Changing energy efficiency technology adoption in households

D 7.1 Draft report on policy implications from the micro-level analysis

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1 Objective

This report is submitted as deliverable 7.1 in the CHEETAH project with the aim of summarizing the policy recommendations derived from the micro-level analysis that was conducted as part of work package 4.

The CHEETAH project has the objectives of providing evidence-based input to energy efficiency policy-making by investigating the role of policy in household energy efficiency decision-making on three levels:

1) On the micro level, the project provides empirical evidence of household energy-efficiency technology choices and responses to policy employing large-sample household surveys in eight EU member states and micro-econometric analyses based on stated preferences discrete choice experiments

2) On the meso level, the project explores the impact of policies affecting household energy efficiency decision-making in the residential sector in Europe up to 2030. The project uses inputs from the micro-level analysis in order to improve the representation of investment decisions in energy demand modelling tools.

3) On the macro level, CHEETAH explores the long-term macroeconomic impacts of changes in micro-economic decision-making and of energy efficiency policy on employment, GDP and exports in the EU up to 2030.

The objective of this report is to summarize the findings and policy recommendations following from the micro-level analysis relying on the CHEETAH survey. The report is designed as a dynamic document, which will be extended as the project proceeds and will eventually also include the recommendations from the meso-level (deliverable 7.2) and the macro-level (deliverable 7.3).

Section 2 provides an overview of the energy efficiency policies which were included in the CHEETAH survey. Their operationalization in the survey is briefly discussed in Section 3. Section 4 summarizes the findings of the discrete choice experiments. The policy implications of these results are derived in section 5.

The findings of the econometric analysis on the three technologies refrigerators, thermostats and heating systems are reported in detail in deliverable 4.4. and Milestone 3. The findings from the survey experiments on policy acceptability are reported in detail in deliverable 4.5.

2 Overview of Energy Efficiency Policies and Key Household Characteristics Addressed in the Survey

Energy efficiency policies aim at accelerating the adoption of energy efficiency technologies. This section briefly describes and discusses the key energy efficiency policies in light of the academic literature. Focussing on the policies which were considered in the survey, addressing policy acceptability in general and the adoption of household appliances, thermostats and heating systems in particular. The review focuses on European policy, however, where relevant examples from other countries are included. Measures that affect energy prices (e.g. energy taxation) are not considered here. Likewise, policies addressing household energy use in general, like feedback on electricity consumption are not included. A more extensive discussion of energy efficiency policies can be found in CHEETAH deliverable 3.3, which built the literature foundation for the selection of policies to be addressed within the survey.

Besides understanding the general mechanisms behind certain energy efficiency policies, understanding citizens' perspectives on these policies and the policy context is crucial for policy effectiveness and success (Dietz & Stern, 2008). Normatively, citizen perspectives are important to consider if policy-making is to be democratic and accountable; substantively, citizens possess valuable knowledge and experience, which can add unique perspectives to policies and ultimately improve their quality; and instrumentally, policies which take account of citizens' perspectives are more likely to be accepted (see deliverable 4.5 for a detailed discussion; see also Fiorino, 1990; Stirling, 2006; Wesselink, Paavola, Fritsch, & Renn, 2011). Therefore, the survey addresses on one hand the general acceptability of policies and the favouring preconditions for acceptance and on the other hand their direct effect in technology adoption decision making.

2.1 Key Policies

2.1.1 Energy labels for household appliances[1]

Labelling schemes are typically designed to make consumers aware of the relative energy-efficiency of appliances and associated potential cost savings through the provision of observable, uniform, and credible standards (e.g. Truffer et al., 2001). In this sense, energy labeling schemes are often considered as a cost-effective measure to overcome barriers related to information and search costs (transaction costs), or to bounded rationality on the part of appliance purchasers (Sutherland, 1991; Howarth et al., 2000, Mills and Schleich 2010). In turn, providing consumer information on appliance energy efficiency is expected to create market incentives for appliance manufactures to design more energy-efficient products (see e.g. Fraunhofer ISI, 2014). Usually, labelling schemes are complemented by technology standards to improve energy efficiency performance of new appliances and remove the worst performing appliances from the market through minimum energy performance standards (MEPS).

Currently, mandatory energy labelling schemes exist in more than 50 countries and more countries are in the process of introducing such schemes (World Energy Council 2013, p. 95). In the early 1990ies, the European Union (EU) introduced a mandatory labelling system through the Framework Directive 92/75/EEC on Energy Labelling of Household Appliances.[2] The system is considered to be one of the core regulatory instruments to address energy use of household appliances.

Evaluation studies based on aggregate observed data typically find that the existing energy labelling programs for household appliances in the EU, the U.S. or Australia are effective in terms of energy and carbon reductions (e.g. Sanchez et al., 2008; Lane et al., 2007; Banerjee and Solomon, 2003; Bertoldi, 1999; Waide, 2001; Waide, 1998). Sammer and Wüstenhagen (2006) find that the EU energy label, which is also applied in Switzerland, affects Swiss consumers' stated purchasing decisions. In particular, Swiss consumers are willing to pay a premium of 30% of the average market price for energy-efficient washing machines. Similarly, Heinzle and Wüstenhagen (2012) observe a higher willingness to pay by German households for televisions with a higher (hypothetical) energy efficiency class. Gallaraga et al (2011) find that 15.6% of the final price of dishwashers in Spain is actually paid for the energy efficiency attribute. This accounts for about €80 of the average market price. Newell and Siikamäki (2013) conducted a study on the impact of information on purchase decisions with the following results. Simple information on the economic value of saving energy is the most important element. Additional information on the

[1] Some parts of this section draw heavily, at times also verbatim, on Mills and Schleich (2010) and were part of deliverable D3.3.

[2] Labels have been introduced in the EU for refrigerators, freezers, washing machines, dryers, dishwashers, air-conditioners, TVs, and household lamps; the system was recently extended to cover further appliances, including vacuum cleaners and ventilation fans. See also http://www.eceee.org/ecodesign/products

amount of energy use and CO2 emissions had lesser impact on decision-making though they have incremental value.

Sammer and Wüstenhagen (2006) also observed that Swiss consumers have higher willingness to pay for A-labelled energy efficient products. For a low-involvement decision-making product (i.e. light bulb), a label plays more important role than for a high-involvement product. Consumer's willingness to pay for A-labelled products is higher than the actual cost savings expected over the lifetime of the product.

A study by Consumer Focus (2012) in the UK finds that the majority of consumers are influenced by the A-G rating while there are other factors such as price that have a great impact. For consumers who are not influenced by the energy rating, they either were not aware of, or did not understand the label. In other cases, they did not think the energy savings would sufficiently cover the higher upfront costs.

Davis (2008) observes that the adoption of high efficiency washing machines is profitable in terms of energy and water use saving relative to the price premium for most households, except for those with very low use levels. Reiss and White (2008) observe that consumers respond to both energy prices and information campaigns to reduce energy consumption, with higher energy use households being more responsive to energy prices.

In general, it is difficult to separate the impact of the labelling scheme on the diffusion of more energy-efficient appliances from other factors such as electricity prices, minimum efficiency standards, subsidies or "business as usual" technical development. To quantify the impact of other factors, minimum performance standards may serve as a baseline. Some of these factors may also interact with the labelling scheme. Reiss and White (2008) observe that consumers respond to both energy prices and information campaigns to reduce energy consumption.

2.1.2 Financial instruments - Rebate schemes

Especially in the U.S. and Canada, the adoption of energy-efficient appliances is often promoted via rebates. For example, in the U.S. utilities and federal and local governments offer financial incentives to purchasing ENERGY STAR-labelled appliances, typically via mail-in-rebates. For lighting, different rebate schemes have been applied in many states in the U.S. and in Canada (see e.g. Parlin et al., 2014, Wobus, 2014). In some states, they help utilities fulfilling their obligations under the Energy Efficiency Resource Standard (EERS) programme. Similarly, in Europe, rebate schemes may be part of utilities' efforts to meet the provisions of energy efficiency obligations according to the Energy Efficiency Directive (EED)[3], or of tendering schemes, such as the one that is currently under implementation in Germany. In Germany, rebates have been applied by local utilities for purchases of appliances with the highest energy class as part of a local or municipal effort to meet climate targets. Furthermore, rebates are applied in Germany for low-income households in the "Stromspar-Check-PLUS"-program (Seifried and Albert-Seifried 2015). In general, rebates are typically monetary, but may also be in-kind (e.g. points collected for purchasing energy efficient products may be redeemed elsewhere in the local community).

In providing up-front financial incentives, rebates help overcome lack of capital, present bias (in time discounting), or inertia. Rebates also lower the financial risk. Only few studies have analysed the impact of rebate programs at the individual (i.e. microeconomic) level. Notably, relying on stated preferences, Revelt and Train (1998) and Train and Atherton (1995) find that financial incentives (rebates and loans) affect appliance choice. In Revelt and Train (1998), rebates induced 8.5% of customers to switch from a standard refrigerator to a higher efficiency refrigerator. For the "Renove" plan in Spain, Galarraga et al. (2013) conclude that a subsidy scheme promotes adoption of energy efficient appliances (focusing on dishwashers), but is inferior to a tax on purchases of inefficient products.

3 Directive 2012/27/EU

In the discrete choice experiments (described below) not only the effect of the presence of subsidies was tested, but also whether different effects are observable when the subsidy is provided by public or by private actors. This was done in order test if also the design of a financial instrument as a subsidy granted by a public institution or as an energy efficiency obligation scheme or a similar instrument, where the subsidy is given by the obliged private actors is relevant for the investor.

2.1.3 Information and Advice

Energy audits provide information on energy savings potentials, on specific technologies and on costs and benefits of implementation of energy efficient technologies. Hence, energy audits are expected to help overcome, in particular, information-related barriers, but also bounded rationality and possibly behavioural biases. Energy audits are often subsidized by national, regional or local authorities or municipalities, and may be targeted at specific socio-demographic household groups. Examples are the German program Stromspar-Check for low income households.

The few existing analyses of audit effectiveness for the residential sector generally provide mixed evidence (e.g. or Hirst and Goelz 1985, Frondel et al. 2013, Murphy 2014, Alberini and Towe 2015, Considine and Sapci, 2016)). In an early review of evaluations of utility home energy programs in the US, Hirst et al. (1981, p. 624) complain that “the lack of control groups in all but two of the evaluation efforts seriously impairs the validity of the conclusions.”

Furthermore, the discrete choice experiments analyse the effects of participants’ energy literacy on the choices made. This allows for insights on the impact of programs raising energy literacy and / or in lowering the barrier to understanding e.g. the information on the label on the adoption of energy efficient appliances. Additionally, it is tested whether the type of provider of the recommendation for a certain appliances makes a difference: i.e. whether people are more likely to adopt technologies that are recommended by friends, the energy provider or experts. This allows to identify actors, which might be particularly effective in providing recommendations about energy efficient appliances.

2.2 Key Household Characteristics

2.2.1 Income and adoption of energy-efficient appliances

Income is likely to affect adoption of energy-efficient appliances (see for example, Schleich 2019). In particular, low-income households may not have the financial means to purchase energy-efficient appliances, which typically have a higher purchase price than less efficient appliances. Similarly, low-income households are more likely to suffer from credit constraints because they often cannot offer adequate collateral. At the same time though, low-income households typically spend a higher share of their income on energy services. Thus, low-income households may particularly benefit from adopting energy-efficient technologies (e.g., Schleich and Mills, 2012), or from rebates for energy-efficient appliances.

Existing empirical studies tend to find a positive relation between (household) income and the adoption of energy-efficient appliances (e.g., Mills and Schleich, 2010, 2012; Ramos et al., 2015; Trotta, 2018, Schleich et al., 2019, Schleich, 2019).

2.2.2 Energy literacy and adoption of energy-efficient appliances

In the past, several empirical analyses have included education as a covariate when exploring the adoption of EET. More recent literature has also considered the role of energy literacy. Typically, the literature finds higher levels of education to be positively related with household purchase of EET (e.g., Mills and Schleich, 2012; Ramos et al. 2016) or household awareness of the energy label (Mills and Schleich, 2010). In Brounen et al. (2013), more educated individuals were more likely

to make rational decisions when comparing two heating systems differing in up-front costs and fuel bills. Defining rational decision makers in this decision exercise as "energy literate", Brounen et al. (2013), however, do not find respondents who are more "energy literate" or more aware of their energy costs to exhibit more energy conserving behaviours. Brounen et al. (2013) further find evidence that energy literacy is higher for male respondents, and positively related with education. Finally, Zografakis et al. (2008) find that introducing energy literacy into school curricula has a positive effect on energy-saving behaviour of students.

Blasch et al. (2018) define energy literacy as "an individual's ability to make informed and deliberate choices in the domain of household energy consumption". Defining energy literacy as an index reflecting individual knowledge about energy prices and energy use of different appliances, they find individuals having a higher energy literacy to be more likely to identify the refrigerator with the lowest lifetime costs in an experiment.

Overall, while there is substantial empirical literature analysing the relation of income and energy-efficient technology adoption, the literature analysing the role of energy-literacy is just emerging.

3 Operationalisation of Policies in the Survey[4]

The first part of this section gives an overview of the survey, including the DCE for refrigerators, thermostats and heating systems, the items used to create an index for energy literacy, and the socio-economic and attitudinal variables employed. The second part briefly introduces the econometric methods used to analyse the DCE and the correlates of energy literacy. Detailed information on the survey and DCE design as well as on the employed econometric models can be found in the deliverable 4.4 and the milestone 3.

3.1.1 Household survey

We implemented an online survey via computer-assisted web interviews (CAWI) among households in eight EU member states: France (FR), Germany (DE), Italy (IT), Poland (PL), Romania (RO), Spain (ES), Sweden (SE), and the United Kingdom (UK). The household panel was provided by NORSTAT.

The survey was fielded in July and August 2018. In each country, participants were selected via quota sampling to be representative in terms of gender, age, income, and regional population dispersion.

The main part of the survey consisted of a stated preference discrete choice experiment (DCE) on hypothetical technology adoption. Socio-demographic information was gathered both at the beginning of the questionnaire (to ensure that quota requirements were met), and at the end of the questionnaire.

Table 1 summarizes the items on socio-economic characteristics, attitudes, and dwelling characteristics which were collected in the survey. For a more detailed description of the operationalization within the survey refer to deliverable 4.4.

Table 1: Household and individual characteristics

Label	Description
Female	Dummy = 1, if respondent is female.
Age	Continuous, between 18 and 65 years old

[4] To allow the reader to fully understand the basis for the policy recommendation, i.e. the eight-country survey including discrete choice experiments, the main elements of D4.4, D.4.5 and Milestone 3 are summarized here. While this also means showing the same material in various documents, this has the advantage that D7.1 stands by itself and can be understood by readers without forcing them to go back to the original documents.

Label	Description
Low income	Dummy = 1, if reported household income falls into the lowest income quartile in a country, and 0 else.
High education	Dummy = 1, if level equal to or higher than country median. Considered levels: no degree or certificate/trade or vocational certificate /high school or equivalent/higher education.
High CRT score	Dummy = 1, if level equal to or higher than country median of number of correct answers to the questions from the Cognitive Reflection Test (CRT) (Fredericks, 2005)
Region	Dummy = 1, if the household lives in Ile-de-France (FR), Eastern Germany (DE), Southern Italy (IT), Eastern Poland/*Poland B* (PL), Central or Eastern Romania (RO), Basque Country, Canary Islands or Catalonia (ES), Northern Sweden (SE), Northern Ireland, Scotland or Wales (UK)
City	Dummy = 1, if the household lives in or close to a major city
Tenant	Dummy = 1, if the household is renting the current dwelling.
Detached housing	Dummy = 1, if house is detached.
High heating costs	Dummy = 1, if heating cost are higher than country median.
Big family	Dummy = 1, if the number of household members > 2
Environmental identity	Score reflecting environmental identity (adapted from Whitmarsh and O'Neill 2010).
Low energy literacy	Dummy = 1, if the number of correct answers in a three-item energy literacy test was below (or equal to) the median score in a country. These items were adapted from Blasch et al. (2018) and deWaters and Powers (2011).

3.1.1 Discrete choice experiment on refrigerator purchase decisions

The discrete choice experiment (DCE) is a method founded in random utility theory (McFadden, 1974). It assumes that products in a given market can be thought of as consisting of different vectors of characteristics. Consumers derive utility from characteristics of products and then choose their preferred product by comparing options available in the market. Therefore, a DCE simulates market transactions by constructing hypothetical choice scenarios where alternatives are described by a range of attributes, and where respondents are expected to make trade-offs between different attributes and select their most preferred alternative. This allows estimating values for multiple attributes of a product and their trade-offs simultaneously.

In our DCE, participants were asked to imagine that their refrigerator had broken down and thus needed to be replaced.[5] They were then asked to make a series of choices between different refrigerator purchase options. These options differed by capacity, energy efficiency class, length of warranty, customer review ratings, purchase price and subsidies available (attributes and levels are summarized in Table 2). Subsidies were only offered for refrigerators with energy class A^{+++}. Attributes were chosen to represent relevant information for customers choosing a refrigerator and to be independent of one another. Attributes for capacity, energy consumption, purchase price and financing measures have already been used in choice experiments on refrigerator purchase decisions. We adapted the attributes to fit the EU refrigerator market and added to the list two quality attributes, length of warranty and customer review ratings.

[5] The exact wording used in the DCE was as follows: "Imagine that your refrigerator has broken down and you need to buy a new one. On the following pages, we will show you different refrigerator purchase options. We would like to know which refrigerator you would choose, if these were your only options .Please assume that all refrigerator options fit properly in your kitchen and are currently available in color and finish of your choice."

Table 2: Levels of different attributes considered in the refrigerator choice experiment

Attribute	Levels
Size	220 L, 240 L, 260 L, 280 L, 300 L, 320 L
Energy class	A^{+}, A^{++}, A^{+++}
Warranty	2 years; 4 years; 6 years
Customer rating	3.5/5 stars; 4.0/5 stars; 4.5/5 stars
Purchase price	250 €, 350 €, 450 €, 550 €, 700 €, 850 €
Subsidy	0 €, 25 €, 50 €, 100 €[a]

Our choice experiment consisted of 24 scenarios divided into three blocks (each respondent was randomly assigned to one of the blocks). An example for a scenario as shown to respondents is depicted below for the experiment in the UK. Since the survey was conducted in countries with different currencies, the monetary amounts used in the DCEs were adjusted to keep the relative value similar between countries in terms of purchasing power.

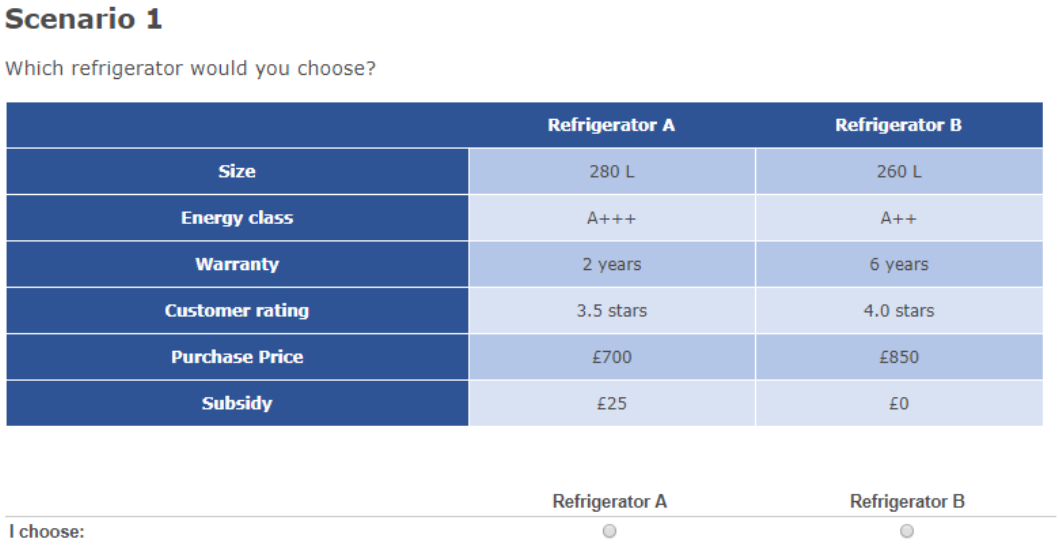

Figure 1. Example for a scenario as shown to respondents in the UK

3.1.2 Discrete choice experiment on thermostat purchase decisions

In this part of the survey, respondents were asked to make a series of choices between different thermostat purchase options.[6] These options differed by six attributes: purchase price, capacity to reduce respondents' heating costs, control of the room temperature via a remote device, display of changes in energy consumption, recommendation by friends or colleagues, by independent energy experts, or by the respondent's energy provider, and lastly subsidies available. Attributes and levels are summarized in Table 3. All attributes were chosen to represent relevant information for customers choosing a thermostat and to be independent of one another. Moreover, attributes and levels were chosen to be realistic and provide options similar to heating control appliances

[6] Framing used to introduce the stated choice experiment
"Heating control devices are devices that allow users to control the temperature of their home throughout the day, for example by setting a different temperature at night. Moreover, some of those devices can be connected to the Internet and allow users to easily adjust the temperature remotely, for example by using a smartphone.
Example of a smart heating control device connected to the Internet using the home Wi-Fi network: <Two photographs of heating control devices were presented>
On the following pages, we will describe different heating control devices. We would like to know which heating control device you would choose, if you were making a purchase and these were your only options."

available on the market. To our knowledge, we were the first to conduct a choice experiment on heating control appliance purchase.

Table 3: Levels of different attributes considered in the thermostat choice experiment

Attribute	Levels
Heating bill	1% less, 5% less, 10% less
Remote temperature control	Yes, No
Display of changes in energy consumption	Yes, No
Recommendation	by friends or colleagues, by independent energy experts, by your energy provider
Purchase price	£150, £180, £210, £240, £270, £300.
Subsidy	£0, £20, £40, £60

The DCE on thermostat purchase decisions consisted of 12 scenarios divided into 2 blocks (each respondent was randomly assigned to one of the blocks). Once respondents made a choice they were asked to indicate on a scale from 1 ("very unlikely") to 4 ("very likely") how likely they were to actually buy their preferred option if it was available on the market. An example for a scenario as shown to respondents is depicted below for the experiment in the United Kingdom.

3.1.3 Discrete choice experiment on heating system purchase decisions

In this DCE, home owners in Poland, Sweden and the UK were asked to make a series of choices between different heating system purchase options.[7] These options differed by six attributes: purchase price, capacity to reduce respondents' heating costs, time needed for installation, length of warranty, amount of available subsidies and subsidies provider. Attributes and levels are summarized in Table 4. All attributes were chosen to represent relevant information for customers choosing a heating system and to be independent of one another. The purpose of this choice experiment was to study household preferences and preference heterogeneity with regard to subsidies from public or private providers. Features such as fuel type were thus not considered. Previous DCEs on heating systems included similar price levels as well as attributes for energy savings, warranty and subsidies (Achtnicht 2011, Willis et al. 2011)

The experiment was conducted in Poland, Sweden and the UK since heating demand is comparatively high in these countries. Moreover, all three countries differ in their experience with private financing of energy-efficient technologies through energy saving obligations or white certificates. In the UK, energy saving obligations have a long tradition. Poland has recently implemented an energy saving obligations scheme, while Sweden is opposing the introduction of white certificates. Comparing household preferences for public or private financing across these countries is thus of particular interest.

Table 4: Levels of different attributes considered in the heating system choice experiment

Attribute	Levels
Heating bill	25% less, 50% less, 75% less
Installation	half a day, three days, one week

[7] Framing used to introduce the stated choice experiment**:** "Imagine your heating system has broken down and you need to buy a new one. On the following pages, different options for a new heating system will be offered to you. We would like to know which heating system you would choose, if these were your only options.
Please assume that all heating systems can be installed in your home and that their fuel type is the one you would like to have (for example oil, gas, coal, wood, other biomass, solar, air, water or geothermal heat).

Warranty	2 years, 5 years, 10 years
Purchase price	£3 000, £5 000, £8 000, £12 000, £15 000, £20 000
Subsidy	5%, 15%, 25% (of the purchase price)
Subsidy provider	Government, energy provider

Heating systems in the hypothetical choice experiment allowed respondents to reduce their heating costs by 25, 50 or 75 percent. Households' individual heating costs were either reported by respondents or estimated based on stated dwelling characteristics.

As in the DCE on refrigerator purchase decisions, a B-efficient design was applied. The priors used for the design were again obtained from a pilot study with 50 UK respondents from Prolific Academic. The DCE on heating system purchase decisions consisted of 12 scenarios divided into 2 blocks (each respondent was randomly assigned to one of the blocks).

3.1.4 Discrete choice experiment on policy acceptability

The DCE on policy acceptability was implemented in the general survey in UK, Poland, Sweden and Italy. These countries reflect differing levels of trust in government (ESS, 2016), energy efficiency policies, and levels of income.

The DCE operationalized key theoretical variables of energy efficiency policy effectiveness, fairness and personal cost via five attributes, each with several attribute levels (see Table 5). Each participant was shown six choice cards and asked to choose between three options: one of two new policies (A or B) or the current policy (Table 6). The attribute levels for Policy A and Policy B varied from one scenario to another. The attribute levels for the current policy were the same across all scenarios and chosen to be similar to energy efficiency policies currently in place in the European Union. The DCE on policy acceptability is core to the deliverable 4.5, where a detailed description of the setup of the experiment can be found.

Table 5: Attributes and attribute levels for the energy efficiency policies

Theoretical construct	Attribute	Attribute levels	Number of levels
Policy effectiveness	Reduction in energy consumption by 2030	Policies reduce energy consumption in COUNTRY by 20, 25, 30 or 40 percent, compared to having no energy efficiency policy in place	4
Policy effectiveness	Import	Policies seek to reduce COUNTRY's energy imports by 5, 10, 30 or 50 percent, compared to having no energy efficiency policy in place	4
Fairness	Share of total costs paid by households	Total costs to reach the energy consumption target by 2030 are shared between households and other sectors (industry, agriculture, private and public services). The share paid by households is 30, 40, 50, or 60 percent. Currently, households consume about 40 percent of total energy.	4
Personal cost/ impact	Main policy measure	The reduction in energy consumption by households is mainly achieved through one of the following policy measures: • Education and information programs on energy-saving measures. • An additional tax on energy (e.g., for electricity, gas, oil, coal). • A limit on energy consumption per person. • Stricter minimum energy efficiency standards for buildings and appliances.	4

Personal cost/ impact	Additional annual cost	Over the next 10 years, Policies A and B will cause additional expenses for your household compared to the current policy (for example because of higher energy taxes). Additional expenses will be 25€, 50€, 100€, 150€, 200€, or 300€ per year	6

Table 6: Example choice card for policy acceptability DCE

	Policy A	Policy B	Current policy
Energy consumption by 2030	25% less	40% less	20% less
Share of total costs paid by households	50%	40%	40%
Import	50%	10%	5%
Main policy measure	Education and information programs	Stricter energy efficiency standards for buildings and appliances	Stricter minimum energy efficiency standards for buildings and appliances
Additional annual cost	50€	200€	0€

3.2 Econometric methods

To analyse the choice experiment, a mixed logit model was employed. Further, to identify sources of heterogeneity in household response to policies, we interacted the policy attributes in the DCE with dummy variables for low income, low energy literacy and age of homeowners, respectively.

In contrast to conditional logit models, mixed logit models do not rely on the so-called Independence of Irrelevant Alternatives (IIA) assumption and allow for unobserved heterogeneity of individual preferences (Revelt and Train, 1998). Thus, coefficients may vary across individuals.

As is standard in mixed logit models, coefficients for all attributes except price were allowed to vary across individuals. Furthermore, the marginal willingness-to-pay (WTP) for an attribute was calculated

A mixed logit with interaction effects for income and for energy literacy (respectively income and homeowner age) is applied in order to analyse to what extent heterogeneity in household response to policies for appliance adoption arises from observable differences in household income and energy literacy. For thermostats and heating systems a mixed logit model is applied with interaction effects for the age of the homeowner and for their income in order to determine to which extent their reaction to policies is heterogeneous between actors who differ concerning these characteristics. The applied econometric methods are explained in detail in deliverable 4.4.

4 Results of the Econometric Micro-Level Analysis

Sample sizes ranged from 415 (Italy) to 599 (Sweden) respondents in each country. It is worth noting that energy literacy was overall found to be higher in Germany, Italy, and Sweden compared to the other countries. In these 3 countries, respondents with less than 2 correct answers were labelled as having a low energy literacy (50% in Germany and Sweden, 48% in Italy). In the remaining countries, respondents who answered none of the questions correctly were labelled as having a low energy literacy (33% in France, 29% in Poland, Romania, and the UK, and 26% in Spain).

Brief Summary of Results for the Discrete Choice Models for Refrigerator Purchase Decision[8]

This section summarizes in brief the findings of the discrete choice models for refrigerators. More details on these findings including the result tables can be found in deliverable 4.4.

An increase in net price lowers the latent utility and hence the propensity to purchase a refrigerator in all countries. Higher capacity, higher energy class, longer warranty periods and better customer ratings generally increase respondents' propensity to purchase a refrigerator. Results indicate (unexplained) heterogeneity of these parameters across respondents, and therefore corroborating the appropriateness of using a mixed logit model.

For some households rebates provide an additional, non-monetary benefit. For respondents with high energy literacy from households in high income groups, this is the case in all countries except the UK. For the average respondent from a household in the lowest income quartile, in Italy, Romania and Spain, rebates do not provide additional non-monetary benefits. Moreover, in Poland respondents from households in the lowest income quartile value higher energy class less compared to respondents from higher income households, independent of whether or not a rebate is available. In Germany (Sweden), on the other hand, respondents from households in the lowest income quartile value energy class A++ (A+++ without rebates) more, compared to respondents from higher income households.

In France, Poland and Sweden, the results suggest that respondents with low energy literacy value an A+++ label less compared to respondents with higher energy literacy. In Germany, we observe a similar effect, but only in the absence of rebates. In the UK, rebates further decrease the propensity to purchase an A+++ refrigerator for respondents with low literacy. Finally, in Italy, we find that respondents with low energy literacy value energy class A++ less, compared to respondents with high energy literacy.

Furthermore, the willingness to pay for certain characteristics was calculated for the different household groups. Overall, we find that average willingness to pay for energy labels A++ and A+++ is positive for all countries and groups of respondents, with the exception of low-income respondents in Poland who are not willing to pay for an increase in energy class from A+ to A++.

In France, Germany, Poland and Sweden, respondents with low energy literacy are willing to pay considerably less for an A+++ label (on average 44€ to 158€ less) compared to respondents with higher energy literacy. Note that in Germany, low energy literacy does not negatively affect willingness to pay for A+++-labelled refrigerators, if rebates are available. In Italy, for respondents with low energy literacy, willingness to pay for A++-refrigerators is reduced by 83€ compared to respondents with higher energy literacy. Furthermore, in Poland, respondents from households with above quartile income are on average willing to pay 128€ to 198€ more for an increase in energy class compared to respondents from households in the lowest income quartile. In Germany, low-income households are on average willing to pay 99€ more for an A++ refrigerator compared to higher income households. Lastly, in Sweden, the average low-income household is willing to pay 138€ more for an A+++-labelled refrigerator without a rebate than the average higher income household. The fact that this is not the case for A+++-labelled refrigerators with a rebate suggests that being low income has a negative effect on the valuation of rebates, which cancels out its positive effect on the valuation of increased energy efficiency.

In the absence of rebates, average willingness to pay for an A+++ label is higher than the willingness to pay for an A++ label for most but not all household groups. Notably German respondents with low household income or low energy literacy as well as French, Polish and Swedish respondents with low energy literacy are not willing to pay for an increase in energy class from A++ to A+++ without rebates. When there is a rebate, willingness to pay for an A+++ label

[8] This section resumes verbatim the results previously presented in deliverable D4.4.

generally increases. The only exceptions are households in the UK and low-income households in Sweden, whose willingness to pay for an A+++ label decreases when there is a rebate.

The increase in willingness to pay for A+++ refrigerators when there is a rebate is on average less pronounced for low-income households in Italy, Romania and Spain. In Italy, Romania and Spain, high-income respondents are on average willing to pay an extra 148€, 142€, and 116€, respectively, for an A+++ refrigerator if there is a rebate. Low-income households, on the other hand, are on average only willing to pay an extra 30€, 35€, and 20€, respectively.

To sum up, our findings suggest that being a low-income household reduces the positive effect of rebates on the propensity to purchase A+++ -labelled refrigerators (Italy, Romania, Spain). At the same time, the effects of low income on the valuation of energy class A++ and A+++ are limited and vary across countries (negative in Poland, positive for A++ in Germany and A+++ without rebate in Sweden). Moreover, our results suggest that low energy literacy reduces the propensity to purchase A+++-labelled refrigerators (France, Germany, Poland, Sweden). In Germany, this effect is mitigated by rebates.

To explore the relation between energy literacy and socio-economic and attitudinal factors, we ran a standard probit model for each country. Similar to the finding by Brounen et al. (2013) for the Netherlands, the findings for Poland and Romania suggest that men are more likely to have a high energy literacy. For example, in Poland, being a woman lowers the likelihood of having a high energy literacy by about 14 percentage points. Likewise, age was found to be statistically significant in three countries. That is, older people in Italy, Sweden, and the UK were more likely to have a high energy literacy. For Italy, one additional year of age translates into an increase in the likelihood to have a high energy literacy by about one percentage point. In contrast, income did not turn out to be statistically significant in all eight countries, thereby suggesting no relationship between income and energy literacy. At the same time, and in line with Brounen et al. (2013), more highly educated participants appear to be more prone to have a high energy literacy in France and Spain. The effect size of education is particularly large in France. Participants with a higher CRT score are more likely to have a high energy literacy in five of the eight countries, i.e., in Germany, Italy, Poland, Spain and the UK. The factor supposed to reflect intrinsic motivation to have a high energy literacy, i.e., environmental ID, was only found to be statistically significantly (and positively) related with energy literacy in two countries: in France and Romania. Similarly, the factors supposed to reflect that economic incentives lead to high energy literacy turned out to be statistically significant in few countries only: participants from households with high heating costs in Italy and Spain, from large families in Sweden, and those living in detached houses in Germany were found to have a higher energy literacy. Living in an urban environment was associated with lower energy literacy in Germany, but with higher energy literacy in Spain. Finally, regional effects were found in Poland, Spain and Sweden.

Brief Summary of Results for the Discrete Choice Experiments for Thermostats Purchase Decision

This section summarizes in brief the findings of the discrete choice experiments for thermostats. The respective result tables can be found in the report on Milestone 3 (table 8 and 37ff.).

The DCE on thermostats were performed in all eight surveyed countries. An increase in net price lowers the latent utility and hence the propensity to purchase a thermostat in all countries. The effects for the existence of subsidies were tested, as well as whether it makes a difference by whom recommendation for the thermostat is provided (by friends, by providers or by experts)

The existence of subsidies shows mixed effects on the purchase propensity. Only in Rumania a subsidy has a positive effect (i.e. one additional Euro of subsidy is equivalent to a price decrease of more than one Euro). In Germany, UK, and Spain one Euro additional subsidy is valued less than one Euro in price decrease

Furthermore, the DCE tested whether the type recommendation provider makes a difference for the propensity to purchase a thermostat. When the recommendation is made by a provider instead of a friend, respondents are more likely to purchase the device in all countries except for Poland, where the effect is negative and Sweden, where no significant effect can be observed. If the recommendation is made by an expert as compared to a friend, it increases the purchase propensity in all countries.

When individual characteristics income and age of homeowner are interacted with all other parameters similar effects are observed. The interaction terms suggest that in France older respondents value heating cost savings more compared to respondents below the age of 55, the opposite seems to be the case in Poland, while in all other countries no significant interaction can be observed. Respondents from households in the lowest income quartile value savings in heating costs less, compared to respondents from households in higher income quartiles in France, Poland and Spain. For no countries positive effects are observed. The availability of a remote control is generally valued positive in all countries. However, households in the lowest income quartile in France value remote control less than respondents from households in higher income quartiles, the same holds true for elder respondents in Poland The display of energy savings generally increases respondents' latent utility in all countries and is valued higher by low- than by high-income households in Romania.

Elder homeowners' propensity to purchase thermostats increases through the recommendation by providers as compared to the recommendation by friends in Spain and Italy. Additionally, in Italy, Spain and Poland the propensity increases for elder homeowners who receive recommendations by experts. For all other countries there is no significant interaction effect between age of the homeowner and sender of recommendation. When interacting the sender of the recommendation with the income, for Romania a negative effect for the recommendation by experts is observed. For all other countries there are no significant effects for the recommendation by providers and the recommendation by experts. Low-income households in Sweden value subsidies less than their actual worth. This means, that for low-income households in Sweden one additional Euro of subsidy is equivalent to a price decrease of less than one Euro. For all other countries there are no significant effects observed.

Brief Summary of Results for the Discrete Choice Experiments for Heating System Purchase Decision

The DCE for heating systems was conducted in Poland, Sweden and UK. Detailed results are provided in Milestone 3 and particular in the tables 12, 53 and 54. As expected, higher prices have negative effects on the propensity to select a technology in all three countries. The experiment tested whether subsidies provided by public actors have a different effect than subsidies provided by private actors. Only in Poland a positive effect on the purchase propensity can be observed when the subsidy is provided by a public actor. When the subsidy is provided by a private actor instead, positive effects are observed in all three countries. Understandably, the reduction of heating costs has a positive effect on the propensity to select a certain alternative in all three countries. The same holds true for an increase in warranty time. Furthermore, the more days are needed to install the system, the less likely households are to select this alternative in all three countries.

When individual characteristics income and age of homeowner are interacted with all other parameters similar effects are observed. In all three countries, elder homeowners' propensity to purchase heating systems does neither increase when the subsidy is provided by public actors nor when it is provided by private actors. However, the results suggest that elder homeowners in Poland value savings in heating costs less than the remaining respondents in Poland.

Low-income households in the UK value subsidies less than high-income households, regardless of whether they are provided by public or by private actors. However, they value an extended

warranty more than the high-income households. Low-income households in Poland value savings in heating costs less than high-income households.

While the results are quite homogenous at the country level for the three countries, differences appear when looking at the interactions between elder households (and low-income households respectively) and the characteristics of the choices. This once more shows the importance of allowing for differences across countries, as well as employing a mixed logit approach in order to identify particularities.

Brief Summary of Results for the Discrete Choice Experiments analysing the household acceptance of energy efficiency policies[9]

The DCE on policy acceptability was conducted in Italy, Poland, Sweden, and UK. Detailed results are presented in deliverable 4.5.

As expected, additional costs lower respondents' propensity to prefer a certain policy alternative in all countries. In the UK, Poland and Italy, respondents generally prefer the status quo (i.e. no change in policy), to alternative policies, independent of other attributes. Respondents in all countries prefer more ambitious policies with regard to reduction of both energy consumption and energy imports. Furthermore, respondents in Italy, Poland and Sweden are indifferent as to how costs are shared between households and other sectors. In the UK, contrary to expectations, respondents prefer on average higher shares of total costs paid by households (rather than industry). In Sweden and Poland the average respondent prefers the status quo policy "stricter minimum standards" over taxes or a per capita limit for energy consumption. Arguably, the latter may be interpreted as the implementation of a sufficiency strategy. Lastly, in Italy, Poland and the UK, implementing education and information programs rather than stricter minimum standards increases the average respondent's propensity to select this policy alternative.

Consistent with expectations on the importance of policy effectiveness for public support, we found respondents generally prefer more ambitious policies with regard to reduction of both energy consumption and energy imports. WTP to reduce energy consumption by 1 percentage point ranges from 5.74€ per year in Sweden to 18.41€ per year in the UK, while WTP to reduce energy imports by 1 percentage point ranged from 1.37€ per year in Sweden to 3.93€ in the UK. These findings are in line with previous research, which consistently finds that the perceived effectiveness of a specific policy is associated with acceptance and support for the policy (e.g., Eriksson et al., 2008).

Contrary to expectations, respondents appear largely indifferent as to how costs are shared between households and other sectors (though in the UK there is actually a preference for households to pay more than other sector, in line with their greater WTP for effective energy policies).

The number of times in which respondents preferred the status quo are quite substantial, in Italy in 44% of cases the status quo was selected in UK in more than half of the cases (54%) the status quo was preferred (Poland and Sweden having a preference rate of the status quo in 47% of the cases). Furthermore, in the UK 31% of respondents always chose the status quo. This share was smaller in the other countries (Italy: 19%, Poland: 22% and Sweden: 23%).

In addition to the DCE, multivariate regression analyses were carried out in D4.5 to explore the factors related with individual WTP for stricter targets and for policy types (compared to the status quo). On the individual level, a higher Willingness-to-Pay (WTP) for more ambitious targets for reduction of energy consumption is found for respondents with a high level of trust in government in all countries. In Sweden and the UK, green identity is also associated with higher WTP for ambitious targets. Moreover, we find that WTP for ambitious targets is lower for older respondents in Italy and the UK, for women in Italy, Sweden and the UK, and for respondents

[9] This section resumes verbatim the results previously presented in deliverable D4.5.

with low household income and high level of education in Poland. Finally, WTP for ambitious targets is higher for respondents who have benefited from financial support for energy efficiency investments in their home in Italy and the UK.

In Poland and Sweden, we observe that WTP for additional taxes is lower for respondents with high trust in government compared to respondents with low trust. At the same time, Swedish respondents with high trust in government are less opposed to per capita limits on energy consumption. We further find that in Italy and Poland respondents with high trust in government are willing to pay more for education and information programs compared to respondents with low trust. Green identity is found to be negatively related to WTP for additional taxes on energy and WTP for limits on energy consumption in Poland. In the UK, respondents with green identity have a higher WTP for education and information programs compared to other respondents.

5 Policy Implications Derived from the Micro-Level Analysis

Employing demographically representative discrete choice experiments in eight EU countries, allows for various policy implications. In the following, the derived policy implications are described with respect to the three technologies tested, refrigerators, thermostats and heating systems as well as for the DCEs on policy acceptability. Where applicable an outlook on wider implications is sketched. The policy implications for refrigerators were already provided previously in deliverable 4.4., the policy implications for the policy acceptability DCE were derived in more detail in deliverable 4.5.

As described above the DCE on refrigerator purchase decision allowed participant responses to the EU energy labelling scheme and to rebates for A+++-labelled refrigerators to vary by income and energy literacy. This allows for various policy implications.

Overall, we find that respondents in all countries typically prefer A+++-labelled refrigerators to refrigerators with lower energy classes. Thus, the EU energy label appears to effectively signal additional benefits of these appliances to the consumer such as energy-cost savings. Yet, low energy literacy was found to substantially lower the WTP for A+++-labelled refrigerators in half the countries included in this study (France, Germany, Poland and Sweden). This finding holds for low- and high-income households. In addition, the findings suggest that rebates for A+++-labelled refrigerators are an effective measure to boost the adoption of A+++-labelled refrigerators in all countries. The results further suggest, that on average, rebates are most effective for high income household in Italy, Poland and Romania, and low literacy households in Germany and Poland (looking at the difference between A+++ sub and A+++0). In some countries (Italy, Romania, Spain), the positive effect of rebates is stronger for high-income households than for low-income households. This finding tends to hold for low and high levels of energy literacy. Thus, in these countries, providing a rebate for energy-efficient refrigerators may be regressive, and thus have unwanted distributional effects. In this case, rebates could be offered to low-income households only. To keep transaction costs (e.g., for providing proof of income) low, such schemes could be linked to household eligibility for existing social-security support. Restricting rebates for A+++--labelled refrigerators to low-income households would also be expected to limit free riding.

In countries such as the UK, where consumers may perceive rebates and subsidies as signalling low quality, rebate and subsidy schemes could be complemented by customer ratings or by reports from organizations providing credible product ratings and reviews such as Consumer Reports.

The findings on energy literacy suggest that labelling schemes are more effective for customers with a higher energy literacy. Thus, raising the level of energy literacy via education and information programs (e.g., brochures, online or on-site courses) may be an effective means. Ideally, such programs would be targeted at particular socio-economic groups. Specifically, the

results from running probit regressions on the factors related to energy literacy imply that such programs should be targeted at women in Poland and Romania, at younger people in Italy and Sweden, or at individuals with low formal education in France and Spain. For some countries, notably Poland, Spain and Sweden, focussing such programs on particular regions also promises to be effective. In addition, information and tools on how to calculate energy cost savings for the various appliances may be provided at the point of sale, i.e., either in the store or through an internet platform (see also Blasch et al., 2018b).

Finally, the results of the choice experiments for refrigerators (particularly concerning energy literacy) lead us to contemplate that if information on the energy label was more informative, energy literacy may not play as big a role. Arguably, providing energy costs (in €) rather than energy use (in kWh) would help customers to identify the refrigerator with the lowest costs (e.g., lowest total costs of ownership).

In all countries the results of the DCE for thermostats show that if the recommendation for a certain appliance is provided by experts it has a more positive effect on the adoption decision than if the recommendation is provided by a friend (only). These results are particularly strong for elder homeowners in Italy, Spain and Poland. The results offers some leverage for recommendations and suggests that thorough, independent and transparent information provision might increase the adoption likelihood (e.g. through decreasing doubt on the actual savings). In combination with the findings on energy literacy from the DCE on refrigerators it is suggested that providing these information as accessible as possible, e.g. in terms of potential monetary savings rather than energy savings, would be beneficial for their adoption. Furthermore, recommendations provided by the provider have positive effects in all countries except for Poland and low-income households in Romania (negative effects) and Sweden (no significant effect). Being particularly positive for elder homeowners in Spain and Italy. Therefore, it would be worth exploring which incentives could be set to providers to facilitate the adoption of thermostats by their clients.

The results of the DCE for thermostats for Rumania suggest that a subsidy for efficient appliances has an overall positive effect for their adoption. Here, one additional Euro of subsidy stirs a propensity to adopt a certain technology that goes beyond the mere monetary value. In all other countries subsidies do not have a positive effect on adoption decision. Particularly the results suggest that subsidies for efficient thermostats in Germany, UK and Spain as well as for low-income households in Sweden do not stir positive effects, since they are valued less than their actual monetary value. Overall the results from the DCE for thermostats suggest that providing information on savings and recommending certain energy efficient appliances through experts and providers is more beneficial than providing subsidies. This might also be due to the fact that the savings for thermostats are more complex and less directly accessible to households than savings from other appliances.

The DCE for heating systems, which were conducted in Poland, Sweden and UK, suggest positive effects of subsidies which are provided by private actors in all three countries, while only in Poland a positive effect of subsidies provided by a public actor is observed. Therefore, it seems to be most beneficial to provide incentives to private actors which can be forwarded to technology adopters rather than providing financial schemes through public actors. Low-income households in the UK value subsidies less than high-income households, regardless of whether they are provided by public or by private actors. This suggests that subsidies in UK, like subsidies for refrigerators for some countries, would be regressive in nature. Therefore, it should be considered to provide subsidies for heating systems in UK only to low-income households in order to avoid increased free-rider effects. Aside from subsides, the reduction of heating costs, an increase in warranty time and a shortened installing period are beneficial for the installation of energy efficient heating systems in all three countries. Providing upfront and accessible information on these items might therefore be beneficial for adoption.

The detailed study of policy acceptability allows for conclusions concerning the type of policies that are more likely to be accepted and concerning preconditions (such as trust) that support the acceptability of energy efficiency policies in general (see deliverable 4.5). Overall, citizen support for and resistance to different types of policies can be found, and also variation in preferences amongst different countries and groups of citizens. In particular, our research highlights that energy efficiency policies are more acceptable when they are particularly effective (i.e., ambitious in reducing energy consumption and imports) while also incurring minimal costs on, or coercion of, citizens. Unfortunately, these criteria may be difficult to reconcile as the most effective policies are likely to include at least some degree of 'push' or coercion that limit consumer choices in respect of the most energy intensive choices. This may suggest a need to involve the public in more deliberative debate about the inevitable trade-offs involved with achieving a sustainable energy transition, for example spelling out that addressing climate change and energy security might incur costs in terms of higher bills and/or reduced consumer choices but potentially reduce costs for adapting to climate change or dealing with energy disruption/shortages (e.g., Pidgeon et al., 2014). Such deliberative citizen engagement might also help foster a sense of procedural justice in, and thus greater support for, policies developed through this participatory process.

At the same time, the results show that those who trust government more, who have benefited directly from energy efficiency policies in the past, and have higher green identity, are generally more supportive of energy efficiency policies (albeit with some cross-national variation). These findings point to where policy-makers might focus in building support for future energy efficiency measures, for example, by introducing financial support measures in advance of more coercive or costly measures or by designing informational measures that remind people of any benefits they have already experienced from energy efficiency policies. In addition, building trust in government would appear to be an important pre-condition for public support for policies, and therefore should be a focus of efforts (e.g., through more transparent and participatory policy-making; Blind, 2006). Environmental education might also serve to increase green identity and values amongst the public, which may also lead to more support for energy efficiency policies. Finally, since public support in some countries, like the UK, appears to be higher than elsewhere, and in light of cross-national variation in predictors of policy support, this indicates that policies need to be established with cultural or national differences in mind.

Summarizing, the result from the micro-level analysis conducted in the survey allowed to derive overarching policy implications such as the importance of building trust, the importance of transparent policy-making and an open discourse to foster understanding of direct and indirect long-term costs and benefits and the importance of enabling consumers to make informed decisions by increasing energy literacy as well as by providing relevant information (such as monetary savings) in a more accessible manner. While the results show that certain policies will probably have no effect in a certain area (and thus do neither harm nor good), other polices (like rebates for refrigerators in Italy, Romania and Spain) seem to be regressive in nature, and are thus likely to increase freeriding. The results therefore emphasize that the here taken approach of a multi-country analysis which accounts for different types of households is crucial in order to get a more detailed understanding of the adoption behaviour of energy efficient appliances as well as the acceptability of energy efficiency policies, which in turn allows to design policies in a more fitting and efficient manner, avoiding unintended side-effects.

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