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Energy literacy, awareness, and conservation behavior of residential households[☆]

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ABSTRACT

The residential sector accounts for one-fifth of global energy consumption, resulting from the requirements to heat, cool, and light residential dwellings. It is therefore not surprising that energy efficiency in the residential market has gained importance in recent years. In this paper, we examine awareness, literacy and behavior of households with respect to their residential energy expenditures. Using a detailed survey of 1721 Dutch households, we measure the extent to which consumers are aware of their energy consumption and whether they have taken measures to reduce their energy costs. Our results show that "energy literacy" and awareness among respondents is low: just 56% of the respondents are aware of their monthly charges for energy consumption, and 40% do not appropriately evaluate investment decisions in energy efficient equipment. We document that demographics and consumer attitudes towards energy conservation, but not energy literacy and awareness, have direct effects on behavior regarding heating and cooling of the home. The impact of a moderating factor, measured by thermostat settings, ultimately results in strong variation in the energy consumption of private consumers.

1. Introduction

Energy conservation is a significant element of international policies addressing pollution, global warming, and fossil fuel depletion. The housing market is an important element in these endeavors, since about one-fifth of the global energy demand stems from the residential sector. Finding novel ways to reduce residential energy consumption has not only triggered the attention of policymakers, but of academics and the real estate industry itself as well.[1] But, to what extent this increasing focus on energy efficiency is also acknowledged, shared and supported by the households that consume the energy in their homes, is still unclear.

Although household utility bills in most countries are on the rise – mostly due to increasing oil and gas prices, but also following increases in income and taxation – there is limited evidence that energy efficiency is in fact finding its way into the market equilibrium pricing. The prospects of reduced energy bills should be a firm and reliable base for energy efficiency investments in a dwelling, but private market initiatives often struggle to succeed without governmental support (Jaffe and Stavins, 1994). This struggle is especially prominent in the residential market. In contrast, recent research suggests that institutional property investors and tenants capitalize energy savings in commercial real estate quite precisely (Eichholtz et al., 2013).

To assess properly the implications of increased energy efficiency in the residential market, evidence of the willingness to pay for energy-saving measures and the discount rate applied by private consumers is crucial (Horowitz and Haeri, 1990). Moreover, an important condition for the effective capitalization of energy efficiency into housing prices is that buyers (and sellers) are aware of residential energy consumption, and the influence of home characteristics therein. Variation in future utility bills will only be reflected in the transaction prices of homes if energy efficiency is properly understood and decision-making is rational. There is an emerging literature on the use of energy labels to resolve information asymmetry on the energy efficiency of dwellings (Brounen and Kok, 2011) and the relevance of information provision in changing consumer behavior has been addressed in field experiments providing feedback on energy consumption to consumers (Alcott and Mullainathan, 2010).

In this paper, we analyze an important link between energy policy design and household energy consumption, through examining the extent to which households: are aware of their energy consumption; understand the energy efficiency of their homes; and appropriately adapt their behavior. In line with recent work on financial literacy

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[1] The literature on residential energy demand and price elasticity has a long history. See for example Houthakker (1951) and Halvorsen (1975) for early analyses, and Reiss and White (2005) for more recent work.

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by van Rooij et al. (2011), we generate and exploit a survey among 1721 Dutch households, inquiring into consumer knowledge of energy consumption, by posing simple questions such as: *How much do you pay for your monthly gas (electricity) bill? At which temperature do you set your thermostat during the evening? What type of thermal insulation have you added to your current home?* These carefully constructed survey questions allow us to measure the awareness of the household towards energy use, and to assess "energy literacy" — whether households are able to make a trade-off between long-term savings from energy efficiency investments and the upfront investments that are required to achieve improvements in energy efficiency. We also measure the willingness to conserve energy by addressing consumer attitudes and ideology towards energy conservation. Importantly, we relate our constructs of awareness, energy literacy, demography, attitude and ideology to decisions that household make on a daily basis about comfort and temperature, and then to actual measures of household energy consumption.

Our results show that, although the average energy bill in the Netherlands amounts to 222 euro per month (some eight percent of the net household income, on average), just 56% (47%) of the respondents are aware of their monthly charges for gas (electricity) consumption. This lack of "energy awareness" is the strongest among younger households enjoying higher incomes. We also confirm that the awareness of energy consumption is higher among households that keep organized financial records and that generally pay more attention to conserving resources (measured by their driving style). Interestingly, the level of education is unrelated to awareness of energy consumption, but we do find that it is the most important household characteristic explaining energy literacy — making the optimal choice when considering an investment in more energy-efficient equipment. Environmental ideology, measured by voting preferences, is unrelated to either awareness or literacy.

We then focus on energy conservation behavior, measured by the evening temperature in the home and, importantly, the propensity to lower the thermostat at night. We document that attitude and demographics, but not awareness, literacy or ideology, explain the choice of thermostat setting and the likelihood of lowering the temperature at night. Elderly people, and those with higher incomes, select a higher comfort temperature. The former are also less likely to reduce home temperatures at night. Those respondents that are willing to "make sacrifices in the short run in order to secure future income" settle for a lower home temperature in the evening, presumably to save on energy expenditures.

The outcome of literacy, ideology, attitude and behavior regarding residential energy conservation can ultimately be measured in household energy consumption. Within the sample of respondents that are aware of the household energy expenditures, we explain the variation in energy consumption by a set of dwelling characteristics, household demographics and their behavior related to ambient comfort, using the Heckman (1979) model to account for sample selection bias. In line with Brounen et al. (2012), we document the substantial effect of dwelling vintage on energy consumption — homes constructed pre-1980 consume, on average, about fifty percent more energy. Importantly, modeling the effect of demographics on energy expenditures through the evening temperature as a moderating factor, we find that consumer behavior, as measured by the choice for comfort level, has a significant effect on household energy consumption. Energy literacy does not have a direct impact on household energy consumption.

Our results have some implications for policy makers. Many of the current energy conservation policies are aimed at providing incentives for investments in the energy efficiency of private homes. However, our findings show that only about fifty percent of households in our sample are aware of their actual energy consumption. Energy use does not seem to be on the mind of the typical consumer. Moreover, many households forego savings on energy payments through ignoring temperature control. We refer to this group of consumers as "sleepers." Also, the rationality in decision-making that is expected from private consumers might be overly optimistic — basic financial calculus seems to provide a challenge for consumers. Comparable to what has been documented for financial literacy (see, for example, Lusardi and Mitchell, 2008), "energy literacy" is much lower than policy makers tend to assume.

This paper also relates to the literature on environmentalism and consumer choice that increasingly focuses on residential energy consumption. Ideology and attitude increase awareness of energy consumption and the propensity of buying green energy, but do not necessarily affect behavior. "Greens" may drive a Prius (Kahn, 2007; Sexton and Sexton, 2011), but we do not find evidence that they actively reduce comfort temperatures or lower the night temperature to save on resources.

The remainder of this paper is organized as follows: the next section describes the data and provides descriptive statistics and details regarding the setup of the survey analysis. Section 3 provides the empirical results explaining energy awareness and literacy, while Section 4 focuses on energy behavior and consumption. Section 5 is a brief conclusion.

2. Data

We use data from the 2011 Dutch National Bank Household Survey (DHS). DHS is a long-standing, annual household survey that includes extensive information about demographic and economic household characteristics, focusing on wealth and savings data. The data set is representative of the Dutch population, and it contains over 2000 households.[2]

The DHS is built up in several sections. Section A inquires into the financial background of the respondent (i.e., income, savings, spending behavior, etc.). Section B focuses on whether households rely on external advice for their financial matters. Section C deals with the pension plan of the household, while section D asks questions with respect to housing and mortgage details.

In addition to using data from the core of the DHS, we also use data from additional, self-designed survey modules on financial literacy and residential energy consumption, added to the survey in April 2011. This section of the survey is designed to assess the ability of households to make proper financial decisions and to trade off long-term benefits with short-term investments.

In total, the survey consists of 50 questions, and requires 18 min to complete, on average. Survey participants are interviewed via the Internet.[3] A total of 1721 out of 2028 households completed the financial literacy and residential energy module — a response rate of 84.9% (in line with the response rate for the main survey). The respondent for these residential energy questions typically represents the member of the household that is in charge of household finances.

DHS offers a wide variety of background characteristics on the households in our sample, enabling an analysis of factors determining energy awareness across our sample. The dataset also benefits from existing survey data on the panel, enriching our survey results with additional background items that were addressed in other DHS surveys executed in 2011. For an overview of the survey questions, we refer to an online appendix.[4]

[2] See Nyhus (1996) for a detailed description of this survey and an assessment of the data quality. CentERdata is a survey research institute at Tilburg University that specializes in Internet surveys and manages the panel. For more information about the survey agency, see http://www.uvt.nl/centerdata/en.

[3] Although the Internet connection rate in the Netherlands is among the highest in Europe (some 80% of Dutch households are connected to the Internet at their home), households need not have an Internet connection to participate in the survey. Recruitment and selection of households are first done by phone through a randomly selected sample of households. Households without an Internet connection are provided with a connection or with a set-top box for their television (for those who do not have access to a personal computer). This method of data collection has several advantages. For example, data collected using Internet surveys suffer less from reporting biases than data collected via telephone interviews (see Chang and Krosnick, 2003).

[4] See http://fsinsight.org/docs/download/brounen-kok-quigley-appendix-survey-overview.pdf.

Table 1 reports summary statistics for the main variables in the survey analysis. Panel A of the table reports the characteristics of respondents and their homes. The typical dwelling offers 138 m^2 of living space, and about 36% of the respondents reside in a home that has been constructed between 1980 and 2011. This corresponds quite precisely with the size and age distribution of the total Dutch housing stock (see Brounen et al., 2012). Table 1 also presents the demographic composition of the respondents in the sample: some 54% of the respondents are male and the average age of the respondents is 57 years. The monthly net income of respondents is €2883. Among the respondents, just 39% has at least some college education.

The last section of Panel A of Table 1 summarizes the survey data on the ideological background of the households in our sample. This information is available for a smaller subset of the respondents. We document that about 9% of the respondents vote for the "Green Party," which is slightly higher than the average during the most recent elections, and slightly higher than the fraction of "Green" voters reported by Brounen and Kok (2011), but of course, our data are self-reported. We measure driving behavior on a scale from one to five, and create a binary dummy, which is one if respondents indicate that they drive very efficiently, or just efficiently, to save petrol. This variable does not relate to the specification of the vehicle, but merely to the driving style of the respondent. Some sixty percent of the respondents indicate that they in fact drive efficiently in order to save gas (which, at current petrol prices of €1.70/l, is not too surprising). We also asked respondents about their spending patterns. On a scale from one to seven, with one representing self-declared "spenders" and seven representing "savers," we document an average response of 5.1. This savings-oriented behavior corresponds quite closely with macro-economic statistics indicating that the Dutch population (and the rest of Northwestern Europe for that matter) has relatively high net savings rates, at about 14% of household disposable income in 2007 (see Leetmaa et al., 2009).

Table 1
Descriptive statistics.

	Mean	Median	St. Dev	Min	Max
Panel A					
Home characteristics					
Size (m^2)	137.98	120	148.20	8.00	3300
Period of construction					
>2000	8.19	0	27.43	0	100
1980–2000	28.01	0	44.92	0	100
1960–1980	31.96	0	46.65	0	100
1940–1960	9.06	0	28.72	0	100
1920–1940	7.79	0	26.80	0	100
<1920	8.25	0	27.52	0	100
Household demographics					
Male respondent (%)	53.92	100	49.86	0	100
Age of respondent (years)	57.14	58	13.62	23	89
Household size (number of people)	2.41	2	1.22	1	7
Some college education (%)	38.99	0	48.79	0	100
Monthly net household income (in €s)	2883	2600	4684	0	15,800
Ideology and attitudes					
Voting for Green Party (%)	8.84	0	28.40	0	100
Driving efficiently to save gas (%)	59.85	100	49.05	0	100
Spending behavior disposable income (1–7)	5.07	5	1.17	1	7
Well-organized (%)	41.60	0	49.30	0	1
Sacrificing short term for future income (1–7)	3.33	3	1.48	1	7
Panel B					
Energy awareness & literacy					
Respondent knows energy expenditures (%)	56.25	100	49.62	0	100
Gas expenditures (€/month)	125.72	110	107.36	0	1500
Electricity expenditures (€/month)	96.64	80	66.01	0	550
Rational choice for heating system (%)	60.12	1	48.98	0	1
Using green power (%)	52.01	1	49.97	0	1
Thermostat control					
Day temperature (°C)	18.17	18.50	2.20	8.00	23.00
Evening temperature (°C)	19.34	20.00	2.16	7.00	24.00
Night temperature (°C)	15.65	15.00	1.95	7.00	23.00

Notes:
Table 1 provides summary statistics regarding households and dwellings in the sample. Statistics are all derived directly from answers to the survey questions. Panel A contains a list of variables that relate to the home, household, and respondents' attitude and ideology. Panel B contains a list of variables that all relate to the energy awareness and behavior of the respondents.

3. Energy awareness and literacy

3.1. Measuring energy awareness and literacy

Contrasting the literature on residential energy efficiency, which mostly assumes that households are aware of their residential energy consumption, our survey allows the direct assessment of how much households know about their residential energy consumption. The first question to measure the "energy awareness" of households is the following:

Q1. How much do you pay for your monthly gas (electricity) bill?

A. […] euro
B. I have no idea.

The non-parametric outcomes are presented in Panel B of Table 1, and show that about 44% of the respondents have no information about the cost of their monthly energy use. This is perhaps one of the most important outcomes of the survey, since the unawareness is crucial when considering policy interventions aimed at stimulating energy conservation. The respondents with information on their monthly energy expenditures have an average monthly bill of €126 for gas consumption and €97 for electricity use. This corresponds with residential energy data of the Dutch Central Bureau of Statistics for the total Dutch population, but is slightly higher than energy expenditures for Dutch households as reported by Brounen et al. (2012) (our sample also includes rental units).

Panel B of Table 1 also reports the results of our main energy literacy question. This question has been designed to assess whether the respondents are willing and able to make a trade-off between long-term savings from a more expensive heating system with the short-term benefits of buying a cheaper, less efficient model that is associated with higher gas consumption:

Q2. Suppose you own your home, your heating system breaks down and is beyond repair. As a replacement, you can choose between two heating systems. Model A sells for €3750 and is expected to result in a monthly gas bill of €100. Model B is more expensive, with a retail price of €5000, but will result in a monthly gas bill of €80. You can assume that both models have an economic lifespan of 15 years. Which heating system do you prefer?

A. Heating system A
B. Heating system B
C. I have no preference, both models are equally adequate
D. I have no idea.

Questions like these are designed to measure the "literacy" of respondents. Lusardi and Mitchell (2007) have demonstrated on multiple occasions that many households are often unable to answer simple numeric questions, which also limits their ability to adequately make financial decisions. We introduce this "heating system" question to explore whether the typical consumer is able to make optimal (and financially wise) investments in energy efficient equipment. Answering this question involves a trade-off between the long and short-term and provides some evidence on the rationality of private consumers in energy efficiency investments. Some 60% of the respondents opted to answer model B. The remaining 40% did either not know how to make this choice, or made the suboptimal choice. This result for example is similar to 56% of respondents that correctly answered the question *"If five people all have the winning number in the lottery and the prize is two million dollars, how much will each of them get?"* as posed in Lusardi and Mitchell (2007).

A large proportion of households do not seem to be "literate" when it comes to their residential energy consumption. To explain further these findings, we graphically represent the results, based on gender and age. In Fig. 1A, we plot the answer on the questions related to energy awareness, energy literacy, and choice for green power. We include the latter to measure the role of environmental ideology in consumer choice (see, for example, Kahn, 2007). For the first two questions, we find higher scores among the male respondents. This is in line with Lusardi and Mitchell (2007), who document that financial literacy is significantly higher among male respondents. Regarding the use of green power, there is no sign of any gender variation. Perhaps more surprising are the results presented in Fig. 1B, in which we split our sample into three age groups; younger than 60 years, between 60 and 70 years, and older than 70 years. Regarding the questions on energy awareness and green power, the variation is small and lacks a clear pattern (senior citizens between 60 and 70 years old are more aware of energy consumption, but less likely to purchase green power). But when it comes to choice of the heating system, we document a substantially lower average score for the oldest subgroups. This may imply that older respondents are less rational in their energy efficiency investment decisions. However, the survey also allowed respondents to fill out comments for each question. With respect to the "heating system" question, several elderly respondents indicated that they opted for model A, rather than the more rational model B, since they did not expect to be utilizing the heating system for the full economic life — they expected to live shorter than the duration of the payback period of the more expensive system. This finding indicates that some of the elderly respondents are explicitly considering their shorter investment horizons when making investment decisions.

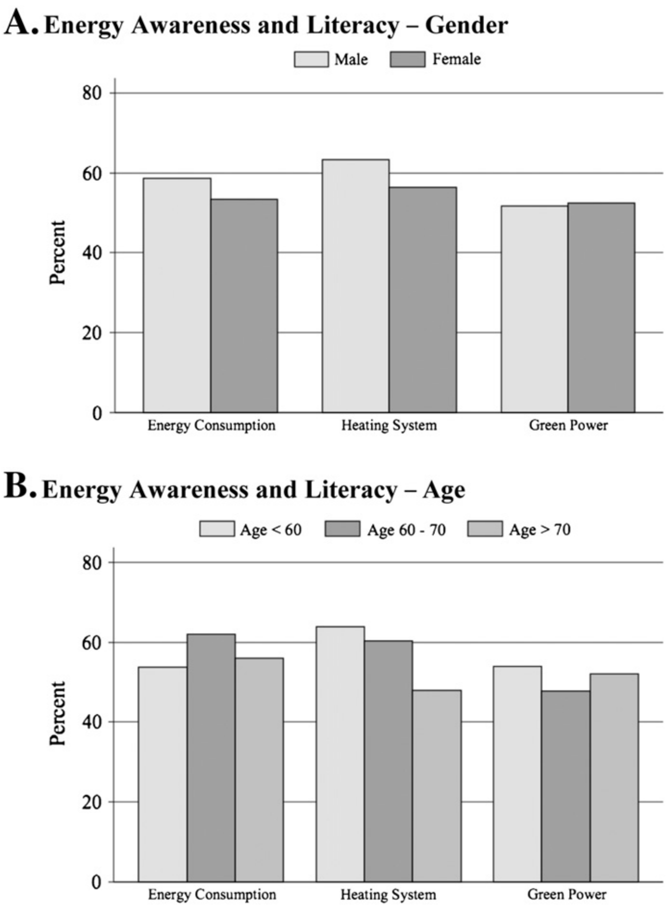

Fig. 1. Explaining energy literacy (n = 1722). A. Energy awareness and literacy — gender. B. Energy awareness and literacy — age.

3.2. Explaining energy awareness and literacy

To isolate further the effect of demographics on the energy awareness, literacy and ideology measures in our survey, we estimate a logit model, using the following equation:

$$P(En\,Lit)_i = a_i + \beta_i D_i + \delta_i AI_i + \varepsilon_i \quad (1)$$

where $En\ Lit_i$ is a binary dummy indicating whether respondent i is "energy literate," based on the outcome of the questions "Do you know your gas bill?", "Can you make the correct heating system choice?", and "Do you use green power?". We estimate the logit model separately for each of these three constructs. We first regress the "energy literacy" dummy on a series of household demographics (D) for each household i, including gender, age, education, and income. In a second specification, we extend this model by adding a set of household attitude and ideology characteristics (AI), including political preferences, spending behavior, driving style, and the quality of the financial administration. This second specification applies to the smaller subsample for which the additional variables are available.

The results of the logit estimations are presented in Table 2. The fit of the models appears quite low, but the explanatory power is comparable to related work on financial literacy by Lusardi et al. (2012). Explaining the cross section of households' awareness and understanding of financial matters is far from straightforward. Obvious explanations, like for example education, income, and age, all have limited effects. Including factors that relate to the attitude and ideology of respondents generally increases the model fit, as shown in Table 2. More recent work by Muehlfeld et al. (2013) points out that personal trades, like risk attitude, locus of control, and self control, may well be relevant in further enhancing the explanatory power of models on consumer literacy. The swiftly developing field of economic psychology continues to offer new hypotheses and variables that should be considered in future research.

In explaining consumer awareness of the monthly energy consumption, we find that gender and age also matter within a multivariate setting, in which we include additional controls for education of the respondent and household income. Older, male respondents are more likely to have information about their gas bill. Importantly, income does not affect energy awareness, which is in line with the general consensus on the low price-elasticity of energy consumption (Reiss and White, 2005). The age variable remains statistically significant when we add control variables for household attitude and ideology. Regarding these attributes, we document that well-organized respondents and more efficient drivers are more likely to have information on their gas consumption. Also, consumers that indicate to spend rather than save disposable income have a lower likelihood of energy awareness. This confirms intuition, since being (financially) organized is partly a result of having information about household expenses, and saving requires awareness of energy consumption.

In columns (3) and (4), the estimations related to the selection of heating systems are presented. The results show that this question is more likely to be answered correctly by well-educated respondents: awareness of energy consumption is not related to education, but rational decision-making on investments in energy-efficient equipment is positively related to training. The inverse relation between rational investment choices and age are confirmed in the analysis. The older the respondent, the lower the likelihood to answer the question correctly.

Table 2
Regression results, energy awareness and literacy (logit model).

	Energy consumption		Heating system		Green power	
	(1)	(2)	(3)	(4)	(5)	(6)
Demographics						
Male respondent	0.204**	0.022	0.275***	0.278	−0.032	0.026
(1 = yes)	[0.099]	[0.191]	[0.103]	[0.192]	[0.099]	[0.185]
Age of respondent (60–70 years)	0.321***	0.574**	−0.123	0.108	−0.243**	−0.373
	[0.117]	[0.242]	[0.121]	[0.237]	[0.115]	[0.227]
Age of Respondent (>70 years)	0.061		−0.672***		−0.067	
	[0.134]		[0.138]		[0.133]	
Some college education	0.077	−0.117	0.678***	0.550***	0.159	0.101
(1 = yes)	[0.104]	[0.199]	[0.110]	[0.204]	[0.103]	[0.193]
Monthly net household income (in €s)	−0.043	−0.132	0.212***	0.039	0.017	−0.069
	[0.054]	[0.108]	[0.056]	[0.107]	[0.054]	[0.104]
Ideology and attitudes						
Voting for Green Party		0.570		0.228		0.357
(1 = yes)		[0.397]		[0.400]		[0.371]
Spending behavior disposable income		−0.212**		0.034		−0.068
(1–7)		[0.082]		[0.081]		[0.078]
Driving efficiently to save gas		0.676***		−0.289		0.655***
(1 = yes)		[0.197]		[0.200]		[0.191]
Sacrificing short term for future income		−0.062		0.038		0.030
(1–7)		[0.070]		[0.069]		[0.067]
Well-organized		0.689***		0.134		−0.019
(1 = yes)		[0.198]		[0.198]		[0.190]
Constant	0.156	1.181**	−0.509***	−0.138	0.059	0.075
	[0.183]	[0.548]	[0.188]	[0.544]	[0.182]	[0.524]
Observations	1720	497	1709	495	1716	496
Pseudo R^2	0.006	0.058	0.045	0.023	0.003	0.025

Notes:
Table 2 provides the regressions results of a set of multivariate logit models, explaining the cross-sectional variation in the variables: "energy consumption", "heating system", and "green power."
"Energy consumption" refers to the question whether respondents know how much they pay for their monthly gas and electricity bill (1 = yes).
"Heating system" refers to the question in which respondents are asked to choose between two alternative heating systems; a cheap inefficient system versus a more expensive efficient system (1 = choice for the efficient system).
"Green power" reflects the proportion of respondents that use the "green" electricity (1 = yes).
Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***.

This result may be related to the shorter investment horizon of the elderly. Within the smaller subsample, including the attitude variables, we document that the influence of education remains significant. Attitude and ideology are not related to energy literacy.

Finally, when considering the use of green power, we find some evidence suggesting that older respondents are less likely to use this more eco-friendly alternative. But in the extended model, the effect of age factor disappears and the variable measuring driving style remains significant. Like "greens" driving more efficient vehicles (Kahn, 2007), consumers with an energy-saving attitude are more likely to reflect their environmental ideology in their product choice (i.e., the use of green power).

Summarizing, some 44% of households in our sample have no information about their energy bill, and this lack of awareness is the strongest among young female respondents that are poorly organized, and those respondents that qualify themselves as "spenders" rather than "savers." When facing the choice to select the financially optimal and most efficient heating system, we find that 40% of our respondents make an irrational choice. This fraction of our sample is not able to make an appropriate trade-off between long-term benefits and short-term costs. This "illiteracy" is the highest among the lower educated households. Regarding the use of green power, we document that this eco-friendly alternative is most popular among the households that have a tendency to save energy while driving.

4. Household behavior and energy consumption

It is important to understand better what households actually know about the residential energy consumption, but the ultimate outcome of energy awareness and literacy can be measured in behavior and consumption. In section E of the DHS household survey, we therefore ask the following questions:

> Q3A. At which temperature do you set your thermostat during the evening? […] degrees Celsius
>
> Q3B. At which temperature do you set your thermostat at night? […] degrees Celsius.

Modifying the thermostat is a deliberate action by the household, reflecting a trade-off between comfort temperature and energy consumption. We are interested in two aspects related to setting the comfort temperature. We first analyze the absolute setting during the evening. (We also inquired into the thermostat settings during the day. But we assume that the day temperature is to a large extent determined by demographics. For instance, elderly households are more likely to remain at home during the day.) Which households prefer comfort to energy savings? Second, we address the switching of temperature settings between evening and night. Lowering the night temperature is a simple, but considerate action that may result in significant energy savings.

To examine the household attributes determining "energy behavior", we control for a series of households characteristics and proxies for attitude and ideology, following Model (1). In Table 3, we present the regression results on the choice of the level of evening temperature (i.e., the comfort level) in columns 1–4, and the results of a logit model with the independent variable indicating a decrease in the night setting of the thermostat are presented in columns 5 and 6.

In column (1), we document that the choice for evening temperature mainly a function of household age and income. Elderly households choose higher comfort levels. This confirms results documented by Brounen et al. (2012), who provide evidence that the age structure of

Table 3
Regression results behavior, demographics and attitudes (OLS, 2SLS, and logit models).

	OLS		2SLS		Logit	
	Evening temperature (in Celsius)		Evening temperature (in Celsius)		Lower thermostat at night? (1 = yes)	
	(1)	(2)	(3)	(4)	(5)	(6)
Demographics						
Male respondent	−0.098	−0.110			−0.091	−0.416
(1 = yes)	[0.112]	[0.210]			[0.171]	[0.330]
Age of respondent (60–70 years)	0.649***	0.833***	0.570***	0.827***	−0.511***	−0.522
	[0.130]	[0.250]	[0.156]	[0.285]	[0.197]	[0.393]
Age of respondent (>70 years)	0.480***	0.000	0.236	0.000	−0.473**	0.000
	[0.152]	[0.000]	[0.290]	[0.000]	[0.232]	[0.000]
Some College Education	−0.112	0.086	0.118	0.293	0.243	0.535
(1 = yes)	[0.117]	[0.219]	[0.293]	[0.458]	[0.180]	[0.350]
Monthly net household	0.221**	0.626***	0.320*	0.639***	0.141	−0.078
Income (in €s)	[0.111]	[0.193]	[0.183]	[0.221]	[0.172]	[0.360]
Evening temperature					0.935***	0.902***
(in Celsius)					[0.052]	[0.097]
Ideology and attitudes						
Voting for Green Party		0.245		0.364		0.534
(1 = yes)		[0.427]		[0.537]		[0.717]
Spending behavior disposable income		0.059		0.076		0.048
(1–7)		[0.092]		[0.103]		[0.143]
Driving efficiently to save gas		−0.086		−0.243		−0.062
(1 = yes)		[0.216]		[0.340]		[0.341]
Sacrificing short term for future income		−0.205***		−0.194*		0.030
(1–7)		[0.077]		[0.103]		[0.120]
Well-organized?		−0.305		−0.250		0.342
(1 = yes)		[0.214]		[0.246]		[0.336]
Energy literacy						
Heating system choice			−1.531	−1.947		
(1 = yes)			[1.732]	[3.494]		
Constant	17.432***	14.783***	17.511***	15.744***	−17.259***	−15.268***
	[0.856]	[1.525]	[0.927]	[2.382]	[1.629]	[3.100]
Observations	1557	448	1550	447	1557	448
R^2	0.020	0.066				
Adj. R^2	0.017	0.047				
F-Value			5.17	2.76		
Prob > F			0.000	0.004		
Pseudo Adj. R^2					0.402	0.403

Notes:
Table 3 reports the regression results explaining the cross-sectional variations in evening temperature settings and whether or not the respondents changes the thermostat settings at night (compared to the evening setting).
Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***.

the household has a significantly positive effect on gas consumption (using a detailed microeconomic dataset on energy consumption for 300,000 Dutch households). There is a large body of mostly qualitative research on gender preferences on thermal comfort (see, for example, Karjalainen, 2007), but our results provide no indication that women have a preference for higher ambient temperatures than men.

We also document that income is an important determinant of evening home temperature. This is an indication that thermal comfort preferences are substantially different across income classes (Fritzsche, 1981). Comfort comes at a price, and high-income households appear to have a higher willingness to pay for higher ambient temperature levels. We then extend the model with attitude and ideology variables. The significance of age and income remains, and we find that those respondents that "are willing to sacrifice the short term for future income" choose for an evening temperature that is lower than average (presumably to reduce their energy bill).

In columns (3) and (4), we add the energy literacy variable to the model, estimated using a two-stage least-squares (2SLS) regression and instrumented by basic household demographics to account for the endogeneity of literacy. The results show that energy literacy does not significantly affect household behavior in thermostat setting (although the negative coefficient provides some indication that more literate consumers choose lower temperature setpoints) — energy conservation behavior is not a direct outcome of awareness and education.[5] (Indeed, Alcott and Mullainathan, 2010, show that additional nudges are needed to create behavioral change.)

In columns (5) and (6), we estimate a set of logit regressions on a binary dummy that indicates whether the household lowers the thermostat temperature from evening to night (a value of one indicates that the night temperature is lower than the evening temperature). Clearly, there are households that prefer a lower and relatively stable temperature setting over a more volatile temperature that peaks during the evening. Lowering the night temperature is more common among the households that have the highest evening temperature settings, but elderly households opt for higher temperatures at night. When including our proxies for attitude and ideology, the age factor loses significance and just the evening temperature remains a factor that is important in explaining the "switching" decision. Environmental ideology and a more active stance towards conserving resources (monetary as well as natural resources) have no impact on the choice of comfort level.

The outcome of energy awareness, energy literacy, environmental ideology and attitude, and thermal comfort settings is ultimately

[5] In unreported regressions, we substitute the energy literacy variable for the energy awareness measure and document a similar negative, but insignificant effect. Results are available upon request.

Table 4
Regression results, energy consumption, dwelling characteristics and behavior (Heckman selection model).

	OLS		2SLS	
	(1)	(2)	(3)	(4)
Home characteristics				
Size (m^2)	0.001***	0.000***	0.001***	0.001***
	[0.000]	[0.000]	[0.000]	[0.000]
Household size	0.081***	0.098***	0.110***	0.100***
	[0.020]	[0.023]	[0.034]	[0.027]
Period of construction				
1980–2000	0.183**	0.202**	0.346**	0.340***
	[0.085]	[0.084]	[0.138]	[0.115]
1960–1980	0.409***	0.422***	0.565***	0.561***
	[0.082]	[0.081]	[0.126]	[0.102]
1940–1960	0.429***	0.482***	0.601***	0.571***
	[0.101]	[0.101]	[0.159]	[0.125]
1920–1940	0.467***	0.518***	0.887***	0.767***
	[0.112]	[0.111]	[0.245]	[0.185]
<1920	0.483***	0.515***	0.708***	0.691***
	[0.102]	[0.101]	[0.178]	[0.148]
Demographics				
Percentage of male respondents		−0.485		
		[0.895]		
Age of respondent (60–70 years)		0.191***		
		[0.057]		
Age of respondent (>70 years)		0.187***		
		[0.068]		
Monthly net household income (in €s, logs)		0.165***		
		[0.053]		
Evening temperature			0.327**	0.247**
(in Celsius)			[0.136]	[0.103]
Lower thermostat at night?				−0.737**
(1 = yes)				[0.344]
Selection variable ($\hat{\lambda}$)	−0.309	−5.465	0.029	−0.086
	[0.573]	[10.578]	[0.846]	[0.665]
Constant	4.269***	6.669	−2.582	−0.266
	[0.410]	[7.853]	[2.939]	[1.942]
Observations	661	661	619	619
R^2	0.125	0.160		
Adj. R^2	0.114	0.144		
F-Value			5.60	7.86
Prob > F			0.000	0.000

Notes:
Table 4 presents the regressions results of a cross-sectional analysis of gas consumption, estimated using the Heckman (1979) two-step method. Columns (3) and (4) are estimated in a 2SLS model, in which the evening temperate settings and night temperature switching behavior is instrumented by household demographics.
Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***.

reflected in the gas consumption. For the subsample of respondents that provided information on monthly energy expenditures (we note that we are dealing with self-reported energy use here) we estimate cross sectional regressions to disentangle the gas bill into factors that relate to the thermal quality of the dwelling – the age and size of the home – and to a set of household characteristics. In the estimation of this model, we face a sample selection issue, because we observe the energy expenditures for just a subset of the total sample. To correct for a potential bias in the regression results, we use the Heckman (1979) two-step method. As an exogenous determinant of energy awareness, we use "some level of college education." This variable is exogenous to energy awareness and has a very low correlation with household energy consumption (0.02). We first estimate a probit model on the probability of a household having knowledge about their energy expenditures, similar to Model (1). We then construct consistent estimates of the inverse Mills ratio, and include this selection variable as an instrument in the following model:

$$\log(E)_i = \alpha + \beta_i D_i + \delta_i X_i + \theta\hat{\lambda} + \varepsilon_i. \qquad (2)$$

In Eq. (2), the dependent variable is the logarithm of gas consumption (in euros) for dwelling *i*. D_i is a vector of demographic characteristics, including age and gender of the head of the household, household composition, education and income. X_i is a vector of the hedonic characteristics of building *i*, including dwelling size and period of construction. [6] λ_i is the inverse Mills ratio constructed based on the first step of the estimation.

Table 4 presents the regression estimates for energy consumption. Standard errors are corrected for heteroskedasticity following White (1980). We first run a set of OLS regressions (columns 1 and 2), and then include the evening temperature as a proxy for household behavior. We estimate columns (3) and (4) using a two-stage least-square model, instrumenting household behavior by demographic characteristics. At 13–16%, the explanatory power of the models is quite low — Brounen et al. (2012) explain some 50% of household energy consumption in their model. However, we do not have information on important explanatory variables such as dwelling type (e.g., apartment, detached, row house, etc.), insulation quality, and local climatic condition. Moreover, our data on consumption and dwelling characteristics is self-reported.

Column (1) shows that doubling of the surface of the average dwelling (some 138 m^2) increases gas consumption by some 14%. This is quite

[6] We acknowledge that the energy consumption of the household is not only a function of the physical structure of the building and demographic composition, but it also depends on the choice of durable goods (i.e., appliances) in the dwelling. However, the latter are unobserved; we cannot further control for them directly.

similar to results documented in Brounen et al. (2012).[7] Each additional person in the household increases the gas consumption by just eight percent, reaffirming the well-documented economies of scale in residential energy consumption. Relative to dwellings constructed in this century, we document that gas consumption increases with the aging of dwellings. The results seem to suggest that thermal building conventions (or standards) improved greatly after 1980 — the 1960–1980 cohort uses 41% more energy, while the 1980–2000 cohort consumes 19% more energy, than the post-2000 cohort. This pervasive difference may well be the result of changes in building codes or building techniques.

The coefficient on the selection variable, the inverse Mills ratio, is negative but not significant. This result provides some indication that the error terms in the selection equation and the primary equation are negatively correlated. So, (unobserved) factors that increase awareness of energy expenditures tend to be associated with lower energy consumption.

In the second column, we add household demographics to the model. Older respondents consume about 19% more gas as compared to households where the household head is younger than sixty years. This result may well be attributed to intensity of use (or occupation) of dwellings, which is likely to be lower among working respondents than among retired households. The effect of income on gas consumption is quite strong — a one-percent increase in disposable income is associated with an 18% increase in household gas usage.

In column (3), we add the evening temperature setting to the model, instrumented by household demographics, ideology and attitude. Not surprisingly, we find that setting the evening temperature higher than average increases the gas bill quite substantially. The behavior of the household in "switching the knob" results in statistically significant effects. In the final model specification, we also add the night switching dummy, indicating whether a household lowers the home temperature at night. The results confirm that switching to lower night temperatures significantly reduces the gas bill. Household behavior matters strongly for residential energy consumption.

5. Conclusions and discussion

Energy consumption in the residential sector offers an important opportunity for conserving resources. Understanding the key determinants of residential energy consumption is important for the design and implementation of effective policies aiming to increase the energy efficiency of the building stock. Kempton and Layne (1994) document that inefficient allocation of data on energy consumption restricts the energy saving behavior of consumers. Indeed, some have argued that increased information transparency in energy consumption can be instrumental as a "nudge" to encourage energy conservation among private consumers. Some recent experiments show that providing feedback to consumers on energy consumption can substantially reduce energy bills (Ayers et al., 2009).

In this paper, we contribute to the debate and literature on residential energy efficiency by addressing some fundamental assumptions underlying policies related to energy efficiency improvements and experiments to encourage energy conservation. Instead of assuming that consumers have information about their energy consumption and understand the mechanisms that help them conserve, we design and execute a survey on energy awareness and literacy. By relaxing assumptions about rationality in consumer choice, we shed new light on the effectiveness of existing energy efficiency policies and interventions, and offer some suggestions that may help to "nudge" households into lowering their utility bill.

Using survey data from a long-standing household panel, we first examine the awareness of consumers regarding their monthly energy expenditures, and the ability of consumers to make rational decisions on energy-efficiency investments — energy literacy. The results indicate that energy awareness is mostly influenced by environmental ideology and the conservation attitude of consumers. Those respondents that tend to drive more efficiently, save more, are better organized, and are more likely to be aware of their residential energy consumption. Awareness is only to some extent determined by demographics — most importantly the age of the respondent. Rational decision-making (i.e., energy literacy) is determined primarily by education, and is unrelated to either ideology or attitude.

We then measure energy behavior by the choice of thermal comfort (i.e., thermostat settings) during the evening and the propensity to lower that setting during the night. Our results show that older respondents with higher incomes choose higher comfort levels, and age is negatively related to lowering the temperature at night. More frugal respondents opt for a lower comfort temperature during the evening. Importantly, energy literacy and awareness are unrelated to conservation behavior.

When modeling actual household energy consumption, we document that behavior related to thermal comfort has an important influence on energy expenditures. "Turning the knob" affects energy consumption, even when controlling for the characteristics of the dwelling. We do not find evidence on the effect of energy awareness and literacy on actual energy consumption.

For policy makers, the results of this paper may shed light on the main assumption underlying most energy efficiency policies: the ability of the market to rationally capitalize energy efficiency in investment decisions. Energy use does not seem to be on the mind of the typical consumer. In line with earlier work by Brounen and Kok (2011), which provide some evidence that just 17% of households adopt an otherwise mandatory "energy performance certificate" (EPC) in a sample of residential transactions, we identify a large group of households that have no knowledge about their utility bill, and that is not considering the thermostat night settings to save on energy and outgoings. We refer to this group of consumers as "sleepers," comparable to the "woodheads" of Quigley and Deng (2002), ignoring substantial savings on mortgage payments that could be realized through refinancing. Our survey shows that the fraction of "sleepers" is quite high in our sample, and that changing their behavior will require a careful use of "nudges."

Behavioral "nudges", like the provision of home energy scorecards, have been shown to be quite effective in affecting residential energy consumption. However, those triggers work through a crucial moderating factor: the home temperature control. Those devices are often overly simplistic, requiring manual adjustment at night, or extremely complicated, almost requiring advanced computing skills. Setting temperatures at the average and adjusting the thermostat at night affects the aggregate residential energy demand quite substantially. But in the hands of "sleepers" these thermostats have little effect. Pre-programmed, smarter temperature control devices would be an obvious solution, comparable to automated enrollment into retirement saving programs. Current smart meter rollouts offer the opportunity to test the effectiveness of smarter temperature control devices through randomized field experiments. Analyzing the treatment effects of these smart meters in randomized field experiments is a natural next step for future research.

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[7] The comparability of results is somewhat reassuring, since the Brounen et al. (2012) study is based on a dataset of over 300,000 energy bills instead of self-reported data. This finding provides some evidence that the DHS survey is filled out in a consistent manner.

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