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# The role of energy and investment literacy for residential electricity demand and end-use efficiency*

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**Abstract**

This paper estimates the level of transient and persistent efficiency in the use of electricity in Swiss households using the newly developed generalized true random effects model (GTREM). An unbalanced panel dataset of $1,994$ Swiss households from 2010 to 2014 collected via a household survey is used to estimate an electricity demand frontier function. We further investigate whether energy and investment literacy have an influence on the household electricity consumption. The results show significant inefficiencies in the use of electricity among Swiss households, both transient ($11\%$) and persistent ($22\%$). We note that the high persistent inefficiency is indicative of structural problems faced by households and systematic behavioral shortcomings in residential electricity consumption. These results indicate a considerable potential for electricity savings and thus reaching the reduction targets defined by the Swiss federal council as part of the *Energy Strategy 2050*, wherein end-use efficiency improvement is one of the main pillars. The results support a positive role of energy and, in particular, investment literacy in reducing household electricity consumption. Policies targeting an improvement of these attributes could help to improve efficiency in the use of energy within households.

**Keywords:** Stochastic frontier analysis; Transient and persistent efficiency; Energy literacy; Investment literacy; Energy saving behaviour; Residential electricity demand; Household data

**JEL Classification Codes:** D12, D13, D80, Q41, Q48.

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# 1 Introduction

In Switzerland, electricity is primarily produced by hydropower plants ($60\%$) and nuclear power plants ($40\%$). In 2011, after the Fukushima Daiichi nuclear accident, the Swiss federal council decided to abandon nuclear energy. For this reason, the Swiss federal council developed a new energy policy concept, called *Energy Strategy 2050*. One important goal of this strategy is to reduce electricity consumption by improving the level of efficiency in the use of electricity and to increase the share of electricity produced with new renewable sources of energy such as wind and solar. The efficiency improvement and the development of new renewable sources should, therefore, allow substituting the amount of electricity produced by nuclear power plants. In this context, the residential sector is characterized by great potential for energy efficiency gains and could make an important contribution to a reduction of total end-use electricity consumption.[1]

Against this background, it is important for policy makers to have information on the potential for electricity savings in the residential sector. Moreover, it is important to know which are the determinants that influence the level of efficiency in the use of electricity. A low level of efficiency, as discussed in Filippini and Hunt (2015), may be due to the fact that households do not adopt and use energy efficient appliances or do not use their appliances in an optimal way. For instance, a household might postpone substituting an old and inefficient refrigerator that consumes a lot of electricity, or does not use a cooling system or washing machine in the most efficient way.

The determinants of residential energy efficiency have been widely covered in the economic literature (Gillingham et al., 2009; Allcott and Greenstone, 2012; Frederiks et al., 2015). The potential explanations for an inefficient use of appliances on the one hand and for an under-investment in energy-efficient household appliances on the other can be attributed to either market failures or behavioural failures (Broberg and Kazukauskas, 2015). Market failures that prevent investments in energy-efficient appliances can take the form of information problems (e.g., lack of information and information asymmetries), misplaced incentives and principal-agent problems such as the landlord-tenant problem. But even if these market failures could be overcome, several behavioral failures such as bounded rationality, loss aversion, status-quo bias, risk aversion or inattentiveness potentially reduce the level of efficiency in a household's energy use. All these behavioral failures tend to prevent households from identifying the appliances that minimize lifetime costs or from using the appliances in an efficient way. On the contrary, as shown by Blasch et al. (2016), households that are scoring high with respect to investment and energy literacy seem to be less prone to boundedly rational behaviour.

To our knowledge, relatively few studies have looked into the relationship between energy and investment literacy and residential energy efficiency (for an example, see Brounen et al. (2013)). Investment literacy can be defined as the ability to perform an investment analysis and to calculate the lifetime cost of an appliance or energy-efficient renovation. Energy literacy can be defined as an individual's cognitive, affective and behavioral abilities with respect to energy-related choices. According to DeWaters and Powers (2011), energy literacy comprises an individual's or household's *(1)* knowledge about energy production and consumption and its impact on the environment and society; *(2)* attitudes and values towards energy conservation; and *(3)* corresponding behaviour. In this paper, we therefore put particular emphasis on examining the influence of energy literacy, investment literacy and energy-saving behavior on a household's level of efficiency in the use of electricity.[2]

Hence, in this paper, we provide an answer to the following questions: Which are the factors that influence the electricity demand at the household level? What is the level of efficiency in the use of electricity of Swiss households? How large are the potentials for energy savings in the residential

[1] Although we have sometimes used the general term 'energy' in the discussions, the reader is informed that the analysis in this research refers to 'electricity' consumption at the residential level.

[2] We consider a slightly narrower definition of energy literacy (described in Section 2) in this study.

sector for a given level of energy services? Does a household's level of energy and investment literacy influence its level of efficiency in the use of electricity?

To answer these questions, it is important to remember that a household's energy demand is not a direct demand for energy or electricity, but rather a derived demand for the production of energy services such as warm food, clean clothes and lit rooms. Therefore, behind electricity demand there is a production function. A reduction in energy consumption for the production of a given level of energy services can be achieved either by improving the level of efficiency in the use of inputs (i.e. in the use of appliances), or by adopting a new energy-saving technology (i.e. purchase of new appliances, investments in energy-saving renovations), or both. Technological change can induce a reduction of energy consumption for a given level of energy services, provided that the inputs are used in an efficient way, i.e. given that the households are productively efficient. The total reduction in residential energy consumption is therefore a result of the interplay of technological change and a household's behaviour.[3]

The level of energy efficiency of households can be measured with a bottom-up approach, by making an on-site efficiency analysis of buildings. However, with such an economic-engineering approach, the behavioural aspects in energy use are often not accounted for. In addition, this approach is not based on the microeconomics of production. In this paper, we therefore estimate a household's level of energy efficiency with econometric methods, accounting for total electricity consumption and factors such as the size and characteristics of the dwelling, household composition and other socioeconomic attributes, level of energy services consumed, energy literacy, investment literacy and energy-saving behaviour. With this approach a broader and more adequate bench-marking of Swiss households with respect to their electricity consumption can be performed.

The existing literature on the measurement of the level of energy efficiency in the residential sector using an economic approach is relatively small. While the Stochastic Frontier Analysis (SFA) has been used with aggregated energy data (e.g., Filippini and Hunt (2012); Filippini et al. (2014)), we use dis-aggregated data since residential consumers are typically very heterogeneous and household level data can add more detail to the knowledge of consumer response. Weyman-Jones et al. (2015) are one of the first to estimate energy efficiency using SFA with dis-aggregated household survey data. They estimate an energy input demand frontier function, originally proposed by Filippini and Hunt (2011), using a cross-sectional household dataset from a survey in Portugal. However, the model used by Weyman-Jones et al. (2015) is relatively simple with only a few explanatory variables. In contrast, Boogen (2016) uses a much richer model using not only the information on appliance stock but also on the amount of energy services consumed within a household to estimate the technical efficiency of a set of Swiss households using a sub-vector distance function. However, as Boogen (2016) uses a cross-sectional dataset, the unobserved heterogeneity cannot be accounted for. Moreover, only the level of technical efficiency is estimated. Alberini and Filippini (2015) employ an energy demand frontier approach similar to Weyman-Jones et al. (2015) using a large panel dataset from US households to estimate the level of energy efficiency. By using panel data they are able to distinguish and estimate the level of persistent and transient energy efficiency.[4] The limitation of Alberini and Filippini (2015) is to be unable to use as explanatory variables the amount of energy services consumed by a household.

In this paper, we follow the energy demand frontier approach using an unbalanced panel dataset from 2010 to 2014 of $1,994$ Swiss households. Moreover, using an approach proposed by Coelli et al. (1999), we will also measure the level of efficiency by comparing the electricity consumption of all households to the optimal level obtained from an energy input demand frontier function associated

[3]For a discussion on the concept of energy efficiency based on the production theory and on the measurement methods, see Filippini and Hunt (2015).

[4]The concept of persistent and transient efficiency was introduced by Colombi et al. (2014) and significantly developed by Filippini and Greene (2016).

with a high level of investment literacy.

The contribution of this paper is two-fold: firstly, we estimate the persistent and transient efficiency in electricity consumption of a large sample of Swiss households and demonstrate an application of the newly developed GTREM model (Colombi et al., 2014; Filippini and Greene, 2016) that estimates both types of efficiency conveniently by a simulated maximum likelihood approach. We benefit from a unique panel dataset covering a five-year period collected via a household survey conducted in 2015. The dataset includes information on the level of energy services, which is usually not measured as it can be difficult to collect this information.[5] Information on the level of energy services is a critical issue when using SFA (Filippini et al., 2014). Finally, to our knowledge, this paper is the first one to provide a systematic analysis of the impact of both energy and investment literacy on the total electricity consumption of households while controlling for the effects of the general level of education of the household members. Our results can therefore provide new insights into the interrelations between the three variables and their role for transient and persistent efficiency in residential electricity consumption.

The rest of the paper is organized as follows. Section 2 discusses the role of energy literacy and investment literacy for energy efficiency. Section 3 presents an econometric model of residential electricity demand using dis-aggregated household data and discusses the empirical specifications for estimating the level of efficiency in the use of electricity. Section 4 describes the household survey data and the variables used in the model. Section 5 presents the results and Section 6 concludes.

## 2 Energy and Investment Literacy

Residential energy efficiency is a function of the efficiency of the inputs used to produce a certain energy service (type of appliance) and of the efficiency in the use of these inputs (use of appliance). Both, the choice of electric appliances and the efficiency of their use, are necessarily influenced by the user's knowledge about the baseline energy consumption of an appliance and how it can be steered by a specific user behavior, such as switching it off after use rather than leaving it on stand-by. The choice of appliances requires, in addition, some ability to evaluate different appliances with respect to their lifetime cost, accounting for the initial purchase price and the future spending for its electricity use. This evaluation requires complex calculations that are based on assumptions about the expected lifetime of the appliance, the electricity price now and in the future, as well as on the anticipated intensity of use of the appliance. The decision-maker thus does not only need to dispose of knowledge about the electricity price and the consumption of the appliance but also of the ability to calculate and to compare the net present values of several appliances to choose from (Sanstad and Howarth, 1994a,b; Scott, 1997; Gerarden et al., 2015).

Making these calculations can be burdensome for consumers, as suggested by the results presented in Allcott and Taubinsky (2015). Participants of an online randomized control trial in the US could choose between light bulbs with different levels of energy efficiency. If information about total lifetime cost of the light bulbs was provided, more consumers opted for the more efficient compact fluorescent light bulbs compared to the control condition. Also Blasch et al. (2016) test whether providing consumers with information about the average yearly electricity cost for an appliance increases the probability that they opt for a more efficient appliance. They find a significantly positive relationship between the provision of monetary information on electricity consumption and the probability to perform an investment calculation rather than following a decision-making heuristic, and hence the probability to choose a more efficient appliance. In addition, they also find a positive impact of an individual's level of energy and investment literacy on the choice of the more efficient appliance.

[5] Generally, the energy services are approximated by household characteristics that influence the level of energy services in a household, e.g., in Alberini and Filippini (2015).

A definition of what energy literacy comprises can be found in DeWaters and Powers (2011). According to them, energy literacy entails a cognitive (knowledge), affective (attitudes, values) and behavioral component. In our study, we focus on the cognitive aspect of energy literacy and add the dimension of investment literacy measured by a compound interest rate task. Compound interest rate tasks are frequently used to elicit an individual's level of financial literacy, such as in Lusardi and Mitchell (2009) or Brown and Graf (2013). Lusardi and Mitchell (2009) provide evidence that individuals who know about interest compounding are 15 percentage points more likely to be retirement planners (Lusardi and Mitchell, 2007). Brown and Graf (2013) find in a study on financial literacy in Switzerland that respondents scoring high on financial literacy are more likely to have an investment related custody account and to make voluntary retirement savings. That investment literacy may also be related to the choice of efficient appliances is suggested by results provided in Attari et al. (2010) who show that US citizens with a higher affinity to numerical concepts had more accurate perceptions of the energy consumption of different household appliances than their peers.

Whether, and if yes, how strongly, an individual's energy-related knowledge and ability to make complex calculations eventually impacts on the final energy consumption of the individual's household is an interesting question to ask. If there is a significant influence, educating individuals about energy-related issues and instructing them how to perform an investment calculation would be a potential lever to enhance residential end-use energy efficiency. Nation-wide education campaigns, for example also in schools, could give a strong boost to energy efficiency of households.

So far, only a few studies have investigated the relationship between energy and investment literacy and actual energy consumption of households. As one of them, Brounen et al. (2013) study the influence of energy and investment literacy on conservation behavior of households in the Netherlands. Analysing data from a large national household survey, they find that energy literacy among households is very low. For example, only about half of the respondents are aware of the monthly amount they spend on energy consumption and about 40% were not able to correctly evaluate an investment into new and more energy-efficient equipment. Yet, they do not observe a significant effect of energy literacy on a household's self-reported energy consumption, and also not on a household's choice of the thermostat setting.

Mills and Schleich (2012) analyze how strongly the level of general education influences a household's energy use behavior and adoption of more efficient appliances based on survey data collected in 11 European countries. They observe a significantly positive influence of the level of education of the household head on the adoption of more efficient appliances (measured by an energy-efficient technology adoption index). In addition, they build an energy-use-knowledge index and find that the level of the index rises if the household head holds a university degree and is lowest if the household head holds a vocational degree. University education of the household head also impacts positively on the energy conservation index the authors built. Apart from these studies, Zografakis et al. (2008) report results from a small-scale energy-related information and education project in Greece that impacts positively on stated energy-saving behaviors of students and their parents. Overall, there is thus no conclusive evidence on the role of energy and investment literacy for the total energy consumption of a household, especially if the effect of the general level of education of the household members is accounted for.

## 3 An Econometric Model for Electricity Demand

Within the framework of household production theory, energy demand is derived from the demand for energy services. We assume that households purchase inputs such as energy and capital (household appliances) and combine them to produce outputs which are the desired energy services such as cooked food, washed clothes or hot water – which appear as arguments in the household's utility function (Muth, 1966; Flaig, 1990). Within this theoretical framework, it is possible to derive the optimal input demand functions for energy and capital (Flaig, 1990; Alberini and Filippini, 2011). Conventional theory assumes perfect knowledge of technical relationships and prices, and results in a situation characterized by overall productive efficiency[6] in the production of energy services. In practice, however, inefficiencies in the use of the inputs, i.e. combinations of inputs that do not minimize costs, are likely to occur.

Filippini and Hunt (2011, 2015) propose a non-radial input specific measure of efficiency in the use of energy based on the difference between the optimal use of energy (one which minimizes input costs) and the observed use of energy. In this paper, we follow this approach and estimate a measure of efficiency in the use of electricity based on the estimation of a single conditional input demand frontier function, i.e. the demand function for electricity. The function represents the minimum or baseline electricity demand of a model household that has a highly efficient appliance stock and uses the most efficient production process to produce a given level of energy services, given electricity price, price of capital stock and other factors. If a household is not on the frontier, the distance from the frontier measures the level of inefficiency in the use of electricity. In our empirical work, which uses dis-aggregated data from Swiss households, we posit the following household electricity demand function:

$$\begin{aligned}\ln E_{it} = \alpha_0 + \alpha_p \ln p_{it}^E + \alpha_M M_{it} + \alpha_H H_{it} + \alpha_{AS} AS_{it} + \alpha_{ES} ES_{it} \\ + \alpha_L LOC_{it} + \alpha_w W_{it} + \alpha_{LT} LIT_{it} + \alpha_{BE} BEH_{it} + \alpha_T T_t + \varepsilon_{it}\end{aligned} \tag{1}$$

where $E_{it}$ is the electricity demand (in kWh), $p_{it}^E$ is the electricity price, $M_{it}$ is a vector of household characteristics, $H_{it}$ is a vector of dwelling characteristics, $AS_{it}$ is a vector of special appliance stock, $ES_{it}$ is the amount of energy services consumed, $LOC_{it}$ is the utility service area and $W_{it}$ is the number of heating degree days (HDD) and cooling degree days (CDD) that the household lives in. $LIT_{it}$ represents the level of energy and investment literacy of the respondent, $BEH_{it}$ captures the energy saving behaviour of the household, $T_t$ is the time trend, and $\varepsilon_{it}$ is the overall error term. This equation represents the minimum electricity consumption as a function of electricity price, weather influences, household and dwelling characteristics, stock of special appliances[7], level of energy services, energy and investment literacy, and energy saving behaviour.

In order to obtain the level of efficiency in the use of energy, we estimate Eq. (1) using the stochastic frontier function approach introduced by Aigner et al. (1977). Traditionally, the SFA approach has been used in production theory to empirically assess the economic performance of production processes. The basic idea is that the frontier function estimates the maximum (or minimum) level of an economic indicator reachable by a decision making unit, e.g., a firm or an economic agent like a household. In the case of residential electricity consumption, the frontier gives the minimum level of electricity input used by a household for any given level of energy services. The difference between the observed input and the optimal input demand on the frontier represents inefficiency. Furthermore, the difference between the observed input and the cost-minimizing input demand on the frontier depicts both technical as well as allocative inefficiency (Kumbhakar and Lovell, 2000).

In the SFA approach the so called error term $\varepsilon_{it}$ is composed of several components. One of these is a symmetric disturbance capturing the effect of noise assumed to be normally distributed as usual. The other components, discussed in details in Section 3.1, are interpreted as an indicator of the inefficient use of electricity at the household level.

[6] As defined by Farrell (1957).

[7] Equation (1) should be interpreted as a long-run electricity demand function, because the capital stock can vary. We just include a few variables to take into account the presence of a second fridge, a separate freezer, and whether or not the household owns a special appliance, such as a sauna. Further, the price for appliances is assumed to be the same for all households.

### 3.1 Estimation Methodology

There are several econometric models available for estimating a stochastic frontier model using panel data. Below we briefly mention some of the most commonly used models used in empirical analysis.

The first is the basic random effects model by Pitt and Lee (1981) (REM hereafter). Next is the true random effects model (TREM hereafter) proposed by Greene (2005a,b) and the third is the generalized true random effects model (GTREM hereafter) by Colombi et al. (2014) and Filippini and Greene (2016).[8] As discussed in Filippini and Greene (2016), some of these models estimate time invariant values of the level of efficiency (persistent efficiency) whereas others produce time variant values (transient efficiency).

The REM by Pitt and Lee (1981) overestimates the level of inefficiency since it regards any time-invariant and group-specific unobserved heterogeneity as inefficiency. The REM does not provide an estimation of the time-varying transient inefficiency indicator. On the other hand, the TREM model by Greene (2005a,b) controls for time-invariant unobserved heterogeneity, but any time-invariant component of inefficiency is then completely absorbed in the household-specific constant terms. Hence this model tends to underestimate the level of inefficiency and as such gives only a measure of the transient inefficiency and not of any time-invariant persistent inefficiency.

In the context of a household, the persistent inefficiency component might relate to the presence of structural problems in the production process of energy services like old electrical appliance stock or old buildings with very poor insulation. It might also relate to systematic behavioural shortcomings like frequently opening the windows and not switching off lights after use. Similarly, the transient inefficiency part might point towards the presence of non-systematic behavioural failures that could be solved in the short term, e.g., the use of an additional cooling appliance for a few weeks during a hot summer, or the temporary presence of guests visiting the household, hence increasing the demand for energy services temporarily.[9]

This paper focuses on the third and the most recent model, the GTREM, which offers the possibility to simultaneously estimate the persistent and transient parts of inefficiency. Colombi et al. (2014) provided a theoretical construct that distinguishes between persistent and transient inefficiency and Filippini and Greene (2016) have developed a straightforward empirical estimation method for the GTREM by exploiting the Butler and Moffitt (1982) formulation in the simulation. The GTREM is obtained by adding to the TREM model a time persistent inefficiency component in the time varying stochastic frontier.

As shown in Table 1, this model has a four-part disturbance term with two time-variant and two time-invariant components. One of these components ($h_i$) captures the persistent inefficiency in the use of energy that may be due to regulations, investments in inefficient appliances or buildings, or habits and consumption behaviours that tend to waste energy. Another component ($u_{it}$) captures the transient inefficiency that may be, e.g., due to non-optimal use of some electrical appliances or heating systems. In the short run, even in the presence of some inflexibility, a household may be able to adjust the use of appliances and heating systems. The remaining two components are assumed to be normally distributed and they respectively represent a symmetric disturbance capturing the effect of noise ($\nu_{it}$) and time-invariant household specific effects ($w_i$).

[8] See Tsionas and Kumbhakar (2014) and Filippini and Greene (2016) for an overview of all these models. The reader is also referred to Filippini and Hunt (2015) which provides a summary of different econometric specification and comparison between these models.

[9] Although such a distinction between transient and persistent inefficiency has been partially neglected in empirical studies, we believe it will gain much more importance in future research. This distinction is crucial with respect to the choice of policy instruments to improve end-use energy efficiency.

**Table 1:** The GTREM specification for the stochastic cost frontier

| | |
|---|---|
| Model: | $y_{it} = \alpha_i + \beta' \mathbf{x}_{it} + \varepsilon_{it}$ |
| Full random error ($\varepsilon_{it}$): | $\begin{cases} \varepsilon_{it} = w_i + h_i + u_{it} + \nu_{it} \\ u_{it} \sim N^+[0, \sigma_u^2] \\ h_i \sim N^+[0, \sigma_h^2] \\ \nu_{it} \sim N[0, \sigma_\nu^2] \\ w_i \sim N[0, \sigma_w^2] \end{cases}$ |
| Noise: | $N(0, \sigma_\nu^2)$ |
| Household specific effects: | $N(\alpha, \sigma_w^2)$ |
| Persistent inefficiency estimator: | $\mathrm{E}(h_i \vert \mathbf{y}_i)$ |
| Transient inefficiency estimator: | $\mathrm{E}(u_{it} \vert \mathbf{y}_i)$ |

The approach used here therefore relies on the approximation of the level of the energy efficiency of Swiss households by two one-sided non-negative terms, $u_{it}$ and $h_i$. In order to estimate these two error terms, one makes use of maximum likelihood techniques.[10]

Following Filippini and Greene (2016), the level of efficiency in the use of electricity can be expressed in the following way:

$$EF_{it} = \frac{E_{it}^F}{E_{it}} \tag{2}$$

where $E_{it}$ is the observed electricity consumption and $E_{it}^F$ is the frontier or minimum demand of household $i$ in year $t$. An electricity efficiency level of one indicates a household on the frontier, thereby implying an efficiency level of 100%. Households that are not located on the frontier receive efficiency scores below one, thereby implying the presence of inefficiency in household electricity consumption.

## 4 Data

The data for this research was gathered by means of a large household survey in cooperation with six Swiss utilities.[11] Utilities operating in urban and suburban areas were selected in order to get a sample of household as homogeneous as possible in terms of environment. The participating utilities invited either all or a sub-sample of their customers to take part in an online survey. If sub-samples of customers were drawn, all household customers had the same probability of being in the sample. The invitation was sent either separately or in the form of a letter that accompanied a bi-monthly, quarterly or yearly electricity or gas bill.[12]

The survey questionnaire was developed based on insights from the survey methodology literature

[10] These estimation procedures are readily available in `STATA` (Belotti et al., 2012) and `NLOGIT` (Greene, 2012). In this paper, the models were estimated using `NLOGIT`.

[11] The six utilities are Aziende Industriali di Lugano (AIL), IBAarau (IBA), Stadtwerk Winterthur (SW), Energie Service Biel/Bienne (ESB), Energie Wasser Luzern (EWL), Aziende Municipalizzate Bellinzona (AMB) that operate respectively in (and the surrounding areas of) Lugano, Aarau, Winterthur, Biel/Bienne, Lucerne and Bellinzona. Among these regions, Aarau, Winterthur and Lucerne are German speaking; Lugano and Bellinzona are Italian speaking; and Biel/Bienne is bilingual (German/French speaking).

[12] The response rates (defined as share of survey page visits over total number of invited customers) varied between 3.2% and 7.4%.

(Dillman et al., 2009; Groves, 2004), reviewed by several experts in the field of residential energy-efficiency and pre-tested on a student sample. It included questions on dwelling characteristics, socio-economic attributes, appliance stock and the level of energy services consumed by the household. In addition, the survey comprised questions about the respondents' environmental attitudes, energy saving behaviour at home, energy-related literacy and investment literacy.

At the end of the survey questionnaire, sociodemographic characteristics such as age, gender, employment status and level of education of the respondent were recorded. On completion, respondents were asked whether they agreed that the survey data be linked to the actual energy consumption data of their household. In case of the consumer's accordance, the actual electricity (and if applicable, also gas) consumption data from 2010 to 2014 was linked to the survey data of the respective household to allow a joint analysis. The variables used for the household electricity demand estimation are explained below and an overview of the summary statistics can be found in Table 2.

*Dwelling Characteristics*

The residence-related attributes comprise non-varying features of the dwelling like the area size in square meters (`SQM`), the time-period when the building was built[13], a dummy indicating whether the dwelling is built according to the Minergie standard, a standard for efficient buildings in Switzerland, (`MINERGIE`)[14] and another binary variable captures whether the household uses electricity for cooking (`COOKEL`). It is also known in which of the six utility service areas the dwelling is located.

*Household composition and Socioeconomic attributes*

With respect to household composition, our data set includes information on the presence of children/teens younger than 20 years (`HAS_YOUN`), or elderly person above 64 years (`HAS_ELDE`) in the household at the end of the year 2014. The total number of people who have regularly lived in the residence between 2010 and 2014 (i.e. yearly household size `HHSIZE`) is accounted for. Furthermore, the households reported the average number of weeks per year in which their residence remains unoccupied, e.g., due to longer work-related assignments, vacations or stays at a second home. Finally, with respect to the level of education, we also capture whether the survey respondents (`UNIV`), as well as their partners (`UNIV_PAR`), hold a university degree.[15]

Monthly gross household income is captured by dummies representing three income classes: less than CHF $6,000$ (`INC6K` as reference); between CHF $6,000$ to $12,000$ (`INC6_12K`); and more than CHF $12,000$ (`INC12K`).

*Energy services and Appliance stock*

Information on the consumption level of several energy services is available – number of warm meals prepared per week (`NMEALS`) which is the sum of total number of prepared lunches and dinners in a typical week; number of dishwasher cycles in a typical week (`NDISHWCY`); number of washing-related cycles per week (`NWASHING`), which is the sum of total number of washing machine and clothes dryer cycles in a typical week; number of entertainment services consumed per day (`NENTT`) which is the sum of total hours of typical daily usage of all the TVs (CRTs and flat-screens) and computers (desktops and laptops) within the residence.

Two dichotomous variables represent if the household own a second fridge (`HAS_FR2`) or a separate freezer (`HAS_FREEZER`). Another binary variable captures whether the household owns a special

[13]In four categories: before 1940 (`BLT1940`) as reference; 1940–1970 (`BLT1970`); 1970–2000 (`BLT2000`) & after 2000 (`BLT2015`).

[14]The Minergie certificate can be acquired not only for new buildings but also for renovated buildings.

[15]`UNIV` and `UNIV_PAR` is $1$ if a person holds a degree from a university, university of applied sciences or university of teacher education.

energy intensive appliance or equipment like an air-conditioner.[16]

*Weather*

The yearly weather related information comprises of the total number of heating degree days (HDD) and cooling degree days (CDD) which is measured at a weather station that is located in, or nearby, each of the six different service regions.[17]

*Electricity consumption*

The yearly electricity consumption (response variable Q_E) ranges from $501$ kWh to $38,124$ kWh, with a mean value of about $3,123$ kWh.[18] The residential sector can be highly heterogeneous in terms of electricity consumption. For example, dwellings with electricity based space or water heating system would be expected to consume much larger amounts of electricity compared to the dwellings using oil or gas based heating. Since we are interested in measuring the *inefficiency in the use in electricity*, households having an electricity-based space or water heating system (including heat pumps) were excluded from the sample as these would exhibit significantly higher electricity consumption than households with non-electricity-based heating systems.

The electricity price during the period 2010–2014 is measured as an average of the peak and off-peak marginal prices using the average time-of-use share of peak consumption as weight.[19]

From the sample, we also exclude the households who reported that on average their residence in completely unoccupied either for more than 8 weeks a year, or for more than 4 days a week (e.g., due to regular travel for work). Lastly, we have an unbalanced panel data comprising of households for which electricity consumption in the same residence for at least 2 out of the 5 time periods from 2010 to 2014 is available.

*Energy and Investment literacy*

Energy literacy was measured by an index that accounts for several dimensions of energy literacy: knowledge of the average price of 1 kWh of electricity in Switzerland, knowledge of the usage cost of different household appliances (running a PC for one hour, running a washing machine cycle with full load) as well as knowledge of the electricity consumption of various household appliances. For example, respondents were given two energy services and were asked which of the two consumed more electricity or whether they consumed about the same, e.g., boiling 1 litre of water on a stove compared to boiling 1 litre of water using an electric kettle. Responses to all these questions were combined into a simple measure of energy literacy by assigning a certain amount of points for each correct answer. Depending on the number of correctly answered questions, respondents could achieve a value between $0$ and $11$ on the energy literacy score (ENLIT).

Investment literacy (INVLIT) was measured by a binary variable that takes the value one if the

[16] The variable NONE_APPL takes the value $1$ if a household reports that it does not own any of these appliances: Home theater system, Electric/Hybrid Car, Swimming pool, Jacuzzi, Sauna, Solarium, Water-bed, Aquarium/Terrarium, Air Conditioner(AC) or Infra-red heater.

[17] HDD and CDD data is gathered from *MeteoSchweiz* and is based on SIA (1982) and ASHRAE (2001) respectively.

[18] Given the context of household electricity consumption, we impose a minimum yearly consumption of $500$ kWh.

[19] The yearly marginal electricity prices were obtained from the tariff-sheets of each of the six utilities in our sample. In order to avoid any endogeneity problems, instead of individual share of peak consumption (i.e. $[{}^{E_{peak}}/_{E_{total}}]_{it}$), we use a representative mean value of the share of peak consumption over 8 household categories (defined by ELCOM) across the 6 regions and from 2010 to 2014 ($\overline{TOU}_{peak}$). For customers on a peak/off-peak tariff system, we used $p^E_{it} = \overline{TOU}_{peak} \cdot MP_{peak} + (1 - \overline{TOU}_{peak}) \cdot MP_{off-peak}$ and for those on a single tariff, the marginal price was used directly.

**Table 2:** Summary statistics (unbalanced panel of $1,994$ households)

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| *Panel variables...* | | | | | |
| Q_E | 3122.77 | 2326.19 | 501 | 38124 | 8295 |
| MP_AVG | 18.68 | 2.47 | 13.06 | 24.32 | 8295 |
| HHSIZE | 2.36 | 1.19 | 1 | 6 | 8295 |
| INC6K | 0.3 | 0.46 | 0 | 1 | 8295 |
| INC6_12K | 0.52 | 0.5 | 0 | 1 | 8295 |
| INC12K | 0.18 | 0.39 | 0 | 1 | 8295 |
| HDD | 2949.75 | 386.83 | 1925.6 | 3602.2 | 8295 |
| CDD | 177.31 | 86.79 | 73 | 458.6 | 8295 |
| IS_SFH | 0.29 | 0.46 | 0 | 1 | 8295 |
| SQM | 122.69 | 54.41 | 20 | 400 | 8295 |
| BLT1940 | 0.19 | 0.39 | 0 | 1 | 8295 |
| BLT1970 | 0.26 | 0.44 | 0 | 1 | 8295 |
| BLT2000 | 0.37 | 0.48 | 0 | 1 | 8295 |
| BLT2015 | 0.17 | 0.38 | 0 | 1 | 8295 |
| MINERGIE | 0.07 | 0.26 | 0 | 1 | 8295 |
| WABS5TO8 | 0.08 | 0.27 | 0 | 1 | 8295 |
| HAS_FR2 | 0.19 | 0.39 | 0 | 1 | 8295 |
| HAS_FREEZER | 0.53 | 0.5 | 0 | 1 | 8295 |
| NONE_APPL | 0.68 | 0.46 | 0 | 1 | 8295 |
| COOKEL | 0.89 | 0.31 | 0 | 1 | 8295 |
| LUG | 0.26 | 0.44 | 0 | 1 | 8295 |
| AAR | 0.11 | 0.31 | 0 | 1 | 8295 |
| WINT | 0.13 | 0.34 | 0 | 1 | 8295 |
| BIEL | 0.18 | 0.39 | 0 | 1 | 8295 |
| LUZ | 0.24 | 0.42 | 0 | 1 | 8295 |
| BELL | 0.08 | 0.27 | 0 | 1 | 8295 |
| UNIV | 0.36 | 0.48 | 0 | 1 | 8295 |
| UNIV_PAR | 0.17 | 0.38 | 0 | 1 | 8295 |
| *Cross-sectional variables (2014) ...* | | | | | |
| HAS_YOUN | 0.23 | 0.42 | 0 | 1 | 1994 |
| HAS_ELDE | 0.31 | 0.46 | 0 | 1 | 1994 |
| NMEALS | 8.52 | 3.41 | 0 | 14 | 1994 |
| NDISHWCY | 2.99 | 2.32 | 0 | 8 | 1994 |
| NWASHING | 3.04 | 3.82 | 0 | 30 | 1994 |
| NENTT | 6.57 | 4.99 | 0 | 44 | 1994 |

respondent correctly solved a compound interest rate calculation. Compound interest rate calculations are usually used to assess an individual's investment literacy (Lusardi and Mitchell, 2007, 2009; Brown and Graf, 2013).

Similar to findings reported in the study of Brounen et al. (2013), we observe a rather low level of energy literacy in our sample. For example, only about $27\%$ of the respondents knew about the average price of electricity in Switzerland. Regarding the level of investment literacy among Swiss consumers, we find that $71\%$ of the participants in our survey were able to correctly solve the compound interest calculation.

*Energy-saving behaviour*

One section of the survey asked respondents whether they exercised certain energy-saving behaviours when consuming energy services at home. The respondents had to indicate their agreement on a 5-point likert scale ranging from 'strongly disagree' to 'strongly agree' with respect to these behaviours – completely switching off electronic appliances after use (no standby); running the washing machine only on full load; washing clothes on a lower water temperature of less than 30°C; and selecting a dishwasher program cycle based on the level of dirtiness. From these four types of energy-saving behaviour we calculated an index score. The household received one index point for each of these behaviours if they stated that they exercised this behaviour 'always' or 'very often'. Therefore, the values of the score lie within the range from 0 to 4 points (BEHAV).

An overview of the energy-saving behaviour score, the energy literacy score and investment literacy can be found in Table 3. The survey questions are presented in the Appendix.

**Table 3:** Overview of energy literacy, investment literacy and energy saving behaviour

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| ENLIT | 4.39 | 2.84 | 0 | 11 | 1994 |
| INVLIT | 0.71 | 0.45 | 0 | 1 | 1994 |
| BEHAV | 2.35 | 1.05 | 0 | 4 | 1994 |

# 5 Empirical results

Results for two model specifications are presented in Table 4. GTREM-1 presents estimation results for the electricity input demand frontier function defined in Eq. (1), whereas GTREM-2 presents a more traditional model without any energy services. Both specifications include energy literacy, investment literacy and the energy saving behaviour of the households. The traditional specification that does not include information on energy services should lead to a lower level of energy efficiency. In fact, within this model, the households that consume a relatively high amount of energy services are less efficient than the households that consume a lower amount of energy services. This is of course not an appropriate assessment, as the fact that a household consumes more energy services could be due to special preferences and needs. In this paper, we are mainly interested in estimating the level of efficiency in the use of energy among households that consume a similar amount of energy services.

Most estimated coefficients have the expected signs and are seen to be statistically significant at the 1% level. The parameter $\lambda$, which represents the relative contribution of the transient inefficiency term over the complete disturbance term, is significant in both specifications. Further, $\sigma_h$, the standard deviation of the one-sided time-invariant component $h_i$ is also significant. This result shows the presence of persistent inefficiency. Since we use a log-log functional form for the total electricity demand and other continuous variables in the model, the estimated coefficients on such variables can be interpreted as demand elasticities, e.g., the price elasticity is found to be statistically significant and negative.

Electricity consumption increases with dwelling size and single family houses have higher electricity consumption than households living in apartments. Compared to the buildings built before 1940 (reference category), newly built houses generally consume lower electricity, with the exception of those built between the years 1970 and 2000.

Table 4: Estimation results

| | GTREM-1 | | GTREM-2 | |
|---|---|---|---|---|
| | *Coefficient* | *Std. error* | *Coefficient* | *Std. error* |
| LNP_E | $-.280\,83$*** | .03653 | $-.121\,36$*** | .03253 |
| IS_SFH | $.173\,78$*** | .00729 | $.229\,07$*** | .00652 |
| LN_HS | $.341\,06$*** | .01109 | $.435\,23$*** | .00956 |
| LN_SQM | $.386\,84$*** | .00885 | $.451\,30$*** | .00795 |
| HAS_YOUN | $-.038\,63$*** | .00794 | $-.032\,77$*** | .00708 |
| HAS_ELDE | $.037\,56$*** | .00581 | $.050\,70$*** | .00526 |
| INC6_12K | $-.009\,35$ | .00591 | $.002\,42$ | .00559 |
| INC12K | $-.013\,51$ | .00871 | $.000\,49$ | .00796 |
| BLT1970 | $-.076\,57$*** | .00772 | $-.039\,15$*** | .00696 |
| BLT2000 | $.047\,08$*** | .00737 | $.095\,40$*** | .00657 |
| BLT2015 | $-.053\,95$*** | .00912 | $.038\,98$*** | .00815 |
| MINERGIE | $.025\,33$** | .01016 | $.044\,05$*** | .00924 |
| WABS5TO8 | $-.143\,62$*** | .00894 | $-.053\,83$*** | .00837 |
| HAS_FR2 | $.103\,98$*** | .00676 | $.121\,68$*** | .00610 |
| HAS_FREEZER | $.113\,84$*** | .00547 | $.105\,11$*** | .00500 |
| NONE_APPL | $-.081\,21$*** | .00572 | $-.075\,61$*** | .00517 |
| LNMEALS | $.002\,44$ | .00613 | — | — |
| LNDISH | $.116\,74$*** | .00412 | — | — |
| LNWASHIN | $.102\,72$*** | .00354 | — | — |
| LNENTT | $.172\,83$*** | .00423 | — | — |
| COOKEL | $.098\,59$*** | .00840 | $.146\,54$*** | .00740 |
| LNHDD | $.386\,54$*** | .06743 | $.376\,11$*** | .05450 |
| LNCDD | $-.052\,76$** | .02455 | $-.073\,01$*** | .01932 |
| AAR | $-.028\,01$** | .01396 | $-.006\,18$ | .01230 |
| WINT | $.067\,08$*** | .02352 | $.123\,25$*** | .01890 |
| BIEL | $-.030\,15$* | .01590 | $-.101\,54$*** | .01300 |
| LUZ | $-.120\,71$*** | .01083 | $-.243\,65$*** | .00926 |
| BELL | $.079\,74$** | .03670 | $.008\,49$ | .02871 |
| UNIV | $-.014\,54$*** | .00555 | $-.051\,45$*** | .00509 |
| UNIV_PAR | $-.018\,88$*** | .00688 | $-.015\,64$** | .00639 |
| LNENLIT | $-.012\,68$*** | .00397 | $-.010\,68$*** | .00380 |
| INVLIT | $-.112\,22$*** | .00554 | $-.085\,94$*** | .00504 |
| LNBEHAV | $-.024\,91$*** | .00673 | $-.031\,77$*** | .00603 |
| T | $.015\,97$*** | .00206 | $.018\,67$*** | .00182 |
| $\alpha_i$ | $2.790\,94$*** | .48053 | $2.717\,78$*** | .39277 |
| $\sigma_w$ | $.397\,31$*** | .00240 | $.397\,07$*** | .00212 |
| $\sigma_{(\nu+u)}$ | $.253\,88$*** | .00295 | $.384\,73$*** | .00252 |
| $\lambda$ | $.740\,05$*** | .04176 | $3.806\,71$*** | .11065 |
| $\sigma_h$ | $.552\,99$*** | .01733 | $.752\,34$*** | .01101 |
| Observations: | 8295 | | 8295 | |
| Log Likelihood: | -1763.497 | | -2156.834 | |

***, **, * $\Rightarrow$ Significance at 1%, 5%, 10% level.

Electricity consumption also increases with household size. Households, in which elderly people of 60 years or older are present, tend to consume more electricity, whereas households with children consume less. Income levels are found to be insignificant when accounting for all other variables included in the model.

The coefficients for the presence of a second fridge or a separate freezer are positive and significant. Electricity consumption is higher for higher levels of energy services with stronger effects for entertainment services (TVs and Computers), followed by dishwashers, and washing services. The preparation of warm meals does not appear to be significant, although using electricity as the energy source for cooking is naturally associated with a higher demand for electricity.

Using the region of Lugano as the reference, it appears that households in the region of Lucerne consume significantly less electricity, whereas households in the region of Winterthur consume more. In terms of weather, we observe that HDD naturally show a much stronger effect on consumption than CDD, as people might stay indoors (hence consuming more electricity) during winter as compared to the summer months. The coefficient that captures the time trend is positive, which indicates an overall rising trend in household electricity consumption from 2010 to 2014.

In both specifications, the estimates of the energy literacy score, investment literacy and behavioural index are negative and significant. This means that for households exhibiting energy-saving behaviour, electricity consumption is seen to be lower. Similarly, households possessing a higher level of energy-related literacy and investment literacy are also associated with lower electricity consumption, although investment literacy seems to play a more vital role.[20] As discussed later in this section in detail, the fact that households with a high level of investment literacy consume (ceteris paribus) less electricity, implies that it is possible to identify different demand frontier functions *conditional* on the level of investment literacy.

*Level of Efficiency*

Using the estimations above and Eq. (2), we can estimate the level of efficiency. Table 5 provides summary statistics of the estimated efficiency levels for the two GTREM specifications.

**Table 5:** Efficiency scores (transient and persistent)

| *Efficiency type* | *Median* | *Mean* | *Std. Dev.* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|
| **GTREM-1** (with energy services) | | | | | |
| Transient | 0.896 | 0.893 | 0.026 | 0.625 | 0.974 |
| Persistent | 0.783 | 0.782 | 0.013 | 0.392 | 0.838 |
| **GTREM-2** (without energy services) | | | | | |
| Transient | 0.807 | 0.773 | 0.119 | 0.168 | 0.973 |
| Persistent | 0.768 | 0.767 | 0.018 | 0.317 | 0.932 |

In GTREM-1, the short-run or the transient part of the efficiency in residential electricity consumption is found to be between $62.5\%$ and $97.4\%$, with a mean value of about $89.3\%$. The long-run component representing the persistent part of the efficiency ranges from $39.2\%$ to $83.8\%$ and has a mean value of $78.2\%$.

In GTREM-2, which is a more traditional SFA model without any energy services, the mean level of

[20]It needs to be stated that, in the literature on stochastic frontier analysis, it is possible to find econometric models that assume that the energy and investment literacy variables explain the level of efficiency in the use of electricity instead of directly the demand for electricity as in Eq. (1). This would mean that the one-sided error terms $h_i$ and $u_{it}$ are functions of `ENLIT` and `INVLIT`. Unfortunately, such an estimation strategy within the econometric approach proposed by Filippini and Greene (2016) is relatively complicated and currently it is not implemented for GTRE. As a robustness check, we decided to estimate Eq. (1) using some econometric models that do not distinguish between the two components of inefficiency (transient and persistent) but allow the level of inefficiency to be a function of `ENLIT` and `INVLIT`. For this purpose, we decided to use the REM (Pitt and Lee, 1981), Battese and Coelli (Battese and Coelli, 1995), and TREM (Greene, 2005a,b); both energy and investment literacy were found to be significant in explaining the level of efficiency.

transient efficiency is observed to be at $77.3\%$, and the level of persistent efficiency at $76.7\%$. When comparing these values to that of GTREM-1, higher levels of transient and persistent efficiency in GTREM-1 indicate that the inclusion of energy services helped explaining part of the error terms that are used to calculate the efficiency values.

Persistent efficiency is observed to be lower both in terms of the mean value and the variance in both specifications, implying that inefficiencies are seen to be higher in the long-run. This high value of inefficiency is indicative of structural problems faced by Swiss households, which probably rely on an old appliance stock within their homes. Moreover, this also possibly points to systematic behavioural shortcomings in terms of consumption of energy services.

The efficiency levels presented above indicate that there is a high potential for the Swiss residential sector in the urban and sub-urban areas to save energy. In fact, households could save as much as $22\%$ of their electricity usage in the long-run if they could improve on systematic and structural inefficiencies. With the reduction of transient inefficiencies in the short-run, the potential to save electricity is up to $11\%$.

*Level of Efficiency conditional on level of Investment Literacy*

In the context of residential electricity demand and given the discussion on stochastic frontier models, it is interesting to note that one could identify several frontiers. For example, structural frontiers may exist based on building-age wherein dwellings built in two different time-periods represent different reference frontiers.

Similarly, considering the level of investment literacy in our specification which is represented by a dummy, one could identify two distinct best practice frontiers – with, and without high investment literacy. The inefficiency values given by the estimation is conditional on their respective best practice frontiers (*net inefficiency*). Moreover, the inefficiency resulting as a consequence of the distance between the two frontiers can be measured by the coefficient on the dummy variable capturing investment literacy which indicates the difference in the level of efficiency in the use of electricity conditional on the level of investment literacy.[21] Given the *net inefficiencies* and the coefficient on the dummy variable, one can obtain a measure of *gross inefficiencies* by comparing every household to the most favorable frontier (Coelli et al., 1999).

Table 6 shows the mean gross and net efficiency levels for both GTREM specifications. Gross efficiency levels are seen to be significantly lower which emphasizes the role of investment literacy on the level of efficiency in the use of electricity.

**Table 6:** Mean efficiency conditional on investment literacy

| | **GTREM-1** | | **GTREM-2** | |
|---|---|---|---|---|
| | *Net-eff* | *Gross-eff* | *Net-eff* | *Gross-eff* |
| Transient | 0.893 | 0.798 | 0.773 | 0.709 |
| Persistent | 0.782 | 0.699 | 0.767 | 0.704 |

[21] Of course, we are aware that it could be interesting to estimate the level of efficiency in the use of electricity conditional on the level of energy literacy. However, due to the fact that the level of energy literacy is not measured with a dummy variable, the definition of the reference frontier is not straightforward.

# 6 Conclusions

A household's energy demand is not a demand for energy per se but a derived demand for energy services, such as cooling, heating, cooking and lighting. A reduction in energy consumption for the production of a given level of energy services can be achieved by either improving the level of efficiency in the use of inputs (i.e. in the use of appliances), by adopting a new energy-saving technology (i.e. purchase of new appliances, investments in energy-saving renovations) or by both processes. Technological change can induce a reduction of energy consumption for a given level of energy services, provided that the inputs are used in an efficient way, i.e. given that the households are productively efficient. The total reduction in residential energy consumption is therefore a result of the interplay of technological change and a household's behaviour.

To measure this inefficiency in the use of electricity in Swiss households, we estimate a stochastic frontier model for residential electricity demand. We use data from a Swiss household survey conducted in 2015 that collected panel data over five years. The dataset includes information on the level of energy services, which is crucial, but often difficult to measure. The generalized true random effects model (GTREM) is used to estimate the transient and persistent levels of efficiency in the use of electricity. The median persistent inefficiency is found to be around $22\%$ whereas the transient inefficiency is seen around $11\%$. These results suggest that there is a considerable potential for saving electricity and thus reaching the reduction target defined by the Swiss federal council as part of the *Energy Strategy 2050*.

We further investigate if energy literacy, investment literacy and energy-saving behaviour have an influence on the household electricity consumption. We construct a score on energy literacy, a binary variable for investment literacy, and an index that aggregates several energy saving behaviours and included these in our GTREM specification. The results show that for households exhibiting energy saving behaviour, electricity consumption is seen to be lower. Similarly, households possessing a higher energy literacy or investment literacy are also associated with lower electricity consumption.

From the point of view of policy makers, we note that the high persistent inefficiency is indicative of structural problems faced by households and systematic behavioral shortcomings in residential electricity consumption. The results presented here indicate a positive role of energy literacy, investment literacy and energy-saving behaviour in reducing household electricity consumption and perhaps addresses part of the systematic behavioural failure exhibited by households. Policies that target an improvement of energy literacy, investment literacy and promote energy-saving behaviour among the Swiss population could help in improving efficiency in the use of energy within households, which could prove much more beneficial in the long run. Finally, we emphasize again that clear distinction has to be made between the persistent and transient inefficiencies faced by households in order to appropriately channel the relevant policy measures. For instance, energy policy measures that try to promote energy saving (such as an information campaign) or try to increase the level of energy literacy (such as distribution of information leaflets and booklets among households) will probably have an impact on the level of transient efficiency. On the other hand, policy measures that try to improve the level of investment literacy, such as short courses in investment or web-pages and mobile-apps that help to calculate the life-cycle cost of appliances, could have an impact on the buying process of appliances, and therefore, on the level of persistent efficiency.

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# Appendix

**How much do you think 1 Kilowatt hour (kWh) of electricity currently costs in Switzerland (on average)?**
Please indicate your best guess without checking your bill or other resources.

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

**Figure 1:** Energy-related literacy question on the price of 1 kWh of electricity.

**How much do you think it costs in terms of electricity to run:**

| Amount in Rappen / Centimes: | 0-19 | 20-39 | 40-59 | 60-79 | 80-100 | More than 100 | Don't know |
|---|---|---|---|---|---|---|---|
| a desktop PC for 1 hour | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| a washing machine (load of 5 kg at 60ºC) | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Figure 2:** Energy-related literacy questions on monetary cost of energy services.

**In the following pairs, which of the two consumes more electricity?**

**Pair 1:**

- Bringing 1 litre of water to a boil in an average pot with lid
- Running a washing machine with a load of 5kg at 60ºC
- Both consume about the same
- Don't know

**Pair 2:**

- Bringing 1 litre of water to a boil in an average pot with lid
- Bringing 1 litre of water to a boil in an electric kettle
- Both consume about the same
- Don't know

**Pair 3:**

- Running a desktop PC for 1 hour
- Running a laptop for 1 hour
- Both consume about the same
- Don't know

**Figure 3:** Energy-related literacy questions on comparison of electricity consumption of appliances.

*Let's say you have 200 CHF in a savings account. The account earns 10% interest per year.*

**How much would you have in the account at the end of 2 years?**

- ○ 220 CHF
- ○ 240 CHF
- ○ 242 CHF
- ○ 204 CHF
- ○ Don't know

**Figure 4:** Survey question on mathematical/investment literacy.

**How regularly do you and other members of your household perform the following activities in your daily life?**

| | Never | Rarely | Sometimes | Very often | Always | Don't know | N/A |
|---|---|---|---|---|---|---|---|
| Running only full loads when using the washing machine | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Washing clothes using 30°C or less rather than higher temperatures | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Completely switching off electronic devices (TV, computer) [no standby] | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Choosing different program of dishwasher depending on level of dirtiness of the dishes | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Figure 5:** Survey questions on energy-saving behaviour.

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