Empower the Consumer! Energy-related Financial Literacy and its Implications for Economic Decision Making

Julia Blasch,[a] Nina Boogen,[b] Claudio Daminato,[b] and Massimo Filippini[c]

ABSTRACT

Untapped energy savings potential in the residential sector might lead to substantial welfare losses. While several studies have focused on the role of behavioral biases in explaining the lack of adoption of energy-efficient durable goods, little is known about the role of limited energy-specific knowledge and financial literacy. In this paper, we propose an integrated concept of 'energy-related financial literacy', which combines both energy cost-specific knowledge and skills needed to process this information. Using data from a large household survey in three European countries, we explore the determinants of different measures of literacy and, most importantly, we provide empirical evidence on the association between limited knowledge and skills to perform an intertemporal optimization and the adoption of energy-efficient light bulbs. Our findings support the promotion of energy-specific financial education programs and tools to increase the adoption of energy-efficient durable goods.

Keywords: Household decision making, Bounded rationality, Financial literacy, Consumer durables, Energy efficiency

https://doi.org/10.5547/2160-5890.10.2.jbla

1. INTRODUCTION

The ability to optimize in intertemporal decisions affects many aspects of an individual's life. However, many individuals are boundedly rational. They make sub-optimal inter-temporal choices due to limitations in their capacity to process available information (Simon, 1955, 1959). A large literature has shown that limited cognitive abilities and knowledge influence several economic outcomes: individuals with relatively higher cognitive abilities and financial literacy are more likely to have considered their retirement saving needs (Lusardi and Mitchell 2014, Angrisani et al. 2016), are more likely to enroll in a supplemental health insurance plan that ensures various benefits (Chan and Elbel, 2012) and are less likely to make financially sub-optimal decisions in the domains of credit card use and applications for home loans (Agarwal and Mazumder, 2013).

Consumers' decisions of investment in energy-using durables represent another type of intertemporal decision with important implications on household finances. In the context

[a] Corresponding author. Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam and Centre of Economic Research (CER-ETH), ETH Zürich, Switzerland. Send correspondence to Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, De Boelelaan 1111, 1081 HV Amsterdam, Netherlands. E-mail: julia.blasch@vu.nl.

[b] Centre of Economic Research (CER-ETH), ETH Zürich, Switzerland.

[c] Centre of Economic Research (CER-ETH), ETH Zürich, Università della Svizzera Italiana, Lugano, Switzerland.

of consumer goods more generally, it has been observed that individuals are often inattentive or myopic with respect to additional costs associated with the purchase of goods, such as sales taxes (Chetty et al., 2009) or add-on products needed for future operation (Gabaix and Laibson, 2006), which has also been observed for operating cost of energy-using durables (Andor et al., 2020; Houde and Myers, 2019). Although many investments in energy-efficient electric appliances, heating systems or energy-efficient home renovations ensure net savings over their lifetime (McKinsey & Company, 2009), households often fail to make these investments (Allcott and Taubinsky, 2015; Houde and Myers, 2019). In the literature, this is referred to as the energy efficiency gap (Jaffe and Stavins, 1994). Various market and behavioral anomalies have been discussed in the literature as potential determinants of the energy efficiency gap (Broberg and Kazukauskas, 2015; Gillingham and Palmer, 2014). For instance, Allcott et al. (2014) refer to the presence of salience bias, biased beliefs, endogenous inattention and present bias.

What is specific to optimal investments in energy-using durables is that they require not only awareness of future operation costs but also a combination of specific knowledge and skills: information about the energy consumption and the lifetime of appliances as well as of possible new, more efficient, appliances that could replace the old ones. Furthermore, consumers need to know the cost of electricity and make assumptions on how frequently they plan to use their appliances. Eventually, they need the skills to process all this knowledge in order to identify the possible savings from replacing their appliances by more energy-efficient ones. Blasch et al. (2017b) show that these processing costs are relatively high for a substantial share of individuals. The lack of energy-specific knowledge and skills might represent an important barrier to households' energy conservation behavior, together with other internalities studied in the literature (Cattaneo, 2019; Allcott, 2011b; Andor and Fels, 2018; Fiorillo and Sapio, 2019).

A relatively large body of literature has recently developed around the role of financial literacy and its importance of economic decision making in several contexts (Hastings et al., 2013; Lusardi and Mitchell, 2014). Brent and Ward (2018) extend this literature on financial literacy to the energy domain and test in a stated preferences experiment whether an augmented measure of financial literacy — including the "Big Three" questions and questions on the lifetime cost and payback periods of alternative hot water systems — increases the willingness to pay for energy efficiency, and hence increases the chances that consumers reap the benefits of investing in efficient appliances.

Other studies have considered the role of different measures of energy-related knowledge, usually referred to 'energy literacy', on households' electricity consumption and energy conservation behavior (Brounen et al., 2013; Kalmi et al., 2017; Blasch et al., 2017a, 2019, 2017b). The US government defines energy literacy rather broadly as 'an understanding of the nature and role of energy in the universe and in our lives' as well as 'the ability to apply this understanding to answer questions and solve problems.' (U.S. Department of Energy, 2017, p.1) and explicitly acknowledges that an individual's energy literacy has consequences for economic outcomes. However, a common understanding of how to measure energy literacy has not developed yet. Part of the literature proposes a broad concept of energy literacy that focuses on energy-related knowledge, attitudes and behavior (DeWaters and Powers, 2011, 2013; van den Broek, 2019), whereas other studies propose a concept of energy literacy based on lifetime cost calculations (Brounen et al., 2013; Kalmi et al., 2017; Blasch et al., 2017a, 2019, 2017b; Filippini et. al. 2020).

In the first part of this paper, we therefore summarize the various possible definitions of the term 'energy literacy' as well as its relation to the concept of 'financial literacy' (Lusardi and Mitchell, 2014). Moreover, we propose an integrated concept that we call 'energy-related financial literacy'. This concept combines both (1) the energy cost-specific knowledge households need in order to take informed energy-related decisions and (2) the set of skills needed to process this information, which is comparable to the set of skills needed for intertemporal investment decisions like pension planning. We propose that the combination of these elements predicts rational energy-related investment decisions better than a pure financial literacy measure, which we verify based on survey data on actual technology adoption from three European countries.

Using data from a large sample survey carried out in Italy, the Netherlands and Switzerland, we present evidence about the level of financial literacy (as measured with the "Big Three" questions as in Lusardi and Mitchell 2014) and our measure of energy-related financial literacy. We document a substantial lack-of energy cost-specific knowledge among the respondents in our sample. We further perform two econometric analyses: First, we analyse the determinants of both literacy measures using multivariate regression analysis, with particular emphasis on the role of gender. The results of the multivariate regression analysis show the existence of a substantial gender gap in energy-related financial literacy, consistently with previous findings for financial literacy (Almenberg and Dreber, 2015; Lusardi and Mitchell, 2014). Finally, we explore the role of financial literacy and 'energy-related financial literacy' for the adoption of energy-efficient technologies by exploiting data on actual investment decisions in durable goods. We consider the decision of consumers with respect to the adoption of energy-efficient light bulbs, which are especially interesting due to the large relative efficiency gains that consumers can achieve. The empirical analysis shows that energy-related financial literacy is positively associated with the lighting efficiency at home. Consumers with high energy-related financial literacy are associated with a 5 percent higher share of LED light bulbs at home. We do not find an influence of financial literacy on the adoption of lighting efficiency, which suggests that financial literacy alone is not sufficient to ensure optimal energy-related investment choices.

This paper contributes to the literature in several ways. We discuss various existing concepts and definitions of 'energy literacy' and propose an integrated concept of 'energy-related financial literacy' that combines the set of knowledge and skills needed by consumers to take optimal decisions of investment in energy-consuming durable goods. We provide empirical evidence about the determinants of 'energy-related financial literacy', documenting an important gender gap and complementing previous findings for financial literacy. Finally, our study is the first to provide empirical evidence about the consequences of limited energy-specific intertemporal optimization skills for the actual adoption of energy-using durable goods. While our proposed measure of energy-related financial literacy captures similar dimensions as the augmented financial literacy measure used by Brent and Ward (2018), our study adds to the literature by investigating the role of literacy using revealed preference data on investment choices, rather stated preferences data. Further, compared to Blasch et al. (2017a) who consider the role of energy literacy and basic financial literacy separately on households' electricity consumption, we explore the role of a more comprehensive and integrated measure of literacy specifically on the adoption of efficient energy-consuming durables.

The rest of the paper is organized as follows. Section 2 discusses the concepts and definitions of energy and financial literacy used in the literature, the link between energy and financial literacy and economic outcomes, and introduces the new concept of energy-related financial literacy. Section 3 presents the data from the European household survey. Section 4 reports results on the determinants of energy-related financial literacy, while Section 5 presents the results on the influence of energy-related financial literacy on the adoption of energy-efficient light bulbs. Section 6 concludes.

2. THE IMPORTANCE OF ENERGY AND FINANCIAL LITERACY FOR DECISION-MAKING

2.1 Definitions of Financial and Energy Literacy

The concept of 'financial literacy' has a longer tradition than the concept of 'energy literacy' but faces a similar debate around different definitions and concepts of the term 'financial literacy' (Hung et al., 2009). In PACFL (2008), financial literacy is defined as 'the ability to use knowledge and skills to manage financial resources effectively for a lifetime of financial well-being' (PACFL, 2008, p.7). However, the most common concept cited in the literature was introduced by Lusardi and Mitchell (2008a, 2011c) who define financial literacy as the 'knowledge of basic financial concepts, such as the working of interest compounding, the difference between nominal and real values, and the basics of risk diversification' (Lusardi and Mitchell, 2008a, p.2). In line with their definition, financial literacy is usually measured with three questions related to numeracy and the capacity to do (compound) interest calculations, understanding the concept of inflation and understanding the concept of risk diversification—the "Big Three" questions as in Lusardi and Mitchell (2014).

Although the economic literature on the role of energy-related knowledge and skills for individuals' investment decisions in the energy-context, usually referred to as 'energy literacy', is growing steadily (Attari et al., 2010a; Brounen et al., 2013; Blasch et al., 2019, 2017a,b; Kalmi et al., 2017; Brent and Ward, 2018; Andor et al., 2019, 2020), a common understanding of the related concept has currently not yet developed. In a recent literature review, van den Broek (2019) suggests a differentiation of four types of energy literacy: 1) device energy literacy, 2) action energy literacy, 3) financial energy literacy and 4) multifaceted energy literacy, which she considers as partly overlapping concepts with multifaceted energy literacy being the most comprehensive concept that includes all of the other types of literacy.

This multifaceted energy literacy concept also includes knowledge about energy production and supply as well as the environmental and societal impact of energy production and consumption. It is reflected in the relatively broad definition used by DeWaters and Powers (2011) who consider an energy-literate individual to *'[have] a sound conceptual knowledge base as well as a thorough understanding of how energy is used in everyday life, [understand] the impact that energy production and consumption have on all spheres of our environment and society, [be] sympathetic to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources, [be] cognizant of the impact that personal energy-related decisions and actions have on the global community, and—most importantly—[strive] to make choices and exhibit behaviors that reflect these attitudes with respect to energy resource development and energy consumption'* (p.1700). They thus define energy literacy across three domains: the cognitive (knowledge), affective (attitudes, values), and behavioral domain. Moreover, they refer back to the literature on technological literacy (Pearson and Young, 2002) and environmental literacy (Disinger and Roth, 1992; Roth, 1992; Hollweg et al., 2011).

However, such an encompassing definition of energy literacy may not necessarily be predictive for optimal energy-related investment decisions. Another stream of recent economic literature uses measures that are more specifically aimed to predict an individual's performance in intertemporal investment decisions. Brounen et al. (2013) and Kalmi et al. (2017) measure 'energy literacy' as an individual's ability to calculate and compare lifetime costs of energy-consuming durables. According to Brounen et al. (2013), energy literacy is related to *'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'* (p. 43). They observe that less than half of the respondents in their sample are able to correctly evaluate investment decisions in energy-efficient equipment. Using the respondents' choice between two alternative heating systems differing in lifetime cost as an indicator for energy literacy, they do not observe a relationship between energy literacy and energy conservation behaviors and self-reported energy use. Kalmi et al. (2017) use a similar, but slightly broader definition and include in their concept of energy literacy *'awareness of different actions that consume energy and the price formation of household energy; how to evaluate the long-term decisions related to investments that improve energy efficiency; the willingness to take energy conserving measures; and the information needs of consumers and their willingness to gather information.'* (p.2).

2.2 Energy and Financial Literacy and Economic Outcomes

As mentioned, a relatively large literature has recently developed around the role of financial literacy and its importance of economic decision making in several contexts (Hastings et al., 2013; Lusardi and Mitchell, 2014). Mitchell and Lusardi (2015) summarize that more financially literate individuals are more likely to engage in financial planning and saving, are more likely to invest in the stock market and in more sophisticated assets, manage their credit card debt and mortgages more wisely, and consequently reach higher levels of wealth throughout their lives. In fact, based on panel data from US households, Lusardi et al. (2017a) estimate that about 30 to 40 percent of retirement wealth inequality can be explained by financial knowledge. Recent empirical evidence shows that an individual's willingness to acquire financial literacy (Meier and Sprenger, 2013) and to seek financial advice (Kramer, 2016) may depend on characteristics such as time preferences and self-confidence.

On the contrary, the literature on the influence of energy literacy on economic outcomes is still relatively scarce. While there is ample evidence for low levels of energy literacy of the population for several countries, the consequences of this lack of literacy are less understood (van den Broek, 2019). Some first empirical evidence points out that a lack of knowledge and awareness regarding energy efficiency in residential homes negatively impacts on the financial situation of households. In Blasch et al. (2017a) it is shown that more literate households are more likely to tap the savings potentials in their homes: they live in households with an overall lower electricity consumption. The results presented in Blasch et al. (2019, 2017b) suggest that individuals with a higher level of energy and investment literacy are more likely to calculate rather than using a rule of thumb when comparing two appliances. Consequently, these individuals are much more likely to identify the appliances with the lowest lifetime cost. On the contrary, Brounen et al. (2013) do not find an association between their indicator of energy literacy and household energy use.

Brent and Ward (2018) test the relevance of an augmented measure of financial literacy, which also includes questions on the lifetime cost and payback periods of alternative hot water systems, for energy-related decision making in a stated preferences experiment. They aim to assess whether financial literacy increases the willingness to pay for energy efficiency. They indeed find that individuals with a higher level of the augmented financial literacy measure express a higher willingness to pay for reduced operating cost of energy-using durables.

Their results also suggest that financial literacy makes choices more consistent with a model of consumer behavior that assumes standard preferences. In a similar stated preferences setting, Andor et al. (2019) find that individuals scoring higher in a standard cognitive reflection test display a higher willingness to pay for energy efficiency. These findings suggest that, besides energy literacy, also financial literacy and high cognitive abilities positively influence rational energy-related choices.

The overall financial implications of a low level of energy and financial literacy can only be estimated. Allcott and Taubinsky (2015) suggest that, in the year 2010 alone, not tapping the potential energy savings from replacing all incandescent by compact fluorescent light bulbs cost US consumers a total of 16 billion USD. As the total expenditure on energy-using durables is relatively high, Allcott (2016) assumes that consumers' inability to tap energy-efficiency potentials can sum up quickly to large welfare losses.

2.3 Gender Differences in Energy and Financial Literacy

Another robust and striking insight from the literature on financial literacy is the large and persistent gender gap in financial literacy, which seems to be stable across countries and age groups (Lusardi and Mitchell, 2014). Almenberg and Dreber (2015) show that women's lower levels of financial literacy can explain the gender gap in stock market participation, especially when accounting for the numeracy aspect of financial literacy. A conclusive explanation for the gender gap in financial literacy has not been found yet. Hsu (2016) suggests that women's lower level of financial literacy is a result of the division of labour between husbands and wives. She shows that in households in which the husband takes the role of the financial decision-maker most women catch up in financial literacy once approaching widowhood (Hsu, 2016). According to Lusardi and Mitchell (2014), however, also single women show lower levels of financial literacy, which cannot be explained by this theory. On the contrary, Fonseca et al. (2012) find that married women are more financially literate than unmarried women. Hung et al. (2012) suggest that, besides differences in education and skills, also cultural aspects and societal norms assign the primary responsibility for certain aspects of financial decision-making to men, which gives women less exposure to financial products and less opportunities for learning-by-doing. As a further explanation, they suggest that men and women differ in the way they acquire financial knowledge, even if they dispose of the same skills and opportunities to learn.

Whether there is a direct analogy between financial decision-making of households and energy related decisions is unclear. At least for the multifaceted type of energy literacy there is mixed evidence for gender differences (van den Broek, 2019). Less research has been conducted on the decision-making processes in households when it comes to energy-related financial decision-making. However, findings of Albert and Escardíbul (2017), confirm the result of Fonseca et al. (2012) in the context of consumer durables: for a Spanish sample they show that a higher level of education of both spouses favors a more egalitarian decision-making regarding expensive purchases of consumer durables. According to Albert and Escardíbul (2017), expensive purchases of consumer durables are mostly the result of joint decision-making of both spouses, contrary to the daily shopping. Belch and Willis (2006), however, find that in the US the decisions around the purchase of new household appliances are mainly made by the female partner. This suggests that the women's level of energy-related financial literacy could have a particularly strong influence on the energy-related purchase decisions of households. Yet, there is no consistent picture across countries and domains. Schneebaum and Mader (2013), show that in most southern European countries it is less likely that women are the main decision-maker in the household, irrespective of the area of decision-making. Overall, there is not enough evidence in the literature about the extent to which males and females influence the household decisions when it comes to the purchase of new electric appliances. It is therefore unclear how a potential gender gap in energy-related financial literacy would affect the overall level of energy-efficiency of a household.

2.4 The concept of energy-related financial literacy

As the different existing definitions of energy literacy and financial literacy capture various different dimensions of energy-related knowledge, awareness behaviors and cognitive skills, we propose a concept that can predict the economic outcomes of energy-related choices: energy-related financial literacy (ERFL). While the indicators used by DeWaters and Powers (2011), Brounen et al. (2013) or Brent and Ward (2018) capture part of the relevant skills, optimal energy-related investment decisions can only be made if the decision-maker disposes of financial and energy cost-related knowledge in combination with intertemporal optimization skills. Blasch et al. (2017a) have previously proposed to explore both the role of energy literacy and basic financial literacy separately in residential electricity consumption. Compared to this work, in this paper we suggest the usage of an integrated measure of energy-related of financial literacy which incorporates a more comprehensive measure of financial literacy, as suggested in Lusardi and Mitchell (2014), as well as a lifetime cost calculation task, similar to Brent and Ward (2018). In addition, we include a set of questions that specifically aim at eliciting knowledge about the elements necessary to compute the per-period operating costs. The proposed concept of 'energy-related financial literacy' can therefore be defined as the *combination of energy cost-specific knowledge, financial literacy and cognitive abilities that are needed in order to take decisions with respect to the investment for the production of energy services and their consumption*. Building on previous research, we propose that these are the relevant dimensions for optimal energy-related investment decisions and offer an example how these dimensions can be measured.

3. DATA AND THE MEASUREMENT OF ENERGY-RELATED FINANCIAL LITERACY

3.1 European Household Survey

In this section, we present descriptive statistics on the level of financial literacy as well as on the level of energy-related financial literacy for a sample of European households. The data used has been collected through a large household survey completed in 2017 in three different countries in Europe (Italy, Netherlands, Switzerland).[1] The survey itself collected detailed information on household characteristics, dwelling characteristics, energy consumption, and information on the level of energy-related financial literacy.

1. The survey was conducted within the EU H2020 Project "PENNY" (Psychological social & financial barriers to energy efficiency), which applies a behavioral science approach to better understand individual behavior in the domain of energy efficiency. The project runs from 2016–2019 and is funded by the European Commission, Horizon 2020 Programme and the Swiss Government. The survey was implemented in collaboration with four different utilities (Italy: ENI, Netherlands: Qurrent, Switzerland: Stadtwerk Winterthur and Aziende Industriali Lugano). ENI and Qurrent serve customers everywhere in Italy and the Netherlands, respectively. However, note that ENI is the second largest electricity provider in Italy, and thus serves a large customer range. In contrast, Swiss households do not have the freedom to choose their electriciy provider, but face one single provider, that serves a certain area. While Stadtwerk Winterthur is a city utility located in the German part of Switzerland, Aziende Industriali Lugano is a regional utility serving a region in the Italian part of Switzerland. These four utilities each invited part of their customer base for the survey. Overall 3.22% of the households that received the invitation also completed the survey.

In such a household survey, representativeness of the sample cannot be ensured ex-ante, and external validity is not easily established in general. However, in Table A3 in the Appendix, we provide descriptive statistics about residents characteristics, household income and education for the three countries in the sample and compare it with the corresponding statistics at the national level. For the majority of the characteristics we do not find severely large difference between the sample and national statistics. Therefore, we can conclude that the sample selection bias is not large overall. However, we do find a larger share of individuals with tertiary education in our sample compared to that reported in the national statistics. Further information on the household survey, its implementation and representativeness can be found in the Appendix.

The empirical analyses are performed on a sample of 4450 households.[2] In Table A4 in the Appendix, we provide descriptive statistics on the relevant socio-economic characteristics that we will use in the econometric analysis, such as age of the respondent, household income, educational attainment and the working status.

3.2 The Measurement of Energy-related Financial Literacy

We elicit the respondents' level of energy-related financial literacy using eight survey questions. The first question asks about the knowledge of the average electricity price in the respondent's country. The second and third questions aim at assessing the level of knowledge of the households about the operating costs of appliances. We ask about the approximate cost of using a desktop computer for one hour and that of running a washing machine with a load of 5 kg at 60°C. The fourth question aims at understanding whether respondents are aware about the savings potential of LED technology. Moreover, we include a question that aims at understanding whether respondents can perform an investment calculation and identify a fridge that minimizes the total lifetime costs. Finally, we include the three standard financial literacy questions on compound interest, inflation and risk diversification introduced by Lusardi and Mitchell (2014) to capture the extent to which respondents are familiar with fundamental concepts related to investment decisions. The exact phrasing of these eight questions can be found in the Appendix.

For the main analysis we construct four different variables: 1) an index for energy-related financial literacy, that we create by summing the scores obtained from each of the eight questions (e.g. a respondent that answers four of the eight questions correctly, gets the value 4 as his energy-related financial literacy score), 2) a dummy for energy-related financial literacy, which takes the value of 1 when a respondent is above the median score, 3) an index for financial literacy, that we create by summing the scores obtained from the three standard financial literacy question and 4) a dummy of financial literacy that takes the value of 1, when a respondent answers all three financial literacy questions correctly (which is the definition used by Lusardi and Mitchell (2008a, 2011c, 2014)).

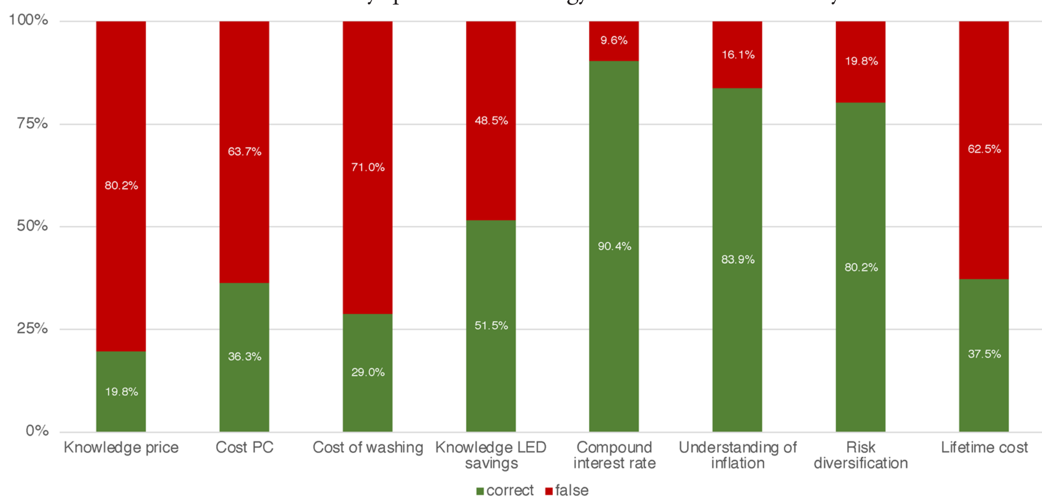
Energy cost-specific knowledge and financial literacy

Figure 1 shows the share of respondents who answer the different questions correctly for the entire sample. While respondents perform well in the standard financial literacy ques-

2. In our empirical analysis, we drop observations with missing values. For the descriptive analysis of the ERFL index, we work with a sample of 4450 households. For the analysis of socio-economic determinants in section 4, we work with a sample of 2895 households, mainly due to missing values for the income variable.

tions, a substantial share of households lack energy-specific knowledge according to our definition.

FIGURE 1
Results of survey questions on energy-related financial literacy.



Only around 20% of the respondents know about the electricity price in their country, whereas 80% either indicate a wrong value or don't know at all.[3] The data also show limited knowledge about the appliances' operating cost. In fact, only around 29% of the respondents in our sample are aware of the monetary costs of running a washing machine cycle and, similarly, around 37% of respondents know the costs of running a desktop PC for one hour.[4] Moreover, only about half of the respondents are aware of the energy savings potential associated with using an LED light bulb compared to a conventional halogen bulb.[5] Finally, only around 38% of the respondents could perform a lifetime cost calculation correctly.[6]

In contrast, a large majority of respondents answered correctly to the three standard questions that aim at measuring financial literacy as introduced by Lusardi and Mitchell (2008a, 2011c). In particular, 91%, 84% and 81% of households in our sample answered correctly to the questions on compound interest rate, inflation and risk diversification, respectively.[7]

3. The average electricity price per kWh actually charged to residential customers in 2017 is 20 cents for Italy and Switzerland (based on values published by Eurostat and ElCom), and 15 cents for the Netherlands (based on values published by Eurostat). We define respondents as correct in their answer when the value they estimate for electricity price in kWh ranges between ±5 cents the above mentioned average electricity price (meaning 15–25 cents for Italy and Switzerland and 10–20 cents for the Netherlands). However, in the empirical analysis we use two additional definitions as a robustness test.

4. We define respondents as correct in their answer when they chose 0–59 cents for a washing machine cycle and 0–19 cents for running a desktop PC for one hour.

5. We count a saving potential of 70–80% as correct.

6. In order to check whether respondents did actually make a calculation and the correct solution was not only a guess, we ask the respondents how they reached their answer. Respondents that actually made the calculation should have reached the conclusion that the lower energy consumption of Fridge B is not sufficient to justify the higher price. Therefore we only count an answer to the lifetime cost calculation as correct in case the conclusion was correct as well. We are aware that this question is more complex than the other ones.

7. These statistics compare to the 67, 75 and 52 percent of respondents answering correctly to the same three financial literacy questions in the 2004 HRS Planning Module for the United States, as computed by Lusardi and Mitchell (2014).

The different components of energy-related financial literacy

When assessing the importance of jointly considering the different components of literacy in the context of energy-related decision making, we are interested in both the correlation between (sub-groups of) components as well as the reliability and internal consistency of the scales adopted.

First, we explore the correlation between the different survey items about energy-related financial literacy distinguishing between those related to energy-specific knowledge and those related to the skills required to perform an intertemporal optimization, typically referred to as financial literacy. We then build an index of energy-specific knowledge summing up the scores obtained from the questions about the knowledge of the average electricity price in the respondent's country, the cost of running a desktop computer and a washing machine, the awareness of the savings potential of the LED light bulbs, as well as the indicator for whether the respondent could identify the appliance that minimizes the lifetime costs. The second index is obtained using the three standard financial literacy questions. The correlation between the two indices is 0.30.

TABLE 1
Internal consistency of indices of literacy in the context of energy-related decision making.

	Energy-specific knowledge	Financial literacy	Energy-related financial literacy
Cronbach's alpha	0.4993	0.5697	0.6111
Observations	4450	4450	4450

Although the correlation between these measures of literacy is moderate, the data suggest an adequate degree of internal consistency reliability. In Table 1, we report the values of Cronbach's alpha for the components used to build the energy-specific knowledge (Column 1), the three components of financial literacy indicator (Column 2) and the set of components considered to build the comprehensive energy-related financial literacy index.[8] The highest level of internal consistency reliability (Cronbach's alpha = 0.61) is associated with the scale that combines all eight components.[9] Not satisfactory or low values are below 0.55 or 0.1. The results of this descriptive correlation analysis inform about the importance of measuring the dimensions of energy cost-specific knowledge and investment-related skills jointly when aiming at studying the implications of lack of literacy in energy-related decision making.

3.3 Level of Energy-related Financial Literacy in our Sample

Figure 2 shows the distribution of the energy-related financial literacy index, and that of an index built by summing only the scores from the three standard financial literacy questions.

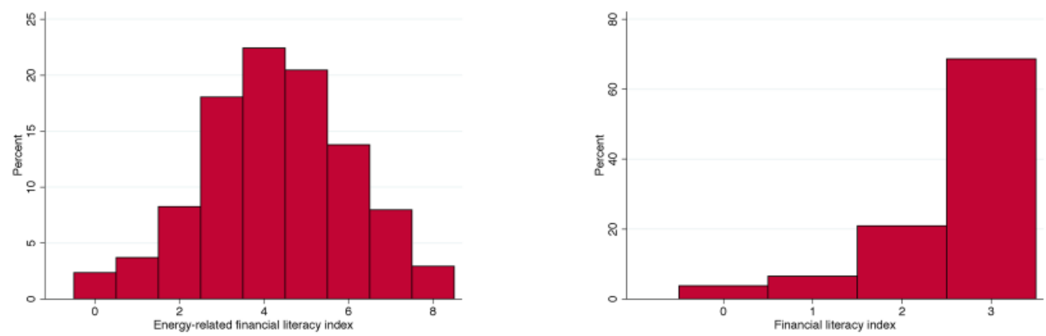
8. Cronbach's alpha measures internal consistency, in particular how closely related a set of items are as a group. In addition, it is used to measure scale reliability. See for instance Tavakol and Dennick (2011) for further discussion.

9. Although some studies mention 0.7 as a cut-off for a good value of the Cronbach's alpha, there is debate in the literature. According to the meta-analysis in Taber (2018), a value of Cronbach's alpha around 0.6 has been typically interpreted as either moderate (0.61–0.65), satisfactory (0.58–0.97), acceptable (0.45–0.98) or sufficient (0.45–0.96). Not satisfactory or low values are below 0.55 or 0.1.

FIGURE 2

Distribution of the energy-related financial literacy index.

(a) Energy-related financial literacy index **(b) Financial literacy index**



The disaggregation of the energy-related financial literacy index by household characteristics gives first insights into its determinants and possible consequences on energy-related decision making. Figure 3 shows the heterogeneity in energy-related financial literacy among different age groups (panel a), education groups (panel b) and gender (panel c), in each country. The data show three striking patterns: (i) the index is hump-shaped in the respondent's age, with lower levels of literacy among the young and elderly;[10] (ii) individuals with higher education levels are associated with higher scores of energy-related financial literacy; (iii) male respondents are associated with substantially higher levels of literacy than females. These results are consistent with those previously shown for financial literacy (Lusardi and Mitchell, 2014).[11] Clearly, without additional information, it is not possible to identify direct links between individuals' characteristics and the level of literacy. The econometric analysis presented in the next section aims at formally identifying the most relevant determinants of the level of energy-related financial literacy.

4. SOCIO-ECONOMIC DETERMINANTS OF ENERGY-RELATED FINANCIAL LITERACY

Next, we regress three measures of literacy on socio-economic variables. The first measure of literacy is our measure of energy-related financial literacy (as defined in Section 3.2). The second measure is a binary indicator for whether the respondent scores above the median in the energy-related financial literacy index. The third measure is the financial literacy indicator summing up the "Big Three" questions. We consider the respondent's age, education, gender, country of residence, household income and whether the household is a couple household as possible socio-economic determinants. We also include dwelling characteristics, such as number of rooms and home-ownership status, in order to test whether households owning their homes and living in larger homes (i.e., dedicating more financial resources to energy

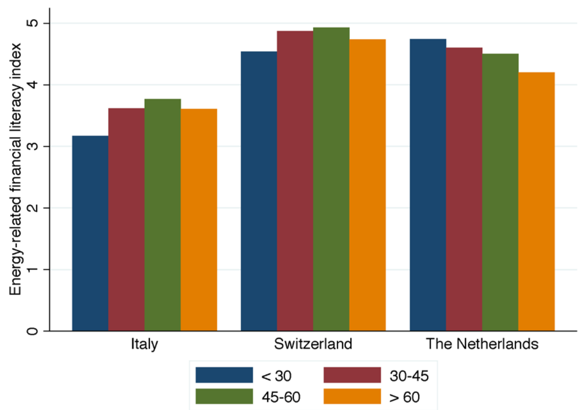
10. An exception is the age profile of energy-related financial literacy in the Netherlands, which is found to be decreasing with the age of the respondents.

11. The patterns observed are similar even when excluding the three questions typically used to measure financial literacy from the calculation of the energy-related financial literacy index.

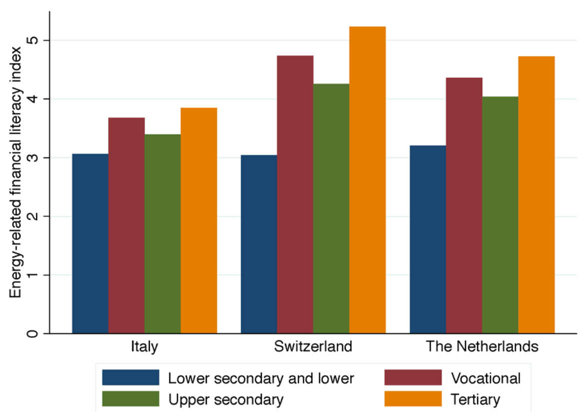
FIGURE 3

Energy-related financial literacy by country and household characteristics.

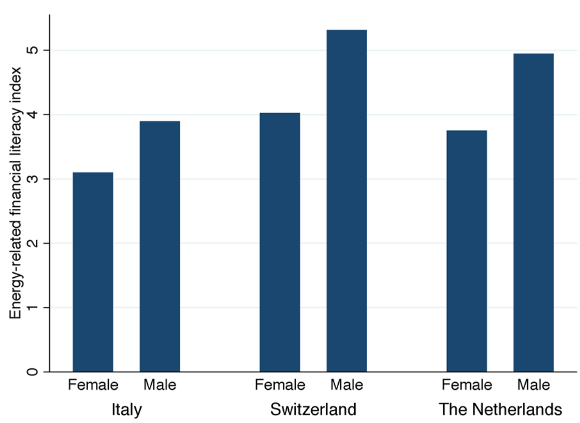
(a) By age group



(b) By educational attainment



(c) By gender



consumption) have stronger financial incentives to accumulate energy-related investment skills and knowledge.[12]

We report results obtained estimating the three regressions using OLS. Because two of the measures could be considered ordinal outcome variables, i.e. variables for which the values have a natural ordering, we also estimate (ordered) probit models using the same explanatory variables.[13]

In Table 2, we show the results of the estimation for the three literacy measures. Generally, the majority of the coefficients across the three model specifications are statistically significant and have the expected sign. The OLS estimates are consistent with those obtained estimating the (ordered) probit models. The results highlight age as a significant determinant of energy-related financial literacy, with the latter showing a hump-shaped profile over an individual's lifetime. Higher income levels and higher educational attainments are associated with higher levels of energy-related financial literacy. We find that households with income between 4501 and 9'000, and above 9'000, have a higher level of literacy compared to the reference group (income below 4'500). Education shows a strong association with all three literacy measures, with more educated respondents displaying higher scores of literacy.[14] Also, respondents living in a couple household are associated with a higher level of energy-related financial literacy.

Further, we find some evidence consistent with accumulation of energy-related financial literacy being driven by the incentives that individuals face. First, respondents living in larger houses (dwelling size in m^2) are associated with a higher level of both financial literacy and energy-related financial literacy, conditional on other characteristics. Second, households living in older dwellings (built before 1970) are associated with higher level of energy-related financial literacy. Finally, also whether the respondents own their dwelling seems to play a role in the accumulation of energy-related financial literacy, with owners scoring higher than tenants. This result is consistent for all three literacy measures.

Gender is found to be a strong determinant of the three measures of literacy we consider. In particular, our results confirm previous findings about the gender gap in financial literacy, with males being associated with higher levels of the index (Lusardi and Mitchell, 2014). We find a significant gender gap also for our measure of energy-related financial literacy. Substantial heterogeneity in literacy is also found across countries. Italian respondents in the sample are associated with a significantly lower value of the index for energy-related financial literacy than Dutch and Swiss respondents.

5. IMPLICATIONS FOR THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGY

We also investigate whether respondents that have a higher level of energy-related financial literacy are more likely to invest in energy-efficient durables. To this end, we consider households' decisions in a revealed preference setting with respect to the adoption of energy-efficient light bulbs. We believe this is a particularly interesting decision to study for at least two

12. Households living in older buildings or larger homes may have additional incentive to accumulate energy-related financial literacy because they have more to gain (i.e., higher potential of monetary savings from energy efficiency investments) from the investment in knowledge.

13. See Greene (2003) and Wooldridge (2002) for more details on the ordered probit model.

14. Considering that the sample is over-representing highly educated individuals, this result suggests that the average level of literacy observed in our sample is overstating, if anything, the level of energy-related knowledge in the population.

TABLE 2
Determinants of energy-related financial literacy, financial literacy and lifetime cost calculation

	Energy-related financial literacy index		Dummy for energy-related financial literacy		Financial literacy	
	(OLS) (1)	(Ordered probit) (2)	(OLS) (3)	(Probit) (4)	(OLS) (5)	(Ordered probit) (6)
Age	0.022	0.001	0.004	0.004	0.017**	0.012***
	(0.016)	(0.000)	(0.005)	(0.004)	(0.007)	(0.004)
Age^2	–0.000**	–0.000**	–0.000	–0.000	–0.000**	–0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Income: 4’501–9’000	0.113	0.003	0.056***	0.050**	0.051*	0.041**
	(0.072)	(0.002)	(0.020)	(0.020)	(0.030)	(0.020)
Income: Above 9’000	0.162*	0.005*	0.071***	0.074***	0.044	0.045**
	(0.086)	(0.003)	(0.025)	(0.023)	(0.040)	(0.022)
Upper secondary school diploma	0.648***	0.020***	0.159***	0.118***	0.408***	0.163***
	(0.156)	(0.005)	(0.045)	(0.034)	(0.083)	(0.031)
Vocational secondary school diploma	0.266	0.008*	0.087*	0.046	0.268***	0.083**
	(0.162)	(0.005)	(0.046)	(0.036)	(0.084)	(0.033)
University degree	0.794***	0.025***	0.182***	0.146***	0.427***	0.189***
	(0.152)	(0.005)	(0.043)	(0.033)	(0.080)	(0.030)
Female	–1.035***	–0.032***	–0.214***	–0.196***	–0.248***	–0.152***
	(0.064)	(0.003)	(0.019)	(0.016)	(0.029)	(0.015)
Couple household	0.109	0.003	0.003	–0.001	0.059	0.021
	(0.098)	(0.003)	(0.029)	(0.025)	(0.049)	(0.024)
Multi-family house	0.132	0.004	0.005	0.002	0.071*	0.035
	(0.088)	(0.003)	(0.025)	(0.023)	(0.037)	(0.023)
Tenant	–0.217***	–0.007***	–0.050**	–0.046**	–0.072**	–0.040**
	(0.078)	(0.003)	(0.023)	(0.021)	(0.036)	(0.020)
(Log) dwelling size in m^2	0.215***	0.007***	0.037*	0.038*	0.116***	0.076***
	(0.077)	(0.002)	(0.021)	(0.021)	(0.032)	(0.021)
Dwelling built: 1970–2000	0.135	0.004	0.007	0.008	0.010	0.003
	(0.092)	(0.003)	(0.024)	(0.025)	(0.037)	(0.025)
Dwelling built: Before 1970	0.161**	0.005**	0.012	0.012	0.031	0.009
	(0.078)	(0.002)	(0.021)	(0.021)	(0.031)	(0.021)
Italy	–0.574***	–0.018***	–0.126***	–0.114***	–0.170***	–0.099***
	(0.086)	(0.003)	(0.026)	(0.022)	(0.039)	(0.021)
Switzerland	0.365***	0.012***	0.041*	0.049**	–0.015	–0.011
	(0.081)	(0.003)	(0.021)	(0.023)	(0.033)	(0.022)
Intercept	2.755***		0.389**		1.371***	
	(0.591)		(0.160)		(0.254)	
Observations	2,895	2,895	2,895	2,895	2,895	2,895
Adjusted R^2	0.23		0.15		0.12	
Log likelihood	–5206.79		–1481.70		–2662.27	

Note: Regressions additionally control for household size, savings rate, biospheric values, absence from the home, moving between 2012–16 and working status. OLS estimates are reported in columns (1), (3) and (5). Average marginal effects for the probit model are reported in column (4). Average marginal effects at the median outcome are reported for the ordered probit models in columns (2) and (6). Robust standard errors are reported in parentheses in columns (1), (3) and (5). Standard errors are reported in parentheses in Columns(2),(4) and (6). */**/*** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

reasons: first, energy services for lighting account for around 10% of residential electricity consumption in the EU (Mills and Schleich, 2014), which makes it a relevant decision in terms of its implications for the household’s overall electricity consumption. Second, the monetary savings coming from the adoption of efficient light bulbs are particularly relevant, as highlighted by comparing the energy costs of the different light bulb technologies reported in Table 3.

Light emitting diodes (LED) and compact fluorescent lamps (CFL) are associated with substantially lower annual energy costs (1.6 and 2.4 euros/year, respectively) compared

TABLE 3
Common bulb technologies and their characteristics.

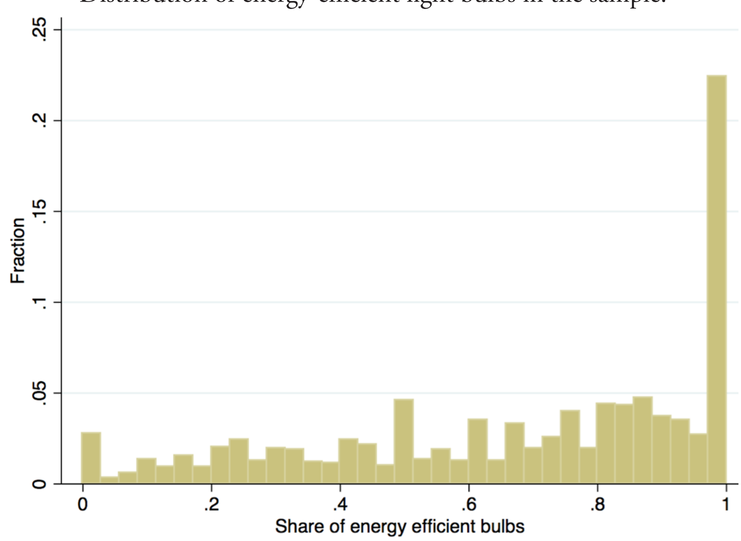
	Power use	Energy cost†	Lifetime	Efficiency
Incandescent lamps	60W	12.00 Euros/year	1 year	13.43 lumen/W
Halogen incandescent lamps	48W	9.60 Euros/year	1–3 years	16.79 lumen/W
Compact fluorescent lamps (CFLs)	12W	2.40 Euros/year	6–10 years	67.16 lumen/W
Light emitting diodes (LEDs)	8W	1.60 Euros/year	15–20 years	100.75 lumen/W

† We assume an electricity price of 0.20 Euros per kWh. All lamps have a comparable brightness of around 806 lumen.

to halogen and incandescent lamps (9.6 and 12 euros/year, respectively). Assuming average lifetimes of 2 and 10 years, and market prices of 2 and 15 euros, for halogen and LED bulbs, respectively,[15] a comparison of total lighting costs over a period of ten years shows that a rational and fully informed consumer would need to discount future energy costs by more than 65 percent yearly to choose a halogen light bulb over an LED bulb. Also, light bulb purchase decisions are also taken by tenants who typically have, depending on the conventions in the respective country, limited or no influence on the efficiency of their major home appliances.

We hypothesize that households scoring high in energy-related financial literacy will assign more value to the energy savings coming from the adoption of the energy-efficient light bulbs, and therefore increase the share of efficient light bulbs at home. We exploit information on the efficiency of the stock of light bulbs at home, and define light bulbs as "efficient" if they are either a compact fluorescent lamp (CFL) or a light emitting diode (LED). The average share of energy-efficient light bulbs in our sample is around 67%. As shown in Figure 4, a substantial share of the respondents (around 22%) reported that all the light bulbs in their homes are either light emitting diode (LED) or compact fluorescent lamp (CFL). However, almost 27% of the respondents reported less than half of their light bulbs to be energy efficient.

FIGURE 4
Distribution of energy-efficient light bulbs in the sample.



15. These are conservative numbers provided that the lifetime of LED bulbs typically varies between 10 and 20 years (Swiss Federal Office of Energy).

We use the share of energy-efficient light bulbs as our main outcome variable, as well as an indicator for whether the share of energy-efficient light bulbs is below the first quartile, which we take as an *indicator for low lighting efficiency* at home. To provide evidence on the predictive power of the energy-related financial literacy measure on the adoption of efficient light bulbs, we estimate the following model:

$$y_i = \alpha' + \gamma \cdot L_i + X_i \beta' + \varepsilon_i \tag{1}$$

where y_i represents either the share of energy-efficient light bulbs in respondent *i*'s dwelling or the *indicator for low lighting efficiency* at home. We use either the level of financial literacy or the level of energy-related financial literacy as the main variable of interest, L_i, to investigate the importance of considering both financial literacy and energy-specific knowledge. To this end, we consider both the corresponding index and a binary indicator for financial literacy and energy-related financial literacy. The financial literacy dummy takes the value 1 if the household answers correctly to all three questions on financial literacy. The binary indicator for energy-related financial literacy takes the value 1 if a household scores above the median. The set of controls X_i includes the variables that have been found to be correlated with the literacy measures such as the respondent's age, gender, educational attainment and country of residence and household's income. Moreover, we control for other relevant characteristics for the choice of adoption of light bulbs as the home-ownership status, dwelling type, respondent's working status and household type. Finally, ε_i represents the usual idiosyncratic error term. We estimate Equation 1 using Ordinary Least Squares (OLS) for the share of energy-efficient light bulbs and using a probit regression model for the indicator for low lighting efficiency.

Table 4 reports selected coefficients estimated using the different OLS and probit regression models.[16] Columns (1)–(4) show the results for the share of energy-efficient light bulbs, while columns (5)–(8) report results for the indicator of a low level of energy-efficient lighting (share of energy-efficient light bulbs below the first quartile).[17]

The financial literacy indicators do not show any significant associations with the share of energy-efficient light bulbs (columns (1) and (2)), nor the probability to have a low lighting efficiency at home (columns (5) and (6)). Compared to (Brent and Ward, 2018), who use a stated preference approach, we do not find the standard indicator of financial literacy (the "Big Three" questions as in (Lusardi and Mitchell, 2014)) to be a good predictor for the adoption of energy-efficient durable goods in a revealed preference setting. In contrast, the comprehensive energy-related financial literacy indicators show a strong positive association with the share of energy-efficient light bulbs (columns (3) and (4)), and a coherent negative association with the probability to have a low lighting efficiency at home (columns (7) and (8)). This finding suggests that, in the context of investment in energy efficiency, general financial literacy should be considered together with more energy cost-specific knowledge as a predictor of individual behavior.

In Table B3 in the Appendix we also report the estimation results obtained including financial literacy and energy-cost related literacy separately in Equation 1. The results show

16. The complete estimation results are reported in Table B1 in the Appendix.

17. We also check for the robustness of our results to the definition of the item "Knowledge electricity price". For this purpose, we use two additional definitions: We define respondents as correct in their answer when the value they estimate for electricity price in kWh ranges between ±10% and ±50%, respectively. The results are shown in Tables B4 and B5. It seems that there are no major differences in the coefficients of interest compared to the baseline results.

TABLE 4
Lighting Efficiency and Literacy: Financial Literacy and Energy-Related Financial Literacy

	Share of energy-efficient light bulbs *(Regression coefficients)*				Indicator of low lighting efficiency *(Marginal effects)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Financial literacy index	–0.0007				–0.0353			
	(0.0084)				(0.0428)			
Financial literacy dummy		0.0132				–0.0761		
		(0.0127)				(0.0632)		
ERFL index			0.0164***				–0.0803***	
			(0.0036)				(0.0179)	
ERFL dummy				0.0475***				–0.233***
				(0.0131)				(0.0641)
Constant	0.626***	0.625***	0.579***	0.606***	–0.533	–0.583	–0.362	–0.504
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2895	2895	2895	2895	2895	2895	2895	2895

Notes: Columns (1) to (4) report OLS estimates for the share of energy-efficient light bulbs at home. In columns (5) to (8), we report the estimated marginal effects from the probit models for the binary indicator of low lighting efficiency. Regressions control for respondent's age, gender, education level, working status and country of residence, household type and income, home-ownership status and dwelling type.
Robust standard errors are reported in parentheses in Columns (1) to (4). Standard errors are reported in parentheses in Columns (5) to (8). * / ** / *** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

that, also when we condition on energy-cost related knowledge, there is a positive but not significant association between financial literacy and lighting efficiency. The energy cost-related literacy indicator is instead found to be positively associated with lighting efficiency. Together, these results confirm our main finding that general financial literacy needs to be complemented by energy cost-specific knowledge for individuals to make efficient investment choices in energy-consuming durables.

A one point increase in the energy-related financial literacy index is associated with a 1.65 percentage points higher share of energy-efficient light bulbs and a decrease in the probability for low lighting efficiency of 2.35 percentage points. To provide an intuition about the magnitude of these estimates, moving from a low level of energy-related financial literacy index (equal to 3, corresponding to the value at the first quartile of the distribution), to a moderately high level (equal to 6, corresponding to the value at the third quartile of the distribution) predicts an increase in the share of energy-efficient light bulbs of around 5 percentage points. Considering that the unconditional mean of the share of energy-efficient light bulbs in the sample is equal to 0.67, this result implies an increase in the share of around 7.5 percent. Further, when the respondent scores above the median in the energy-related financial literacy index, the share of energy-efficient light bulbs increases by around 5 percentage points, while the probability for low lighting efficiency decreases by almost 7 percentage points.

Clearly the interpretation of γ in Equation (1) as the causal impact of energy-related financial literacy on the share of energy-efficient light bulbs relies on the validity of the following assumptions: first, no unobservable characteristics should be correlated with both the share of energy-efficient light bulbs and the level of energy-related financial literacy; second, we can exclude the issue of reverse causality between the decision of purchase of efficient light bulbs and literacy and, finally, we measure literacy without error. In the context of financial literacy in particular, Lusardi and Mitchell (2014) discuss that potential issues of reverse causality and measurement error may bias the OLS estimates downwards. For these reasons, even though we control for a rich of socio-demographic characteristics in our regression analysis, we are cautious in the interpretation of the estimated γ as causal impact. However, our results show an important predictive power of our combined literacy measure on the behavior of consumers with respect to the investment in energy efficient durables.

5.1 Heterogeneity Analysis

Finally, we wish to explore whether the association between energy-related financial literacy and measures of lighting investment efficiency is different between subgroups of our sample. We are especially interested in testing whether this association is similar among male and female respondents, considering the large literacy gender gap we document in Section 4. To this end, we estimate Equation (1) separately for male and female respondents, respondents' country of residence and tenants and homeowners. The results are reported in Table B2 in the Appendix. Generally, we find no statistically significant difference in the estimated coefficients across groups. However, we find a slightly stronger association between energy-related financial literacy and lighting efficiency among male respondents, individuals living in Italy and the Netherlands, as well as among homeowners. However, considering that the estimates across groups are not statistically different, we would like to be cautious in drawing conclusions from these results.

6. CONCLUSIONS

In this study, we explore the consequences of consumers' limited energy cost-specific knowledge and investment skills on the adoption of energy-consuming durables. We show that, while the majority of the respondents in our sample perform quite well in the standard financial literacy questions, a substantial lack of energy cost-specific knowledge and ability to compute the lifetime cost of appliances emerges. Our results are informative of a substantial gender gap in our measure of energy-related financial literacy, with males scoring higher levels of the index, consistently with previous findings about the gender gap in financial literacy (Lusardi and Mitchell, 2014).

Using data on actual consumers' choices, we document a positive influence of our measure of energy-related financial literacy on the adoption of energy-efficient light bulbs. These findings are robust to using different indicators for lighting efficiency and energy-related financial literacy. We further show that the standard financial literacy indicator is a poor predictor of consumers' choices in lighting efficiency, suggesting that general financial knowledge is not enough for individuals to invest efficiently in the energy sector. Our study is complementary to studies by that show a positive association between scores of financial literacy (Brent and Ward, 2018) or cognitive reflection (Andor et al., 2019), respectively, and willingness to pay for energy efficiency using stated choice data.

Our results inform models of consumer behavior for the choice of energy-consuming durables about the importance of considering limited energy-specific knowledge and skills to perform an intertemporal investment calculation. We identify a lack of energy-related financial literacy as an important determinant of the energy-efficiency gap. In this sense, we complement previous studies highlighting the role of other behavioral anomalies on the consumers valuation of the monetary savings coming from energy efficiency (Allcott et al., 2014; Gillingham and Palmer, 2014). Moreover, we add to previous evidence about the costs of ignorance on household finances due to limited planning for retirement and participation to the financial markets (Lusardi and Mitchell, 2014).

While we provide evidence of the importance of limited energy-related financial literacy in explaining sub-optimal decisions of households with respect to lighting efficiency, future research should explore the consequences of (lack of) energy-related financial literacy on households' choices with respect to the adoption of larger energy-consuming durables, such as home appliances and vehicles, and energy-efficient home renovations.

Our findings support the promotion of energy-specific financial education programmes and tools to increase the adoption of energy-efficient durables. The aspects captured by the proposed multidimensional ERFL index can be guiding in determining the content of such dedicated information and education programmes to support consumers in identifying the optimal investments in energy-efficient equipment. In addition, easy-to-use apps, calculator tools or energy labels that indicate the average estimated lifetime cost of an appliance could support individuals with low energy-related financial literacy in identifying durables that minimize the household's expenditure over their lifetime. As mentioned, moving from a low level of the ERFL index to a moderately high level predicts an increase in the share of energy-efficient light bulbs of around 5 percentage points, implying an increase in the share of around 7.5 percent. While the cost-efficiency of educational programmes and information interventions to achieve such an improvement in energy-related financial literacy in comparison to alternative policies—like financial incentives for energy-efficient appliances and lighting—would ideally have to be evaluated based on a randomized controlled trial (Allcott and Mullainathan, 2010; Gillingham et al., 2018), there is suggestive evidence that the per-kWh cost of education programmes and information interventions are lower than the per-kWh cost of subsidy or rebate schemes (Alberini and Towe, 2015; Gillingham et al., 2018). Houde and Aldy (2014) and Alberini and Towe (2015) suggest that the cost-efficiency of financial incentives may be reduced by freeriding, as many participating households would have replaced their devices by more efficient ones anyway. Yet apart from this downside of financial incentives, the opportunities for digital implementation and distribution of energy-related financial information and educational programs and tools (webpages, apps, etc.) open up a the potential to target a large audience at relatively low cost.

Lastly, while strengthening energy-related financial literacy is important to reach energy-efficiency goals as the decision of adoption of durables have implications in the long-run electricity consumption, educational programs would be even more relevant in the light of the prevailing energy poverty within several EU Member States (Pye et al., 2015) and other parts of the world, which is often associated with further problems such as poor health of household members (Thomson et al., 2017). In the context of financial literacy, there is evidence that women are more aware of, and more likely to self-report, their lack of financial literacy as compared to men (Hung et al., 2012; Lusardi and Mitchell, 2014). If the same held true for energy-related decision making, it could be worthwhile to explore ways to specifically educate women in energy-related investment decisions. Future research should therefore explore what drives the differences in energy-related financial literacy across gender and countries and how target-specific education programs could reduce the inequality in literacy.

APPENDIX

A.1 European household survey

The survey was implemented in collaboration with different utilities in the three countries (Italy: ENI, Netherlands: Qurrent, Switzerland: Stadtwerk Winterthur and Aziende Industriali Lugano). ENI and Qurrent serve customers everywhere in Italy and the Netherlands, respectively. Stadtwerk Winterthur is a city utility located in the German part of Switzerland and Aziende Industriali Lugano is a regional utility serving a region in the Italian part of Switzerland.

The target population of the survey are the customers of the four electric utilities.[18] Customers of each electric utility were invited with a letter accompanying the electricity (or gas) bill to access an online questionnaire.[19] In total 149,100 households were contacted. In Italy, households were selected to be representative at the customer level of ENI based on the place of residence, contract characteristics, and historical consumption. In the Netherlands, target households were those having a smart meter and that had been customers of Qurrent for at least 6 months at the time of the survey. In Switzerland, targeted households were randomly drawn from the population of customers in Winterthur and the district of Lugano.[20] In Italy and the Netherlands, the households were contacted via e-mail, while in Switzerland postal letters were sent out as invitations. Table A1 reports details on the recruitment process.

In addition, Table A2 gives a summary of the number of participants in each country, how many individuals accessed the survey and the number of respondents that finished the questionnaire. Overall 3.22% of the households that received the invitation to take the survey completed the survey (the country-specific response rates can be found in Table A2). This low response rate may be due to the fact that the questionnaire was relatively long.

A total of 4,796 households took part in the survey in the three countries. Representativeness of the sample cannot be ensured ex-ante due to two reasons: (1) Part of the sample

TABLE A1
Implementation of the large sample survey in the different countries.

	Switzerland	Netherlands	Italy
No. of households contacted	28,100	19,000	102,000
Means of contact	postal letter	e-mail	e-mail
Recruitment	Random sample of customers of two utilities: 13,100 in Lugano (city and surrounding municipalities) and 15,000 in Winterthur (city)	Participants with a smart meter. Customer for at least 6 months[a]	ENI customers who have provided ENI with an explicit and written consent to be contacted by third parties for research purposes. The customer sample is layered so that it is representative[b] based on the place of residence, contract characteristics, and historical consumption.

[a] The research team in the Netherlands tried to go for 12 months (instead of 6 months), yet this would not have resulted in a large enough sample.
[b] Representative on the customer level of ENI.

18. Participants to the survey were randomly selected only in Switzerland, whereas the in the other countries customers were selected upon different criteria.

19. The survey questionnaire was pre-tested among university students and employees of the participating utility companies. Based on feedback from the expert review and the pre-tests, the survey questionnaire was further refined and adapted.

20. In Switzerland, the electricity market is not yet open to competition for residential customers. Thus, the partner utilities in Winterthur and Lugano serve the whole population in the respective service area.

TABLE A2
Number of respondents in the sample.

	Switzerland	Netherlands	Italy
No. of participants in the sample			
Entered the survey	1,477	2,252	1,508
Completed the survey	1,080	1,923	1,475
Response rate	3.69%	11.85%	1.48%

has not been randomly drawn from the target population, i.e. the target population in the Netherlands has been selected according to specific criteria (presence of smart meters) and (2) a self-selection might occur when invited individuals decide to take the survey. For this reason, we compare some relevant characteristics in the sample to corresponding statistics at the national level in order to provide indication of the representativeness of the sample.

In Table A3, we provide descriptive statistics about residents characteristics, household income and education for the four countries in the sample. In addition, the table reports a comparison with the corresponding statistics at the national level.[21] We report the statistics at the national level as computed by Eurostat (residence characteristics, household type and education) and by OECD (household income).

The majority of households in the Dutch sample (around 73%) live in single-family houses. In contrast, only around 44% of households in the Italian sample live in single-family houses. This evidence is consistent with the corresponding statistics at the national level. The

TABLE A3
Selected household characteristics in the sample and in the national statistics.

	Italy		**Netherlands**		**Switzerland**	
	Sample (%)	Statistic	Sample (%)	Statistic	Sample (%)	Statistic
Residence characteristic						
Single-family house	43.63	47.20	73.21	76.50	51.62	37.00
Apartment in multi-family house	56.37	52.20	26.79	19.90	48.38	60.10
Ownership status						
Owned	84.68	72.90	73.21	67.80	58.59	44.50
Gross monthly household income (in Euro/CHF)						
below 1'500	15.12		6.16		1.01	
'501 to 4'500	**50.93**		**47.70**		10.28	
'501 to 6'000	8.95		19.18		11.96	
'001 to 9'000	5.74		15.38		**28.04**	
'001 to 12'000 CHF	1.75		5.73		22.46	
more than 12'000 CHF	17.51		5.85		26.26	
Household disposable income		4417.95		4614.34		6993.87
Education of respondent						
Lower secondary education and less	11.21	41.60	5.91	27.90	2.11	18.20
Upper secondary/Vocational	54.24	42.70	24.09	41.10	40.42	46.30
Tertiary	34.55	15.70	70.01	31.00	57.46	35.40

21. Although we targeted the population of customers of local and regional utilities in Switzerland we still compare the statistics at the national level to inform about the differences between the characteristics of the households in the sample and in the country. Unfortunately, for the service area of the two Swiss utilities no official statistics are available on the important socio-economic characteristics reported in Table A3.

share of households living in single-family houses in the Swiss sample is around 51%. This contrasts with the statistic at the national level showing a figure around 37%. The ownership rate ranges from around 59% in Switzerland to around 85% in Italy. This heterogeneity reflects differences in the ownership rates across countries as indicated in the national statistics. Compared to the national statistics, home-owners are only slightly over-represented in the sample.

The median gross monthly household income in the sample varies substantially across countries: In the Italian and the Dutch sample this figure ranges between 1,500 and 4,500 Euros, in the Swiss sample it ranges between 6,000 and 9,000 CHF. This is consistent with the median household income for the three countries as reported by OECD statistics. Further, educational attainments in the sample differ largely across the countries, with the share of respondents with tertiary education ranging from around 35% in Italy to around 70% in the Netherlands. This heterogeneity across countries in tertiary educational attainments is also reflected in the national statistics. However, the share of respondents with *tertiary education* is consistently higher in the sample than what is reported at the national level in each country. Concluding, we can say that even though there are some differences between sample characteristics and national statistics, they are not severely large. In addition, there also some characteristics where we can find a relatively good match between sample and national statistics, such as household income and ownership rate.

Finally, in Table A4, we provide descriptive statistics on the relevant socio-economic characteristics used in the econometric analysis.

A.1.1 Questions used to measure energy-related financial literacy

Knowledge of electricity price: How much do you think 1 Kilowatt hour (kWh) of electricity currently costs in [*target country*] (on average after taxes)? Please indicate your best guess without checking your bill or other resources.

- Amount in cents/Rappen (no decimals)
- Don't know

Running cost of appliances: How much do you think it costs in terms of electricity to run: (a) A desktop PC for 1 hour, (b) A washing machine (load of 5 kg at 60°)

- 0–19 cents/Rappen
- 20–39 cents/Rappen
- 40–59 cents/Rappen
- 60–79 cents/Rappen
- 80–100 cents/Rappen
- More than 100 cents/Rappen
- Don't know

Knowledge of LED technology savings: How much do you think is the energy saving associated with using an LED light bulb instead of a conventional Halogen bulb (with the same brightness)?

- 5–10 percent
- 30–50 percent
- 70–80 percent
- Don't know

Financial literacy 1: Suppose you had 100 CHF/Euros in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?

TABLE A4
Summary statistics.

Variable	Mean	Std. Dev.	N
Age	51.208	14.273	4404
Income: Below 4,500 (Reference)	0.363	0.481	4384
Income: 4'501–9'000	0.235	0.424	4384
Income: Above 9'000	0.184	0.388	4384
Income: Don't know	0.217	0.413	4384
Up to lower secondary school (Reference)	0.068	0.252	4415
Upper secondary school diploma	0.213	0.409	4415
Vocational secondary school diploma	0.168	0.374	4415
Tertiary education diploma	0.551	0.497	4415
Rented dwelling (Reference)	0.261	0.439	4450
Owned dwelling	0.261	0.439	4450
Multi-family house (Reference)	0.419	0.493	4450
Single-family house	0.581	0.493	4450
Male (Reference)	0.65	0.477	4411
Female	0.35	0.477	4411
Switzerland (Reference)	0.241	0.428	4450
Italy	0.336	0.472	4450
Netherlands	0.423	0.494	4450
Non-couple household (Reference)	0.278	0.448	4416
Couple household	0.722	0.448	4416
Working (Reference)	0.67	0.47	4416
Not working	0.33	0.47	4416
Number of rooms	7.236	2.127	4335

- More than Euro/CHF 102
- Exactly Euro/CHF 102
- Less than Euro/CHF 102
- Don't know

Financial literacy 2: Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?

- More than today
- Exactly the same
- Less than today
- Don't know

Financial literacy 3: Please tell me whether this statement is true or false: "Buying a single company's stock usually provides a safer return than buying stocks of several companies."

- True
- False
- Don't know

Lifetime cost calculation: Suppose you own your home, your fridge breaks down and you need to replace it. As a replacement, you can choose between two alternatives that are identical in terms of design, capacity and quality of the cooling system. Fridge A sells for 400 Euro/CHF and consumes electricity for the amount of 300 kWh per year. Fridge B has a retail price of 500 Euro/CHF and consumes electricity for the amount of 280 kWh per year.

Assume the average cost of energy is 0.20 Euro/CHF per kWh, the two models have both a lifespan of 15 years and that you would get a return of 0 percent from any alternative investment of your money.

Which choice of purchase minimizes the total costs of the fridge over its lifespan?

- Fridge A
- Fridge B
- Fridge A and B are equivalent in terms of total costs
- Don't know

Check for lifetime cost calculation: How did you reach your conclusion?

- Fridge A has a lower retail price than Fridge B.
- The lower energy consumption of Fridge B is sufficient to justify the higher price.
- The lower energy consumption of Fridge B is not sufficient to justify the higher price.
- Do not know

A.2 Additional analysis

In this Section of the Appendix we report the full estimation results from the analysis about the effect of energy-related financial literacy on the adoption of energy efficient light bulbs. Specifically, we report here the complete set of estimated coefficients associate to the socio-demographic variables used as controls in the econometric analysis. Further, we report the results of the heterogeneity analysis that we discuss in the main text as well as the results of the robustness analysis.

TABLE B1
Financial literacy and energy-related financial literacy

	Share of energy efficient light bulbs *(Regression coefficients)*				Indicator for low lighting efficiency *(Marginal effects)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Financial literacy index	–0.000				–0.035			
	(0.008)				(0.042)			
Financial literacy dummy		0.013				–0.076		
		(0.013)				(0.063)		
ERFL index			0.016***				–0.080***	
			(0.0036)				(0.018)	
ERFL dummy				0.047***				–0.233***
				(0.013)				(0.064)
Age	0.012***	0.012***	0.012***	0.012***	–0.037**	–0.036**	–0.035**	–0.036**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.015)	(0.015)	(0.015)	(0.015)
Age^2	–0.000***	–0.000***	–0.000***	–0.000***	0.000**	0.000**	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Female	–0.013	–0.011	0.004	–0.003	–0.012	–0.016	–0.086	–0.056
	(0.012)	(0.012)	(0.013)	(0.012)	(0.062)	(0.062)	(0.064)	(0.063)
Upper secondary	–0.038	–0.041	–0.049*	–0.046*	0.051	0.053	0.092	0.077
	(0.028)	(0.027)	(0.027)	(0.027)	(0.136)	(0.136)	(0.136)	(0.136)

(continued)

TABLE B1 *(continued)*
Financial literacy and energy related financial literacy

	Share of energy efficient light bulbs *(Regression coefficients)*				Indicator for low lighting efficiency *(Marginal effects)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Vocational	–0.070**	–0.071**	–0.074**	–0.074**	0.244*	0.244*	0.256*	0.258*
	(0.029)	(0.029)	(0.029)	(0.029)	(0.139)	(0.139)	(0.139)	(0.139)
University	–0.047*	–0.051*	–0.061**	–0.056**	0.175	0.178	0.226*	0.206
	(0.027)	(0.027)	(0.027)	(0.027)	(0.131)	(0.131)	(0.131)	(0.131)
Household size: 2	–0.013	–0.013	–0.011	–0.014	0.008	0.010	0.004	0.015
	(0.022)	(0.022)	(0.021)	(0.021)	(0.104)	(0.104)	(0.104)	(0.104)
Household size: 3	–0.001	–0.001	–0.001	–0.002	–0.064	–0.064	–0.062	–0.058
	(0.024)	(0.024)	(0.024)	(0.024)	(0.116)	(0.116)	(0.116)	(0.116)
Household size: 4	0.019	0.019	0.021	0.019	–0.108	–0.108	–0.117	–0.106
	(0.026)	(0.026)	(0.026)	(0.026)	(0.128)	(0.128)	(0.128)	(0.128)
Household size: >=5	0.016	0.017	0.017	0.016	–0.293*	–0.293*	–0.290*	–0.286*
	(0.030)	(0.030)	(0.030)	(0.030)	(0.154)	(0.154)	(0.154)	(0.154)
Biospheric values	0.008*	0.008*	0.009*	0.009*	–0.028	–0.028	–0.031	–0.031
	(0.005)	(0.005)	(0.005)	(0.005)	(0.023)	(0.023)	(0.023)	(0.023)
Couple household	0.029	0.029	0.027	0.029	–0.021	–0.022	–0.013	–0.023
	(0.019)	(0.019)	(0.019)	(0.019)	(0.091)	(0.091)	(0.091)	(0.091)
Not working	0.002	0.002	–0.002	0.001	–0.004	–0.005	0.016	0.003
	(0.015)	(0.015)	(0.015)	(0.015)	(0.076)	(0.076)	(0.077)	(0.076)
Income: 4’501–9’000	–0.011	–0.012	–0.013	–0.014	0.006	0.008	0.015	0.018
	(0.014)	(0.014)	(0.014)	(0.014)	(0.071)	(0.071)	(0.071)	(0.071)
Income: Above 9’000	–0.002	–0.003	–0.005	–0.005	0.026	0.028	0.039	0.042
	(0.016)	(0.016)	(0.016)	(0.016)	(0.084)	(0.084)	(0.084)	(0.084)
Savings rate: 0%	0.029	0.028	0.026	0.026	–0.079	–0.079	–0.071	–0.069
	(0.021)	(0.021)	(0.021)	(0.021)	(0.102)	(0.102)	(0.102)	(0.102)
Savings rate: 1–5%	0.020	0.019	0.014	0.015	–0.084	–0.083	–0.063	–0.068
	(0.019)	(0.019)	(0.019)	(0.019)	(0.092)	(0.092)	(0.092)	(0.092)
Savings rate: 6–20%	0.043**	0.042**	0.034*	0.036**	–0.143	–0.142	–0.107	–0.120
	(0.018)	(0.018)	(0.018)	(0.018)	(0.088)	(0.088)	(0.088)	(0.088)
Savings rate: > 20%	0.017	0.015	0.007	0.010	0.014	0.017	0.055	0.045
	(0.022)	(0.022)	(0.022)	(0.022)	(0.101)	(0.101)	(0.102)	(0.101)
Tenant	0.025	0.025*	0.028*	0.027*	–0.147*	–0.148*	–0.166**	–0.158**
	(0.015)	(0.015)	(0.015)	(0.015)	(0.076)	(0.076)	(0.076)	(0.076)
(Log) size in m^2	–0.036**	–0.037**	–0.039***	–0.038**	0.141*	0.142*	0.152**	0.145*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.074)	(0.074)	(0.074)	(0.074)
Absence: <= 5 weeks	–0.012	–0.012	–0.013	–0.012	–0.084	–0.085	–0.079	–0.086
	(0.013)	(0.013)	(0.013)	(0.013)	(0.063)	(0.063)	(0.063)	(0.063)
Absence: <= 8 weeks	0.034	0.032	0.032	0.031	–0.213*	–0.210*	–0.209*	–0.205*
	(0.022)	(0.022)	(0.022)	(0.022)	(0.117)	(0.117)	(0.117)	(0.117)
Absence: > 8 weeks	–0.030	–0.030	–0.025	–0.025	–0.049	–0.050	–0.076	–0.076
	(0.027)	(0.027)	(0.027)	(0.027)	(0.130)	(0.130)	(0.130)	(0.130)
Absence: 1 to 3 days	–0.008	–0.008	–0.007	–0.009	0.003	0.003	–0.002	0.006
	(0.016)	(0.016)	(0.016)	(0.016)	(0.080)	(0.080)	(0.080)	(0.080)
Absence: > 4 days	–0.014	–0.013	–0.011	–0.013	–0.091	–0.091	–0.103	–0.091
	(0.027)	(0.027)	(0.027)	(0.027)	(0.144)	(0.144)	(0.144)	(0.144)
MFH	–0.063***	–0.064***	–0.065***	–0.063***	0.322***	0.322***	0.332***	0.325***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.086)	(0.086)	(0.087)	(0.087)
Moved in 2012–16	0.061***	0.061***	0.061***	0.060***	–0.245***	–0.246***	–0.247***	–0.242***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.072)	(0.072)	(0.072)	(0.072)
DB: 1970–2000	–0.048***	–0.048***	–0.050***	–0.048***	0.233***	0.233***	0.247***	0.239***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.090)	(0.090)	(0.090)	(0.090)
DB: Before 1970	–0.036**	–0.036**	–0.039***	–0.037**	0.142*	0.140*	0.156**	0.148*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.076)	(0.076)	(0.076)	(0.076)
Italy	–0.038**	–0.036**	–0.028*	–0.031*	0.073	0.072	0.032	0.048
	(0.016)	(0.016)	(0.016)	(0.016)	(0.083)	(0.082)	(0.083)	(0.083)
Switzerland	–0.170***	–0.170***	–0.176***	–0.172***	0.582***	0.582***	0.614***	0.594***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.076)	(0.076)	(0.076)	(0.076)
Constant	0.626***	0.625***	0.579***	0.606***	–0.533	–0.583	–0.362	–0.504
	(0.112)	(0.111)	(0.111)	(0.111)	(0.533)	(0.530)	(0.533)	(0.531)
Observations	2895	2895	2895	2895	2895	2895	2895	2895

Notes: Statistical significance at the 1%, 5% and 10% levels are denoted by *, ** and ***, respectively. Standard errors in parentheses.

TABLE B2
Heterogeneous associations

	Gender		Home-ownership		Country		
	Male (1)	Female (2)	Homeowners (3)	Tenants (4)	Switzerland (5)	Netherlands (6)	Italy (7)
Panel A: Share of energy-efficient light bulbs—OLS estimates							
ERFL dummy	0.0499***	0.0373*	0.0548***	0.0265	0.0316	0.0532***	0.0541**
	(0.0174)	(0.0202)	(0.0153)	(0.0252)	(0.0323)	(0.0198)	(0.0212)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1986	909	2183	712	729	1338	828
Panel B: Indicator of low lighting efficiency—Marginal effects							
ERFL dummy	–0.217***	–0.252**	–0.263***	–0.127	–0.0913	–0.251**	–0.304***
	(0.0839)	(0.102)	(0.0744)	(0.132)	(0.137)	(0.103)	(0.108)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1986	909	2183	712	729	1338	828

Note: Dependent variable in Panel A is the share of energy efficient light bulbs. OLS estimates are reported. Dependent variable in Panel B is a dummy variable indicating whether the share of energy efficient light bulbs is below the first quartile. The estimated marginal effects from the Probit model are reported. Standard errors in parentheses. * / ** / *** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

TABLE B3
Financial literacy and energy cost-related literacy

	(1)	(2)	(3)
Panel A: Share of energy-efficient light bulbs—OLS estimates			
FL dummy	0.0132		0.0059
	(0.0127)		(0.0128)
ERL dummy		0.0463***	0.0456***
		(0.0113)	(0.0114)
Controls	Yes	Yes	Yes
Observations	2895	2895	2895
Panel B: Indicator of low lighting efficiency—Marginal effects			
FL dummy	–0.0225		–0.0123
	(0.0186)		(0.0188)
ERL dummy		–0.0628***	–0.0612***
		(0.0166)	(0.0167)
Controls	Yes	Yes	Yes
Observations	2895	2895	2895

Note: Dependent variable in Panel A is the share of energy efficient light bulbs. OLS estimates are reported. Dependent variable in Panel B is a dummy variable indicating whether the share of energy efficient light bulbs is below the first quartile. The estimated marginal effects from the Probit model are reported. Standard errors in parentheses. * / ** / *** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

Robustness

In order to check for the robustness of the item ''Knowledge electricity price", we recalculated the energy-related financial literacy index in two ways. First, instead of the +/–5cents range for the answer to be counted as correct, we used a ±10% range (e.g. for the Netherlands the correct price is between 13–17 cents per kWh and for Italy and Switzerland between 18–22 cents per kWh). The results of this can be found in Table B4. Secondly we used a a ±50% range for the correct electricity price (e.g. for the Netherlands the correct price is between 7.5–22.5 cents per kWh and for Italy and Switzerland between 10–30 cents per kWh). The results are shown in Table B5. Compared to the main results in Table 4 we do not see large changes in the coefficients of interest. Thus, the results seem to be robust to our definition of the correct electricity price.

TABLE B4
Robustness test of results in Table 4, ±10% range

	Share of energy-efficient light bulbs (Regression coefficients)				Indicator of low lighting efficiency (Marginal effects)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Financial literacy index	–0.001				–0.035			
	(0.008)				(0.043)			
Financial literacy dummy		0.013				–0.076		
		(0.013)				(0.063)		
ERFL index			0.018***				–0.087***	
			(0.004)				(0.019)	
ERFL dummy				0.052***				–0.255***
				(0.013)				(0.063)
Constant	0.626***	0.625***	0.579***	0.601***	–0.533	–0.583	–0.353	–0.479
	(0.112)	(0.111)	(0.111)	(0.111)	(0.533)	(0.530)	(0.533)	(0.531)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2895	2895	2895	2895	2895	2895	2895	2895

Notes: Columns (1) to (4) report OLS estimates for the share of energy-efficient light bulbs at home. In columns (5) to (8), we report the estimated marginal effects from the probit models for the binary indicator of low lighting efficiency. Regressions control for respondent's age, gender, education level, working status and country of residence, household type and income, home-ownership status and dwelling type.
Robust standard errors are reported in parentheses in Columns (1) to (4). Standard errors are reported in parentheses in Columns (5) to (8). * / ** / *** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

TABLE B5
Robustness test of results in Table 4, ±50% range

	Share of energy-efficient light bulbs (Regression coefficients)				Indicator of low lighting efficiency (Marginal effects)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Financial literacy index	–0.001				–0.035			
	(0.008)				(0.043)			
Financial literacy dummy		0.013				–0.076		
		(0.013)				(0.063)		
ERFL index			0.016***				–0.073***	
			(0.003)				(0.018)	
ERFL dummy				0.056***				–0.244***
				(0.011)				(0.058)
Constant	0.626***	0.625***	0.578***	0.606***	–0.533	–0.583	–0.375	–0.489
	(0.112)	(0.111)	(0.111)	(0.111)	(0.533)	(0.530)	(0.533)	(0.531)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2895	2895	2895	2895	2895	2895	2895	2895

Notes: Columns (1) to (4) report OLS estimates for the share of energy-efficient light bulbs at home. In columns (5) to (8), we report the estimated marginal effects from the probit models for the binary indicator of low lighting efficiency. Regressions control for respondent's age, gender, education level, working status and country of residence, household type and income, home-ownership status and dwelling type.
Robust standard errors are reported in parentheses in Columns (1) to (4). Standard errors are reported in parentheses in Columns (5) to (8). * / ** / *** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

ACKNOWLEDGMENTS

This paper is based on data collected within the EU H2020 Project "PENNY" (Psychological social & financial barriers to energy efficiency). We acknowledge financial support from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723791 - project PENNY "Psychological, social and financial barriers to energy efficiency", and financial support from the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 16.0087. We would like to thank Cristina Cattaneo, Angela Ruepert, Ellen van der Werff and Linda Steg for the collaboration in collecting the survey data used in this study. Furthermore, we would like to thank the utilities that cooperated during the data collection process. This research is also part of the activities of SCCER CREST, which is financially supported by the Swiss Commission for Technology and Innovation (CTI) / Innosuisse. The authors would also like to thank participants at the 11th International Workshop on "Empirical Methods in Energy Economics", the 8th Atlantic Workshop on Energy and Environmental Economics and the 5th European Conference on Behaviour and Energy Efficiency for helpful suggestions. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the Swiss Government nor the European Commission. All omissions and remaining errors are the authors' responsibility.

References

Agarwal, S. and Mazumder, B. 2013. "Cognitive abilities and household financial decision making." *American Economic Journal: Applied Economics*, 5(1):193–207. https://doi.org/10.1257/app.5.1.193.

Ajzen, I. 2006. Behavioral Interventions Based on the Theory of Planned Behavior. Technical Report.

Alberini, A. and Filippini, M. 2018. "Transient and persistent energy efficiency in the us residential sector: evidence from household-level data." *Energy Efficiency*, 11(3):589–601. https://doi.org/10.1007/s12053-017-9599-z.

Alberini, A. and Towe, C. 2015. "Information v. energy efficiency incentives: Evidence from residential electricity consumption in Maryland." *Energy Economics*, 52(Supplement 1):30–40. https://doi.org/10.1016/j.eneco.2015.08.013.

Albert, C. and Escardíbul, J.-O. 2017. "Education and the empowerment of women in household decision-making in Spain." *International Journal of Consumer Studies*, 41(2):158–166. https://doi.org/10.1111/ijcs.12326.

Allcott, H. 2011a. "Consumers' perceptions and misperceptions of energy costs." *American Economic Review: Papers & Proceedings*, 101(3):98–104. https://doi.org/10.1257/aer.101.3.98.

Allcott, H. 2011b. "Social norms and energy conservation." *Journal of Public Economics*, 95:1082–1995. https://doi.org/10.1016/j.jpubeco.2011.03.003.

Allcott, H. 2016. "Paternalism and *Energy Efficiency*: An Overview." *Annual Review of Economics*, 8:145–176. https://doi.org/10.1146/annurev-economics-080315-015255.

Allcott, H. and Mullainathan, S. 2010. "Behavior and energy policy." *Science*, 327(5970):1204–1205. https://doi.org/10.1126/science.1180775.

Allcott, H., Mullainathan, S., and Taubinsky, D. 2014. "Energy policy with externalities and internalities." *Journal of Public Economics*, 112:72–88. https://doi.org/10.1016/j.jpubeco.2014.01.004.

Allcott, H. and Taubinsky, D. 2015. "Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market." *American Economic Review*, 105(8):2501–2538. https://doi.org/10.1257/aer.20131564.

Allcott, H. and Wozny, N. 2014. "Gasoline Prices, Fuel Economy, and the Energy Paradox." *The Review of Economics and Statistics*, 96(5):779–795. https://doi.org/10.1162/REST_a_00419.

Almenberg, J. and Dreber, A. 2015. "Gender, stock market participation and financial literacy." *Economics Letters*, 137:140–142. https://doi.org/10.1016/j.econlet.2015.10.009.

Andor, M. and Fels, K. 2018. "Behavioral economics and energy conservation—a systematic review of non-price interventions and their causal effects." *Ecological Economics*, 148:178–210. https://doi.org/10.1016/j.ecolecon.2018.01.018.

Andor, M., Frondel, M., Gerster, A., and Sommer, S. 2019. "Cognitive reflection and the valuation of energy efficiency." *Energy Economics*, 84, Supplement 1:104527. https://doi.org/10.1016/j.eneco.2019.104527.

Andor, M., Gerster, A., and Sommer, S. 2020. "Consumer inattention, heuristic thinking and the role of energy labels." *The Energy Journal*, 41(1):83–112. https://doi.org/10.5547/01956574.41.1.mand.

Angrisani, M., Kapteyn, A., and Lusardi, A. 2016. The national financial capability study: Empirical findings from the american life panel survey. Working Paper, pages 1–43.

Attari, S. Z., DeKay, M. L., Davidson, C. I., and Bruin, W. B. d. 2010a. "Public perceptions of energy consumption and savings." *Proceedings of the National Academy of Sciences*, 107(37):16054–16059. https://doi.org/10.1073/pnas.1001509107.

Belch, M. and Willis, L. 2006. "Family decision at the turn of the century: has the changing structure of households impacted the family decision-making process?" *Journal of Consumer Behaviour*, 2(2):111–124. https://doi.org/10.1002/cb.94.

Berns, G., Laibson, D., and Loewenstein, G. 2007. "Intertemporal choice-toward an integrative framework." *Trends in Cognitive Sciences*, 11(11):482–488. https://doi.org/10.1016/j.tics.2007.08.011.

Beshears, J., Choi, J., Laibson, D., and Madrian, B. 2013. "Simplification and saving." *Journal of Economic Behavior & Organization*, 95:130–145. https://doi.org/10.1016/j.jebo.2012.03.007.

Blasch, J., Boogen, N., Filippini, M., and Kumar, N. 2017a. "Explaining electricity demand and the role of energy and investment literacy on end-use efficiency of Swiss households." *Energy Economics*, 68 (Suppl. 1):89–102. https://doi.org/10.1016/j.eneco.2017.12.004.

Blasch, J., Filippini, M., and Kumar, N. 2019. "Boundedly rational consumers, energy and investment literacy, and the display of information on household appliances." *Resource and Energy Economics*, 56:39–58. https://doi.org/10.1016/j.reseneeco.2017.06.001.

Blasch, J., Filippini, M., Kumar, N., and Martinez-Cruz, A. L. 2017b. Narrowing the energy efficiency gap: The impact of educational programs, online support tools and energy-related investment literacy. Technical report, Center of Economic Research (CER-ETH). https://doi.org/10.2139/ssrn.3043233.

Boogen, N. 2017. "Estimating the potential for electricity savings in households." *Energy Economics*, 63:288–300. https://doi.org/10.1016/j.eneco.2017.02.008.

Brent, D. A. and Ward, M. 2018. "Energy efficiency and financial literacy." *Journal of Environmental Economics and Management*, 90:181–216. https://doi.org/10.1016/j.jeem.2018.05.004.

Broberg, T. and Kazukauskas, A. 2015. "Inefficiencies in Residential Use of Energy-A Critical Overview of Literature and Energy Efficiency Policies in the EU." *International Review of Environmental and Resource Economics*, 8(2):225–279. https://doi.org/10.1561/101.00000070.

Brounen, D., Kok, N., and Quigley, J. M. 2013. "Energy literacy, awareness, and conservation behavior of residential households." *Energy Economics*, 38:42–50. https://doi.org/10.1016/j.eneco.2013.02.008.

Cattaneo, C. 2019. "Internal and external barriers to energy efficiency: which role for policy interventions?" *Energy Efficiency*, 12(5):1293–1311. https://doi.org/10.1007/s12053-019-09775-1.

Chan, S. and Elbel, B. 2012. "Low cognitive ability and poor skill with numbers may prevent many from enrolling in medicare supplemental coverage." *Health Affairs*, 31(8):1847–1854. https://doi.org/10.1377/hlthaff.2011.1000.

Chetty, R., Looney, A., and Kroft, K. 2009. "Salience and taxation: Theory and evidence." *American Economic Review*, 99(4):1145–1177. https://doi.org/10.1257/aer.99.4.1145.

Cho, S.-Y. 2017. Explaining gender differences in confidence and overconfidence in math. MACIE Paper Series Nr. 2017/03. https://doi.org/10.2139/ssrn.2902717.

Choi, J., Laibson, D., Madrian, B., and Metrick, A. 2004. For better or for worse: default effects and 401(k) savings behavior. In Wise, D., editor, *Perspectives on the Economics of Aging*, pages 81–121. Chicago, IL: The University of Chicago Press. https://doi.org/10.7208/chicago/9780226903286.003.0003.

DellaVigna, S. 2009. "Psychology and Economics: Evidence from the Field." *Journal of Economic literature*, 47(2):315–72. https://doi.org/10.1257/jel.47.2.315.

DeWaters, J. and Powers, S. 2013. "Establishing Measurement Criteria for an Energy Literacy Questionnaire." *The Journal of Environmental Education*, 44(1):38–55. https://doi.org/10.1080/00958964.2012.711378.

DeWaters, J. E. and Powers, S. E. 2011. "Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behavior." *Energy Policy*, 39(3):1699–1710. https://doi.org/10.1016/j.enpol.2010.12.049.

Di Maria, C., Ferreira, S., and Lazarova, E. 2010. "Shedding light on the light bulb puzzle: the role of attitudes and perceptions in the adoption of energy efficient light bulbs." *Scottish Journal of Political Economy*, 57(1):48–67. https://doi.org/10.1111/j.1467-9485.2009.00506.x.

Dianshu, F., Sovacool, B. K., and Minh Vu, K. 2010. "The barriers to energy efficiency in China: Assessing household electricity savings and consumer behavior in Liaoning Province." *Energy Policy*, 38(2):1202–1209. https://doi.org/10.1016/j.enpol.2009.11.012.

Disinger, J. F. and Roth, C. E. 1992. "Environmental literacy." *ERIC/CSMEE Digest*, ED351201:1–7.

Ecofys. 2016. Prices and Costs of EU Energy-Annex 3 Household case studies. In *ECOFYS, editor, Prices and Costs of EU Energy*, page Annex 3. European Commission.

Feldstein, M. and Liebman, J. 2002. Social security. In Auerbach, A. and Feldstein, M., editors, *Handbook of Public Economics*, Vol. 4, pages 2245–2324. Amsterdam: Elsevier. https://doi.org/10.1016/S1573-4420(02)80011-8.

Filippini, M., Blasch, J., Boogen, N., and Kumar, N. 2018. Energy efficiency, bounded rationality and energy-related financial literacy in the swiss household sector-final report. Technical report, Swiss Federal Office of Energy (SFOE).

Filippini, M. and Hunt, L. C. 2011. "Energy Demand and *Energy Efficiency* in the OECD Countries: A Stochastic Demand Frontier Approach." *The Energy Journal*, 32(2). https://doi.org/10.5547/ISSN0195-6574-EJ-Vol32-No2-3.

Filippini, M., Kumar, N. and Srinivasan, S. 2020. "Energy-related financial literacy and bounded rationality in appliance replacement attitudes: evidence from Nepal." *Environment and Development Economics*, 25: (4): 399–422, https://doi.org/10.1017/S1355770X20000078.

Fiorillo, D. and Sapio, A. 2019. "Energy saving in italy in the late 1990s: Which role for non-monetary motivations?" *Ecological Economics*, 165:1–15. https://doi.org/10.1016/j.ecolecon.2019.106386.

Fonseca, R., Mullen, K. J., Zamarro, G., and Zissimopolous, J. 2012. "What Explains the Gender Gap in Financial Literacy? The Role of Household Decision Making." *The Journal of Consumer Affairs*, 46(1):90–106. https://doi.org/10.1111/j.1745-6606.2011.01221.x.

Gabaix, X. and Laibson, D. 2006. "Shrouded Attributes, Consumer Myopia, and Information Suppression in Competitive Markets." *The Quarterly Journal of Economics*, 121(2):505–540. https://doi.org/10.1162/qjec.2006.121.2.505.

Gillingham, K., Keyes, A., and Palmer, K. 2018. "Advances in Evaluating *Energy Efficiency* Policies and Programs." *Annual Review of Resource Economics*, 10:511–532. https://doi.org/10.1146/annurev-resource-100517-023028.

Gillingham, K. and Palmer, K. 2014. "Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence." *Review of Environmental Economics and Policy*, 8(1):18–38. https://doi.org/10.1093/reep/ret021.

Gneezy, U., Niederle, M., and Rustichini, A. 2003. "Performance in Competitive Environments: Gender Differences." *Quarterly Journal of Economics*, 118(3):1049–1074. https://doi.org/10.1162/00335530360698496.

Greene, W. H. 2003. *Econometric analysis*, 5th edition. Prentice Hall.

Hastings, J., Madrian, B., and Skimmyhorn, W. 2013. "Financial literacy, financial education, and economic outcomes." *Annual Review of Economics*, 5:347–373. https://doi.org/10.1146/annurev-economics-082312-125807.

Hollweg, K., Taylor, J., Bybee, R., Marcinkowski, T., McBeth, W., and Zoido, P. 2011. Developing a framework for assessing environmental literacy. North American Association for Environmental Education, Washington, DC.

Houde, S. and Aldy, J. E. 2014. Belt and suspenders and more: The incremental impact of energy efficiency subsidies in the presence of existing policy instruments. Resources for the Future Discussion paper, RFF DP 14-34. https://doi.org/10.3386/w20541.

Houde, S. and Myers, E. 2019. Heterogeneous (mis-) perceptions of energy costs: Implications for measurement and policy design. NBER Working Paper Series, Working paper, 25722. https://doi.org/10.3386/w25722.

Hsu, J. W. 2016. "Aging and Strategic Learning—The Impact of Spousal Incentives on Financial Literacy." *The Journal of Human Resources*, 51(4):1036–1067. https://doi.org/10.3368/jhr.51.4.1014-6712R.

Hung, A., Parker, A. M., and Yoong, J. 2009. Defining and measuring financial literacy. RAND Working Paper Series, WR-708. https://doi.org/10.2139/ssrn.1498674.

Hung, A., Yoong, J., and Brown, E. 2012. Empowering Women Through Financial Awareness and Education. OECD Working Papers on Finance, Insurance and Private Pensions No. 14, OECD, Paris.

Jaffe, A. B. and Stavins, R. N. 1994. "The energy-efficiency gap: What does it mean?" *Energy Policy*, 22(10):804–810. https://doi.org/10.1016/0301-4215(94)90138-4.

Jappelli, T. and Padula, M. 2013. "Investment in financial literacy and saving decisions." *Journal of Banking & Finance*, 37(8):2779–2792. https://doi.org/10.1016/j.jbankfin.2013.03.019.

Kalmi, P., Trotta, G., and Kazukauskas, A. 2017. The Role of Energy Literacy as a component of Financial Literacy: Survey-based evidence from Finland. Technical report, IAEE conference in Vienna, www.eeg.tuwien.ac.at/conference/iaee2017.

Kramer, M. 2016. "Financial literacy, confidence and financial advice seeking." *Journal of Economic Behavior & Organization*, 131(Part A):198–217. https://doi.org/10.1016/j.jebo.2016.08.016.

Loewenstein, G. and Thaler, R. 1998. "Anomalies-intertemporal choice." *Journal of Economic Perspectives*, 3(4):181–193. https://doi.org/10.1257/jep.3.4.181.

Lusardi, A., Michaud, P.-C., and Mitchell, O. 2017. "Optimal financial knowledge and wealth inequality." *Journal of Political Economy*, 125(2):431–477. https://doi.org/10.1086/690950.

Lusardi, A. and Mitchell, O. S. 2008. "Planning and Financial Literacy: How Do Women Fare?" *American Economic Review*, 98(2):413–417. https://doi.org/10.1257/aer.98.2.413.

Lusardi, A. and Mitchell, O. S. 2011a. "Financial Literacy and Planning: Implications for Retirement Well-being." In *Financial Literacy: Implications for Retirement Security and the Financial Marketplace*, pages 17–39. Oxford University Press, Oxford and New York. https://doi.org/10.1093/acprof:oso/9780199696819.003.0002.

Lusardi, A. and Mitchell, O. S. 2011b. "Financial literacy and retirement planning in the United States." *Journal of Pension Economics & Finance*, 10(4):509–525. https://doi.org/10.1017/S147474721100045X.

Lusardi, A. and Mitchell, O. S. 2011c. "Financial literacy around the world: An overview." *Journal of Pension Economics & Finance*, 10(4):497–508. https://doi.org/10.1017/S1474747211000448.

Lusardi, A. and Mitchell, O. S. 2014. "The Economic Importance of Financial Literacy: Theory and Evidence." *Journal of Economic Literature*, 52(1):5–44. https://doi.org/10.1257/jel.52.1.5.

Madrian, B. 2014. "Applying Insights from Behavioral Economics to Policy Design." *Annual Review of Economics*, 6:663–688. https://doi.org/10.1146/annurev-economics-080213-041033.

Madrian, B. and Shea, D. 2001. "The power of suggestion: inertia in 401(k) participation and savings behavior." *The Quarterly Journal of Economics*, 116:1149–1187. https://doi.org/10.1162/003355301753265543.

McKinsey & Company 2009. *Unlocking energy efficiency in the US economy*. McKinsey & Company.

Meier, S. and Sprenger, C. 2013. "Discounting financial literacy: time preferences and participation in financial education programs." *Journal of Economic Behavior & Organization*, 95:159–174. https://doi.org/10.1016/j.jebo.2012.02.024.

Mills, B. and Schleich, J. 2014. "Household transitions to energy efficient lighting." *Energy Economics*, 46:151–160. https://doi.org/10.1016/j.eneco.2014.08.022.

Mitchell, O. and Lusardi, A. 2015. "Financial Literacy and Economic Outcomes: Evidence and Policy Implications." *The Journal of Retirement*, 3(1):107–114. https://doi.org/10.3905/jor.2015.3.1.107.

PACFL 2008. President's Advisory Council on Financial Literacy—2008 Annual Report to the President. Technical report, President's Advisory Council on Financial Literacy.

Pearson, G. and Young, A., editors 2002. *Technically Speaking: Why All Americans Need to Know More About Technology*. National Academy Press, Washington D.C.

Pye, S., Dobbins, A., Baffert, C., Brajkovic, J., Grgurev, I., De Miglio, R., and Deane, P. 2015. Energy poverty and vulnerable consumers in the energy sector across the eu: analysis of policies and measures. Technical report, Insight Energy. https://doi.org/10.3917/eufor.378.0064.

Roth, C. E. 1992. Environmental Literacy: Its Roots, Evolution and Directions in the 1990s. ERIC/CSMEE Publications ED348235, ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, OH.

Ruepert, A., Keizer, K., and Steg, L. 2017. "The relationship between Corporate Environmental Responsibility, employees' biospheric values and pro-environmental behaviour at work." *Journal of Environmental Psychology*, 54:65–78. https://doi.org/10.1016/j.jenvp.2017.10.006.

Schneebaum, A. and Mader, K. 2013. The gendered nature of intra-household decision making in and across Europe. Department of Economics Working Paper Series, 157.

Schwartz, S. H. 1981. Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In Zanna, M., editor, *Advances in Experimental Social Psychology*, Vol. 25, pages 1–65. Orlando, FL: Academic Press. https://doi.org/10.1016/S0065-2601(08)60281-6.

Schwartz, S. H. and Howard, J. A. 1981. A normative decision-making model of altruism. In Rushton, J. P. and Sorrentino, R. M., editors, *Altruism and Helping behavior*, page 89–211. Hillsdale: Erlbaum.

Simon, H. 1955. "A behavioral model of rational choice." *The Quarterly Journal of Economics*, 69(1):99–118. https://doi.org/10.2307/1884852.

Simon, H. A. 1959. "Theories of Decision-Making in Economics and Behavioral Science." *The American Economic Review*, 49(3):253–283.

Stadelmann, M. and Schubert, R. 2018. "How do different designs of energy labels influence purchases of household appliances? a field study in Switzerland." *Ecological Economics*, 144:112–123. https://doi.org/10.1016/j.ecolecon.2017.07.031.

Steg, L., Perlaviciute, G., van der Werff, E., and Lurvink, J. 2014. "The Significance of Hedonic Values for Environmentally Relevant Attitudes, Preferences, and Actions." *Environment and Behavior*, 46(2):163–192. https://doi.org/10.1177/0013916512454730.

Taber, K. S. 2018. "The use of cronbachâ€™s alpha when developing and reporting research instruments in science education." *Research in Science Education*, 48(6):1273–1296. https://doi.org/10.1007/s11165-016-9602-2.

Tavakol, M. and Dennick, R. 2011. "Making sense of Cronbach's alpha." *International Journal of Medical Education*, 2:53. https://doi.org/10.5116/ijme.4dfb.8dfd.

Thomas Weyman-Jones, Júlia Mendonça Boucinha, and Catarina Feteira Inácio 2015. "Measuring electric energy efficiency in Portuguese households." *Management of Environmental Quality: An International Journal*, 26(3):407–422. https://doi.org/10.1108/MEQ-03-2014-0035.

Thomson, H., Snell, C., and Bouzarovski, S. 2017. "Health, well-being and energy poverty in europe: A comparative study of 32 european countries." *International Journal of Environmental Research and Public Health*, 14(6):584–603. https://doi.org/10.3390/ijerph14060584.

UNESCO 2006. Education for All, Literacy for Life | Global Education Monitoring Report. Technical report.

U.S. Department of Energy 2017. Energy Literacy-Essential Principles and Fundamental Concepts for Energy Education. Technical report, U.S. Department of Energy.

van den Broek, K. L. 2019. "Household energy literacy: A critical review and a conceptual typology." *Energy Research & Social Science*, 57:1–9. https://doi.org/10.1016/j.erss.2019.101256.

Van der Werff, E., Steg, L., and Keizer, K. 2013. "The value of environmental self-identity: The relationship between biospheric values, environmental self-identity and environmental preferences, intentions and behaviour." *Journal of Environmental Psychology*, 34:55–63. https://doi.org/10.1016/j.jenvp.2012.12.006.

Van Rooij, M. C., Lusardi, A., and Alessie, R. J. 2012. "Financial literacy, retirement planning and household wealth." *The Economic Journal*, 122(560):449–478. https://doi.org/10.1111/j.1468-0297.2012.02501.x.

Wooldridge, J. M. 2002. *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, Massachusetts.

Yamamoto, Y., Suzuki, A., Fuwa, Y., and Sato, T. 2008. "Decision-making in electrical appliance use in the home." *Energy Policy*, 36(5):1679–1686. https://doi.org/10.1016/j.enpol.2008.01.022.