Are dwellers deliberative or heuristic in their decisions to invest in energy efficient renovation measures?

Victoria Taranu
Hasselt University
Faculty of Architecture and Arts
Agoralaan Gebouw E
3590 Diepenbeek
Belgium

Sebastien Lizin
Hasselt University
Environmental Economics group
Agoralaan Gebouw D
3590 Diepenbeek
Belgium

Griet Verbeeck
Hasselt University
Faculty of Architecture and Arts
Agoralaan Gebouw E
3590 Diepenbeek
Belgium

Keywords

behavioural change, energy efficiency investments, policy-making, existing residential buildings, decision-making process, renovation, choice experiment, heuristic thinking

Abstract

In order to develop behaviourally-informed policies it is important to understand the mechanisms behind investment decisions in energy efficient (EE) renovation. This study contributes to understanding both deliberative and heuristic thinking of house owners. Unlike previous research, it does not limit to testing biases in isolation, but explores the balance between deliberative/heuristic thinking. The undertaken survey (n=178) consists of two parts complementing each other: a ranking exercise and a labelled choice experiment (CE).

The ranking exercise consists in pairs of questions with arguments in favour of and against undertaking five EE renovation measures. It aims at verifying whether deliberative or heuristic thinking prevails. For example, a deliberative reasoning is "It is good for the environment to save energy", denoting slow, self-aware thinking based on values, beliefs and personal norms. An example of heuristic thinking is "All my neighbours have changed their windows" denoting social norm bias that works as a shortcut. The labelled CE further explores motivations to undertake renovation measures. Respondents had to choose between four measures, with varying levels of the following characteristics: visual changes, thermal comfort obtained, CO_2 reduction, investment cost, hassle during renovation and source of advice.

By joining insights from both parts of the survey we can assess the consistency and draw conclusions. Results of the ranking exercise show that arguments in favour of uptake are mostly deliberative, whereas arguments against depend on whether the respondent installed the measure or not. The relevance of investment cost and reduction in CO_2 in the adoption intention was reconfirmed by the CE. Since deliberative reasoning such as monetary and CO_2 savings are already perceived as motivations while investment cost is still a barrier for those who did not install the measures, providing information on financing schemes might be more effective than underlining monetary savings.

Introduction

Energy efficiency is central for climate policies and every country possesses this resource in abundance (International Energy Agency 2016). Alongside with renewables, energy efficiency is expected to contribute to achieving the EU proposed target of 40 % reduction of CO_2 emissions by 2030 compared to 1990 levels and energy savings of at least 27 % (European Comission 2016). The residential sector is an important share and accounted for 25 % of the final energy consumption in the EU, according to 2014 data (Bertoldi, Lorente et al. 2016). The minimum requirements of 2010/31/EU Directive (EC 2010) have translated into substantial improvements for the new construction of dwellings. Yet the existing building stock still has a considerable untapped potential, with 75 % of the existing buildings being inefficient and the availability of cost effective renovation measures (European Comission 2016).

In the present paper, by referring to energy efficient (EE) renovation measures, we include the following:

- insulation (roof and wall insulation, EE windows)

- production of hot water and energy-efficient heating, ventilation and air-conditioning (HVAC) (EE boilers, solar water heaters, geothermal heat pumps)
- production of renewable energy (photovoltaic solar panels)

The residential building stock of many EU member states, including Belgium, is characterized by high ownership rates of over 70 % (BPIE 2011). Additionally, in Flanders terraced, semidetached and detached houses (94,9 %) prevail over apartment blocks (Kadastrale statistiek). Therefore, the decision to invest in EE renovation measures is usually an individual decision of the house owner who is also the occupier.

In order to achieve the EU targets, EE renovations have to be scaled up in member states with both 'hard' and 'soft' policy measures (Groote, Lefever et al. 2016). The former implies mandates, such as mandatory minimum energy performance requirements, while the latter consist mostly in information provision, financing schemes and incentives. Most of the 'soft' measures, such as information campaigns and incentives assume that raising awareness on environmental and economic benefits of the EE renovation is sufficient for increasing its uptake. However, evidence shows that the actual decisions are affected by limited memory, limited attention and limited cognitive abilities (Simon 2000). When processing information, people often avoid engaging in effortful, cognitive thinking – System 2, in favour of using a shortcut – System 1 (Darnton 2008). In this paper, we will refer to System 2 thinking as *deliberative* and System 1 thinking as *heuristic*. The latter is intuitive, effortless and automatic and people are usually unaware of it. The rational processing of the information regarding EE renovation might be affected by heuristics and *biases* (Tversky and Kahneman 1973). Overload and complexity of the information and emotions are only some of the factors that might contribute to a heuristic thinking.

Biases affect the proper estimation of probability and in economics, biases are defined as "errors when attempting to maximize the utility U(x)" (Rabin 1998). People do not always behave as perfect homo economicus, as expected from the formula of maximization of expected utility (Simon 2000). Many theories in *behavioural economics* explain consumer behaviour using research methods and insights from psychology. The theory of *bounded rationality* (Simon 1955) takes into account the human limitations such as limited memory, attention and cognitive abilities.

Another theorization of the deviation the modern neoclassical economics assumptions is the *Judgment under uncertainty* (Tversky and Kahneman 1973). The empirical studies of Tversky and Kahneman provide evidence of the interference of heuristics and biases in the actual decisions. Their main heuristics are *representativeness*, *availability* and *anchoring* with their subsequent biases (Kahneman, Slovic et al. 1982). Representativeness heuristic explains how people assess the probability of events merely based on the "degree to which A resembles B" (Tversky and Kahneman 1974), ignoring important factors such as sample size and base rate frequency of the outcome. Availability heuristic affects the assessment of the probability of an event by the ease with which it can be recalled (Tversky and Kahneman 1974). If the event is present in the memory, it is due to *retrievability* bias, otherwise it is due to *imaginability* bias. Anchoring heuristic explains how the assessment of the final value or probability is influenced by the reference point, so that "different starting points yield different estimates" (Kahneman, Slovic et al. 1982). Besides, people often do not take cold-minded and rational decisions because they are affected by emotions – *affect heuristic* (Finucane, Alhakami et al. 2000).

Recently, there is a growing interest to apply these findings to policy making. One of the applications is the commonly known *libertarian paternalism* (Thaler and Sunstein 2008). It advocates to elaborate policy instruments that preserve the freedom of choice, *nudges*, instead of using mandates (Sunstein 2014). At the same time, nudging aims to take into account and correct the unrealistic optimism, limited attention and the problem of self-control characteristic to individuals (Sunstein 2014). Nevertheless, libertarian paternalism is only one of the possible applications of behavioural economics to policy (Lunn 2013). Traditional policy tools such as mandates or incentives can be elaborated and implemented taking into account the evidence of heuristic thinking. These are the *behaviourally-informed* and *behaviourally-aligned* policy measures (Lourenço, Ciriolo et al. 2016).

In order to elaborate effective policy measures for promoting EE renovation, it is necessary to consider both the deliberative and heuristic thinking of the house owners. For this purpose, a survey consisting of a ranking exercise and a choice experiment (CE) was undertaken among Flemish dwellers. The survey does not limit individuating motivations and barriers, but explores the way of reasoning behind the decisions regarding EE renovation measures. Both aspects were cross checked with a ranking exercise and a CE. The present paper is structured as follows: the first section details the method of the survey, the second section summarizes the findings and in the conclusion section the implications to policy are presented.

Method

The data for this research were collected conducting a quantitative survey in Dutch in Belgium. The survey contained three main sections: socio-demographics and housing conditions, a ranking exercise and a CE. In the first section, the respondents and their living situation were profiled. For example, we asked respondents to provide their age, sex, education, whether are they owning or renting, with how many people they live, the construction and the purchase year of the dwelling, whether they have plans to renovate, etcetera. In the second section, the respondents were asked to fill out a ranking exercise (see Ranking exercise subsection for more detail). In brief, the ranking exercise allows finding out whether deliberative or heuristic reasoning is behind arguments in favour of or opposing renovation. In the third section, respondents were first introduced to the concept of a CE by means of an example, after which they had to fill out four choice sets consisting of four labelled alternatives (see the Choice experiment section for more information). The CE further explores the features that stimulate or discourage undertaking renovation measures.

The survey was collected using computer-assisted personal interviews by trained surveyors using random intercept sampling at the largest construction fair in Belgium and at the entrance of a construction materials retail store. By consequence, our target population consists of people interested in construction and renovation – 15.2 % are currently renovating and 30.9 % plan to renovate in the next five years, see Table 4. Besides, 43.3 % of the sample plan to invest in EE renovation measures in the next five years, a higher percentage compared to 5–13 % of the Flemish population as identified in representative samples (VEA 2013). This data collection method and sample was deliberative, because literature points out to external conjuncture or major life event (such as purchase of a dwelling, family enlargement, etc.) as triggers to renovation (Wilson, Crane et al. 2015). These triggers, at their turn, are conditioned by social practices and everyday domestic life (Shove 2003). Once a renovation is decided, the house owner has yet to decide how much will be invested in EE renovation measures, alongside investments in amenity renovation measures. Therefore, the house owners interested in renovating are an important target group for information campaigns regarding EE renovation. The data were collected from March to September 2016 and in total, 178 useable responses were obtained.

RANKING EXERCISE

Goal and format

The purpose of the second part of the survey, the ranking exercise, was to investigate the use of deliberative and heuristic thinking, when dwellers process information regarding EE renovation measures. We verified whether the arguments in favour of renovation are mostly deliberative and/or the ones against are mostly heuristic. These hypotheses are based on the findings from Schwartz' study from 1979 "when subjected to positive affects, people tend to move the eyes to the right and when subjected to negative affects – to the left" (Cacioppo and Petty 1983). Since the left hemisphere is responsible for cognitive thinking and the right for the intuitive thinking, the study provides evidence that positive emotions are processed by System 2, while the negative by System 1.

More clues supporting these hypotheses resulted from a focus group on behavioural insights in EE renovation organized in April 2015 by our research group with municipal officials in the context of Werfgoed Living Lab. Among arguments in favour of renovation were listed "to reduce the footprint" (ecological values, beliefs), "house increases in value" (expected utility); while among arguments against the renovation were listed "a lot of cluster, noise, dust" (affect heuristic), "I like how my house looks now" (endowment effect, status quo bias). The aim of the ranking exercise was not to individuate the specific reason or obstacle for the uptake of a particular renovation measure. This kind of analysis has been made in large scale surveys in the Flemish Region (VEA 2013, Ceulemans and Verbeeck 2015) and these findings were taken into account when elaborating the survey. Our objective was to sort out the way of reasoning, i.e. to determine whether deliberative or heuristic thinking prevails.

The ranking exercise regarded five renovation measures: wall insulation, EE windows, EE boiler, solar panels and solar water heater. For each measure a set of two questions was presented to respondents: with arguments in favour and against the uptake, see Table 1. These were based on the most frequently reasons cited by Flemish private owners in large scale surveys (VEA 2013, Ceulemans and Verbeeck 2015). Each question included four options, with two deliberative arguments (based on Value-belief-norm, Expected Utility, Information deficit theories) and two heuristic arguments (based on biases such as social norm, loss aversion, endowment bias, mental accounts, affect heuristic). The description of the behavioural models were not visible to respondents who had to rank the four options of the question, assigning 1 to the most preferred option and 4 to the least preferred.

CHOICE EXPERIMENT

Goal and format

The goal of the CE was to find out the preferences of people interested in placing EE renovation measures and their attributes. Moreover, we aimed to verify whether deliberative or heuristic arguments were the stronger factor in influencing renovation choices. The experiment was presented to owners and renters by means of detailed stylized hypothetical renovation scenarios for an average Belgian dwelling. This simultaneously avoided

Table 1. Example of ranking exercise item with the explanation of the behavioural models (not visible to respondents) 1.1 Arguments in favour of placing the measure 1.2 Arguments against placing the measure.

1.1	I would install solar water heater because…			Behavioural Model/ Insight
	A	It is good for environment to save energy	D+	Value-belief-norm theory
	B	Are much cheaper than PV panels	H +	Anchoring bias
	C	All my neighbours installed	H+	Social norm bias
	D	Are cost effective	D+	Expected Utility

1.2	I would not install solar water heater because…			Behavioural Model/ Insight
	A	It is too difficult to install: dirt, mess	H-	Affect heuristic
	B	It costs too much	D-	Expected Utility
	C	I do not know much about its advantages and disadvantages	D-	Information deficit
	D	A friend has a bad experience installing/using solar heaters	H-	Availability heuristic

Table 2 Example of a labelled choice set.

Attributes	Windows Energy-efficient windows	Insulation Roof and wall insulation	Heating system Geothermal heat pumps	Renewable energy PV panels
Changes in the visual aspect of the house	minor	minor	drastic	drastic
Improvement in the level of thermal comfort	big	big	small	small
CO_2 reduction of the dwelling	75 %	50 %	50 %	75 %
Investment cost	12,000 Euros	12,000 Euros	12,000 Euros	8,000 Euros
Level of hassle during works	Little	a lot	little	a lot
Source of advice	Expert	friend	no advice	no advice
CHOICE	**O**	**O**	**O**	**O**

unrealistic values to be presented. In CE, respondents are typically presented with several choice sets consisting of multiple alternatives from which they are asked to choose their most preferred alternative. For an example of a labelled choice set, see Table 2. The latter shows a translated version of the choice sets that were used in the original, Dutch survey. To fill out a choice set, respondents were required to choose their single, most preferred renovation measure. Each choice set contained the following four labelled alternatives: EE windows; roof and wall insulation; geothermal heat pumps and PV panels. Each alternative was described by varying levels of the following characteristics: the degree of visual changes, the thermal comfort obtained, the CO_2 reduction, the investment cost, the hassle during renovation and the source of advice. By capturing which alternatives have been chosen, the relative importance of the different attributes and levels can be estimated (Rose, Bliemer et al. 2008). Compared to other preference elicitation mechanisms, a choice based elicitation format has the advantage of resembling an actual (purchasing) decision (Ward, Clark et al. 2011).

Experimental design

Setting up a CE requires creating an experimental design. The latter involves the process of combining attributes and levels into the choice sets, which consist of a number of alternatives, that are presented to the respondents. Therefore, the labelled alternatives, which shape the respondents' universal choice set, need to be determined as well as the alternatives' respective relevant attributes and levels. We relied on a literature review, expert interviews and calculations based on standardized pricing for their determination. An overview of the alternatives, their attributes and all possible levels are provided in Table 3. A pilot survey was performed to ensure proper understanding of the attributes, levels and the elicitation mechanism. As can be seen from Table 3, the attribute development process has led to the conceptualization of six attributes for the four alternatives. A cap on the number of attributes was set at six and on the levels at three as survey length and cognitive burden increases with the previously mentioned numbers (Caussade, Ortúzar et al. 2005). The levels that will be used as the base levels in the estimation of dummy coded attributes are underlined.

Having acquired the necessary input, one can start the actual statistical design of the experiment. Its two main concerns are the identification and statistical efficiency of the estimates. Identification signals whether main effects and interaction effects between attributes can be (independently) estimated (Hoyos 2010). For our case, the pilot study showed that selected interaction effects (e.g. investment cost * expert advice) were not statistically significant. Consequently, in the final design, they were omitted. Statistical efficiency aims at providing the maximum accuracy of the estimates for the unknown population parameters, given the available sample size. Efficient designs based on minimization of D-error have recently become increasingly popular. Formulae for the computation of D-error or D-efficiency can widely be found in literature (Rose, Bliemer et al. 2008, Kuhfeld 2010, Bliemer and Rose 2011). In brief, obtaining minimum error or maximum efficiency comes down to minimizing the determinant of the asymptotic variance covariance (AVC) matrix of the used non-linear regression model.

However, this optimization is dependent on the coefficients we are trying to estimate. Hence, there is a need to define priors, which reflect the prior information we might have (e.g. we expect that low hassle will be preferred over high hassle). Using the priors obtained by estimating a conditional logit (CL) on the pilot study as point estimates, we created a main effects only, forced choice, D-efficient design for a CL model using the software program NGENE. A forced choice is justified seeing that people have to choose between competing EE renovation measures in order to achieve a certain energy performance. Most of the EU member states have implemented mandatory minimum energy performance requirements for major renovations, stipulated by the EPBD Directive 2010/31/EU (EC 2010). In the view of 2030 and 2050 EE targets these minimum requirements will most likely gradually get tighter (European Comission 2016). The final experimental design is fractional factorial and contains 24 choice sets. A powerful argument in favour of D-efficient designs has been provided by Bliemer and Rose (2011) as they found empirical proof that pursuing the highest D-efficiency minimizes standard errors on coefficients and thus allows smaller sample sizes compared to the previously used design types. Given the large number of choice sets in the design, it was decided to split the full design over six surveys. Hence, each respondent needed to fill out only four choice sets. Using labelled alternatives, one can estimate alternative-specific (e.g. a coefficient for investment cost for specific alternatives, for example for PV panels only) or generic coefficient estimates (e.g. a coefficient for investment cost that is the same for all alternatives) (Hensher, Rose et al. 2005).

Estimation

To formalize the decision making process, CE have adopted the random utility theory (RUT), which was originally developed by Thurstone (1927), and Lancaster's theory of value (Lancaster 1966), which allows seeing the value of a good as the sum of the value of its attributes. McFadden (1974) translated the RUT into the mathematical formulation of the CL model. In short, the derivation from RUT to the general expression for the CL model is as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

$$P_{ij} = P\{V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik};\ \forall k \in t\} \tag{2}$$

$$P_{ij} = \frac{exp(\mu\, V_{ij})}{\sum_{k\in t}^{K} exp\ (\mu\, V_{ik})} \tag{3}$$

$$V_{ij} = \sum_{q\in j}^{Q} \beta_q * X_q \tag{4}$$

RUT assumes that total latent utility U_{ij} for an individual *i* from choosing alternative *j* depends on deterministic part V_{ij} (observable to the researcher) and a stochastic part ε_{ij} (unobservable to the researcher) at the time of choice which for simplicity is omitted (Eq. 1). Hence, the probability P_{ij} that an individual *i* prefers option *j* over all other alternatives *k* in choice set *t* can also be expressed as the probability that the total latent utility of person *i* for option *j* exceeds that of all other alternatives *k* in choice set *t* (Eq. 2). Estimation of this equation requires assumptions to be made about the error terms. The assumption of independently (no cross-correlation) and identically (extreme value type 1) distributed (IID) error terms allows for the convenient closed-form equation of the CL model, which is given in equation 3. Here, μ is a scale parameter which causes different CE results not to be directly comparable. Within a single study it is most often assumed to be equal to one (Ben-Akiva and Lerman 1985). V_{ij} is commonly assumed to be a linear, additive function with X_q a vector of all attribute levels *q* of alternative *j* and their respective attribute coefficients β_q (Eq. 4). V_{ij} transforms the multi-dimensional attribute vector into a one-dimensional utility measure (Louviere, Hensher et al. 2000). Consequently, the higher the attribute (level) coefficient, the higher the utility (ceteris paribus), and the higher the probability that an alternative (i.e. a specific attribute-level combination) will be chosen. Note that β_q is not indexed for the respondents *i*, hence preference homogeneity is assumed when using the CL model.

Findings

Out of 190 collected responses, 12 were incomplete and 178 were complete useable responses (93.7 %). The age of the sample varies from 20 to 76 years, with the mean at 39 years. There is a higher share of males with 61.8 % compared to 49.4 % of

Table 3. Alternatives, attributes and levels.

	Attributes	Windows Energy-efficient windows	Insulation Roof and wall insulation	Heating system Geothermal heat pumps	Renewable energy PV panels
Deliberative	Investment cost (Euros)	8,000 10,000 12,000	8,000 10,000 12,000	12,000 14,000 16,000	6,000 8,000
Heuristic Affect heuristic	Hassle during works	*little* a lot	*little* a lot	*little* a lot	*little* a lot
Heuristic Endowment effect	Changes in the visual aspect of the house	*minor* drastic	*minor* drastic	*minor* drastic	*minor* drastic
Deliberative	Improvement in the level of thermal comfort	*small* big	*small* big	*small* big	*small* big
Deliberative	CO_2 reduction	*25 %* 50 % 75 %	*25 %* 50 % 75 %	*25 %* 50 % 75 %	*25 %* 50 % 75 %
Availability heuristic (friend)/ Deliberative (expert)	Advice	friend advice expert advice *no advice*	friend advice expert advice *no advice*	friend advice expert advice *no advice*	friend advice expert advice *no advice -*

the Flemish population (Eurostat Database 2016) and 62.9 % of the respondents have higher education. Yet the sample is rather representative in terms of ownership, with 23.6 % of renters compared to 21 % of the Flemish population (VEA 2013). The survey targeted dwellers interested in renovation, therefore 15.2 % of the respondents are currently renovating and 43.3 % plan to invest in EE renovation measures in the next five years, see Table 4.

RANKING EXERCISE

After socio-demographics, a ranking exercise regarding deliberative and heuristic thinking followed. This part of the survey concerned five EE measures: wall insulation, EE windows, EE boiler, solar panels and solar water heaters. Firstly, the respondents were divided into house owners (76.4 %) and renters (23.6 %). Secondly, only the house owners were asked which of the following measures they have installed. The measures with the highest uptake are EE windows (54.5 % of the total number of respondents), wall insulation (44.4 %) and EE boiler (44.4 %), see Table 5. The responses of the house owners who have installed any of the measures (EXPERIENCES) were analysed separately compared to the house owners who did not and those who are renters (INTENTIONS). This distinction is important because the former regard stated preferences over revealed choices, while the latter are stated preferences over stated choices. Since the number of respondents who have installed solar panels and solar water heaters are too low for quantitative analysis (35 and 9 responses respectively, see Table 5), the findings over these measures are based only on INTENTIONS answers.

The hypothesis of the ranking exercise is that the dwellers are mainly deliberative in their positive arguments and are mostly heuristic in their negative arguments:

Hypothesis 1: Arguments in favour are mostly deliberative $\Sigma(D+)>\Sigma(H+)$

Hypothesis 2: Arguments against are mostly heuristic $\Sigma(H-)>\Sigma(D-)$

For each EE measure two questions were presented: the first item consisted in arguments in favour (+) and the second in arguments against placing the EE renovation measure (–), see Table 1. For each question, two options denote deliberative thinking (D), while the other two heuristic thinking (H). The respondents ranked the four options of each item. The highest ranked option got 4 points, the second best 3 points, then 2, then 1 point. The points of the two deliberative options are summed (ΣD), as are the points of the heuristic options (ΣH). The possible outcomes of the sums for ΣD are 7 (the two highest ranked options are deliberative), 6 (highest and third ranked option are deliberative), 5, 4 and 3, and then ΣH respectively equals 3, 4, 5, 6, 7.

INTENTIONS include the responses from renters and from the house owners who did not install the measure. Yet, renters might have different external constraints than house owners. In order to verify if their responses are different, we have performed t-tests for independent (unpaired) samples. We have checked if the difference in means is not equal to 0:

$$\Sigma D \text{ renters} - \Sigma D \text{ owners} \neq 0$$

$$\Sigma H \text{ renters} - \Sigma H \text{ owners} \neq 0$$

for both arguments in favour of (D+ or H+) and against installing (D– or H–), for each of the 5 measures. The difference was not significant for any of the t-tests. Therefore, we can analyse the responses of the renters together with the ones of the house owners who did not install it, both belonging to the category INTENTIONS.

In order to verify the two hypotheses, Student's t-tests for paired sample were performed to verify whether differences ΣD–ΣH for each respondent is different from 0. These t-tests were conducted for each of the 5 EE measure: for the positive arguments and negative arguments of the EXPERIENCES and INTENTIONS groups respectively. The first hypothesis would be true if the difference ΣD–ΣH is positive and significant for arguments in favour, while the second hypothesis would be true if the difference ΣD–ΣH is negative and significant for arguments against installing the measure. The results are summarized in Table 6. The results were confirmed also with Mann-Whitney-Wilcoxon test for paired data.

For all the measures the first hypothesis was confirmed: the dwellers are more deliberative in their positive arguments. This is common for both house owners who installed the measure (EXPERIENCES) and the ones who did not or who are renters (INTENTIONS). These deliberative arguments in favour are based mainly on monetary motivations ("I want to save money on heating") or environmental motivations ("It is good for environment to save energy"). Therefore, indepen-

Table 4. The renovation trends of the sample and the difference between renovation and installing EE measures.

		N	Percentage out of total N=178	
Renters		42	23.6 %	100 %
House owners	Have never renovated	65	36.5 %	
	Renovated > 10 years ago	11	6.2 %	
	Renovated 5 to 10 years ago	9	5.1 %	
	Renovated < 5 years ago	24	13.5 %	
	Are currently renovating	27	15.1 %	
Plan to renovate in the next 5 years		55	30.9 %	
Plan to invest in energy efficient renovation measures in the next 5 years		77	43.3 %	

Table 5. Uptake of the five EE renovation measures of the ranking exercise among house owners.

	N	Percentage out of total N=178
Wall insulation	79	44.4 %
EE windows	97	54.5 %
EE boiler	73	41.0 %
Solar panels	35	19.7 %
Solar water heater	9	5.1 %

dently whether they installed the measures or not, dwellers are equally aware of the monetary and CO_2 savings and they prevail over heuristics.

Regarding the negative arguments, the second hypothesis was not confirmed: the heuristic arguments do not prevail. It is important to remark that here the responses between house owners who have undertaken the measure (EXPERIENCES) differ from ones who did not (INTENTIONS). The former show a balanced deliberative and heuristic thinking, whilst for the latter group deliberative thinking still prevails for all the measures except for EE boiler, Table 6. A possible explanation of the different reasoning between EXPERIENCES and INTENTIONS in terms of obstacles might be the investment cost. While both groups are aware of the monetary and environmental savings as main motivations, the respondents who did not install the measures are more concerned about the investment cost. Another possible explanation of this finding is that the house owners who installed the measure (EXPERIENCES) are more self-aware of their own biases, since the responses are self-reported preferences.

CHOICE EXPERIMENT

The estimated utility functions take the following form (see equations 5–8) with ASC being the alternative specific constant and $\beta_{\#}$ the coefficient estimate for that alternative and attribute (level). The significant attributes or attribute levels are indicated in bold to facilitate legibility. Note that all dummy level coefficient estimates, indicated by the d_ prior to the matching the attribute level, should be interpreted relative to the omitted base levels.

U(Energy-efficient windows)= ASC1 + **β_{11}*d_drastic_visual_change** + β_{12}*d_big_thermal_comfort_improvement + β_{13}*d_lots_of_hassle + β_{14}*d_friend_advice + **β_{15}*d_expert_advice** + β_{16}*d_50 %_CO_2_reduction + β_{17}*d_75 %_CO_2_reduction + β_{18}*investment_cost (5)

U(Roof and wall insulation)= ASC2+ β_{21}*d_drastic_visual_change + β_{22}*d_big_thermal_comfort_improvement + β_{23}*d_lots_of_hassle + β_{24}*d_friend_advice + β_{25}*d_expert_advice + β_{26}*d_50 %_CO_2_reduction + **β_{27}*d_75 %_CO_2_reduction + β_{28}*investment_cost** (6)

U(Geothermal heat pumps)= ASC3+ β_{31}*d_drastic_visual_change + β_{32}*d_big_thermal_comfort_improvement + β_{33}*d_lots_of_hassle + β_{34}*d_friend_advice + β_{35}*d_expert_advice + β_{36}*d_50 %_CO_2_reduction + **β_{37}*d_75 %_CO_2_reduction** + **β_{38}*investment_cost** (7)

U(PV panels)= β_{41}*d_drastic_visual_change + β_{42}*d_big_thermal_comfort_improvement + β_{43}*d_lots_of_hassle + β_{44}*d_friend_advice + β_{45}*d_expert_advice + β_{46}*d_50 %_CO_2_reduction + **β_{47}*d_75 %_CO_2_reduction** + β_{48}*investment_cost (8)

The results of the estimation of an alternative-specific CL model are presented in Table 7. For brevity only the significant estimates are displayed. The results pick up on the main effects that are easiest to detect and hence are most likely to have the strongest effect on choices in a follow-up study which allows estimating the sign and size of all significant alternative-specific coefficient estimates. From these results, we can infer the following conclusions. Firstly, visual changes play a significant role in the decision to install energy efficient glazing and as expected people prefer minor changes over drastic changes. Secondly, our respondents do not strongly associate greenhouse gas savings with installing energy efficient glazing, whereas they do for the other alternatives under study. Moreover, as expected, larger savings are preferred over smaller ones. Thirdly, the expected negative coefficient for investment cost could be established for all alternatives, but for windows and PV. The similarity in the size and sign of the coefficients for heat

Table 6. Results of the ranking exercise.

	EXPERIENCES arguments in favour (mean of) ΣR–ΣH	EXPERIENCES arguments against (mean of) ΣR–ΣH	N	INTENTIONS arguments in favour (mean of) ΣR–ΣH	INTENTIONS arguments against (mean of) ΣR–ΣH	N
Wall insulation	1.19***	0.13	76	1.05***	0.93**	98
EE windows	2.63***	0.39	95	2.89***	0.56*	78
EE boiler	2.25***	-0.11	70	2.90***	0.08	104
PV	–	–	34	1.96***	1.84***	140
Solar water heater	–	–	8	1.84***	1.62***	166

Student's t-test for paired sample
significance level * p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001

Table 7. Results of an alternative-specific model.

Coefficient	Estimate	Standard error
Windows: drastic changes in the visual aspect of the house	-0.46*	0.21
Windows: expert advice	0.65**	0.25
Roof and wall insulation: 75 % reduction in CO_2	0.59*	0.27
Roof and wall insulation: investment cost	-0.0002***	0.0006
Geothermal heat pumps: 75 % reduction in CO_2	0.89*	0.44
Geothermal heat pumps: investment cost	-0.0002*	0.0007
PV: 75 % reduction in CO_2	0.60*	0.27
Log-likelihood=-915.00		
Pseudo R^2 = 0.05		
* p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001		

pumps and insulation points out that over the studied price range people are equally price sensitive for those two alternatives. Finally, only for windows could expert advice be identified as a significant factor in influencing choice.

We also estimated a generic model seeing that for some attributes we did not obtain any significant information yet. The utility function for a generic model estimates a single coefficient for each attribute or attribute level, irrespective of the alternative (see equations 9–12). This specification assumes people's attribute (level) weights do not differ significantly depending on the alternative. Based on the overlap in the confidence intervals on the alternative-specific coefficient estimates this assumption is supported empirically.

U(Energy-efficient windows)= ASC1 + β_1*d_drastic_visual_change + β_2*d_big_thermal_comfort_improvement + β_3*d_lots_of_hassle + β_4*d_friend_advice + β_5*d_expert_advice + β_6*d_50 %_CO_2_reduction + β_7*d_75 %_CO_2_reduction + β_8*investment_cost (9)

U(Roof and wall insulation)= ASC2+ β_1*d_drastic_visual_change + β_2*d_big_thermal_comfort_improvement + β_3*d_lots_of_hassle + β_4*d_friend_advice + β_5*d_expert_advice + β_6*d_50 %_CO_2_reduction + β_7*d_75 %_CO_2_reduction + β_8*investment_cost (10)

U(Geothermal heat pumps)= ASC3+ β_1*d_drastic_visual_change + β_2*d_big_thermal_comfort_improvement + β_3*d_lots_of_hassle + β_4*d_friend_advice + β_5*d_expert_advice + β_6*d_50 %_CO_2_reduction + β_7*d_75 %_CO_2_reduction + β_8*investment_cost (11)

U(PV panels)= β_1*d_drastic_visual_change + β_2*d_big_thermal_comfort_improvement + β_3*d_lots_of_hassle + β_4*d_friend_advice + β_5*d_expert_advice + β_6*d_50 %_CO_2_reduction + β_7*d_75 %_CO_2_reduction + β_8*investment_cost (12)

The results of the CL estimation of a generic specification are shown in Table 8. All attribute coefficients have the expected signs, i.e. negative for higher investment costs, positive for expert advice, positive for a 75 % reduction in CO_2 emissions, positive for a 50 % reduction in CO_2 emissions (but not significant), negative for drastic visual changes (but not significant), positive for thermal comfort improvements, negative for lots of hassle (but not significant) and positive for friend advice (but not significant). Regarding the ASC we find that the labels EE windows and roof and wall insulation have a statistically significant positive effect on utility when compared to the effect of the label PV panels. Moreover, the size of the effect is significantly different from each other. Hence, our respondents have the following relative renovation preference: (1) wall and roof insulation (2) installation of EE windows, (3) PV panels or geothermal heat pump heating system. To calculate attribute importance, we need to perform the following steps: (1) calculate the utility range per attribute; (2) sum up the utility ranges; (3) divide the attribute utility range by the sum of the utility ranges. If we only take the significant attributes into account, this procedure leads to the following attribute ranking in a decreasing order of importance: investment cost (69.84 %), CO_2 reduction (14.29 %), and tied are thermal comfort improvement and energy advice. Note, however, that the labels, which are captured by the ASCs, are at least as powerful in determining choices as the attributes.

Conclusions

Previous 'soft' policy measures of information provision and incentives had a limited impact on encouraging the uptake of EE renovation. Most of them are conceived and implemented based on the assumption that house owners are exclusively rational. Our survey aims for a better understanding of both deliberative and heuristic reasoning behind the decisions to install or not to install EE renovation measures. These findings, alongside with other quantitative research further needed, can contribute to the elaboration and implementation of behaviourally-informed policies (Lourenço, Ciriolo et al. 2016).

From the generic CE, we can derive the conclusions described below. Despite the information provided by the attributes in the CE, respondents still largely base their choices on associations with the chosen alternative which are already present in their minds at the time of surveying seeing that the ASCs have the largest impact on utility. Furthermore, the finding that the ASC for geothermal heat pumps is not significantly different from that of PV panels reflects that both of these options are less chosen independently of their characteristics compared to the other alternatives. This might reflect a more averse attitude towards these technologies. On average the respondents were found to be influenced strongly in making the (positive) choice to renovate by deliberative arguments, i.e. investment cost, reduction in CO_2. It is important to note

Table 8. Results of a generic model.

Coefficient	Estimate	Standard error
Windows: ASC	0.40**	0.14
Roof and wall insulation: ASC	0.72***	0.13
Geothermal heat pumps: ASC	0.27	0.22
drastic change in the house's appearance	-0.13	0.12
big thermal comfort improvement	0.30**	0.001
lots of hassle	-0.08	0.08
friend advice	0.003	0.10
expert advice	0.30**	0.11
50 % CO_2 reduction	0.15	0.13
75 % CO_2 reduction	0.54***	0.12
Investment cost	$-0.12*10^{-3}$***	$0.3*10^{-4}$

Log-likelihood = -925.36
Pseudo-R^2 = 0.06
* p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001

that findings from the ranking exercise show that deliberative arguments prevail for motivations. Therefore, even though monetary and environmental factors play an important role in the decision making, these are already perceived in a positive way. At the same time, the dwellers who installed the measure and those who did not show different reasoning in terms of barriers. Only for the latter group investment costs and other deliberative arguments prevail over heuristics. For these reasons, providing information on financing schemes might be more effective than underlining monetary savings during information campaigns. Another possible explanation of this finding is that the house owners who placed the measure are more self-aware of their own biases. An example of availability heuristic, "A friend has a bad experience installing/using solar heaters" could be debunked with statistical data. An alternative to avoiding biases is to use them in the right direction. For example, Living Lab Housing Renovation programmes (Groote, Lefever et al. 2016) can set up new, positive, retrievable in the memory examples.

References

Ben-Akiva, M. and S. Lerman (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand*. Camebrigde, Massachussets, MIT press.

Bertoldi, P., J. L. Lorente and N. Labanca (2016). Energy Consumption and Energy Efficiency Trends in the EU-28 2000-2014. *JRC Science for Policy Report*, Joint Research Centre JRC 242.

Bliemer, M. and J. Rose (2011). "Experimental design influences on stated choice outputs: An empirical study in air travel choice." *Transportation Research Part A: Policy and Practice* 45 (1): 63–79.

BPIE (2011). Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings.

Cacioppo, J. T. and R. E. Petty (1983). *Social Psychophysiology*, The Guilford Press.

Caussade, S., J. Ortúzar, L. Rizzi and D. Hensher (2005). "Assessing the influence of design dimensions on stated choice experiment estimates." *Transportation Research Part B: Methodological* 39 (7): 621–640.

Ceulemans, W. and G. Verbeeck (2015). Grote Woononderzoek 2013, Steunpunt Wonen. 6 Energie: 48.

Darnton, A. (2008). Reference report: an overview of behaviour change models and their uses, GSR Government Social Research.

EC (2010). Directive 2010/31/EU *On the energy performance of buildings (recast)*. The European Parliament and the Council of the European Union. Official Journal of the European Union.

European Comission (2016). Proposal for a directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings.

Eurostat Database (2016). http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/database.

Finucane, M. L., A. Alhakami, P. Slovic and S. M. Johnson (2000). "The affect heuristic in judgments of risks and benefits." *Journal of Behavioral Decision Making* 13 (1): 1–17.

Groote, M. d., M. Lefever, J. Reinaud, P. Fong, Y. Saheb and O. Rapf (2016). Scaling up Deep Energy Renovation. Unleashing The Potential Through Innovation & Industrialisation., Building Performance Institute Europe – BPIE, Industrial Innovation for Competitiveness – i24c, European Climate Foundation – ECF: 46.

Hensher, D., J. Rose and W. Greene (2005). *Applied Choice Analysis: A Primer*. Camebridge, Cambridge University Press.

Hoyos, D. (2010). "The state of the art of environmental valuation with discrete choice experiments." *Ecological Economics* 69 (8): 1595–1603.

International Energy Agency (2016). Energy Efficiency Market Report 2016, International Energy Agency: 141.

Kadastrale statistiek. 2014, from http://statbel.fgov.be/nl/statistieken/cijfers/economie/bouw_industrie/gebouwenpark/.

Kahneman, D., P. Slovic and A. Tversky (1982). *Judgment under uncertainty: Heuristics and biases*, Cambridge University Press.

Kuhfeld, W. (2010). Marketing Research Methods in SAS: Experimental Design, Choice, Conjoint, and Graphical Techniques. Cary: 1,309.

Lancaster, K. (1966). "A New Approach to Consumer Theory." *The Journal of Political Economy* 74 (2): 132–157.

Lourenço, J. S., E. Ciriolo, S. R. Almeida and X. Troussard (2016). Behavioural Insights Applied to Policy. European Report 2016, European Comission. Joint Research Centre JRC: 54.

Louviere, J., D. Hensher and J. Swait (2000). *Stated choice methods: analysis and applications*. Camebridge, Cambridge University Press.

Lunn, P. (2013). Behavioural Economics and Regulatory Policy, Public Governance and Territorial Development Directorate.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behaviour. *Frontiers in Econometrics*. P. Zarembka. New York, Academic Press: 105–142.

Rabin, M. (1998). "Psychology and Economics." *Journal of Economic Literature* 36 (1): 11–46.

Rose, J., M. Bliemer, D. Hensher and A. Collins (2008). "Designing efficient stated choice experiments in the presence of reference alternatives." *Transportation Research Part B: Methodological* 42 (4): 395–406.

Shove, E. (2003). "Converging Conventions of Comfort, Cleanliness and Convenience." *Journal of Consumer Policy* 26: 395–418.

Simon, H. A. (1955). "A Behavioral Model of Rational Choice." *The Quarterly journal of economics* 69 (1): 99–118.

Simon, H. A. (2000). "Bounded rationality in social science: today and tomorrow." *Mind & Society*.

Sunstein, C. R. (2014). "Nudges VS Shoves. Five reasons for choice-preserving approaches." *Harvard Law Review Forum*: 210–217.

Thaler, R. H. and C. Sunstein (2008). *Nudge: improving decisions about health, wealth, and happiness*, Yale University Press.

Thurstone, L. (1927). "A law of comparative judgment." *Psychological Review* 34: 273–286.

Tversky, A. and D. Kahneman (1973). *Judgment under uncertainty: heuristics and biases*.

Tversky, A. and D. Kahneman (1974). "Judgment under uncertainty: Heuristics and biases." *Science*.

VEA (2013). Het energiebewustzijn en -gedrag van de Vlaamse huishoudens 2013.

Ward, D., C. Clark, K. Jensen and S. Yen (2011). "Consumer willingness to pay for appliances produced by Green Power Partners." *Energy Economics* 33 (6): 1095–1102.

Wilson, C., L. Crane and G. Chryssochoidis (2015). "Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy." *Energy Research & Social Science* 7: 12–22.