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ABSTRACT

This paper presents a survey combining a stated choice experiment and a priority evaluator. The survey addresses ways that people would invest in energy efficiency and differences between energy efficiency in housing and private transport. The survey sample consists of 500 homeowners (owner occupiers) owning at least one car and is divided in two parts: a paper and pen questionnaire with Stated Preference experiments followed by an Internet-based Priority Evaluator. Both choice experiments are personalized to present the candidates with meaningful choice sets.

In the stated preference experiments, respondents are asked to choose between four alternatives as a reaction to hypothetically increasing fuel prices: insulating the house, buying a heat pump, buying a new, more efficient car and selling the car and switching to public transport. In the second part of the survey, the Priority Evaluator, respondents interactively optimize their CO_2 output in an Internet application, selecting among long-term investments as well as short-term measures.

Data collected in the survey will be processed using statistical models, such as multinomial logit models, to derive parameters for different efficiency measures used to predict long-term investment behavior of homeowners.

INTRODUCTION

The Intergovernmental Panel on Climate Change states that global warming - caused by increasing emission of carbon dioxide and other green house gases (GHG) - is one of the major problems facing the world *(1)*. Carbon dioxide is generated by burning fossil fuels, such as coal, oil or natural gas, to supply energy. In Switzerland, oil accounts for approximately 60 percent of all energy consumption*(2)*, but cannot be produced inside the country. Switzerland is fully dependent on oil exporting countries and on the highly volatile global market for crude oil, with its possible price spikes like that occurring in summer 2008 *(3)*.

To cope with these kinds of problems, "The 2000 Watt Society" concept was developed at the Eidgenössische Technische Hochschule (ETH) in Zurich. The 2000-Watt Society envisions a society and economic system with an average energy consumption of 2000 watts per person instead of the current 6300 watts *(4)*. The work presented is embedded in a project aimed at simulating the urban metabolism of the city of Zurich using a bottom-up approach. This model will be used in developing strategies to reach the goals of a 2000-watt society. In this bottom-up model, a long-term investment behavioral model is necessary to account for changes in energy consumption over the longer term.

RESEARCH QUESTION

In Switzerland the two main sectors of private energy consumption are housing and transport. According to the "Gesamtenergiestatistik" *(2)*, transportation and household use 34.5% and 28%, respectively, of the energy. The biggest potential household energy savings lie in these two sectors, in contrast to "grey energy" in nutrition and consumer goods, which cannot really be influenced by households.

No literature specifically comparing these two energy sectors - in terms of consumer behavior - was found. The survey presented in this paper addresses this issue for the first time, offering a direct choice between these major energy sectors.

One of the primary research questions asks how people would reduce their energy consumption under specific given economic and legal circumstances and parameters. When forced to reduce their energy consumption, would people, think of their overall consumption as one budget or would they divide it up into budget silos by sector? Would they make trade-offs between sectors (e.g. completely refurbish the house, but maintain the inefficient luxurious car) or reduce energy consumption equally in each sector?

As in the bottom - up model, both economic and policy scenarios will be addressed. The question then arises: how do people react to financial incentives (e.g. monetary savings due to reduced fuel consumption) and what are differences in behavior if people are forced to reduce energy consumption (e.g. laws restricting carbon output)?

Exploring these questions, two different data collection approaches are analyzed and compared; the two alternatives are: first, multivariate open choice experiments - such as stated preference experiments - consisting of several alternatives with different financial incentives and second, constraint choice experiments in the form of a Priority Evaluator in which a budget of carbon output has to be met and adjusted. The survey investigating these questions uses a sample of 400 homeowners, (owner-occupier), from the canton of Zurich, out of a total canton population of 100,000 *(5)*. All homeowners participating in the study must own at least one car, so that the differences in energy use per sector can be determined. The information gathered in the survey will be used to estimate long-term energy efficiency investment decisions made by home- and car-owners.

BEHAVIORAL MODEL

The modeling framework of the bottom up model consists of three main modules, based on agent-based micro-simulation.

The first module is a long-term investment decision model determining the development of energy-consuming infrastructure and appliances, such as houses, furnaces, cars, transit systems, air conditioner, electric appliances, etc. over a time span of 20 to 40 years. It calculates, for every year, the decisions agents make for buying, replacing, or selling energy-consuming appliances. For housing, this includes renovation of roof, windows, facade, installation of solar panels and replacement of the heating system. In transportation it is the private car and/or season tickets for public transport.

The behavioral model uses three different kinds of input data: socioeconomic variables, current situation data and assumed scenario variables such as economic growth, oil price, land price, subsidies or other policy measures.

Once the agents are equipped with mobility tools and the condition of their houses and flats/apartments are defined, the second module calculates travel demand. MATSim, an agent-based micro-simulation tool, is used to estimate the total demand of private transport in the city of Zurich *(6, 7, 8)*. The output of this simulation is not only traffic flows and energy consumption of the transport sector, but also the time schedule for every agent's activity chain, with accuracy down to one second. Dependent on this, the third module, a micro-simulation of all buildings in Zurich called CitySim *(9) (10)*, calculates energy demand of the housing sector. If, for example, the travel demand model estimates that an agent returns home at 6 pm, the building model computes the probability that he would open a window and turn on the heat, which ultimately defines energy demand *(11)*.

Together, these three modules will be able to derive energy demand the housing and transport sectors in different scenarios given by the researcher. In the context of the 2000 Watt project, various strategies for reaching the society's goals in the city of Zurich are evaluated and assessed. The model includes all buildings (54,000) and inhabitants (380,000) of the city *(12)*. The key data used by the model comes from a survey conducted specially for this purpose. The participants, homeowners of the canton of Zurich, are asked hypothetical questions about investment decisions and possible changes in behavior.

MODELING FRAMEWORK

The data collected in the survey will be analyzed using different models. The data from the SP section is used for an estimation of parameters with multinomial logit models. Sets of parameters for socioeconomic variables, energy prices and attributes of different investments (or changes) are derived and implemented in the overall framework. Nested models are also tested to check correlations within sectors. Because each respondent makes nine SP choices, the data can be used to estimate a mixed MNL model to determine distributions of the parameters. The probability of homeowners insulating or buying a heat pump can be successfully modeled with this data. To give more details about which parts of the house would be renovated (and with which probability), data from the priority evaluator is added to the models. The PE data can be processed with more detailed models than simple MNL models. In PE data, participants typically choose different discrete measures to allocate a continuous amount of CO_2 output reduction.

Bhat *(13)* developed a Multiple Discrete-Continuous Extreme Value (MDCEV) model to analyze data from time use surveys. In these surveys, as in the PE, a continuous amount of time is allocated by choosing among discrete measures and activities. We think that using such a MDCEV model gives us tools to process data from the PE more precisely and accurately and derive the information for which the PE originally was developed. With a modified version of the MDCEV model, we should be able to estimate parameters for energy efficiency measures - like insulating the roof, adjusting annual kilometers driven and giving up flights - that can be compared directly to each other.

REVIEW OF THE METHODOLOGIES

Stated Preference

To design the second part of the study, the stated preference methodology is used. Instead of collecting real data, the respondents are asked hypothetical questions. This is necessary if the information needed is about choices that have not been made yet, but are expected to happen in the future and therefore interesting for research. Other reasons to use this method, and a good description, are given by Louviere *et al. (14)* and Train *(15)*. The respondents are asked to imagine a hypothetical (market-) situation and then to choose from a set of alternatives, called a choice set. The alternatives are designed in advance and defined by several specifically chosen variables. By selecting from alternatives, the respondent reveals his intentions and preferences. One major advantage of this method: if information on specific variables is needed, they can be built into the experiments' design in a statistically appropriate and efficient way.

Priority Evaluator

Introduction

The principle of the Priority Evaluator method is to let the respondents make trade-offs within a restricted budget in a controlled test environment. The action that we try to reproduce is similar to putting together a grocery basket using a given budget. The respondents have to make decisions about what attributes (e.g. products) they want and what part of the budget they want to use for it.

The Priority Evaluator by Hoinville

Hoinville *(16)*gives a complete and detailed description of the Priority Evaluator. He conducted several studies in the UK to test the method and its variations. In a survey about location choice, people were asked to make the trade off between indoor space, outdoor space and location of their house. In another survey, respondents had to "purchase" characteristics of a commuting journey, such as: crowds, waiting time, reliability, walking time, interchanges and seating for either underground, train or bus journey. In these surveys, respondents first assess their existing situation by giving points to the different attributes. The total amount of points given then provides the budget. In a second step, attributes then can be reallocated within the budget. He also mentioned the possibility of increasing the points budget by trading it off against financial sacrifice: e.g., accepting a higher rent than primarily stated by the respondents. Another example was given by Permain *(17)* who used the Priority Evaluator to explore preferences of the British railway passenger for railway station features by letting respondents design railway stations within a budget constraint. Every variable had a scale of three to five values and every value had a price. Hoinville *(16)* stated that the best pricing scheme methodology is to use abstract points, so that there is no confusion with possible monetary attributes (e.g. ticket fares in travel surveys) or individual income situations.

The Priority Evaluator used in this paper

In our case, the principle of the Priority Evaluator presented by Hoinville *(16)* is inverted. Instead of using a continuous budget to buy positive attributes, the respondents must fill a given budget by picking negative attributes. In our study, the budget to fill is the Reduction in CO_2 output and the negative attributes are different energy efficiency measures. In early experiments, the variables were mainly one-dimensional and simple (e.g. apartment size-, categorized as small, middle, big, very big; ticket fare: c 10, 15, 20, 25). In this survey, the attributes are two- or three-dimensional: the first dimension is the change in lifestyle or refurbishment, indicated by attribute name (e.g. replace car with a more efficient one). The second dimension is an associated price, always a lump sum, in Swiss francs (CHF) showing respondents the attributes' financial effect. The third dimension consists of associated running costs (or savings) in CHF / year for the same purposes. Note that not all attributes have both kinds of prices. These costs represent actual and realistic costs and do not have to be optimized within the rigorous, closed and predefined budget of the Priority Evaluator (in our case, the reduction of CO_2 output). However, the respondents must still consider costs to remain within their individual actual monetary household budgets. In this survey, we also collect information about the household income level so that we can analyze both aspects of the trade-off (lifestyle and monetary aspects) within the closed frame of the CO_2 output reduction budget. Previous studies did not use statistical models to examine the data, but only used descriptive statistics to identify preferences.

SURVEY PROTOCOL

The survey is divided in three parts: first, general questions about household members, cars, house, financial situation and attitude are asked. Second, the participants are confronted with nine hypothetical scenarios of gasoline and heating oil prices, each with four alternatives to reduce energy expenses. Third, the participants are asked to reduce their carbon output to a pre-set level by choosing among given options.

Sample Size

For this project, the behavior of homeowners of the city of Zurich is significant. According to the Zurich statistics office, 9,899 single-family homes exist in the city *(12)*. To achieve a sample of 500 people, a large portion of all addresses in the city itself would have been needed. To get a wider sample representation, participants are recruited among people living in the 112,644 single-family homes of the canton of Zurich. A canton is an administrative district similar to a state, or county (US), or Bundesland (Germany). As a base for participant recruitment, a list of 5,000 addresses for people living in a single-family home was acquired. The addresses have been randomly ordered; by going through the list from the top down, we obtain a random sample.

Participants

The participants of the study must own the house they live in, as well as at least one car. They must be able to make decisions about the refurbishment of the house or a replacement of the heating system. It is important to exclude people who do not have to bear the costs of potential renovations to prevent bias. Also excluded are homeowners already using a heat pump as a heating system, because one of the major issues of the study is the willingness to pay for, and the acceptance of, heat pumps.

Protocol

In the first step, an announcement letter was sent to people from the list with a very short introduction to the survey topic and an announcement that the survey team would call during the next few days to ask questions about current energy consumption of the house and car. This letter ensures that most people do not get called unexpectedly and have, in the form of the letter, a formal document with the ETH logo; people being called then usually know that the caller is from a widely known and respected institution. They also can prepare their consumption data to make the recruitment process more efficient.

Recruitment

In the second step, an interviewer calls the numbers on the list. If we cannot reach the person after five tries on different days, the address is marked as 'not reached'. Calling time is between 5 and 8 pm, allowing access to working/commuting people as well as residents usually at home all day. People reached by phone are asked the following questions:

1. 'Are you interested in participating in the study?'
2. 'Do you own the house you live in?'
3. 'Do you own a car?'
4. 'Is your house equipped with a heat pump?'

The people answering the first three questions with 'yes' and the last with 'no' count as participants, and are then asked to give the following data on energy consumption: heating system, annual oil, gas or power demand of the heating system, specific consumption of the main car, annual kilometers traveled and age of the participants.

Questionnaire

In the third step, the questionnaire is prepared and sent to the participants. The first part of the questionnaire covers general questions asked all the participants the same way: i.e. on socio-economic issues, car information, house details and inquiries about position on environmental friendliness. The second part consists of nine different Stated-Preference scenarios, personalized so that the energy consumption level corresponds to the information given on the phone. The questionnaires are sent within one week of the call. An instruction letter, a reply-paid envelope and CHF 20 (motivation incentive) are sent together with the questionnaire. Participants under the age of 50 are given a CHF 40 incentive to increase response rate among younger people. A pre-test we made showed that the sample lacked younger participants (compared to the population statistics from the Swiss Federal Statistics Office) *(18)*. Please note that the monetary incentive was not mentioned in either the announcement letter or in the recruitment call.

Priority Evaluator

The next step in the process uses the Priority Evaluator experiment as an Internet application. At the end of the questionnaire, it is mentioned that the last part of the study is on the Internet, and that the participants will be sent a letter with the Internet-address. After the questionnaire is returned, it is analyzed, and the Internet tool for the Priority Evaluator is prepared. Participants who did not fill in the SP completely, or always chose the same answer (non-traders), as well as participants who specified that they do not have an Internet access, are excluded from this part of the study. For every participant, an account is created with a separate password. Because the Priority Evaluator design depends on information given in the questionnaire, the account is personalized within three workdays after questionnaire arrival. A detailed description of the design is given in the Survey Design chapter. When the account is set up, we send a letter with the Internet-address and password to participants, asking them to fill in the last part of the survey. The reason not to use email for the second contact is because we expect a higher response rate to the more formal contact and because it would be an additional expenditure to collect and store email addresses. If participants do not fill in the Priority Evaluator within three to four weeks, we send a reminder letter to increase the response rate.

Comments on the Protocol

The reason for the pre-recruitment by phone, apart from increasing an efficient use of the monetary incentive, is our need for information on energy consumption in advance to personalize the SP section. Personalization is important because the participants differ enormously in terms of their house size, energy demand and kilometers traveled. Normal annual demand for heating oil is between 1,000 liters and 4,000 liters, while the range of kilometers traveled per year goes from 7,000 (for a typical pensioner) up to 60,000 (car also used for home and private business). Non-individualized, a-priori fixed scenarios would have been very unrealistic for most of the participants.

We used traditional mail for the questionnaire in addition to the Internet tool because a questionnaire using paper and pen is more formal, commands more respect and should elicit a better response rate. We also try to avoid adding to the increasing amount of 'spam' an email account receives. We also assumed that homeowners are often between 50 and 80 years old and therefore less used to electronic communication than younger people.

Participants reported needing between 60 and 90 minutes to complete the paper and pen questionnaire. We have no feedback on how long people needed for the PE section. We assume that participants need between 10 and 30 minutes for the PE, depending on the complexity of the household (e.g. number of cars, etc.)

SURVEY DESIGN

Stated Preference

Scenarios

The survey attempts to determine whether energy used for cars has a different perceived value than energy used for housing. The key is allowing participants to select among investments with different cost-benefit ratios under different labels. The costs of investments are lump sums, the benefit the expected annual savings. Therefore, the cost-benefit ratio corresponds to an expected payback time without interest for the investment. For this purpose the participants are confronted with their energy expenses and are asked which alternative they would choose

TABLE 1 Input Data from the Participants

Variable	Name	Unit
D_{Oil}	Oil consumption	liter / year
D_{Gas}	Gas consumption for heating	KWh / year
D_{El}	Electricity consumption for heating	KWh / year
con	Car Efficiency (consumption)	liter / 100 kilometer
kmd	Annual Kilometers driven	kilometer / year
CO2	CO_2 Output	t CO_2 / year

TABLE 2 Variables of the Stated Preference scenarios

Variable	Name	Levels	Unit
P_{Oil}	Oil Price	1 / 2.5 / 4	CHF / liter
P_{Gas}	Gas Price	0.08 / 0.20 / 0.32	CHF / kWh
P_{El}	Electricity Price	0.08 / 0.20 / 0.32	CHF / kWh
T_G	Gasoline Tax	0.5 / 1 / 1.5	CHF / liter
C_{Heat}	Heating costs	$\sum D_i * P_i$	CHF / year
C_{Car}	Variable Mobility Costs	$(P_{Oil} + T_G)$ * con * kmd + 2.500	CHF / year
I_{House}	Investment House	40k / 60k / 80k	CHF
I_{HP}	Investment Heat Pump	20k / 40k / 60k	CHF
I_{Car}	Investment Car	5k / 10k / 15k	CHF
kmd_{CS}	Kilometers driven in 'Car Sharing'	[0.2 / 0.3 / 0.4] * kmd	km / year
S_{Insu}	Financial Savings for 'Insulation'	[0.7 / 0.5 / 0.3] * C_{Heat}	CHF / year
S_{HP}	Financial Savings for 'Heat Pump'	[0.7 / 0.5 / 0.3] * C_{Heat}	CHF / year
S_{NC}	Financial Savings for 'New Car'	[0.6 / 0.4 / 0.2] * C_{Heat}	CHF / year
S_{CS}	Financial Savings for 'Car Sharing'	[0.9 / 0.7 / 0.5] * C_{Heat}	CHF / year
$CO2_i$	Reduction in CO_2-Output	S_i / C_i * CO2	t CO_2 / year

to reduce costs. Every participant is given nine scenarios with variable energy prices, each with 5 alternative (described below).

Energy expenses presented are based on two variables: price of heating fuel and price of gasoline. Heating fuel is either: oil [liters], gas [kWh], or power [kWh]. Gasoline price is composed of heating fuel price plus a variable tax, to ensure that gasoline is always more expensive than heating fuel, preventing scenarios with unrealistic relative values. Nevertheless, perfect correlation between these two fuels can be avoided. Each scenario is based on a different composition of energy prices giving heating and variable mobility costs, which include expenses for gasoline, tire, service, reparations, exhaust control and depreciation, but exclude

FIGURE 1 Stated Preference Scenarios

Scenario 1

Measure	No Change	Insulation of House	Installing a Heat Pump	Buy new, more efficient car	Sell Car PT & Car Sharing
Investment Costs CHF	0	20'000	30'000	10'000	Gains from Selling Car
	Gasoline Price: CHF 5.5 / Liter => Variable Mobility Costs [1]: CHF 6'800 / Year				
Savings in Mobility Costs CHF/Jahr	0	0	0	4'100	4'800
Kilometers driven km / Year	12'000	12'000	12'000	12'000	4'800
	Heating Oil Price: CHF 400 / 100 Liter: => Heating Costs: CHF 8'800 / Year				
Savings in Heating Costs CHF/Year	0	4'400	4'400	0	0
CO_2 Savings tons CO_2/Year	0	2.9	2.9	1.1	1.3
Your Choice→	☐	☐	☐	☐	☐

[1] Variable Mobility Costs = depreciation, fuel, tires, service, emission control, reparations

fixed costs. To reduce either heating costs or variable mobility costs, participants are presented with 4 alternatives.

Alternatives

The choice set alternatives follow:

1. Insulation: Insulate the house.
2. Heat pump: Install a heat pump.
3. New Car: Buy a more efficient car to replace the current one.
4. Car Sharing: Sell the car and use public transportation and car sharing instead.

The fifth alternative is a decision not to improve energy efficiency. Two of the four measures concern energy consumption of the house, the other two private transport.

Insulation This alternative would mean a minor or major house refurbishment, depending on investment costs imposed. In the SP, it is not specified what degree of renovation is meant. But annual savings due to the reduced energy consumption of the house are indicated. The savings for the car are zero and annual kilometers driven remain unchanged.

Heat Pump This alternative would mean replacing the current heating system with a heat pump. Investment sums are smaller than for the insulation, but annual savings are in the same range. Savings in mobility costs are zero and annual kilometers driven remain unchanged.

More efficient Car This alternative would entail replacing the current car with a new, more efficient model. No technology is specified (e.g. hybrid, electric, small conventional). Investment is smaller than in the house and savings in variable mobility costs depend on annual kilometers driven. Savings in heating costs are zero and the annual kilometers driven remain unchanged.

Car Sharing and Public Transport This alternative involves selling the car and reducing annual kilometers driven. Public transport would be the primary means of mobility and the remaining annual kilometers of private transport would be traveled via car sharing. Savings in variable mobility costs are larger than in the alternative 'more efficient car'. No investment is needed for this alternative, but the respondent would receive the money from the sale of the car.

Priority Evaluator

In contrast to the Stated Preference part of the survey, where respondents are given the option of making no investment, the Priority Evaluator section forces them to reduce their energy consumption; but they have a wider and more differentiated list of options to choose from. The level of energy consumption in the Priority Evaluator is presented as CO_2 output on a household basis. We are aware of the fact that CO_2 output and energy consumption are not exactly the same, particularly in Switzerland, where electricity is almost CO_2 free *(19)*. CO_2 output was chosen because we assumed that it is better known and easier for respondents to understand than the rather abstract figure of overall energy consumption. We also assumed that a tax or a restriction on CO_2 output is more likely to happen than a restriction on overall energy use and is, therefore easier to imagine. However, for the purpose of the survey, CO_2-free electricity production was ignored and the CO_2 output was computed with the simple assumption: 1 liter of oil is equivalent to 10 kWh of gas or 10 kWh of electricity, which is then equivalent to 2.65 kg of CO_2. In the current situation, any substantial increase in power supply in Switzerland (due to heat pumps) probably would not be CO_2 free anymore.

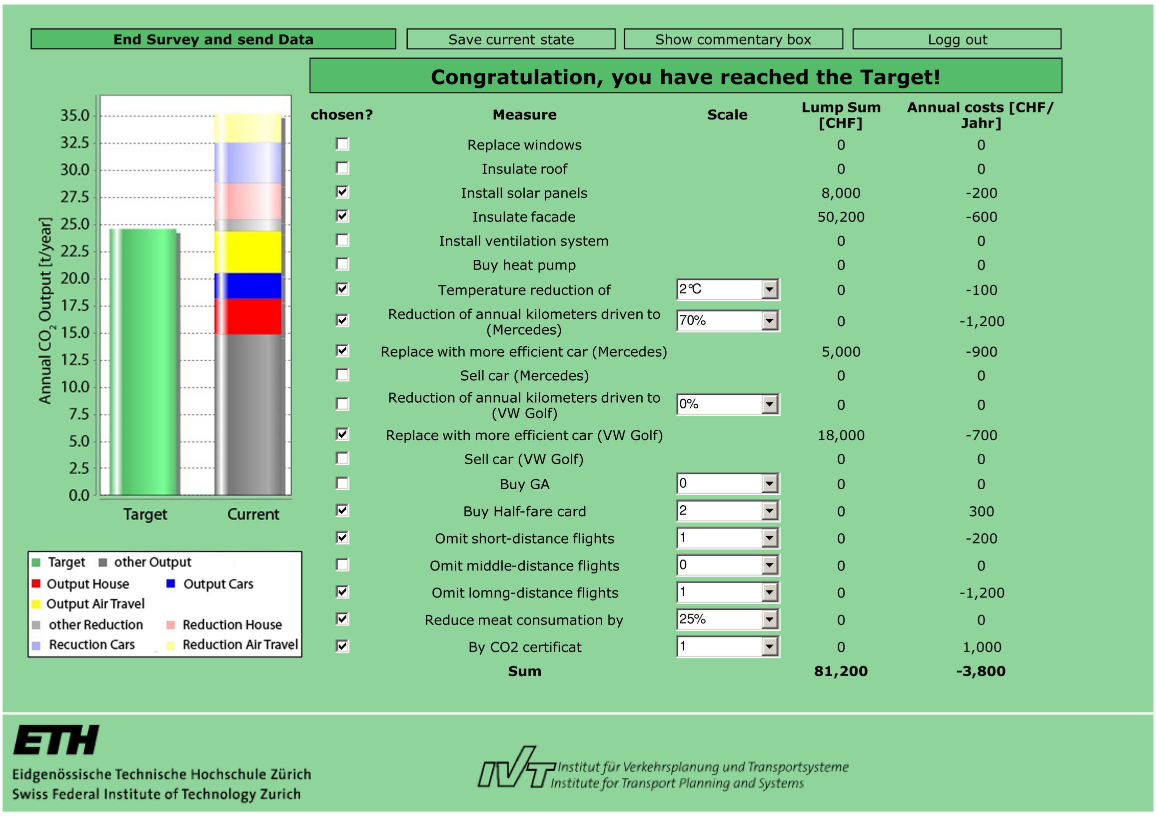
On the left side, two bars indicate the CO_2 output. The right bar shows the current CO_2 output of the household divided in four sectors:

1. Grey energy (grey) is the energy embedded in consumer goods and other indirectly influenced sectors. This is assumed to be the average Swiss CO_2 output of 4.5 tons of CO_2 / year per person.
2. Heating energy (red) corresponds to energy used for heating.
3. Private Transport (blue) is energy for cars and motorbikes dependent on specific consumption and the annual kilometers driven, for all vehicles in the household.
4. Air trips (yellow) are a rough estimate of air travel CO_2 output.

In the first part of the survey, respondents declare how many trips they made over the last 3 years. The trips are divided into short (<1000 km), middle (<5000 km) and long (>5000 km) distances, which are assumed to be equivalent to 0.5, 1 and 2 t CO_2 / a, respectively. The left bar indicates the reduction target consisting of the non-changeable (grey) and 50 percent of the changeable CO_2 output.

On the right side, options for reductions are listed with a column for investment (lump) sum and related savings (or costs). This list contains only options reasonable for the respondent.

FIGURE 2 Priority Evaluator Tool



For example, if one respondent states in the questionnaire that he already replaced his windows after 1995, this option will not be available because it is assumed to be unrealistic.

If a respondent has more than one car, options are given for every car separately. Choosing the option 'Sell car' does not reduce CO_2 output because it is assumed that annual kilometers driven are made through car sharing. It is not possible to choose the options 'Sell car' and 'Buy more efficient car' simultaneously. By offering options for public transport season cards, the respondents can arrange their mobility concept in a very detailed way. The CO_2 output of consuming meat is assumed to be 0.5 t/a per person and can be reduced in steps of 25 percent. To reduce CO_2 output of air travel, respondents can cancel flights each year, depending on what data they submitted in the questionnaire. If the respondents did not indicate any air travel, these options will not be available in the experiment. The last option is buying CO_2 certificates. The (annual) prices for the certificates do not represent current market conditions, but are chosen to be comparable to other prices to avoid easy choices. The price increases exponentially to ascertain a wider range of possible 'willingness to pay' figures from the respondents.

FIELD WORK

Before the main study started, two pre-tests, with 50 participants each, were conducted to test response behavior, as well as difficulty and design of the Stated Response experiments and the Priority Evaluator. In table 4, the response behavior is shown. Please note that numbers for the main study report the current state of fieldwork and are not definitive yet.

TABLE 3 Variables of the Priority Evaluator

Option	CO_2 Reduction [t CO_2 / year]	Price (lump sum) [CHF]	Annual costs [CHF / year] (negative costs = savings)
Refurbishment of the roof	21%[1]	15.000 / t CO_2	-300 / t CO_2
Refurbishment of facades	30%[1]	25.000 / t CO_2	-300 / t CO_2
Replacement of windows	15%[1]	12.000 / t CO_2	-300 / t CO_2
Install solar panels	12%[1]	10.000 / t CO_2	-300 / t CO_2
Install ventilation system	12%[1]	20.000 / t CO_2	-300 / t CO_2
Heat Pump	66%[2]	19.500 + 5.500 / t CO_2	-300 / t CO_2
Temperature Reduction	5% per degree[2]		-300 / t $CO2_i$
Reduction of annual kilometers driven	10% steps of reduction		savings analogue to the reduction of driving
Buy more efficient car (Motorbike)	(con - 5) * kmd / 100 * 2.65	30.000 - Car value	(con - 5) * kmd / 100 * 1.55
Sell current car (Motorbike)		- Car value (- Motorbike value)	- 2.650 + 0.134 * Car value
Buy season ticket			3.100
Buy half-fare card			150
Household reduces meat consumption	Up to 0.5 ton / person		
Buy CO_2 Certificate	1 ton		between 1.000 and 1.900 per ton CO_2

[1] : % of CO_2 output of housing
[2] : % of CO_2 output remaining after refurbishments chosen

The main study started in April, 2010 and will finish in September, 2010. Sample size includes all addresses (obtained from a local address dealer) that were called at least once. Valid addresses can be defined as those people who could be reached with the given phone number and had all the attributes required for the study, including not having a heat pump. Of these potential candidates, almost half agreed to participate in the study, and 35% returned a useable questionnaire. Of people who received the questionnaire, an impressive 80% returned valid responses, meaning they completed the fairly difficult SP section. Results from the main study are similar, although not yet definitive.

One interesting factor from field work: people over 70 often wrote in the commentary field at the end of the questionnaire that they are "...too old to make major changes to the house". Most comments indicated that SP scenarios were difficult to understand, and that the questionnaire took too long to fill in correctly, indicating that the study is clearly on the upper end in terms of complexity. However, there were also several comments saying that other options like electric cars, or better windows, were missing.

TABLE 4 Response Behavior

	Pretests		Main Study	
	[abs]	[%]	[abs]	[%]
Sample Size	451	100.0	1209	100.0
Not reached	139	30.8	419	34.7
Person deceased	8	1.7	30	2.4
Wrong addresses	10	2.4	45	3.7
Not suitable	70	15.5	195	16.1
Valid addresses	224	49.6	790	65.3
Valid addresses	224	100.0	790	100.0
Participation agreed	100	44.6	350	44.3
Valid Responses	80	34.8	213	26.9
PE participated	50	22.3	131	37.4

In the two pre-tests preceding the main study, two versions of the SP were tested. In the first pre-test, the version described in section Survey Design and finally used in the main study was tested. In the second pre-test, a version with three alternatives (plus the Null alternative) was tested. The alternatives of this version are:

1. Renovation on the house.
2. Change in private transport.
3. Combination of alternatives 1 and 2.

The forth alternative was not to invest in energy efficiency.

The alternative 'Refurbishment' is either insulation or heat pump. The alternative 'private transport' is either: buy a more efficient car, or sell the car and switch to public transport. The combination is an alternative that implies savings through energy efficiency in housing as well as private transport. Values of the variable in the combination alternative are independent of the values of the other two alternatives.

However, a simple multinomial model of the data of the second pre-test gave less precise results than the first pretest with 4 alternatives. In addition, the version including a combination of alternatives does not force the participants to trade off between housing and transportation as strongly as the first version and thus is less able to provide the information needed.

The response rate of the survey is comparable to other surveys, using an ex-ante assessment of the response burden. In Axhausen and Weis *(20)* various surveys were collected and compared by response rate. To compare different studies, every question of a survey is assessed with a number, depending on its difficulty. Adding up these numbers gives a value that is a proxy for the response burden. In figure 3, the correlation between the response burden and the response rate is shown.

Assessing the SP experiments is difficult. In this case, the burden of one SP experiment is judged to be 12 times that of a closed 'yes or no' question. Given that the respondent needs to evaluate 5 variables in 4 alternatives in each experiment, we consider this a lower boundary. Compared to the other surveys in figure 3, the response rate of 80% is above average.

FIGURE 3 Response Rate of ex-ante assessed surveys

Source: Axhausen and Weis *(20)*

One explanation is that many homeowners are very interested in energy efficiency - and other topics related to their homes - because it is likely to be their largest asset. Conducting the recruitment by phone, many participants told us that they would be very interested and would like to participate, although they did not fit in the profile.

The fact that only homeowners can participate to the survey meant that, respondents are not representative of the general population. 80% of household heads (person who filled in the questionnaire) and 52.5% of all people reported in the questionnaire are male. In the "Mikrozensus Verkehr" *(21)*, only 48% of the population is male. Higher-income classes are also over represented; in our survey we have 42.2% of all households in the lowest (< CHF 8.000/m), 40.6% in the middle (CHF 8.000/m - CHF 12.000/m) and 17.2% in the highest income class compared to 73.1%, 19.0% and 7.9%, respectively, in the "Mikrozensus". Presumably, homeowners generally have a higher income level than people living in rented housing. As far as the age distribution, we have too many respondents over 65 (45.2% compared to 25.9%) and too few respondents below 45 (7.3% compared to 26.1%). We will try to correct the sample by recruiting more young people.

CONCLUSION

Energy efficiency in the housing sector is an issue in many households and therefore widely discussed. This helps when recruiting participants and generates a high response rate. To collect information about trade-offs between two different energy sectors, a complex choice set is used, but it could be completed by most of the participants. To explore people's trade-off between goods in different sectors is a very interesting research field. In this survey, only long-term investments in energy efficiency are considered.

This survey's big advantage is that the same participants are questioned two different ways. The results can be checked directly for consistency. The PE data supports the SP data in the following way: it not only replicates the narrow experiment space of long term investment choices, but also expands it to short-term choices, like reducing annual kilometers driven or omitting flights.

Further research is planned to explore trade-offs in short-term spending. In the transport field, it is especially interesting how destination choice is made, and where people make trade-offs between the transport costs, the costs of the activity and the activity itself, which are also three different sectors. Energy use is of particular interest both short- and long-term, because we expect energy prices to increase in the future and energy is vital to every aspect of daily life in the industrialized world.

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