondent’s characteristics ( $Z_q$ ) are observed, the model given in Eq. (3) is a simple binomial logit. In general however,  $Z_q$  can include a host of parameters, many of which are not observed. In this case, this term can be considered as an individual fixed effect. The resulting model is a fixed-effect binary logit model proposed by Chamberlain (1980) and can be written as:

$$U_{qj} = \beta X_{qj} + u_q + e_{qj} \quad \text{with } u_q = \alpha Z_q \tag{4}$$

It should be noted that because of the presence of fixed effects in the model, vector  $X_{qj}$  can be equivalently replaced by the  $X_{qj} - X_{q0}$ , which measures the difference between the characteristics of the hypothetical alternative with the status quo. This implies that  $U_{qj}$  measures the net gained value through moving from actual situation (status quo) to a hypothetical status offered in choice task  $j$ . Given that the hypothetical alternatives may equally involve a better or worse situation regarding comfort, the individual specific term  $u_q$  can be interpreted as the (dis)utility of respondent  $q$  from changing their status quo.

Assuming a logistic distribution for the error term, the above model can be estimated by maximization of the conditional likelihood given the fixed effects ( $u_q$ ).<sup>7</sup> Chamberlain shows that for a consistent estimation, incidental parameters  $u_q$  should be replaced by a minimum sufficient statistic namely, the number of positive responses for a given individual. If we denote the individual  $q$ ’s response for  $J$  choice tasks by the sequence  $(y_{q1}, y_{q2}, \dots, y_{qJ})$ , where  $y_{qj}=1$  if offer  $j$  is chosen, and  $y_{qj}=0$  if offer  $j$  is not chosen, then the number of positive responses (accepted offers) for individual  $q$  is obtained by the sum  $s_q = \sum_{j=1}^J y_{qj}$ . The conditional probability can therefore be written as:

$$Pr(y_{q1}, y_{q2}, \dots, y_{qJ} | u_q) = \frac{\exp\left(\sum_{j=1}^J y_{qj} X_{qj} \beta\right)}{\sum_{d_{qj} \in \Omega} \exp\left(\sum_{j=1}^J d_{qj} X_{qj} \beta\right)} \tag{5}$$

where  $\Omega$  is the set of all the sequences  $(d_{q1}, d_{q2}, \dots, d_{qJ})$  in which the number of positive responses is equal to that of the chosen sequence namely,  $\sum_{j=1}^J d_{qj} = \sum_{j=1}^J y_{qj} \equiv s_q$ . Hence, the numerator represents the probability of choosing the sequence  $(y_{q1}, y_{q2}, \dots, y_{qJ})$  and the denominator indicates the sum of the probabilities of all possible outcomes that entail the same number of accepted offers.

The fixed-effect logit model is estimated using the maximum likelihood estimation method. Once the model parameters are estimated, the marginal rate of substitution between different attributes can be calculated. If one of the attributes is a numéraire or a monetary variable like price ( $p$ ) the marginal willingness to pay for attribute  $x$  can be derived as:

$$WTP = \frac{\frac{\partial V}{\partial x}}{-\frac{\partial V}{\partial p}} \tag{6}$$

which is equivalent to the ratio of the corresponding coefficients in Eq. (3).

<sup>7</sup> See Hsiao (1986) and Greene (2003) for more details about the fixed-effects logit model and Ferrer-i-Carbonell and Frijters (2004) for an application.

#### 4. Data description

The data used in this paper were collected during Summer 2003 by telephone interviews in five cantons covering a major part of German-speaking Switzerland. The experiments have been performed on two separate samples for apartment buildings and single-family houses respectively. The first sample consists of tenants of rental flats whereas the second sample includes homeowners. Both samples have been selected from the households who have recently moved, thus have faced a housing choice decision within a few months before the experiment. The samples were stratified with the purpose of including a sufficient share of new and existing buildings, of standard and energy-efficient ones, of buildings with and without ventilation receptively.<sup>8</sup> Both samples cover an important share of the German-speaking part of Switzerland. The data sources from which respondents were randomly chosen were different for each stratum of the sample. These data sources include the list of labeled energy-efficient houses published by the *Minergie* association (see Footnote 2), a data base of a supplier of internet housing ads, and a database of another survey on buildings (Jakob and Jochem, 2003). Respondents' names and phone numbers were matched to the buildings' address using the public phone directory.

The telephone interviews have been conducted in two stages. In the first stage the respondents were recruited and basic information were collected to match the respondents to the different sample strata and to obtain information about their actual housing situation. The respondents were then provided with written information and the choice tasks. In the second stage, the choices and additional socio-economic information were collected by phone.

The first stage included 397 interviews for the rented flats and 402 interviews for single-family houses, corresponding to a response rate of 36% and 41% respectively. The response rate of the second stage was 66% for the rented flats and 63% for the single-family houses, resulting in overall response rates of 24% and 26% respectively. The response rate of the second stage is quite high and non-responses are mainly due to unavailability of some of the respondents. Thus the selection bias at this stage is relatively low. However, there could be a self-selection bias at the first stage of the survey. Persons interested in the subject (of energy efficiency and housing comfort) could be more likely to participate in the choice experiment. With the available data we cannot identify the extent of potential selection biases due to unobserved differences between the participants and the Swiss population. Compared to the average values of the Swiss population the studied samples show a slight over-representation of high-income and a considerable over-representation of educated individuals (Ott et al., 2006). Assuming that relatively educated individuals have a higher than average valuation of comfort and energy efficiency, such sample selection biases might result in an overestimation of WTP.

The resulting samples obtained from the survey include 264 tenants of apartment buildings and 253 single-family house owners with a total of 3861 and 3458 observations (choice tasks) respectively. After excluding the choice tasks with dominated alternatives and also the respondents that have consistently preferred their status quo over all the offered alternatives,<sup>9</sup> the final regression samples consist of 163 tenants with 1928 observations and 142 house purchasers with 1685 observations.

The considerable rate of respondents always preferring their actual situation (101 out of 264 and 111 out of 253 respondents) may suggest that focusing on the remaining sample may create selection bias in the estimations. However, it should be noted that the experiment design is such

<sup>8</sup> In the original study (Ott et al., 2006) the buildings constructed after 1995 and those with energy-efficiency labels have been distinguished from other buildings.

<sup>9</sup> The respondents that have not shown any variation in their choices cannot be included in a fixed effects logit model.

that the alternative state does not necessarily have always higher attributes than the actual state. Therefore, the respondents who have never accepted any offer might rather have a relatively high disutility of change, or simply might have not examined all the offers. Therefore, to the extent that such disutilities are not correlated with the WTP, it is reasonable to assume that the WTP estimated from the regression sample is a representative of the entire sample.

A descriptive summary of the sample used in the analysis is given in Table 2. The upper panel of the table lists the descriptive statistics of the respondents and the characteristics of their actual residence while the lower panel gives the attributes of the hypothetical alternatives offered in the experiment.

As seen in this table the share of apartments with installed housing ventilation systems is about 14% of the sample and that of single-family houses is about 9%. These shares are slightly lower than the corresponding ones of the entire samples (about 20% of 264 tenants and 17% of 253 single-family houses). This difference suggests that the respondents living with a ventilation system are relatively less likely to give up their present situation regardless of the offered price discounts.

Regarding the energy-efficiency attributes of the actual situation the sample can be described as follows: the most frequent type of windows is “Standard window” (67% of apartments, 80% of

Table 2  
Descriptive statistics

Respondents and characteristics of their actual residence	Tenants		House buyers	
	Number of respondents	Sample mean	Number of respondents	Sample mean
Number of choice tasks per person	163	11.8 (3.4)	142	14.2 (2.6)
Number of accepted offers	163	3.40 (2.3)	142	2.68 (2.08)
Price of actual situation	163	1550 <sup>1)</sup> (609)	142	659 <sup>1)</sup> (230)
Enhanced window in actual situation	163	0.135	142	0.092
Standard insulated window in actual situation(*)	163	0.669	142	0.796
Medium old window in actual situation	163	0.166	142	0.085
Very old window in actual situation	163	0.030	142	0.028
Enhanced facade insulation in actual situation	163	0.190	142	0.204
Standard facade insulation in actual situation(**)	163	0.337	142	0.317
Repainted facade in actual situation	163	0.117	142	0.162
Old facade in actual situation	163	0.356	142	0.317
Ventilation in actual situation	163	0.141	142	0.085
Old buildings (constructed before 1995)	163	0.650	142	0.549
<b>Hypothetical offers</b>	<b>Number of offers</b>	<b>Sample mean</b>	<b>Number of offers</b>	<b>Sample mean</b>
Offers accepted (positive outcomes)	1928	0.288	1685	0.270
Price	1928	1509 <sup>1)</sup> (624)	1685	661 <sup>1)</sup> (242)
Enhanced window	1928	0.183	1685	0.188
Standard window(*)	1928	0.293	1685	0.256
Medium old window	1928	0.272	1685	0.292
Very old window	1928	0.252	1685	0.264
Enhanced facade	1928	0.172	1685	0.160
Standard facade insulation(**)	1928	0.401	1685	0.398
Repainted facade	1928	0.217	1685	0.216
Old facade	1928	0.210	1685	0.227
Ventilation	1928	0.661	1685	0.690

All variables except prices are dummy variables. Standard deviations for prices are given in parentheses.

(\*)Reference category for windows; (\*\*)Reference category for facade; <sup>1)</sup>Monthly rent in Swiss Francs (CHF); <sup>2)</sup>Purchase prices in thousand Swiss Francs (CHF).

single-family houses) including coated glazing and sealing rubber. Only 13% of apartments and 9% of single-family houses (SFH) have enhanced windows (including coated triple glazing). 17% of the apartments and 9% of the SFHs have “old windows” (i.e. windows that were renovated before 1995 or not at all) including non-coated double glazing and no sealing. A minor fraction of the buildings has still very old windows with only single glazing.

The two most frequent facade qualities in the samples are the standard insulation and the “old facade” (neither painted nor insulated the last few years) covering about one third each of them. More specifically, the shares of standard insulation are 34% (apartments) and 32% (SFH) and the “old facade” ones (nor painted or insulated the last few years) are 36% (apartments) and 31% (SFH).

In the final apartment sample, the number of valid observations (number of answered choice tasks per person) varies between 2 and 17 with an average of about 12 and a standard deviation of about 3.4.<sup>10</sup> The number of accepted offers per person varies between 1 and 14 with an average of 3.4 accepted offers. The number of cards per person in the SFH sample varies between 7 and 18 with an average of about 14, from which 2.7 offers were accepted in average. The rental prices range between 430 and 4000 CHF/month and the standard deviation is 609 CHF/month. The purchase prices of the SFH range from CHF 100,000 to CHF 1.6 Million, with an average of CHF 659,000.

A descriptive summary of the characteristics of the hypothetical offers is given in the lower panel of Table 2. The sample of the choices can be described as a balanced sample in that there is a comparable share of old, standard and enhanced windows in the offered alternatives. This is also valid for the facade quality and the presence of a ventilation system. About 25% of the offers had very old windows. Rental prices of offers vary between 323 and 4600 CHF/month, with an average of 1509 CHF/month. In both samples the average price of offers is about the same as the average price of the actual situation, which is due to similar number of price increases and decreases. Despite the fact that the offers are balanced, only less than one third of the offers were accepted (29% in the apartment sample and 19% in the SFH sample). This result might suggest a significant disutility of change.

The explanatory variables include the price (monthly rent for apartments and purchase price for single-family houses)<sup>11</sup> and the energy-efficiency attributes of the hypothetical offers. These attributes consist of three dummy variables for window attributes and three dummies for the facade characteristics with the standard (insulation) type being chosen as the omitted category in both cases and one dummy for ventilation system (see Table 1). An observation reported by Ott et al. (2006) is that the respondents who already have a given attribute in their households might attach a higher value to that attribute compared to other individuals. In order to control for potentially asymmetric choice behavior,<sup>12</sup> a dummy variable has been constructed to indicate the hypothetical

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<sup>10</sup> For the econometric estimation, the choice situations with dominated alternatives and undecided choice tasks were excluded from the sample. In all the remaining choice tasks, the price of the hypothetical alternative is higher (lower) than that of the actual situation if and only if the alternative offer provides a strict improvement (decline) in at least one of the attributes while other attributes remain at least (most) the same as in the actual state.

<sup>11</sup> Price variable is actually the difference between hypothetical and actual prices for each observation (choice task). Note that thanks to the fixed effects, it would not matter if the price levels of the hypothetical alternatives were used instead.

<sup>12</sup> This asymmetric behavior, commonly referred to as the disparity between the willingness to accept (WTA) and the WTP, is usually observed in similar experiments and widely discussed in the literature (Horowitz and McConnell, 2002; Sayman and Öcüler, 2005). This disparity has been explained by several factors including those related to the survey design and framing effects as well as economic and psychological factors. In our experiment the asymmetry might be exacerbated by the fact that some of the high-level attributes are completely new to the respondents and might be valued less than those already experienced.

Table 3  
Estimation results of the logit model with individual fixed effects

Attributes	Rented flats in apartment buildings			Purchase of single-family houses		
	Coeff.	Std. err.	Sig.	Coeff.	Std. err.	Sig.
Price <sup>1)</sup>	-0.0089	0.0009	***	-0.0229	0.0033	***
Price * dummy decreasing price	0.0047	0.0014	***	0.013	0.0055	**
Enhanced insulated window <sup>2)</sup>	0.15	0.21	n.s.	0.14	0.23	n.s.
Enhanced facade insulation <sup>3)</sup>	0.50	0.20	**	0.51	0.23	**
Housing ventilation system	0.90	0.17	***	0.54	0.21	***
Housing ventilation system* new building	0.46	0.32	n.s.	1.33	0.38	***
Medium old windows <sup>2)</sup>	-1.49	0.22	***	-1.95	0.24	***
Very old windows	-2.68	0.25	***	-3.08	0.29	***
Painted facade <sup>3)</sup>	-0.73	0.22	***	-0.97	0.25	***
Unpainted facade <sup>3)</sup>	-1.10	0.22	***	-1.48	0.25	***
No. of persons	157			142		
No. of observations (choice tasks)	1928			1685		
Log likelihood	-540.44			-435.12		
Pseudo R <sup>2</sup>	0.318			0.298		

<sup>1)</sup>Prices are expressed in CHF/month for rented flats and in thousand CHF for single-family houses.

<sup>2)</sup>Reference category: new standard insulated windows; <sup>3)</sup>reference category: standard insulated facade.

Sig. = Significance level: \*\*\*0.01, \*\*0.05, \*0.1, n.s. = not significantly different from 0 at 10% significance level.

offers with lower-than-actual prices, which entail a decline at least in some of the attributes while others being unchanged. The interaction of this dummy with price is included in the model.

Because of the fixed effects included in the model, the household characteristics can only be included through interaction terms. In a preliminary analysis several interaction terms between alternative attributes and household characteristics have been considered. Using several hypotheses we explored if households with different characteristics and socio-economic variables differ with respect to their valuation of energy-efficiency attributes. For instance, we tested if households with smoking habits or with pets have a different valuation of ventilation systems and/or people living in noisy locations have a higher valuation of insulated windows. The results suggested that all the interaction terms were statistically insignificant at 10% significance level.<sup>13</sup> We expected that household income might have an important effect. However, due to a relatively high share of missing values (about half of the sample) we could not include any income variable.

Therefore, in order to keep the model as parsimonious as possible and avoid unnecessary complication in the interpretation of the results, we decided to exclude such interaction terms from the model. The only exception is the different valuation of ventilation systems across new and old buildings. Our results suggest that the air renewal systems could be valued more in new buildings constructed after 1995 (less than 10-years-old). An interaction term is included in the model to account for such differences.

## 5. Results

The estimation results are shown in Table 3. The results regarding house purchasers and tenants show a very similar pattern. The coefficients of the price and of all energy-efficiency attributes have the expected sign and most of them are significantly different from zero at 5% significance

<sup>13</sup> The details of these analyses are not included in this paper.

Table 4

Marginal willingness to pay derived from discrete choice models, expressed as % of rental price (flats) and purchase price (single-family houses) respectively<sup>15</sup>

Attribute	Rented flats in multi-family houses			Purchase of single-family houses		
	WTP	Sig.	95%- Interval	WTP	Sig.	95%- Interval
Enhanced insulated window (as compared to standard insulated windows)	1%	n.s.	-1% 3%	1%	n.s.	-2% 4%
Enhanced facade insulation (as compared to standard insulation)	3%	*	1% 5%	3%	**	0% 6%
Housing ventilation system (new buildings)	8%	***	4% 11%	12%	***	6% 17%
Housing ventilation system (existing buildings)	8%	***	4% 11%	4%	**	1% 7%
New windows (as compared to medium old ones)	13%	***	8% 17%	13%	***	9% 18%
Medium old windows (as compared very old ones)	10%	***	6% 14%	8%	***	4% 11%
Standard facade insulation (as compared to facade painting)	6%	**	3% 10%	7%	***	3% 10%
Facade painting (as compared to old unpainted facade)	3%	n.s.	-1% 7%	3%	*	0% 7%

WTP = Willingness To Pay, expressed as % of rental price (flats) and purchase price (single-family houses) respectively. Sig. = Significance level: \*\*\*0.01, \*\*0.05, \*0.1, n.s. = not significantly different from 0 at 10% significance level.

level. Exceptions are the coefficients for enhanced windows and the interaction variable between ventilation system and new buildings for the rented flats. A significant difference in the price effects was found between price increases (price of the hypothetical alternative is higher than the price of the actual apartment) and price decreases.

Using Eqs. (3) and (6) we can calculate the willingness to pay for each attribute, which is the ratio of the attribute's coefficient and the price coefficient.<sup>14</sup> The WTP results in Table 4 are expressed as a percentage of the reference purchase price for houses, and as a percentage of the reference rental price for flats. The average prices of both new and old buildings are used as reference.<sup>15</sup> In new buildings the willingness to pay for enhanced facade insulation is about 3% whereas the ventilation system is valued with 4% to 12% of the reference price. In relative terms, house buyers and apartment tenants have a similar WTP for the case of new buildings. It is worth noting that the survey was conducted in Summer 2003 which was an extraordinary Summer with high temperature. This might explain the relatively high WTP for ventilation systems. Even though a comfort ventilation system as considered here is not designed for cooling, the respondents might have associated cooling with this system.

In the existing (not new) buildings we estimate the WTP for energy-efficient facades and windows. Regarding the facade there is a WTP for insulation of 6% and 7% for SFH, whereas the estimated WTP for esthetic reasons is low (about 3%) and only for single-family houses significant at the 10% level. In existing buildings, the willingness to pay is particularly high for window improvements. Indeed, the WTP for a standard insulation window as compared to an old window is 13% for tenants as well as for house purchasers. Note that today's standard insulation windows are coated and have sealing rubber whereas old windows do not dispose of these properties. Coated windows have a higher surface temperature and sealing rubber protect from air infiltration and

<sup>14</sup> The WTA could be calculated similarly accounting for the interaction of price and the decreasing-price dummy. The estimation results suggest that the WTA/WTP ratio is 2.1 in the case of rental flats and 2.3 in the case of single-family houses. This is consistent with the results reported in the literature (cf. Sayman and Öcüler, 2005). In the paper we focus on the WTP that has more importance from a policy point of view.

<sup>15</sup> These prices are 650,000 and 686,000 CHF for new and existing single family houses respectively and 2030 and 1330 CHF/month for flats in new and in existing buildings respectively.

from external noise. Thus, such windows improve thermal comfort and comfort of living which might explain these relatively high WTP.

Comparing the results of windows and facades for old and new buildings shows that the marginal WTP for each further step of energy efficiency is decreasing. This result suggests that the “first” improvement provides a higher utility than that of an additional improvement.

The WTP for ventilation systems in old buildings is below that of new buildings. This could be explained by different preferences of residents living in old and new buildings or by the different reference price level. The respondents who live in new buildings might have a relatively high standard of living, thus higher WTP for comfort. Note that in the case of tenants, the willingness to pay in relative terms, is very similar across old and new buildings. That the willingness to pay for ventilation is different between persons living in new and old buildings could be interpreted as an income effect, since income of people living in new buildings is slightly higher than those living in not new buildings. Finally, it should be noted that the WTP values include both the willingness to pay for improved comfort, for increased energy efficiency i.e. reduced energy costs and eventually for environmental improvements.

The willingness to pay for energy-efficiency attributes can be compared with the capital costs of implementing such attributes. In Jakob et al. (2006) some typical capital costs are given for the example of a typical flat of hundred square meters and for a typical single-family house. For most of the considered attributes the monthly capital costs are significantly lower than the average willingness to pay of the sample as reported in Table 4.

That the willingness to pay exceeds the cost can be interpreted in different ways: On the one hand it could indicate that people actually desire enhanced efficiency but that the housing market has not yet reacted to this demand. On the other hand the values of the estimated willingness to pay could be overestimated.

The estimated values of WTP can be compared with the results obtained from hedonic pricing method (Ott et al., 2006). According to those results in the greater Zurich area the marginal value of Minergie label is about 7.5% of the rental price for new buildings and that of a renovated, insulated facade is about 8%. It is interesting to note that the estimated WTP values in this paper are comparable with these price effects obtained using data from revealed preferences through market prices.

## 6. Summary and conclusion

This paper gives some insight into the willingness to pay for improvements in energy efficiency by studying stated choices of two samples of respondents respectively consisting of tenants of rental apartments and owners of single-family houses. The considered energy-saving measures include air renewal system and different energy-efficiency standards of windows and facade. The data used for the econometric estimation were collected with a choice experiment. The respondents were presented with choice sets and asked to choose between their actual housing situation and a hypothetical one with different energy-efficiency standards and a different price. The decision to use a stated preference method is supported by the fact that revealed preference data is only scarcely available since the market of energy-efficient houses is still small. Further, this method made it possible to compare the willingness to pay of people who have already experienced the additional comfort benefits of energy-saving measures with those who do not have such information.

The econometric analysis of the data has been carried out using a fixed-effect logit model. The coefficients of all attributes have the expected signs and most of them are significantly different from zero. The results show a significant willingness to pay (WTP) for energy-efficiency attributes of rental apartments and of purchased houses. The willingness to pay varies between 3% of the price for an

enhanced insulated facade (in comparison to a standard insulation) and 8% to 13% of the price for a ventilation system in new buildings or insulated windows in old buildings (compared to old windows) respectively. Note that the interrelation of the WTP values for different attributes is quite plausible and the results reflect a decreasing marginal utility for increasing energy efficiency.

The WTP values presented in this paper could be an overestimation of the representative values in the Swiss population, due to possible over-representation of respondents with high education and/or income and the relatively high participation rate of environmentally conscious individuals. Moreover, an overestimation could result from the hypothetical choice situation, relying on individuals stating their behavioral intentions rather than on revealed economic decisions.

The WTP is generally higher than the costs of implementing these attributes. Therefore it would be economically reasonable for owners and housing promoters to invest in energy-saving measures. We assume that besides many legal, structural and socio-economic barriers the observed underinvestment is due to lack of information regarding the advantages of the efficiency measures and perhaps lack of methods to quantify these advantages in economic terms. Indeed house owners, architects, tenants and financial institutions have occasionally deplored this lack of economic foundation.

From a policy point of view, the government can reduce these barriers by supporting the communication and information for decision makers namely consumers, investors and financial institutions. A good example of this kind of promotion is given by advertising campaigns (so called “casa clima”) used by the government of the Italian province Alto Adige, or by information campaigns and subsidies applied to energy-efficient buildings in Switzerland, namely Minergie guidelines that combines efficiency and comfort. The authors recommend that the WTP results presented in this paper could be included in these promotion campaigns. In addition to an enhancement in communication, the governments could grant additional financial resources to the house owners who want to invest in energy-efficiency measures to overcome financial barriers. Some Swiss financial institutions award credits with lower interest rates for Minergie labeled buildings. It should be considered that government intervention could speed up process of the cost reduction (learning curve) of measures improving energy efficiency in buildings.

Nonetheless the WTP values presented in this study should be considered with caution. The results give a first estimate of the magnitude of benefits (willingness to pay) coming from energy-efficiency measures. Given the mostly lower costs of these measures, it may be possible by additional information of house owners, architects and tenants to increase significantly the share of energy efficient buildings.

## References

- Bergmann, A., Hanley, N., Wright, R., 2006. Valuing the attributes of renewable energy investments. *Energy Policy* 34, 1004–1014.
- Cameron, T.A., 1985. A nested logit model for energy conservation activity by owners of existing single family dwellings. *The Review of Economics and Statistics* 67 (2), 205–211.
- Chamberlain, G., 1980. Analysis of covariance with qualitative data. *Review of Economic Studies* 47, 225–238.
- Ferrer-i-Carbonell, A., Frijters, P., 2004. How important is methodology for the estimates of the determinants of happiness? *The Economic Journal* 114, 641–659 (July).
- Greene, W.H., 2003. *Econometric Analysis — International Edition*. New York University.
- Horowitz, J.K., McConnell, K.E., 2002. A Review of WTA/WTP Studies. *Journal of Environmental Economics and Management* 44, 426–447.
- Hsiao, C., 1986. *Analysis of Panel Data*, 2nd ed. Cambridge University Press.
- Jakob, M., 2006. Marginal costs, cost dynamics and co-benefits of energy efficiency investments in the residential buildings sector. *Energy Policy* 34, 172–187.

- Jakob, M., Jochem, E., 2003. Erhebung des Erneuerungsverhalten im Bereich Wohngebäude (survey on the renovation pattern of the residential buildings sector). Study on Behalf of the Swiss Federal Office of Energy, Bern.
- Jakob, M., Baur, M., Ott, W., 2006. An Analysis of Direct and Indirect Benefits and Costs of Energy Efficiency Attributes in Residential Buildings. CEPE Working Paper No. 46, Centre for Energy Policy and Economics (CEPE), Zurich.
- Louviere, J.J., Hensher, D.A., 1982. On the design an analysis of simulated choice or allocation experiment in travel choice modelling. *Transportation Research Record* 890, 11–17.
- Louviere, J.J., Hensher, D.A., Swait, J.D., 2000. *Stated Choice Methods — Analysis and Applications*. Cambridge University Press, University, UK.
- Ott, W., Jakob, M., Baur, M., Kaufmann, Y., Ott, A., Binz, A., 2005. Mobilisierung der energetischen Erneuerungspotenziale im Wohnbaubestand (Mobilisation of the energy efficiency potentials of the residential building stock). Study on Behalf of the Research Program “Energiewirtschaftliche Grundlagen (EWG)” of the Swiss Federal Office of Energy (SFOE), Bern. November.
- Ott, W., Baur, M., Jakob, M., 2006. Direkte und indirekte Zusatznutzen bei energie-effizienten Wohnbauten (Direct and indirect additional benefits of energy efficiency in residential buildings). Study by Econcept and CEPE ETH Zurich on Behalf of the Research Programme EWG ([www.ewg-bfe.ch](http://www.ewg-bfe.ch)) of the Swiss Federal Office of Energy, Bern. January.
- Poortinga, W., Steg, L., Vlek, C., Wiersma, G., 2003. Household preferences for energy-saving measures: a conjoint analysis. *Journal of Economic Psychology* 24, 49–64.
- Sadler, M., 2003. Home Energy Preferences and Policy: Applying Stated choice Modeling to a Hybrid Energy Economic Model. Report to Natural Resources Canada, Simon Fraser University. September.
- Sayman, S., Öcüler, A., 2005. Effects of study design characteristics on the WTA-WTP disparity: a meta analytical framework. *Journal of Economic Psychology* 26, 289–312.
- Thomas, A., 2000. *Économétrie des variables qualitatives*. Dunod, Paris.
- Thompson, Ph.B., 2002. Consumer theory, home production, and energy efficiency. *Contemporary Economic Policy* 20 (1), 50–59.
- Verhoef, P.C., Franses, P.H., 2002. On combining revealed and stated preferences to forecast customer behavior: three case studies. *Econometric Institute Report*, 2002–04. Erasmus University Rotterdam.