Residential Energy Literacy and Capitalization

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Abstract

With the residential sector accounting for some one-fifth of global energy consumption -- resulting from the requirements to heat, cool, and light residential dwellings -- energy efficiency in private dwellings has again gained interest in recent years. In this paper, we examine the importance of awareness and behavior of households with respect to their residential energy use. Using a detailed survey across 1,721 households, we measure the extent to which consumers are aware of their energy consumption and whether they have taken measures to reduce their energy bill. Our results show that "energy literacy" among respondents is low: just 56 percent of the respondents are aware of their monthly charges for energy consumption, and 60 percent appropriately evaluate investment decisions in energy efficient equipment. We document that energy literacy, consumer ideology and attitude towards energy conservation have a direct effect on behavior regarding heating and cooling of the home. The impact of the moderating factor, measured by thermostat settings, ultimately results in strong variation in the energy consumption of private consumers.

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1. Introduction

Energy conservation has developed into 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. However, it remains unclear to what extent residential households have picked up on this increased focus on the energy efficiency of their dwelling.

Although household energy bills in most countries are on the rise -- mostly due to increasing oil and gas prices, but also following increases in 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 the dwelling, but private market initiatives struggle to succeed without governmental support (Jaffe and Stavins, 1994). This struggle, coined the energy paradox, is prominent in the residential market, whereas recent research suggests that professional property investors and tenants seem to value energy savings in commercial real estate quite precisely (Eichholtz et al., 2012).

To properly assess the outlook of energy efficiency investments in the residential market, empirical proof on the willingness to pay for energy-saving measures and the discount rate applied by private consumers is crucial (Horowitz and Haeri, 1990). Most of the existing work on this topic, however, is based on small samples or qualitative measures.[1] 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 energy bills will only be capitalized in the transaction prices of homes, if energy efficiency is properly understood and decision-making is rational.

In this paper, we examine the extent to which households are aware of their energy consumption, understand the energy efficiency of their home, and appropriately adapt their behavior. In line with recent work on financial literacy by Van Rooij et al. (2011), we generate and exploit a survey among 1,721 Dutch households, inquiring into consumer knowledge on energy consumption. We construct survey questions that not only allow us to measure the awareness of the household towards energy use, but we can also assess "energy

[1] One exception is a recent paper by Brounen and Kok (2011), which exploits the EU Energy Performance Certificate to empirically test willingness to pay for energy efficiency in homes, using a large sample of transactions in the Netherlands.

literacy" -- whether households are able make a to 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 energy literacy, demography, attitude and ideology to decisions that household make on a daily basis when it comes to comfort 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 percent (47 percent) of the respondents is aware of their monthly charges for gas (electricity) consumption. This lack of energy awareness is strongest among younger households enjoying higher incomes. We also document that awareness of energy consumption is higher among households that keep an organized financial administration and that generally pay more attention to conserving resources (measured by driving behavior). 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 demographics, but not literacy or ideology, and to a limited extent attitude, 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. The respondents that are willing to "make sacrifices in the short term in order to secure future income" settle for a lower home temperature in the evening, presumable to save on energy consumption.

The outcome of literacy, ideology, attitude and behavior regarding residential energy conservation can ultimately be measured in the household energy consumption. Within the sample of respondents that are aware of the household energy bill, we explain the variation in energy consumption by a set of dwelling characteristics, household demographics and their behavior related to the ambient comfort. 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 the energy bill through the evening temperature as a moderating factor, we

find that the choice for a comfort level has a significant effect on household energy consumption. Also, changing the temperature at night positively affects energy conservation.

Our results have some important 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 the households is aware of their current energy consumption (in our sample, that is). Energy use does not seem to be on the mind of the average consumer. We refer to this group of consumers as "sleepers," comparable to the "woodheads" of Quigley and Deng (2002) that just forego substantial savings on mortgage payments through refinancing. Many households forego savings on energy payments through ignoring temperature control. 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.

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 via 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 enrolment into retirement saving programs. Current smart meter rollouts offer the opportunity to implement such a program.

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, but do not necessarily affect behavior. "Greens" may drive a Prius (Kahn, 2007), but we do not find evidence that they actively reduce comfort temperatures of lower the night temperature to save on resources.

The remainder of this paper is organized as follows: the next section is a review of the literature on energy efficiency in the residential market, discussing how financial literacy may help to understand residential energy consumption. The third section describes the data and provides descriptive statistics and details regarding the setup of the survey analysis.

Section four provides the empirical results explaining energy awareness and literacy, while section five focuses on energy behavior and consumption. Section six is a brief conclusion.

2. Literature Review

The literature on residential energy consumption and capitalization is diverse and consists of several strands, each focusing on specific aspects of residential energy demand: price elasticity, thermal quality and household demographics, lifestyle and family cycles, social norms, and signals in energy preservation policy.

The academic work on residential energy demand and price elasticity has the longest history. In early work, Houthakker (1951) analyzes monthly electricity demand in 42 British provincial towns during the 1937-1938 period. The seminal results show that electricity consumption is a function of the marginal electricity price and of the average holdings of domestic equipment per consumer. Halvorsen (1975) continues along this research line, developing a model permiting a consistent estimation of direct and total elasticities of demand for residential electricity. Analyzing pooled U.S. data for the period 1961-1969, Halvorsen reports elasticities that are robust and indicate that the long-term direct elasticity of demand with respect to electricity price is at least unitary. More recently, Reiss and White (2005) revisited some of the earlier work on household electricity demand, while evaluating the effects of alternative tariff designs on electricity consumption. The model addresses several interrelated difficulties posed by nonlinear pricing, heterogeneity in consumer price sensitivity, and consumption aggregation over appliances and time. The model is estimated using data for a representative sample of 1,300 Californian households, and yields results that indicate a strikingly skewed distribution of household electricity price elasticities. Only a small fraction of households account for most of the previously documented demand response to price adjustments.

During the late seventies, a series of studies appeared that expanded the analysis of energy consumption beyond the traditional price and income elasticities. In the aftermath of the oil crisis, concerns about energy dependence triggered a first wave of policies intended to improve the energy efficiency of private homes. In academic circles, this triggered an interest in understanding the cross-sectional variation of residential energy use. Besides addressing structural characteristics and the thermal quality of the dwelling, studies were undertaken to better grasp the effects of the household composition on energy consumption. Several household demographics emerged as important factors explaining the cross-sectional

variation in household energy consumption. Studying residents' thermal preferences in surveys among couples in their early thirties, Seligman et al. (1979) documents that energy consumption in the summer is related to consumers' perceptions of comfort and health, and Becker et al. (1980) later documented a similar finding for winter energy consumption. However, DeFronzo and Workov (1979) find no evidence that the gender of the household head is important in explaining the level of electricity consumption.

Fritzsche (1981) extends this literature by analyzing households of varying stages in the family life cycle. Examining 19,975 respondents from the 1972-72 Bureau of Labor Statistics's Consumer Expenditures Survey, he documents that middle-aged married couples with children consume most energy. Verhallen and Van Raaij (1981) and Van Raaij and Verhallen (1983) propose a model that relates more specific personal, environmental and behavioral factors to energy use. The authors test their theoretical model to explain the variance in energy used for home heating across 145 households in the Netherlands. Together with home characteristics, sociodemographics and lifestyle and attitude explained 58 percent of the observed energy use variance, much higher than previous studies. Wilhite et al. (1996) show that some of these lifestyles and environmental attitudes are determined by cultural factors, comparing household energy behavior across a sample of homes in Fukuoka (Japan) and Oslo (Norway).

Perhaps the most recent addition to this literature is Brounen et al. (2012), analyzing the extent to which the use of gas and electricity is determined by the technical specifications of a dwelling as compared to the socio-demographic characteristics of the residents. The empirical analysis is based on a sample of more than 300,000 Dutch homes and their occupants. The results indicate that residential gas consumption is determined principally by structural dwelling characteristics, such as the vintage, building type and characteristics of the dwelling, while electricity consumption varies more directly with household composition, in particular income and family composition.

The third stream of literature that relates to residential energy efficiency addresses the pursuit of effective energy conservation. Building on the notion that attitude, culture and lifestyles are important factors, various field experiments have been undertaken to assess the effectiveness of policy initiatives aiming to reduce energy consumption. This literature starts with Hayes and Cone (1977), again at the time of the oil crisis, analyzing the importance of providing information on energy bills and daily feedback on consumption. The study is based on a combined multiple-baseline and withdrawal experiment using units of a university student-housing complex. Feedback on energy use resulted in reductions, while information

about ways to conserve energy and about the cost of using various appliances did not have any effect. The authors conclude that informing households regarding the effects of their decision is paramount when striving for a change in behavior.

Gilmer (1989) tests this hypothesis using a small sample of energy-efficient homes in Minnesota. The use of energy labels has positive effects during the course of economic search -- spreading relevant information regarding the energy-efficiency aspect of the dwelling enhances the fit between buyer and seller. Brounen and Kok (2011) also find evidence on the effect of energy labels providing information to homebuyers. Using a dataset that includes 194,000 housing transactions in the Netherlands, of which some 33,000 transactions have an energy performance certificate, the authors find evidence that the EU energy performance certificate carries a moderately powerful market signal.[2] Within the sample of certified homes, the authors document a significant price premium for homes with an energy label that reflects high standards of energy efficiency. The size of this energy-efficiency increment is positively related to the label outcome, and the results are robust to the inclusions of a wide array of quality characteristics, such as quality of insulation and the maintenance of the exterior.

The power of information is also important in constructing policies that aim to change behavior. Abrahamse et al. (2005) review 38 studies within the field of social and environmental psychology, all targeting household energy conservation. Interestingly, most studies focus on voluntary behavioral change in energy consumption by improving the knowledge and perceptions of individuals, rather than changing contextual factors (*e.g.*, the pay-off structure) that may determine households' behavioral decisions. Information provision tends to result in higher knowledge levels, but not necessarily in behavioral changes or energy savings. Rewards effectively encourage energy conservation, but with rather short-lived effects. Feedback has also proven its merits, in particular when provided frequently.

Schultz et al. (2007) run a field experiment in which normative messages are used to promote household energy conservation. A descriptive normative message, detailing average neighborhood usage produced either desirable energy savings or the undesirable boomerang effect, depending on whether households were already consuming at a low or high rate. Adding an injunctive message (conveying social approval or disapproval) eliminated this boomerang effect. Allcott (2011) recently expanded upon this work with an evaluation of a series of programs run by a company called "OPOWER," sending home energy report letters

[2] For a comprehensive discussion on the implementation of energy certification of buildings across Europe, see Andaloro et al. (2010).

to residential utility customers comparing their electricity use to the consumption of their neighbors. Using data from randomized field experiment on some 600,000 treatment and control households across the US, it is estimated that the program reduces energy consumption by two percent, on average. This effect is equivalent to that of a short-run electricity price increase of 11 to 20 percent, illustrating that non-price interventions can substantially and cost-effectively change consumer behavior.

Another relevant strand of studies, recently emerged in the financial literature, is the work on financial literacy. (This field has been largely developed by Annamaria Lusardi.) In one of the early papers on this topic, Lusardi and Mitchel (2007) use the Health and Retirement Study (HRS) survey framework to assess the ability of households to make their own financial decisions. Results reveal that just a small fraction of older respondents (less than one third) ever tried to figure out how much they need to save for retirement. Moreover, the same survey shows that just 18 percent of the 2,635 respondents are able to answer the following question correctly: "Let's say you have 200 dollars in a savings account. The account earns 10 percent interest per year. How much would you have in the account at the end of two years?". Follow-up studies of Lusardi and Mitchell (2008) and Lusardi and Tufano (2009) explore the extent to which this "financial illiteracy" is related to gender, education and income.

This paper exploits the survey framework on financial literacy to address consumer awareness, ideology and behavior towards residential energy efficiency. Using survey techniques allows for directly measuring the importance and awareness of energy efficiency within the perception of households. We test the standard assumption in the literature that households know and care about their energy bill, explaining the cross-sectional variation by socio-economics factors, ideology and attitudes. We then explore the ability of households to trade off long-term benefits and short-term investments to assess the rationality of private households in considering investments in energy efficiency. This is important information to assess whether policies designed to stimulate private investments in "sustainability" of residential dwellings is sufficiently appealing to convince households.

We directly link the awareness and literacy of households regarding energy consumption to their energy behavior, measured by the thermostat setting and adjustment of their thermostat settings at night. These measures of behavior are the moderating factors between household demographics, ideology and attitudes and actual energy demand. Thus, we aim to analyze the missing link between energy policy design and household energy behavior, which includes the understudied topics of energy awareness and energy literacy.

3. Data

In this paper, 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 2,000 households. See Nyhus (1996) for a detailed description of this survey and an assessment of the quality of the data. CentERdata, a survey research institute at Tilburg University that specializes in Internet surveys, manages the panel.[3]

The DHS is build up in several sections. Section A inquires about 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 the housing and mortgage details.

In addition to using data from the main core of the DHS, we also use data from additional, self-designed survey modules on financial literacy and residential energy use, added to the survey in April 2011. In this paper, we primarily focus on the answers to the question that are posted in section E of the survey; those regarding household energy consumption. The final section F of the survey is designed to assess ability of households to properly make financial decisions and to trade off long-term benefits with short-term investments.

In total, the survey consists of 50 questions, and requires 18 minutes to fill out, on average. A total of 1,721 out of 2,028 households completed the financial literacy and residential energy module -- a response rate of 84.9 percent (in line with the response rate from the main survey). The respondent to these residential energy questions represents the member of the household that is charge of household finances.

Survey participants are interviewed via the Internet. Although the Internet connection rate in the Netherlands is among the highest in Europe (80 percent 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 is first done by phone with 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 presents several

[3] For more information about the survey agency, see http://www.uvt.nl/centerdata/en.

advantages. For example, data collected using Internet surveys suffer less from reporting biases than data collected via telephone interviews (Chang and Krosnick, 2003).

DHS offers a wide variety of background characteristics on the households in our sample, which enable an analysis of factors determining energy awareness across our sample. The dataset also benefits from existing survey data on the panel used, to enrich our survey results with additional background items that were addressed in other DHS surveys over 2011.

Table 1 offers a comprehensive overview of summary statistics of the main variables in the survey analysis. The top panel of the table reports the average characteristics of respondents' homes. The average dwelling offers 138 square meters of living space, and about 36 percent of the respondents live 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 also Brounen et al., 2012). Table 1 also shows the demographic composition of the respondents in the sample: some 54 percent of the respondents are male and the average age is 57 years. The monthly gross income of respondents is €2,882. Among the respondents, just 39 percent has at least some college education.

The next section of Table 1 summarizes the variables on ideological background for the households in our sample. This information is available for a smaller subset of the respondents. We document that about 9 percent of the respondents votes 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 is 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 prices of €1.70/liter, is not surprising). We also asked respondents about 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 percent of household disposable income in 2007 (see Leetmaa et al., 2009).

4. Energy Awareness and Literacy

A. 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 to assess directly how much households really 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 in Panel B of Table 1, and show that some 44 percent of the respondents have no idea about the cost of monthly energy expenditures. 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 saving. The respondents with information about their monthly energy 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.).

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 a higher gas use:

Q2. Suppose you own your home, your heating system breaks down and is beyond repairs. As a replacement, you can choose between two heating systems. Model A is for sale for €3,750 and is expected to result in a monthly gas bill of €100. Model B is more expensive, with a retail price of €5,000, 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 in fact not able to answer such simple numeric questions, which also limits their ability to make

financial decisions adequately. We introduce this "heating system" question to find out whether an average consumer is able to make the sustainable (and financially wise) choice when the opportunity is offered. 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 percent of the respondents opted for answer and model B. The remaining 40 percent did either not know how to make this choice, or made the wrong choice. This result for example corresponds with the 56 percent 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 further explain these findings, we graphically represent the results, based on gender and age. In Figure 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 energy 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 Figure 1B, in which we split our sample into three age groups; younger than 60 years, between 60 and 70 of age, and older than 70 years. For the questions on energy awareness and green power, the variation is mild and lacks a clear pattern (seniors 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 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.

B. Explaining Energy Awareness Literacy

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

$$(1) \qquad P(En\ Lit)_{\mathrm{i}} = \alpha_i + \beta_i D_i + \delta_i AI_i + \varepsilon_i$$

where $En\ Lit_i$ is a binary dummy that indicates whether a 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 these logit estimations are presented in Table 2. First, in explaining consumer awareness of the monthly energy consumption, we find that gender and age also matter within a multivariate setting, in which we also control 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 matter for energy awareness, which is in line with the general consensus on the low price-elasticity of energy consumption (see Reis and White, 2005). The age factor also remains statistically significant when we add controls for household attitude and ideology. Considering the attitude and ideology 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 trying to save requires being aware of your consumption.

In columns (3) and (4), the estimates related to the selection of heating systems are presented. 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 correctly answer the question. This may be related to the short 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 no 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 just 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, about 44 percent of households in our sample have no information on their energy bill, and this lack of awareness is 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 percent 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 inability is strongest among the lower educated households. When it comes to using green power, we find that this eco-friendly alternative is most popular among the households that have a tendency to save energy while driving.

5. Household Behavior and Energy Consumption

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

Q3A. At which temperature do you set your thermostat during the evening?

[…] degrees Celcius

Q3B. At which temperature do you set your thermostat at night?

[…] degrees Celcius

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 day temperature is too a large extent determined by demographics. For instance, older households are more likely to remain at home during the day.) Which households prefer comfort over savings? Second, we address the switching of temperature settings between evening and night. Lowering the night temperature is a simple, but deliberate action that may results in significant energy savings (after all, the night represents one third of a day).

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, columns 1 and 2) and a binary variable indicating a change in the night setting of the thermostat (columns 3 and 4).

In column (1), we document that the choice for evening temperature is mainly a function of household age and income. Elderly households choose higher comfort levels. This confirms results documented by Brounen et al. (2012), which provide evidence that the age structure of the household has a significantly positive effect on gas consumption (using a detailed microeconomic dataset on real 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 requirements are substantially different across income classes (Fritzsche, 1981). Comfort comes at a price, and the wealthier households appear to be willing to pay for higher ambient temperature levels. We then extend the model with attitude and ideology factors. The significance of age and income remains, and we find that those respondents that "are willing to sacrifice the short term for future income" are actively reducing their thermostat setting, choosing for an evening temperature that is lower than average, presumable to reduce their energy bill. "Spenders" seem less concerned about energy expenditures.

In colums (3) and (4), we estimate a set of logit regressions on a binary dummy that indicates whether the household lowers the thermostat temperature between evening to night (one indicates that the night temperature is lower than the evening temperature). 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. Clearly,

there are households that prefer a lower and relatively stable temperature setting over a more volatile temperature that peaks during the evening. 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 of active "switching" behavior.

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

$$(2) \quad \log(E)_i = \alpha + \beta_i D_i + \delta_i X_i + \varepsilon_i$$

In equation (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.[4]

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-squares model, instrumenting household behavior by demographic characteristics.

Column (1) shows that doubling of the surface of the average dwelling (some 138 square meters) increases gas consumption by some 14 percent. This is exactly similar to results document in Brounen et al. (2012).[5] 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 show that gas consumption increases with the ages of dwellings. The results seem to suggest that

[4] 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.

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

thermal building conventions (or standards) improved greatly after 1980 -- the 1960-1980 cohort uses 41 percent more energy, while the 1980-2000 cohort consumes 19 percent more energy, than the post-2000 cohort. This pervasive difference may well be the result of changes in building codes or building techniques.

In the second column, we add household demographics to the model. Older respondents consume about 19 percent 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 percent 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 "turning the knob" results in statistically significant effects. In the final model specification, we also add the night switching dummy that indicates whether the household lowers the home temperature at night. The results confirm that switching to lower night temperatures significantly lowers the gas bill. Household behavior matters strongly for residential energy consumption.

6. Conclusions and Discussion

Energy consumption in the residential sector offers an important opportunity for conserving resources, and 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 savings 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 to reduce it, 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 nudge households into lowering their utility bill.

Using survey data from a long-standing household panel, we first examine the awareness of consumers of their monthly energy expenditures, and the ability of consumers to make rational decisions on energy-efficiency investments. 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 efficient, save more, and are better organized, 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 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, actual behavior related to thermal comfort has an important influence on energy consumption. "Turning the knob" affects energy consumption, even when controlling for the characteristics of the dwelling.

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 average consumer. In line with earlier work by Brounen and Kok (2011), which provide some evidence that just 17 percent of households adopts an otherwise mandatory "energy performance certificate" in a sample of residential transactions, we identify a large group of households that has 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) that just ignore substantial savings on mortgage payments through refinancing. Our survey shows that the fraction of "sleepers" is quite high in our sample, and nudging them into reducing energy consumption will not be straightforward, since information feedback works only in case consumers are aware (and care).

Our findings have some implications for policy makers. We find that both the awareness and the literacy of residential energy consumption are low. The latter hampers the ability of households to make the most efficient choice when it is offered, coinciding with evidence on general financial literacy, which has been documented to be lower than policy makers generally expect, affecting financial decision-making of private consumers, for example when it comes to retirement savings. The first is even more worrying, since unawareness means that instead of not understanding the matter, most households do not even bother to think about it. This does not necessarily imply that household object against energy conservation, but that they do not wish to spend the time to consider it. In line with work by Abadie and Gay (2006), which show that consent legislation is a very power factor that drives up organ donations without long and explicit discussions, we therefore recommend to reconsider the default options regarding residential energy specifications. By simply switching to a default that installs pre-programmed smart meters that safe energy at night, one would swiftly reduce the energy bill without the explicit consent of the household. This way, policy no longer needs be designed to offer compelling information and persuasive arguments, but on the evaluation of implicit actions that become effective right away. Pre-programmed, smarter temperature control devices would be an obvious solution, also comparable to automated enrolment into retirement saving programs. Current smart meter rollouts offer the opportunity to implement such a program.

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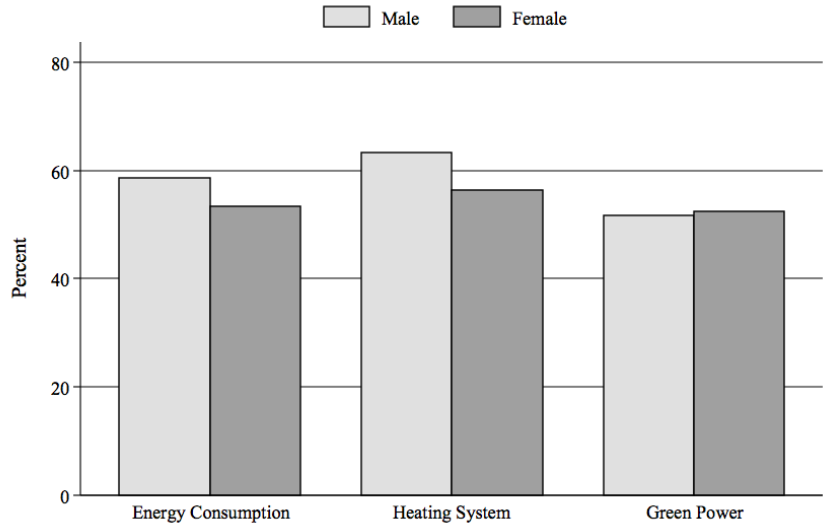
Figure 1| Descriptive Statistics, Explaining Energy Literacy (n = 1,722)

A. Energy Literacy and Gender



B. Energy Literacy and Age

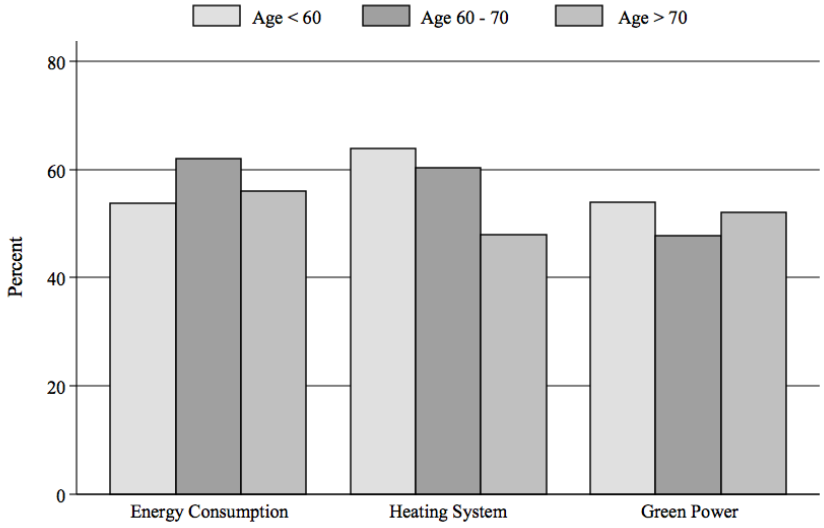


Table 1 | Descriptive Statistics

	Mean	Median	St. Dev	Min	Max
Panel A					
Home Characteristics					
Size (square meters)	137.98	120	148.20	8.00	3,300
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 (percent)	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 (percent)	38.99	0	48.79	0	100
Monthly Net Household Income (in €s)	2,882.74	2,600	4,683.69	0	15,800
Ideology and Attitudes					
Voting for Green Party (percent)	8.84	0	28.40	0	100
Driving Efficiently to Save Gas (percent)	59.85	100	49.05	0	100
Spending Behaviour Disposable Income (1 – 7)	5.07	5	1.17	1	7
Well-Organized? (percent)	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 (percent)	56.25	100	49.62	0	100
Gas Expenditures (€ per month)	125.72	110	107.36	0	1,500
Electricity Expenditures (€ per month)	96.64	80	66.01	0	550
Rational Choice for Heating System (percent)	60.12	1	48.98	0	1
Using Green Power (percent)	52.01	1	49.97	0	1
Thermostat Control					
Day Temperature (degree Celsius)	18.17	18.50	2.20	8.00	23.00
Evening Temperature (degree Celsius)	19.34	20.00	2.16	7.00	24.00
Night Temperature (degree Celsius)	15.65	15.00	1.95	7.00	23.00

Table 2| Regression Results, Energy Awareness and Literacy (OLS Model)

	Know Gas Bill?		Heating System Choice?		Using Green Power?	
	(1)	(2)	(3)[#]	(4)[##]	(5)	(6)
Demographics						
Percentage of Male Respondents	0.204**	0.022	0.275***	0.278	-0.032	0.026
	[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]	
Percentage With Some College Education	0.077	-0.117	0.678***	0.550***	0.159	0.101
	[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	1,720	497	1,709	495	1,716	496
Pseudo R^2	0.006	0.058	0.045	0.023	0.003	0.025

Notes: Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Table 3| Regression Results, Behavior, Demographics and Attitudes (OLS and Logit Model)

Notes: Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

	OLS		Logit	
	Evening Temperature (in Celsius)		Lower Thermostat at Night?	
	(1)	(2)	(3)	(4)
Demographics				
Percentage of Male Respondents	-0.098	-0.110	-0.091	-0.416
	[0.112]	[0.210]	[0.171]	[0.330]
Age of Respondent (60-70 years)	0.649***	0.833***	-0.511***	-0.522
	[0.130]	[0.250]	[0.197]	[0.393]
Age of Respondent (> 60 years)	0.480***	0.000	-0.473**	
	[0.152]	[0.000]	[0.232]	
Percentage With Some College Education	-0.112	0.086	0.243	0.535
	[0.117]	[0.219]	[0.180]	[0.350]
Monthly Net Household Income (in €s)	0.221**	0.626***	0.141	-0.078
	[0.111]	[0.193]	[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		0.534
(1 = yes)		[0.427]		[0.717]
Spending Behavior Disposable Income		0.059		0.048
(1 – 7)		[0.092]		[0.143]
Driving Efficiently to Save Gas		-0.086		-0.062
(1 = yes)		[0.216]		[0.341]
Sacrificing Short Term for Future Income		-0.205***		0.030
(1 – 7)		[0.077]		[0.120]
Well-Organized?		-0.305		0.342
(1=yes)		[0.214]		[0.336]
Constant	17.432***	14.783***	-17.259***	-15.268***
	[0.856]	[1.525]	[1.629]	[3.100]
Observations	1,557	448	1,557	448
R^2	0.020	0.066		
Adj. R^2	0.017	0.047		
Pseudo Adj. R^2			0.402	0.403

Table 4 | Regression Results, Energy Conservation, Home Characteristics and Behavior (OLS and 2SLS Models)

	OLS		2SLS	
	(1)	(2)	(3)	(4)
Home Characteristics				
Size (square meters)	0.001***	0.000***	0.001***	0.001***
	[0.000]	[0.000]	[0.000]	[0.000]
Household Size	0.082***	0.098***	0.110***	0.101***
	[0.020]	[0.023]	[0.034]	[0.026]
Period of Construction				
1980 – 2000	0.190**	0.202**	0.346**	0.341***
	[0.085]	[0.084]	[0.137]	[0.114]
1960 – 1980	0.411***	0.422***	0.564***	0.562***
	[0.082]	[0.081]	[0.125]	[0.102]
1940 – 1960	0.427***	0.482***	0.600***	0.571***
	[0.101]	[0.101]	[0.158]	[0.125]
1920 – 1940	0.472***	0.518***	0.885***	0.768***
	[0.112]	[0.111]	[0.242]	[0.183]
< 1920	0.471***	0.515***	0.708***	0.691***
	[0.102]	[0.101]	[0.177]	[0.147]
Demographics				
Percentage of Male Respondents		-0.024		
		[0.049]		
Age of Respondent (60-70 years)		0.191***		
		[0.057]		
Age of Respondent (> 60 years)		0.187***		
		[0.068]		
Percentage With Some College Education		-0.025		
		[0.050]		
Monthly Net Household Income (in €s, logs)		0.176***		
		[0.056]		
Evening Temperature			0.326**	0.247**
(in Celsius)			[0.134]	[0.101]
Lower Thermostat at Night?				-0.738**
(1 = yes)				[0.339]
Constant	4.050***	2.561***	-2.544	-0.330
	[0.082]	[0.424]	[2.728]	[1.791]
Observations	666	661	619	619
R^2	0.126	0.160		
Adj. R^2	0.117	0.144		
F-Value			6.33	8.73
Prob > F			0.000	0.000

Notes: Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.