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CEPE Working Paper No. 41
April 2005

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Willingness to Pay for Energy-Saving Measures in Residential Buildings*

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Abstract

This paper uses a choice experiment to evaluate the consumers' willingness to pay for energy-saving measures in residential buildings. These measures include air renewal systems as well as thermal insulation of windows and facades. In addition to considerable savings in energy consumption, these systems incur other "private" benefits such as thermal comfort, air quality and protection against noise. The extremely low rates of usage of these systems in Switzerland's residential buildings is generally explained by consumers' lack of information and/or the insignificance of private benefits, which have led the Swiss authorities to adopt a promotion policy through direct subsidies and information campaigns. The valuation of private benefits of energy-saving measures has been estimated using hypothetical choice experiments performed on two samples consisting respectively of 163 tenants living in apartment buildings and 142 residents of single-family houses. The respondents were repeatedly asked to choose between their status quo and an alternative situation characterized by different attributes and prices. The estimation method is based on a fixed effect logit model. The results suggest a significant willingness to pay for energy-saving attributes.

Keywords: energy efficiency, choice experiment, conjoint analysis, discrete choice, housing

JEL classification: Q40, R21, C25, C93

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* The authors would like to thank the Swiss Federal Office of Energy and its Research Program "Energiewirtschaftliche Grundlagen", the "Office Federal du Logement", the House Owners Association of Switzerland, the Canton of Basle and the electric utility of Zurich (EWZ) for their financial support on the project this paper is reporting on. Also we would like to thank the co-authors of the research project, Martin Baur and Walter Ott, from the company econcept AG of Zurich for their research efforts, valuable discussions and enthusiasm.

1 Introduction

As is the case in most industrialized countries in the temperate zone, residential buildings in Switzerland have an important share of the end use energy consumption and of the greenhouse gas emissions. Thus, improvements of energy efficiency have an important impact not only on the energy consumption of this sector, but of the country on the whole. The building sector could contribute considerably to reach the CO_2-emissions goals and thus to make some important steps towards sustainability. The long-term character of renovation in houses has to be considered in order to assess the importance of constructing or renovating a house according to a high energy-efficiency standard (energy-relevant renovations are carried out only every 20 to 40 years).

Besides user influence, the overall energy-efficiency of a building is defined mainly by the standards of the building envelope and the presence of an air renewal system[1] and only secondly by the efficiency of the heating system. If the firstly mentioned elements are implemented in an energy-efficient way they yield two kinds of benefits: first they reduce the energy demand of the buildings and thus the energy cost, and second they generate additional benefits. These so-called co-benefits, include (thermal) comfort of living, enhanced protection against external noise, improved indoor air quality, etc.

Every year 1% to 2% of the building envelop, the most important part that determines energy consumption, is facing a maintenance or renovation measure. Only 30% to 50% of these measures include insulation and exploit the energy efficiency potential offering a reduction of the energy consumption by 50% to 70% and only a very small fraction of the homeowners opt for enhanced energy-efficiency measures (see Jakob and Jochem, 2003). Houses with such enhanced energy-efficiency standards satisfy the conditions set by the label MINERGIE[2] and have an energy consumption which is 70% to 85% lower than the consumption of traditional houses built prior the 1970s or 50% lower of the standard of today's new buildings. Thus, the potential for energy efficiency improvements is great but only little exploited.

The Swiss and the cantonal governments support the renovation or new investments in houses satisfying the standards of the MINERGIE label: Owners can receive some subsidies from the cantons and different banks have preference interest rates for houses constructed or renovated according to the energy efficiency standard of MINERGIE. Although energy-efficient buildings are promoted, a relatively small number of houses are built according to this standard (5 to 10 percent of new single family houses and less than 5% of new apartment buildings) and hardly any renovation follows the MINERGIE guidelines.

In order to define policy actions more suitable to improve the energy efficiency of houses, it is important to have detailed information on the factors that influence the investment decision

[1] Note that the ventilation systems meant here are not air conditioning systems (including cooling and moisturisation) as known for office buildings, but new systems for the housing sector. These systems have reduced air exchange rates which fit to the needs of the housing sector and they do not include cooling or moisturisation. They are also called "housing ventilation" or "comfort ventilation". They provide the apartments with fresh and filtered air which is pre-heated by a heat-exchanger. With the installation of a comfort ventilation it is no longer necessary (but still possible) to open the windows in order to aerate the apartment. Thus, it is possible to avoid the loss of heat linked with the traditional aeration through opening the windows.

[2] Minergie is a quality label for buildings that combines high comfort of living and low energy demand which has to be reached within a limited cost surplus of at the most 10% of the construction price. Controlled air exchange is a requirement, which is mostly met with a housing or "comfort" ventilation system. See www.minergie.com for more information about Minergie in English or www.minergie.ch for information in French or German.

of the homeowners and on their willingness to pay for improvements in energy efficiency. For apartment buildings it is important to know how consumers value apartments in energy-efficient buildings, i.e. how they value the co-benefits of energy efficiency. Given this information it is rather feasible to give home and apartment building owners incentives for enhanced energy-efficient renovations or for investments in new energy-efficient buildings respectively.

Despite the importance of the issue, there are only a few studies that addressed the consumer's valuation of energy-saving measures in buildings. A first, older study of Cameron (Cameron 1985) analyzed the impact of energy-efficiency retrofits such as insulation and storm windows using a two-level nested logit model. The data collected by the national survey on energy consumption included both households who did not retrofit and those who did. The results of the study show a considerable sensitivity of demand for energy conservation retrofits with respect to changes in their capital costs and energy prices and to changes in income. In the more recent literature, conjoint analysis was used in order to elicit the choice behavior of households for energy-saving measures. For the Netherlands, Poortinga et al. (2003) have focused on the characteristics of 23 energy-savings measures – among others home energy savings like house insulation and energy-efficient heating systems – and their acceptability. The conjoint analysis was judged to be useful method for examining the acceptability of these measures, giving a hint which characteristics determine the choice of a measure. The study didn't focus particularly on the housing sector and neither did it aim aim at estimating the willingness to pay for some particular energy-efficiency measures. A choice experiment was also carried out in Canada (Sadler 2003) aiming at understanding the attributes and preferences of residential consumers when making decisions regarding investments in heating system or renovation that impact the efficiency of home energy consumption. The renovation choice was estimated using a binomial logit model, the heating system choice using a multinomial logit model. The results indicate a high preference for the energy efficient renovations. Besides the capital costs, the annual heating costs and the subsidy regime, the comfort level was one of the most important variables explaining the choice to renovate. This indicates that a good air quality increases consumer utility.

Until now, for Switzerland there are no published economic studies analyzing the willingness to pay (WTP) for energy-saving measures in residential buildings. The aim of this paper is to use a choice experiment to estimate empirically the WTP for these energy-saving measures.

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. The conclusions and a summary of the main results 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 (also) to the econometrician (thus, market data are collected), the second method is based on information extracted from interviews or choice experiments. Both methods have advantages as well as drawbacks. For an overview of the strengths and weaknesses of the two methods see for example Verhoef and Franses 2002 or Louviere et al. 2000.

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. Moreover, it is generally difficult to collect data of the available choice set from which the alternative has been chosen.

For the above reasons a stated preference method was chosen, in particular the method of choice experiment. This approach was initially developed by Louviere and Hensher (1982) and is one option in a family of empirical approaches known as choice modeling. A sample of households are presented with choice sets and asked to choose the alternative they prefer the most. In our case, using a combined mail/phone survey respondents were asked to choose between their actual situation and a hypothetical housing situation with different energy efficiency standards and a different price, all the other characteristics remaining the same. The following attributes are integrated into the model:

- windows with different energy efficiency standards;
- façade with different levels of insulation and esthetics;
- presence of a ventilation system;
- price.

Table 1 shows the housing attributes and their categories included to describe the energy efficiency of the hypothetical housing situation. In order to minimize the hypothetical character of the survey, respondents were asked to imagine that their actual housing situation would be improved (downgraded) in terms of the mentioned attributes, with all other characteristics being constant. The respondents already living in housing situations with a high energy efficiency standard were asked to imagine a decline in these features.[3] 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. An orthogonal design was used to specify the attributes in each choice task. The design of the experiment is documented in Ott, Baur and Jakob (2005). The choice situations with dominated alternatives[4] 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 the same as in the actual state. The number of cards for a given respondent depends on their actual situation. This number varies from 11 to 15 for the new buildings from 15 to 18 for the old ones. The survey was conducted in summer 2003.

[3] 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 category 1 and 2 of both window and façade were included in the choice set.

[4] In these cases, either the status quo or the alternative offer involves a lower (higher) level in all attributes with a higher (lower) price.

Table 1 Categories of different attributes (in descending order) and price levels considered in the choice experiment

Attribute	Categories
Window	1. Enhanced insulation (double coated pane) 2. Standard insulation (coated, rubber) 3. Medium old (low insulation, not coated) 4. Very Old (single glazing)
Facade	1. Enhanced insulation 2. Standard insulation 3. No insulation but newly repainted 4. Old (not repainted)
Ventilation	1. With air renewal system 2. Without air renewal system
Price [5]	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

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.[6] The underlying assumption is that households evaluate the characteristics of different housing alternatives and then choose the one which leads to the highest utility (utility maximization model relating to the housing services). 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 façade and the presence of a ventilation system), the characteristics of the building location, household characteristics etc. 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), as well as on 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 *t* can be represented as:

$$U_{qit} = V(X_{qit}, Z_q) + e_{qit} \tag{1}$$

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

$$P_{qit} = \exp(V_{qit}) \Big/ \sum_{j=1}^{J} \exp(V_{qjt}) \tag{2}$$

[5] 1 CHF = 0.65 Euro or 0.75 US $ (June 2003)

[6] The valuation of different housing attributes can also be estimated by applying the hedonic pricing approach. This approach is currently applied in an ongoing research project at CEPE.

Expression (2) is the basic equation of a multinomial logit (cf. Greene, 2000 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 can be written as A={0, 1} with 0 indicating the status quo and 1 representing preference for the offered alternative. The random utilities of the resulting binary logit model can be written as:

$$U_{q1t} = \boldsymbol{b}\, X_{q1t} + \boldsymbol{a}\, Z_q + e_{q1t}\ ;\ U_{q0t} = 0 \tag{3}$$

where Z_q represent the household characteristics that do not vary from choice task to choice task and X_{q1t} the characteristics of the alternative of choice task t for individual q, and $\boldsymbol{a}$ and $\boldsymbol{b}$ are the vectors of model parameters. In a multinomial logit framework, the parameters associated with one of the outcomes are normalized to zero namely, $U_{qot} = 0$. Therefore, U_{q1t} is the random utility of choosing the alternative over the present situation.

If all the relevant respondent's characteristics (Z_q) are observed, the model given in equation (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:

$$U_{q1t} = \boldsymbol{b}\, X_{q1t} + u_q + e_{q1t} \quad \text{with } u_q = \boldsymbol{a}\, Z_q \tag{4}$$

It should be noted that because of the presence of fixed effects in the model, vector X_{q1t} can be equivalently replaced by the X_{q1t}-X_{qot}, which measures the difference between the characteristics of the actual situation and the hypothetical alternative. This implies that U_{q1t} measures the net gained value through moving from actual situation to a hypothetical status. Given that the hypothetical alternatives may equally involve a better or worse situation regarding comfort, the individual specific term u_q represents 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. 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 individual q.[7] The conditional probabilities can therefore be written as:

$$\Pr\left(Y_{q1} = y_{q1}, \ldots, Y_{qT_q} = y_{qT_q} \,\middle|\, u_q\right) = \frac{\exp\left(\sum_{t=1}^{T_q} y_{qt} X_{qt} \boldsymbol{b}\right)}{\sum_{\sum_t d_{qt} = S_q} \exp\left(\sum_{t=1}^{T_q} d_{qt} X_{qt} \boldsymbol{b}\right)} \tag{5}$$

where $S_q = \sum_{t=1}^{T_q} y_{qt}$, the response variable is defined as: $Y_{qt} = \begin{cases} 1: \text{ if offer is chosen} \\ 0: \text{ offer is not chosen} \end{cases}$, and y_{qt} is the observed response.

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

[7] See Hsiao (1986) and Greene (2003) for more details and Ferrer-i-Carbonell (2004) for an application of fixed-effects logit model.

attributes can be calculated. If one of the attributes is a numéraire or a monetary variable the marginal willingness to pay can be derived as (p_{1q} being the price variable):

$$WTP = \frac{\dfrac{\partial U_{1q}}{\partial x_{1q}}}{\dfrac{\partial U_{1q}}{\partial p_{1q}}} \qquad (6)$$

The explanatory variables included in the model (vector X) include the characteristics of the hypothetical offers including dummies representing the window type, façade quality, presence of a ventilation system and the price (monthly rent for apartments and purchase price for single family houses).

4 Data description

Both samples for apartment buildings and single-family houses were stratified with the purpose of including a sufficient share of new and energy-efficient buildings.[8] The samples cover an important share of the German speaking part of Switzerland. The original samples obtained from the survey include 264 tenants (rented flats) and 253 single family house purchasers 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, the final regression samples consist of 163 tenants with 1928 observations and 142 house buyers with 1685 observations.[9]

This considerable failure rate (101 out of 264 and 111 out of 253) 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 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 are 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. All the attributes except prices are represented by dummy variables.

As seen in this table the share of apartments with installed ventilation systems is about 14 percent of the sample and that of single family houses is about 9 percent. These shares are slightly lower than the corresponding ones of the entire samples (about 20 percent of 264 tenants and 17 percent 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 discount in the rent or in the purchase price respectively.

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8 In the original study (Ott, Baur and Jakob 2005) the buildings constructed after 1995 and those with energy-efficiency labels have been distinguished from other buildings.

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

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 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 façade qualities in the samples are the standard insulation and the “old façade” (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 façade” ones (nor painted or insulated the last few years) are 36% (apartments) and 31% (SFH).

In the apartment sample, the number of choice tasks per person varies between 2 and 17 with an average of about 12 and a standard deviation of about 3.4. The number of accepted offers per person varies between 1 and 14 with an average of 3.4 accepted offers (standard deviation = 2.3). 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 (standard deviation = 2.6). Remember that those respondents that preferred always the actual situation are excluded from the estimation sample.

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 and a standard deviation of 230,000.

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 quite balanced: there is a comparable share of old, standard and enhanced windows in the offered alternatives. The same is true for the façade quality and the presence or not of a ventilation system. Note that 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 and a standard deviation of 624 CHF/month. Thus the average price of offers is about the same as the average price of the actual situation, meaning that there is about a same number of price increases and decreases. Indeed the average of the price variation is about 0 (10 CHF/month), with a standard deviation of 219 CHF/month. A similar number of price increases and decreases also holds for the SFH sample. Despite the fact that the sample of the offers is quite balanced, only less than one third of the offers were accepted (29% in the apartment sample and 19% in the SFH sample). This indicates a significant disutility of change.

In addition to prices, all the energy efficiency attributes are included as explanatory variables in the model. These variables include 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). Price variable for each observation (choice task) is actually the difference between hypothetical and actual prices.[10] An important observation reported by Ott, Baur and Jakob (2005) is that the respondents who already have a given attribute in their households attach a higher value to that attribute compared to other individuals. This can be explained by the fact that people are more familiar with the benefits of the measures of which they have a prior experience. In order to control for such asymmetric effects, a dummy variable has been constructed to indicate the choice tasks in which the hypothetical price is lower than the actual one, implying a decline at

[10] Note that because of the fixed effects, it would not matter if the price levels of the hypothetical alternatives were used instead of the price differences.

least in some of the attributes while other attributes have not changed. The interaction of this dummy with price is included in the model.

Table 2 Descriptive statistics

Respondents and characteristics of their actual residence	Tenants' sample Number of respondents	Tenants' sample Sample Mean	House buyers' sample Number of respondents	House buyers' sample 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 [r)] (609)	142	659 [p)] (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

Hypothetical offers	Tenants' sample Number of offers	Tenants' sample Sample Mean	House buyers' sample Number of offers	House buyers' sample Sample Mean
Accepted offers (positive outcomes)	1928	0.288	1182	0.270
Price	1928	1509 [r)] (624)	1685	661 [p)] (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
[r)] Monthly rent in Swiss Francs. [p)] Purchase prices in thousand Swiss Francs.

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. Starting from several hypotheses we tested if households with different characteristics and socio-economic variables differ with respect to their valuation of various 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. However, the results suggested that all the interactions were statistically insignificant at 10% significance level.[11] The income variable could not be included into the model because of the relatively high share of missing values. Indeed, only about two third of the respondents indicated whether their income was below or above a certain threshold (7500 CHF/month) and less than 50% stated their income class.

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 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 0 on the 5% level. Exceptions are the coefficients for enhanced windows and the interaction variable between housing ventilation system and new buildings for the rented flats.

A significant difference in the price reaction on the choices was found between price increases (price of the hypothetical alternative is higher than the price of the actual apartment) and price decreases. Note: no constant is estimated in the fixed effect logit approach (strong affinities, preferences or disutilities for the existing or for the alternative situation are captured by the individual fixed effects).

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

	Rented flats in apartment buildings			Purchase of single family houses		
Attributes	Coeff.	Std. Err.	Sig.	Coeff.	Std. Err.	Sig.
Price [1)]	-0.0089	0.0009	***	-0.0229	0.0033	***
Price * dummy decreasing price	0.0047	0.0014	***	0.013	0.0055	**
Enhanced insulated window [2)]	0.15	0.21	n.s.	0.14	0.23	n.s.
Enhanced facade insulation [3)]	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 [2)]	-1.49	0.22	***	-1.95	0.24	***
Very old windows	-2.68	0.25	***	-3.08	0.29	***
Painted facade [3)]	-0.73	0.22	***	-0.97	0.25	***
Unpainted facade [3)]	-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^2	0.318			0.298		

[1)] Prices are expressed in CHF/month for rented flats and in thousand CHF for single family houses
[2)] Reference category: new standard insulated windows [3)] 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

Using equations (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's coefficient. For the sake of a better

[11] The details of these analyses are not reported in this paper.

comparability for the international reader, the WTP results in Table 4 are expressed as a percentage of the reference purchase price (houses) and as a percentage of the reference rental price (flats). The average prices of both new and old buildings serve as this reference [12]. In new buildings the willingness to pay for an enhanced façade insulation is about 3% whereas the ventilation system is valuated 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. Remember that the survey was conducted in summer 2003 which was an extraordinary summer with hot temperatures that lasted for months. This might explain the relatively high WTP for ventilation systems. Even if a comfort ventilation system as considered here is not designed for cooling the interviewed persons could have associated cooling with this system.

In existing (not new) buildings we ascertain willingness to pay for energy efficient façades and windows. Regarding the façade there is a WTP for insulation of 6% and 7% for SFH, whereas the estimated WTP for esthetic reasons is low (approx. 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 glasses have a higher surface temperature and sealing rubber protect from air infiltration and 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 façades for old and new buildings, the marginal WTP for each further step of energy efficiency is decreasing which is quite plausible. Indeed the utility of the “first” improvement is expected to provide a higher utility than the one of an improvement from an already good to an even better level.

The willingness to pay for ventilation systems in old buildings is below the one in new buildings. The lower willingness to pay for ventilation systems in old buildings could be explained by different preferences of residents living in old or new buildings respectively or by the different reference price level. Persons that choose new buildings might rather prefer a high standard of living and consequently their willingness to pay for ventilation, which is a feature of high standard, could be higher. Note that in the case of tenants, the willingness to pay in relative terms, i.e. if it is referred to the reference price level, is very similar for both old and new buildings. That the willingness to pay for ventilation is different between persons living in new or in old buildings could be interpreted as an income effect, since income of people living in new buildings is slightly higher than of those living in not new buildings.

[12] These prices are 650,000 CHF and 686,000 CHF for new and existing single family houses respectively and 2030 CHF/month and 1330 CHF/month for flats in new and in existing buildings respectively. 1 CHF = 0.65 Euro or 0.75 US $ (June 2003)

Table 4 Marginal willingness to pay derived from discrete choice models, expressed as % of rental price (flats) and purchase price (single family houses) respectively [12]

Attribute	Rented flats in multi-family houses WTP	Sig.	95%-Interval		Purchase of single family houses 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

The willingness to pay for energy-efficiency attributes such as window or façade insulation or for the installation of a ventilation system can be compared with the capital costs of implementing such attributes. In (Ott al. 2005) some typical capital costs are given for the example of a typical flat of hundred square meters. 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.[13] An exception is the enhanced window insulation of new buildings, a result which is quite plausible though. Indeed the marginal utility of an enhanced window is quite small since new buildings have already quite a high standard because of legal requirements. Actually the same result for enhanced façade insulation wouldn't have been a surprise either.

That willingness to pay exceeds cost can be interpreted in different ways: On the one hand these results could indicate that people actually desire enhanced efficiency of their flats but that the housing market did not yet react to this demand. On the other hand it cannot be excluded that the values of the estimated willingness to pay are overestimated, for example because stated preference results generally an overestimation or because the sample is not representative for the Swiss population. Indeed there is a overrepresentation of persons with a higher educational level in the sample. It is generally known, that these persons are more sensitive to environmental and energy related topics.

The willingness to pay can be compared with the results achieved through a study using the hedonic pricing method (Ott et al, 2005 and Jakob, 2005). In that study, some of the characteristics of housing were related to efficiency measures such as ventilation, insulated windows and façade. Preliminary results indicate a price effect of 7.5% for rented flats in new buildings that were built according to the Label Minergie. For old buildings, a price effect of 8% was identified for buildings with a renovated, insulated façade. Both results are valid for the greater Zurich area. Even though the hedonic regression method has also some limitations (limited separability because of collinear explanatory variables, variables included in the model could capture non-observed effects), it is interesting to notice that, although the methods

[13] It is important to consider that we assume that the values of the WTP include also the reduction in energy costs.

applied are quite different, the willingness-to-pay-values found in this paper are comparable with the price effects obtained using the hedonic regression method.

6 Summary and Conclusion

This paper gives some detailed insight into the willingness to pay for improvements in energy efficiency by modeling renters' and house buyers' choices of housing with regard to different energy efficiency standards of windows and façade as well as to the presence of an air renewal system. Given this information it is rather feasible to give apartment building owners incentives for enhanced energy-efficient renovations or for investments in new energy-efficient buildings respectively.

The data used for the econometric estimation were collected with a choice experiment. A sample of households 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 econometric analysis of the data has been carried out using a fixed effect logit model (Greene 2003). The coefficients of all attributes have the expected sign and most of them are significantly different from 0. Based on the estimation results, the willingness to pay (WTP) for attributes that improve comfort and energy efficiency is estimated. The results show a significant willingness to pay for energy-efficiency attributes of rental apartments and of traded houses. The willingness to pay varies between 3% of the price for an enhanced insulated façade (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 (in comparison to old windows) respectively.

The WTP is generally higher than the costs of implementing these attributes. Therefore, for owners of rental apartment buildings it would be economically reasonable to invest in energy efficiency measures. However, it has to be kept in mind that due to a possible overrepresentation in the sample of environmentally sensitive people, the WTP values presented in this study should be used with caution.

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