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Report on assessment of energy-efficient policies and interventions

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1. Introduction

On October 23 2014, EU countries agreed on a 2030 Framework for climate and energy, which sets new and challenging targets for the European Union post-2020 low carbon framework. The European Council endorsed three targets, with one being a binding commitment to improve energy efficiency by at least 27 percent for the year 2030 compared to projections of future energy consumption based on the current criteria. On 30 November 2016 the Commission proposed an update to the Energy Efficiency Directive, which reviews the energy efficiency target to be reached by 2030 to a binding 30% EU level and delivers a list of measures that ensure that the new target is met.

Energy efficiency is a key resource to deliver a range of benefits to the economy and society. Improving energy efficiency results in lower greenhouse gas emissions, in a more competitive, secure and sustainable energy system. Moreover, at the household and firm levels, it allows to cut energy bills, implying higher disposable income and improved competitiveness.

The residential and industry sectors are the ones that hold the largest potential for cost-efficient energy savings. The residential sector accounts for more than a quarter of final energy demand in the EU (Bertoldi, Hirl, and Labanca 2012) and holds a large and cost-effective energy efficiency potential, in particular for renovating existing buildings and purchasing new household appliances (e.g. Eichhammer et al. 2009). Wide-scale upgrading, replacement and deployment of best available technologies can improve energy efficiency in the energy-intensive industry sector (IPCC 2014).

To improve energy efficiency, regulatory approaches and information measures have been extensively applied, along with substantial public resources being invested in research and development for energy-efficient technologies. However, energy efficiency depends not only on the availability of cheap technologies or on policy interventions, but it is largely influenced by behavioural choices of users.

2. Barriers to energy efficiency

It is long being observed that agents underinvest in energy-efficient technologies. Adoptions from both households and firms is low. The concept of “private energy-efficiency gap” also called “energy paradox” has been introduced. It describes an empirical evidence whereby some energy-efficient technologies are not adopted despite they would pay off for adopters (Gerarden, Newell, and Stavins 2017).[1]

An indication of a consumer's valuation of future benefits from current investment is provided by a discount rate. The little investment in energy efficient technologies translates into high implicit discount rates. The existing literature has largely searched the explanations for such underinvestment and correlated high implicit discount rates, despite energy-efficient technologies could reap both private and social rewards (Jaffe and Stavins 1994). Various barriers to the adoption of energy efficiency technologies have been identified and many taxonomies made. Schleich et al. (2016) provide a framework that describes the different factors underlying the implicit discount rates. These factors, that have been classified as external and internal barriers, explain the low adoption behaviour in the domain of energy efficiency. External barriers cover factors that can be easily changed. On the contrary, internal barriers have to do with factors cannot be changed or are difficult to change, because they relate to preferences and behaviour.[2]

2.1 Meta analysis on discount rates

A discount rate reflects the trade-off between upfront capital costs and operating costs that occur over a longer period. Researchers are able to elicit implicit discount rates from observing technology adoption choices and calculating net present values. Only few studies directly ask individuals their willingness to pay for an energy efficient appliance. Implicit discount rates are thus computed from observed technology adoption choices and net present value calculations. The computation of implicit discount rates becomes possible because consumers are seeking to minimize discounted lifecycle costs. Implicit discount rates are such that an actual purchase behaviour becomes economically rational in terms of net present value.

Dating back to Hausman (1979), the existing literature has found extremely high discount rates, that typically exceed the opportunity cost of capital. Empirical evidence

[1] The notion of energy efficiency gap can be defined relative to social optima as well. In this case it is called "social energy-efficiency gap" and refers to the apparent reality that some energy-efficiency technologies are not adopted even though they are socially efficient.

[2] The idea that people underinvest in energy efficient technologies derives from the use of engineering and economic models. Model and measurement errors might create a discrepancy between theoretical predictions and the actual adoption of energy-saving technology and they can ultimately cause an overestimation of the magnitude of the energy-efficiency gap. This implies that in some taxonomies, these errors are treated as a third explanation for the energy efficiency gap (Gerarden, Newell, and Stavins 2017) .

suggests that consumers fail to make energy saving investments, that had positive net present values and this has resulted in a slow diffusion of energy-efficient products.

Despite its importance, there is little attention on the changes in discount rates over time in environmental decisions. In public policy, exponential discounting is often assumed, for its tractability and normative appeal. However, it has already been observed that discount rates are not constant over time, but tend to decrease. The evidence for decreasing impatience comes from studies using different outcomes including money, health and environmental outcomes (Hardisty and Weber 2009). The inconsistency in discounting of environmental outcomes as well as other outcomes could lead to conflicting behaviours in investments and compliance.

Discount rate plays a crucial role in model-based policy evaluation in particular as far as energy efficiency policy assessment are concerned (Schleich et al., 2016). Providing up to date estimates of the discount rates is of paramount importance for policy evaluation and impact assessments. Moreover, ex ante policy analysis performed with models such as integrated assessment models is notoriously sensitive to the parametrization of intertemporal decisions. In some specific sectors, such as residential energy use and private transportation, improving the parametrization and representation of time discounting will allow to generate more robust estimates and answer new policy questions, such as how to evaluate behavioural interventions.

A qualitative review of the literature on discount rates has been provided by Train (1985). However, qualitative reviews have potential limitations. In particular, even if they list and describe findings, results from qualitative reviews must be interpreted with caution because of the differences in methodologies, approaches, research settings adopted to elicit discount rates.

Meta-analysis, on the contrary, allows one to analyze inferentially if these differences significantly moderated the effect sizes of the discount rates. The changes in discount rates can also be observed with discount rates elicited in different point of time. Percoco and Nijkamp (2009) conduct a meta-analysis on individual discount rate estimates. This meta-analysis aims at identifying drivers of discount rate values. The analysis includes 44 studies, published between 1978 and 2002 and providing the rate of time preference at both an individual and collective level. The papers included vary in terms of methodology (experimental versus field work), objects of choice (money, life years or heath), the elicitation method used, which differentiate between real of hypothetical situations, the country where the data has been elicited. Once the studies have been selected, a meta analysis estimates a meta-regression function that correlates the different values of time preference with some observable variables. These are the range of time to estimate the discount rate used in the different papers; whether the situation was hypothetical or real; a variable capturing the elicitation method used; the objects of the choice; the methodology used; the year of the publication; a variable distinguishing between US and non-US studies; the sample dimension; the GDP per capita and life expectancy of the country where the study has been conducted.

The results of the meta-analysis are the following. Longer time horizon, expressed by the range variable, implies lower estimated rate of time preference. Studies that use hypothetical situation tend to elicit lower discount rates. This is eventually because people tend to underestimate their discount rates if faced with a hypothetical situation. GDP has a negative coefficient, indicating that the higher the income, the lower the rate of discount. This is because richer people tend to be more patient.

2.2 Empirical evidence of the impact of external barriers on adoption and energy use

According to Schleich et al. (2016), external barriers capture underlying factors that limit the adoption of energy efficient technologies but can be easily changed. These factors are external to the decision maker and mainly depend on institutional settings. For this reason they are also called "market failure explanations" (Gerarden, Newell, and Stavins 2017). While an extensive literature has discussed the different sources of external barriers and has agreed that these factors potentially inhibit adoption, there is still room to discuss the exact effects of these barriers on energy efficient behaviour. In particular, the following review will distinguish between the impact of external barriers on behaviour related to curtailment, which represents routine, repetitive effort to decrease consumption on a day-to-day basis and to investments, which are one time actions such as purchasing new energy efficient technologies and modification of building or house.

Table 1: External Barriers to energy efficiency

External Barriers		
Capital market failures	Information problems - Lack of Information - Asymmetric Information	Financial and technological risks

Source: Schleich et al. (2016)

2.2.1 Capital market failures

Table 1 reports the different sources of external barriers. One is **capital market failures**, such as liquidity constraints, as some agents cannot obtain capital to invest in energy efficient technologies (Berry 1984; Gillingham, Newell, and Palmer 2009). When owners need to rely on capital markets to finance costly investment and if those markets do not function efficiently, then credit constraints may limit adoption, even though adopting makes sense from an economic standpoint, i.e. (expected) future savings are higher than the costs. Credit risk, high transaction costs, and asymmetric information are factors that may discourage lenders from offering loans for energy efficiency investments (K. L. Palmer, Walls, and Gerarden 2012).

2.2.2 Information problems

Another external barrier is represented by **information problems**, which include **lack of information** or problem generated by **asymmetric information**, such as **split incentives** and **principal-agent** issues. If consumers lack information on product availability and energy efficient attributes, such as potential savings, they tend to invest less in energy efficient technologies. For this reason, lack of information has been quoted as a major barrier, which calls for policy intervention (K. Palmer et al. 2013). To test the importance of lack of information on adoption and on consumer behaviour in energy use, the existing literature has analyzed if a policy intervention such as the provision of information has any impact on consumer choice. The empirical evidence on this link is therefore presented in the section 3.3 below, where the impact of information policies is discussed. Except for few contributions (Allcott and Sweeney 2016; Allcott and Greenstone 2017; Filippini, Hunt, and Zorić 2014), the empirical findings confirm that lack of relevant information leads to underinvestment in energy efficiency (Houde 2014; Allcott and Taubinsky 2015; Kallbekken, Sælen, and Hermansen 2013; Davis and Metcalf 2016; Newell and Siikamäki 2014).

Asymmetric information, linked to split incentives and principal-agent issues, represents a barrier to energy efficiency because one actor cannot appropriate the benefits of the investment or because asymmetric information makes an agent unconvinced about the energy efficient attributes of a product. Mismatched perceptions and preferences between landlords and tenants contribute to suboptimal investment in energy efficiency.

The type of payment regimes and the ownership status are found to influence investment in profitable energy efficient technologies from both the tenant and the landlord sides. Myers (2015) finds that landlords in utility-included apartments are more likely to invest in conversion from inefficient oil heating to more efficient natural gas heating, compared to landlords who do not pay for energy. The authors calculate that around 9% of tenant-pay oil houses do not convert to natural gas due to asymmetric information and this implies a lost savings in heating fuel expenditure of around 12-24%. Energy efficiency is costly to observe and prospective tenants may not be willing to pay higher rents for higher efficiency that they are not aware of or unconvinced. Papineau (2013) however finds that energy efficient yet unlabeled buildings, constructed under an energy code, are associated with significant rent and selling price premiums. This finding is consistent with little asymmetric information. Gillingham, Harding, and Rapson (2012) report that owner-occupied dwellings are more likely to be insulated in the wall and ceiling compared to rented dwellings. Phillips (2012) reports that landlords have a much lower willingness to pay for improved insulation compared to owner-occupiers of private residential dwellings. Krishnamurthy and Kristrom (2015) find that owners are substantially more likely to have access to highly efficient appliances, such as top-rated energy efficient washing machines and refrigerators, and to better insulation as well as to heat thermostats. Similarly, Davis (2010) finds that renters are less likely to purchase energy efficient durables such as refrigerators, clothes washers, and dishwashers. On the contrary, Mills and Schleich (2010) find that renting compared to owing the residence does not significantly influence the adoption of energy-saving compact fluorescent lamps.

The type of payment regimes has also an impact on energy efficient behaviour related to energy consumption, giving support to the importance of split incentives. In particular, utility-included rents contribute to moral hazard. Maruejols and Young (2011) find that tenants living in utility-included apartments opt for increased thermal comfort. Levinson and Niemann (2004) as well find that tenants who do not pay directly for their heat set their thermostats at a higher temperature and this produces an increase in fuel expenditures beard by the landlord. They also find that the higher costs of the energy used do not translate in proportional higher rents compared to metered apartments. This finding supports the hypothesis of information asymmetries. Landlords value the utility-included contract more than the cost of the extra energy, because they can use this type of contracts as a means to attract renters, given that they cannot credibly communicate the energy-efficiency of the apartment.

Asymmetric information may also contribute to adverse selection and thus constrain the market for energy-efficient products. On the one hand, if sellers may not be able to credibly communicate some energy-efficient information, the energy-efficient products may not be offered in the market. On the other, if buyers cannot perfectly observe the energy efficiency of the products, they might not purchase them. Unfortunately, there is little empirical evidence of adverse selection in the domain of energy efficiency choice.

2.2.3 Financial and technological risks

Schleich et al. (2016) consider **financial** as well as **technological risks** two additional external barriers to energy efficiency. Technology performance for example influences the profitability of an investment and the survival of a business, and this in turn affects adoption. Moreover, energy efficiency investments own a certain degree of risks because of uncertainty related to the actual compared to expected energy savings, because of fluctuations in fuel prices and the irreversibility of the investment. Anderson and Newell (2004) confirm that firms fail to undertake profitable investments recommended after an energy audit because of risks, along with information barriers.

2.3 Empirical evidence of the impact of internal barriers on adoption and energy use

According to Schleich et al. (2016) internal barriers to energy efficiency are related to **preferences** and predictable **(ir)rational beahavior**. These factors, in the taxonomy provided by Gerarden, Newell, and Stavins (2017), are also labelled as "behavioural explanations" for the energy efficiency gap. While external barriers are rather known to the literature and their implications for energy efficiency documented, internal barriers are less studied. A full understanding of the exact impacts of internal barriers on energy efficiency is still limited (Gillingham, Newell, and Palmer 2009).

Benefits and costs of an investment vary across agents and if an investment is profitable for one, it may not be so for a different consumer. The heterogeneity of the agents plays a great role in energy efficient behaviour. In particular, individuals differ in their time, risk and pro-environmental preferences (Table 2).

Table 2: Internal Barriers to energy efficiency

Internal Barriers	
Preferences	**(Ir)rational behaviour**
Time Preferences	Reference-dependence and non-linear probability weighting
Risk Preferences	Rational Inattention
Environmental Preferences	Bounded Rationality
	Behavioural Biases - Present Bias - Status Quo Bias

Source: Schleich et al. (2016) and (Frederiks, Stenner, and Hobman 2015)

2.3.1 Time Preferences

Time preference is reflected in time discounting, namely how the consumers value the future relative to the present. Time preference describes the level of (im)patience of an individual, her present or future orientation. Traditional theories of discounting posit that individuals care less about the future than the present. In the context of energy efficiency choices, persons with higher discount rates are expected to be less willing to carry out energy-saving investments, because they devalue rapidly future rewards, expressed in terms of energy savings, and thus are present-oriented.

The literature has typically elicited time preferences from actual energy-saving behaviour. Only few studies measure first individual discount rates from stated behaviour and only then correlate these discount rates to investment and consumption behaviour related to energy efficiency. Newell and Siikamäki (2015) is one of these and use, in a choice experiment, alternative product models and different labelling treatments to elicit individual discount rates. They then confirm that impatient individuals, those with higher discount rates, attach a lower value to the operating cost savings of an energy efficient appliance which occur in the future. Liebermann and Ungar (1997, 2002) apply a similar framework and conclude that people with lower discount rates tend to select more energy-efficient and initially more expensive air-conditioning systems, while people with higher discount rates tend to prefer cheaper and less energy-efficient devices. Bruderer Enzler et al. (2014) relate discount rates to various energy saving behaviours. They find that people with low discount rates avoid leaving their television set on stand-by mode, have environmentally friendly reaction when feeling cold at home in winter, open windows for brief periods in winter, and select the more energy efficient hypothetical choice of refrigerators and light bulbs. For other behaviours considered, such as turning the lights off when leaving a room or the radiators down when away for more than four hours, however, results are not consistent with expectations. Bradford et al. (2014) find that more patient individuals are more likely to have installed energy-efficient lighting and use less air conditioning in summer. Fischbacher, Schudy, and Teyssier (2015) find that time preferences do not influence investment in renovation but are related to energy use behaviour. In particular, more future oriented homeowners consume less energy. Moreover, among renovators, those who value the future particularly strongly own houses with higher energy quality.

2.3.2 Risk Preferences

Given that some degrees of uncertainty surround the benefits of an energy efficient investment, because of uncertain prospects of future cost savings or uncertain performance of the technology, **preferences related to risk** influence adoption. Not only risk preferences vary among individuals, but the same person can change her love and aversion for risks, depending on what is the stake. People tend to be less risk averse for low-stakes than for large-stakes gambles. This behaviour is known as the ‘peanuts effect’ (Weber and Chapman 2005). The literature documents that more risk averse agents are less willing to adopt energy efficient appliances. Qiu, Colson, and Grebitus (2014) apply the same two-step approach described above, whereby risk preferences are first elicited through hypothetical lottery choices and then correlated to some self-reported investment in energy efficient appliances and retrofitting technologies. They find that more risk averse consumers are less likely to retrofit their home or purchase energy efficient appliances. Fischbacher, Schudy, and Teyssier (2015) elicit risk attitudes using an experimentally validated risk questionnaire and confirm larger renovations among more risk takers. Erdem, Şentürk, and Şimşek (2010) measure risk attitude through a self assessment approach rather than through an experimental design, and find that more risk-seeking consumers are more likely to pay a premium for hybrid automobiles. Through a choice-experiment, Farsi (2010) analyzes consumers’ preferences regarding energy saving systems and how it is influenced by risk. The author concludes that risk attitude affects consumers’ behaviour regarding enhanced insulation and ventilation.

2.3.3 Environmental Preferences

Pro-environmental preferences are a third factor affecting energy behaviour. Some people may decide to purchase energy efficient appliances or curtail energy use, even though these decisions are associated with higher individual costs in the short run. People may chose to act pro-environmentally because they want to protect the environment and value the environmental quality more than their personal comfort. Values are antecedents of environmental preferences, intentions, and behaviour. Values are desirable goals that guide principles in everyone’s life (Schwartz 1992). They are important drivers of actions, with some values limiting pro-environmental actions and others promoting them (Dunlap, Grieneeks, and Rokeach 1983). Psychologists believe that two types of values are connected to environmental actions (Steg and De Groot 2012). These are self-enhancement values, which reflect a key concern with one’s individual interests and self-transcendent values, which reflect a key concern with collective interests. In particular, hedonic and egoistic values are self enhancement values that constrain pro-environmental behaviours. Altruistic and biospheric values are self-transcendence values that are positively correlated with pro-environmental behaviour (Steg et al. 2014).

Persons with strong egoistic values behave pro-environmentally considering their own resources. They act pro-environmentally only if the pro-environmental option proves to be the cheapest for themselves. Persons with strong hedonic values are highly concerned with improving own feelings and reducing personal effort. They may not undertake a profitable investment, if this is too costly in terms of personal comfort. Egoistic and hedonic values typically limit pro environmental behaviours, because of trade-offs between resources/ comfort and the environment. Persons who strongly endorse altruistic values behave pro-environmentally based on other people's perceived costs and benefits. A person with strong biospheric values considers the costs and benefits with respect to the nature and the environment. Biospheric values are strong predictors of environmental behaviour, because people who strongly endorse biospheric values are more likely to engage in various pro-environmental behaviours (de Groot and Steg 2008). Individuals typically endorse all four values, but substantial differences exist in the extent to which different individuals endorse specific values. This translates into heterogeneity in the population in terms of pro-environmental preferences.

A growing number of empirical studies have analysed if environmental preferences explain investment in energy efficiency. The evidence is mixed, eventually for two reasons. First, because it is difficult to measure environmental preferences. Different approaches have been adopted to elicit preferences, with some papers measuring environmental preferences through environmental attitudes and others through environmental behaviours. Second because of the different types of energy efficient behaviour considered. Some behaviours are more difficult and demanding than others, and some behaviours are private rather than visible.

Fischbacher, Schudy, and Teyssier (2015) elicit homeowners' preferences for the environment, through a set of items based on the New Environmental Paradigm Scale. This scale was developed by Dunlap and Liere (1978) and it is widely used to measure pro environmental orientation. The authors find that among renovators, persons with strong pro-environmental preferences own houses with higher window, roof and façade quality.

Moreover, environmentally friendly homeowners display lower energy consumption. Kotchen and Moore (2007) use the same scale to measure environmental concern and find that environmentalists are more likely to participate in green-electricity programs. Di Maria, Ferreira, and Lazarova (2010) elicit environmental preferences through responses to a series of questions, assessing the respondent's support to the Kyoto Protocol, how important is it to protect the environment and whether a person has heard of global warming and the greenhouse effects. The paper finds that environmentalists are more likely to adopt energy efficient light bulbs. Harding and Rapson (2017) report that families who display interest in environmental or wildlife issues are more likely to sign up for a carbon offsetting program. Ek and Söderholm (2010) find that people with pro environmental attitudes, namely persons who think that reduced electricity consumption is important for environmental reasons, implement electricity saving activities. Kotchen and Moore (2008) report that people who declare to be members of environmental organizations consume less conventional electricity and are more likely to participate in a green-electricity program. van der Werff, Steg, and Keizer (2013) conducted a lab experiment and find that the more strongly people endorsed biospheric values, the more often they chose the most expensive and most sustainable products.

Ramos, Labandeira, and Löschel (2016) analyse the effect of both environmental attitudes and environmental behaviours. They find that eco-friendly behaviors, elicited from environmental policy activism and recycling actions, are positively correlated to both energy efficient investments in the dwelling and daily energy-saving habits. On the contrary, environmental attitudes are not. For example, the authors find that pro-environmental attitudes poorly predict heating behaviour in winter or investment in energy efficient appliances. The authors notice that measures of environmental attitudes elicited through stated willingness to pay (WTP) may not reflect true environmental preferences because of 'compliance/social desirability bias'. Respondents tend to manifest a higher willingness to pay to protect the environment due to the influence of social norms. Similarly, Lange, Moro, and Traynor (2014) find that environmental behaviour is correlated with environment-friendly heating, whereas attitudes and perceptions are not. This may explain why some papers find that pro-environmental attitudes do not translate into actual investment in energy efficiency or energy-saving actions.

The second reason for the mixed evidence on whether environmental concern effectively translates into action, is due to the different types of energy efficient behaviour considered. Some actions such as energy consumption or household temperature choice are private information, which are unobserved by neighbors. Other actions, such as investment in solar panel or purchase of hybrid cars are visible to others. In the case of green conspicuous products, social approval and prestige rather than strong biospheric values may drive environmental behaviour. Investment in energy efficiency may be undertaken to exhibit pro social behaviour with respect to environmental protection and not by the desire to reduce pollution. The investment in green products is believed to enhance social status, in particularly when it is costly, as it signals to others the availability of sufficient resources to make altruistic sacrifices (Griskevicius, Tybur, and Van den Bergh 2010). This evidence has been largely confirmed in the case of green cars or solar panels (Bollinger and Gillingham 2012; Kahn 2007).

Finally, Sexton (2011) find that consumption of conspicuous green products confers social status that is higher, the greater the strength of environmental preferences of one's peers. Social aspects are important in the domain of energy-efficient choices. Social norms convey guidelines and implicit rules regarding what is common or desirable within a group or society (Cialdini and Trost 1998). Environmental preference can be influenced by the willingness to conform to pro-environmental social norms, because people tend to do what is socially approved. This last consideration is important for two reasons. First because it can guide the identification of strategies that encourage pro environmental actions, for example, by strengthening biospheric and altruistic values. The use of messages that prime and appeal to identities, values and social norms, can lever environmental preferences and prompt a pro-environmental behaviour. Second because it helps guiding policy makers in the selection of products for subsidies. Policies should target less conspicuous investment that will be underprovided relative to those that confer a status benefit.

2.3.4 Reference-dependence and non-linear probability weighting

The behavioural economics literature has drawn attention to numerous cases of behavioural anomalies, which are situations where the individuals behave differently from the assumptions of the neoclassical economic theories. Empirical evidence in the fields of psychology and behavioural economics shows that consumer behaviour is complex and is rarely consistent with the assumption of fully rational agents. People don't behave in accordance with the 'rational choice' model of human behaviour. It should be noted that behavioural economics amend rather than reject the traditional economic assumptions. For example, behavioural economics assume that people *try* to choose their best feasible option, which is simply a variant of the optimization assumption (Laibson and List 2015). For this reason, rather than labeling these behaviours as anomalies or failures, we can label them as "behavioural explanations" for the energy efficiency gap (Gerarden, Newell, and Stavins 2017). This apparent irrational behaviour derives sometimes not from too little information, but from people being unable to process all available information, because of cognitive constraints.

In the taxonomy provided by Schleich et al. (2016) these behavioural explanations are called (ir)rational behaviour and include reference-dependence and non-linear probability weighting, rational inattention, bounded rationality and behavioural biases, such as present bias and status quo bias (Table 2). These behavioural characteristics are considered the most powerful and pervasive ones to influence energy usage and investment are.

Research in psychology has recognized that people tend to strongly prefer avoiding losses to achieving gains. They therefore weight losses more heavily than equal-sized gains. Simply framing one decision as a choice between losses rather than a choice between gains can reverse preferences, everything else equal (Wilson and Dowlatabadi 2007). This is because individuals evaluate the benefits and costs of a decision relative to a reference point. This phenomenon is called **loss aversion** or **reference dependence**. The insight that outcomes are evaluated with respect to a reference point has been formalized in the prospect theory of decision making, which was developed to explain some of the observed violations of the expected utility theory (Kahneman and Tversky 1979). Another behaviour formalized by the prospect theory is that people tend to over-weight small probabilities and under-weight moderate and large probabilities so that they end up using non-linear probability weighting. While in expected utility theory the shape of the utility function is influenced only by risk aversion, in prospect theory it is jointly determined by risk aversion, loss aversion and non-linear probability weighting. Loss aversion and reference dependence have implications for energy efficiency choices. For example, Harding and Hsiaw (2014) analyse individual behaviour with respect to a non-binding goal setting program, aimed at reducing energy consumption. They find support to the presence of reference-dependent preferences. Moreover, they find that individuals with reference-dependent preferences tend to reduce energy use once enrolled in the goal setting program. This is because, the goal acts as a reference point, and people derive utility directly from comparing their consumption against this goal. Dütschke and Paetz (2013) find that loss aversion has implications for energy tariff configurations. In this study, consumers prefer pricing programs characterized by lower spread of charges, so that they can avoid the risk of too high bills.

2.3.5 Rational Inattention

Rational inattention is another behavioural constraint to energy efficiency. Consumers have limited attention and this may contribute to systematically underweight certain information or product attributes, in particular those that are less salient. For example, consumers attach low weights to some product attributes and are less attentive to operating costs compared to purchase prices. Allcott (2011b) confirm that vehicle buyers make their decisions without considering fuel costs. Busse, Knittel, and Zettelmeyer (2013) and Allcott and Wozny (2014) report that consumers tend to undervalue changes in expected future energy costs, despite the undervaluation is not large. Sallee, West, and Fan (2016), on the contrary, report that future fuel costs are not undervalued. Given that the operating costs could not be salient, rational inattention could lead to lower investments in energy efficiency.

It is also true that the use of limited attention when choosing among different durable goods could be rational, because proper valuation of energy efficiency requires time and effort which are not justified when consumers have strong preferences regarding other product attributes (Sallee 2014).

2.3.6 Bounded Rationality

People face cognitive constraints and limitations because of **bounded rationality.** There are limits in human capacity to process and evaluate information. Therefore in complex situations, characterized for example by an overload of information, people rely on a simple counting **heuristic and rules of thumb.** These short-cuts help simplifying the decision-making process. When people are overwhelmed by complexity, they tend to satisfice rather than optimize (Simon 1955) because by satisficing the required effort is reduced. Another heuristic is the use of trust in decision-making (Poortinga and Pidgeon 2003). Trustworthiness is driven by competence-based attributes, such as apparent expertise and experience, and integrity-based attributes, such as perceived openness, honesty, and concern for others. Given bounded rationality, the decision making is less effortful if the problem representation matches the problem-solving processes (Camilleri and Larrick 2014). Information on fuel consumption rather than fuel costs and the use of a more comprehensive mileage scale increase preference toward fuel efficient vehicles. Ungemach et al. (2017) confirm that people often apply simple heuristics when choosing between cars and are influenced by highly correlated attributes, rather than their meaning. Providing multiple translations of energy efficiency metrics could help guiding behaviour.

2.3.7 Behavioural Biases

Present bias and time inconsistency is another behavioural explanation for the energy efficiency gap. While time preference indicates whether a person has a high or low discount rate, present bias refers to a situation where a discount rate is not constant and it changes over time. A constant rate of discounting allows for consistent intertemporal decisions, but both behavioural economics and psychology reject the assumption that agents have constant rate of discounting. Individuals appear to discount the future at a much higher rate in the short than in the long term. The declining impatience with delay has been formalized as a (quasi) hyperbolic time discounting function. Intertemporal trade-offs in decision making process are also central in the theory of myopia, i.e. of a lack of foresight, whereby future (and past) pleasures are valued on a diminished scale compared to the ones realizing in the present. The further into the future an event, the more imprecisely the agent will estimate the utility she will derive from it. As the future gets closer, the model of myopia predicts reversals of preferences similar to the ones predicted by theories of present bias. This model is therefore able to explain why individuals are extremely short-sighted when their decisions have consequences on the environment. The future receives very little weight, not because individuals do not care about the environment, but because of the high uncertainty of the future utility derived from undertaking pro-environmental behaviours. The tendency to be short-sighted and time-inconsistent often leads to procrastination. Tests on present bias and myopia in the context of energy efficiency and impacts on energy-efficient choices is provided by Harding and Hsiaw (2014). The authors find that present-biased agents consume more electricity than consumers who are not present-biased before joining a goal setting program. Bradford et al. (2014) find that present-biased individuals are less likely to have a car with high fuel economy, live in a well-insulated residence and more likely to keep their homes cooler in summer. On the contrary, they report that present bias is not statistically significant correlated to willingness-to-pay for compact fluorescent lightbulbs. This last finding is in agreement with Allcott and Taubinsky (2015), where consumers with present bias do not have lower demand for compact fluorescent lightbulbs.

In many circumstances it is difficult to distinguish the implications of one behavioural factor from another. For example, there is evidence that consumers value future savings less than the initial investment costs (Kőszegi and Rabin 2006) but this may be due to both inattention and loss aversion. Savings occurring in the future are undervalued because they turn to be less salient, and this due to rational inattention, or it could be that investment costs are evaluated as a loss and are weighted more than gains, because reference dependence. Moreover, both rational inattention and myopia can explain why consumers undervalue changes in energy costs that will occur in the future, or do not consider (future) fuel costs when choosing between vehicles. Given the difficult distinction between the two behavioural characteristics, evidence of myopia and implications for investments in energy efficiency arises as well from Busse, Knittel, and Zettelmeyer (2013) and Allcott and Wozny (2014) in the context of automobile purchase, which have been described above.

Another individual behaviour that has implications for energy efficiency choices is the **status quo bias**, also called the endowment effect. Agents tend to stick to default settings and display preference for the current state. As decisions could be postponed entirely, the decision process is characterized by inertia. According to Samuelson and Zeckhauser (1988), there are three main categories of explanations for the status quo bias "(1) transition costs and/or uncertainty; (2) cognitive misperceptions; (3) psychological commitment stemming from misperceived sunk costs, regret avoidance, or a drive for consistency." Moreover, the status quo or default option tend to be favoured because individuals display an anchoring bias, such that any arbitrary framing, such as a number, received before making a decision, tends to bias the answers towards this initial anchoring point (Tversky and Kahneman 1974). Ek and Söderholm (2010) suggest a strong presence of inertia in household decision-making concerning electricity use. Brennan (2007) as well observed reluctance to switch from an incumbent electricity supplier to an entrant. McCalley (2006) finds that removing the default temperature settings from washing machines brings to significant energy saving, as users set lower washing temperatures using an anchor point of zero temperature. Brown et al. (2013) report that manipulating the default settings on office thermostats reduces the chosen temperature. The status quo bias can be reinforced by uncertainty. Alberini, Banfi, and Ramseier (2013) report that individuals tend to prefer the status quo of no renovation in case of future energy-price uncertainty.

As it was discussed within the different behavioural explanations, the distinction between the two classes of barriers, external and internal, is more practical than theoretical. In many circumstances it is difficult to disentangle one failure from the other. For example, lack of information is defined as an external barrier to energy efficiency, but a person can lack information as a consequence of inattention or difficulty in assessing available information. Newell and Siikamäki (2014) is one of the few attempt that disentangles the effect of imperfect information from alternative explanations linked to consumer behaviour, such as intertemporal preferences. They find that lack of relevant information is the most important constraint to cost-effective energy-efficiency decisions. Additional research is needed to better disentangle behavioural effects from market failures and evaluate the ability of practicable policies to address these behavioural effects on energy efficiency.

3 Policy Interventions

As indicated in the above section, consumers often fail to make energy efficiency choices, because of the listed barriers. Policies and interventions to increase energy efficiency have been introduced to overcome these barriers. However, there is a broadly held view that a substantial portion of the potential benefits of energy efficiency is still uncaptured, as the effectiveness of policies and interventions that address both external and behavioural failures can be improved. The objective of the following section is to present the government policies and interventions that have been designed and match them to the specific barriers. A discussion of the effectiveness of these interventions will be presented. There are three types of policy instruments that have been used to influence energy efficiency by addressing both internal and external barriers to energy efficiency. These can be classified as regulatory instruments, economic and financial programs and information-based instruments.

Regulatory instruments, such as energy efficiency standards, define enforceable actions aimed at meeting specific environmental quality targets or performance standards. Efficiency standards often translate into minimum energy performance standards (MEPS) that all covered products must. Products that do not meet such standards are removed from the market. For example, building energy codes define the minimum efficiency standard of newly constructed buildings, the Corporate Average Fuel Economy (CAFE) standards set a minimum average fuel efficiency to vehicle fleet. Standard have been applied to lightbulbs, which resulted in the phase-out of incandescent lightbulbs, to refrigerators and freezers, dishwashers, clothes washers, clothes dryers, televisions.

Economic and financial programs provide monetary incentives for energy efficiency such as grants and loan facilities, subsidies, tax deduction, tax credits, rebates and guarantees. Grants and loan facilities, such as loan offered at subsidized interest rate, aim at facilitating access to capital for implementing energy-efficient choices. Rebates, tax credits and tax deductions are incentives that encourage energy efficiency actions by reducing capital costs to make the investments. Taxes are also a financial instrument that contributes to energy efficiencies by increasing the relative prices of less efficient products.

Finally, **informational instruments** are intended to influence consumers' behaviour by disclosing crucial information, such as energy saving, through energy audits, labelling, certifications and information campaigns. Within this group of instruments can be included persuasion strategies also called "nudges", which represent well-crafted interventions that provide feedback, peer comparisons, commitment and goal setting, injunctive norms, or that manipulate the default setting and the information metrics.

Table 3 provides a direct link between the different policy options and the barriers they aim to address.

3.1 Regulatory instruments

Regulatory instruments are an effective tool to improve energy efficiency because they can lead to an effective ban on certain classes of products that do not meet certain efficiency standards or impose stricter requirements for heating and cooling systems and for housing envelope. By removing energy-inefficient products from the market, regulatory instruments are designed to address **rational inattention** to costs and benefits of energy-efficient products and **present bias,** in particular **self-control** problems. Moreover regulatory instruments such as standards or building codes are also justified by the presence of **imperfect information**.

Davis (2008); de Melo and Jannuzzi (2010); Greening, Sanstad, and McMahon (1997); Mills and Schleich (2014); Tao and Yu (2011) analyse the effects of stricter energy standards and document energy saving potentials due to the transitions towards more energy-efficient investments. Examples in the context of building codes are Costa and Kahn (2011, 2010); Aroonruengsawat (2012); G. D. Jacobsen and Kotchen (2013).

Table 3: Policy options to address the specific barrier to energy efficiency

Barriers	Policy option
Capital market failures	Subsidies, tax deduction, tax credits, rebates, loans
Information problems	Standard, subsidies, tax deduction, tax credits, rebates, loans, energy audits, product labelling, certificates
Financial and technological risks	Guarantees on energy efficient investments
Time Preference	Commitment and goal setting programs
Risk Preference	Subsidies, tax deduction, tax credits, rebates, loans, guarantees on energy efficient investments, loss-framed messages
Environmental Preference	Messages framed in terms of intrinsic goals, moral suasion and appeal to intrinsic values
Reference Dependent Preference and non linear probability weighting	Subsidies and tax credits, loss-framed messages, goal setting programs, pricing programs characterized by lower spread of charges
Bounded Rationality	Energy audits, product labelling, certificates, peer-comparison, information metrics that match the problem-solving, provision of multiple translations of energy-efficiency metrics
Rational Inattention	Standard, subsidies, tax deduction, tax credits, rebates, loans, energy audits, product labelling, certificates, feedback
Present Bias	Standard, commitment and goal setting programs
Status Quo Bias	Set the default option that favours energy conservation to opt-out rather than opt-in

However, calculations of the energy savings and welfare effects of stricter standards are often made without taking into account the welfare losses due to lower available choices. Product standards could also reduce welfare, because they impose a restriction on product choice and forces behavioural change on those who gain little from energy efficiency. Allcott and Taubinsky (2015) find that **imperfect information** and **inattention** alone cannot justify a ban on incandescent lightbulbs. Standards are only a second-best policy compared to information disclosure programs. The latter directly address information asymmetries and rational inattention without reducing the available choices. A ban to incandescent lightbulbs produces welfare losses to consumers who strongly prefer these inefficient lightbulbs even after being informed of the apparently large cost savings. In the paper, these welfare losses outweigh the gains to uninformed or inattentive consumers. On the contrary, Tsvetanov and Segerson (2014) acknowledges that stricter standards on top-freezer refrigerators could make some consumers worse off, but they find that these instruments are on average welfare improving under a **self-control** framework where individuals are characterized by **temptation**. In particular, standards benefit lower-income households the most, because of the inverse relationship between income and the degree of temptation. This paper indicates how important is to identify the underlying behavioural assumption used in evaluating the welfare effects of energy efficiency standards.

Concerns about the use of standards arise also in the context of fuel-economy. Higher CAFE standards are generally found to be inferior to gasoline taxes in improving energy efficiency. Austin and Dinan (2005) report that gasoline tax would accumulate savings much earlier than CAFE standards. A tax not only encourages the purchase of more fuel-efficient vehicles, but it also discourages driving. Taxes induces two mechanisms rather than one in addressing energy efficiency. Jacobsen (2013) confirms that gasoline taxes are more efficient than CAFÉ regulation. Moreover, examining both the new and used vehicle markets, the author finds that in the long-run fuel economy standards are less progressive than expected as they generate larger proportional welfare losses for low-income households. Fischer, Harrington, and Parry (2007) conclude as well that the efficiency rationale for raising fuel economy standards is weak.

The inefficiency of standards is confirmed also in papers in the context of fuel-economy that introduce some behavioural failures. Parry, Evans, and Oates (2014) compare the welfare effects of energy efficiency standards and pricing policies in the case of rational inattention or bounded rationality. They conclude that even with large misperceptions, an optimal policy portfolio should make only a limited use of fuel economy and power sector efficiency standards. Pricing policies should be the first best option, while efficiency standards can play a role only if practical constraints on gasoline/electricity taxes arise.

Ito and Sallee (2014) document that “attribute-based” standards generate an additional distortion to the market. This type of policies are designed conditional on product attributes rather than the target they wish to achieve.[3] Attribute-based policies tend to provide a less stricter standard for products that are larger and more polluting, thus creating perverse incentives. The authors find that as a consequence of weight-based standards, the Japanese car market has experienced an increase in vehicle weights, and this lowers fuel economy and increases externalities related to accidents.

[3] The same problem applies to attribute-based tax and subsidies.

To summarize, efficiency standards are an inferior instrument compared to other policies, such as information programs or taxes, as they not influence behaviour by discouraging the use of energy-using products. They also introduce some distortions, reducing the available choice and creating perverse incentives. Other policies represent a more direct, efficient and responses to the market failures that standards tend to address.

3.2 Economic and financial instruments

Economic instruments are an important instrument for energy efficiency as they can make investments more attractive by lowering upfront costs. They can also influence the operating costs of the investment, relative to other less-efficient products. Financing the initial investment in energy-efficient equipment is facilitated by easy access to credit with appropriate finance conditions. In principle, these incentives apply to actions that are cost effective from the collective point of view, but which would not otherwise be undertaken by consumers.

Economic incentives such as subsidies, tax deduction, tax credits, rebates, loans offered at subsidized interest rates are primarily designed to address **capital market failures**. Moreover, Blumstein (2010) reports that some individuals choose to make energy efficiency investment because their awareness has been raised by the existence of the incentive schemes. In this respect, economic incentives may address an **information problem**. If loans are given directly to installer, they reduce information barriers, as installers may have a commercial approach to promoting energy efficiency. Rebates are also particularly relevant for persons who are **risk averse**. Finally, subsidies and taxes can address the same type of barriers of standards, in particular **present bias**, and **rational inattention**. This is because the implications of product subsidies and taxes is quite similar to the implications of standards. Finally guarantees should address **risk preferences** as well as **financial and technological risks**.

Standard imposes a relative shadow cost on less efficient products, which causes consumers to have to pay relatively less for more efficient products, just like a product subsidy on efficient products or taxes on inefficient products. As described above, taxes should be preferable to standards, given that their cost is transparent, they promote behavioural changes, and they take into consideration the heterogeneity of consumers. Taxes have drawbacks as well. They produce negative distributional effects and their impact is limited if price elasticity of energy demand is small. Wagner (2016) find that environmental preferences shape the efficacy of relative price and tax incentives, with environmentalists being less sensitive to changes in prices and taxes than their less environmental counterparts.

The literature suggests that if there are no behavioural anomalies, the social optimum is to apply a Pigouvian tax or equivalent instruments (Gillingham and Palmer 2014). For example, Galarraga, Abadie, and Kallbekken (2016) find that in Spain a tax scheme on dishwashers, refrigerators and washing ensure greater energy savings than a subsidy scheme. In the presence of behavioural anomalies, however, subsidies for energy efficient investments represent the optimal policy option. Hassett and Metcalf (1995) report that subsidies are much more effective than an equivalent tax. One possible explanation for the effectiveness of subsidies and tax credits compared to taxes is related to the presence of **loss aversion and reference dependence.** People strongly prefer avoiding losses to achieving gains, and a subsidy tends to reduce the loss (represented by the cost of the investment) rather than increasing the gains (because of lower operating costs due to lower use). Allcott and Taubinsky (2015) as well report that a moderate subsidy could be optimal to increase the market for compact fluorescent lightbulbs in case of imperfect information and inattention.

Allcott, Mullainathan, and Taubinsky (2014) report that, if consumers undervalue energy costs because of **inattention** or imperfect information, the optimal combination of tax and subsidy implies a quite large product subsidy. A subsidy is more effective than a tax in targeting the most biased consumer, because consumers who undervalue energy costs the most are also the least sensitive to the energy tax. As a general rule, targeting the corrective measures to the different groups of consumers is crucial to achieve the highest energy conservation. From a welfare perspective it matters if the consumers affected by the distortions are also affected by the policy interventions. If the eligibility of subsidies cannot be restricted to a specific group from an institutional point of view, targeted marketing at the groups most affected by the distortion could produce large gains to increase their adoption of the subsidy (Allcott, Knittel, and Taubinsky 2015).

An important concern with subsidies and rebates is that they lead to a rebound effect Alberini, Gans, and Towe (2016), they encourage free-riding (Houde and Aldy, forthcoming), they need to be financed through for example a distortionary tax and are often not cost-effective. Davis, Fuchs, and Gertler (2014) evaluate a subsidy programme in Mexico to replace inefficient refrigerators and air conditioners with new models and conclude that the programme is not cost-effective. Boomhower and Davis (2014) as well report that large subsidies are not cost-effective as most households in their analysis would have participated even with much lower subsidy. Datta and Gulati (2014) find that rebates affect only the demand of energy star clothes washers and not of dishwasher and refrigerator. A meta-analysis of 42 utility conservation programs in the residential, commercial, and industrial sectors found that actual energy-savings estimates for residential retrofit programs are lower than ex ante engineering-economic estimates (Nadel and Keating 1991). Allcott and Greenstone (2017) analyse the impact of an energy efficiency program, which subsidizes a home energy audit and subsequent recommended investments. They find that the marginal investment probabilities decrease sharply as the subsidy increases. While the subsidy induces additional households to audit, these marginal households are less and less interested in making subsequent investments. This implies a negative social welfare induced by the program. The externality benefit from reduced energy does not compensate for the reduction in consumer utility, due to the higher taxes to finance the program. However, they also conclude that subsidizing energy conservation remains an important means to improve energy efficiency. In their analysis, the market for home energy audits and retrofits would almost entirely disappear in the absence of government intervention.

Not all schemes have the same efficacy. Gallagher and Muehlegger (2011) compare the effect of a variety of incentives to induce consumer adoption of hybrid electric vehicles and conclude that, conditional on value, sales tax waivers produce a much larger increase in hybrid sales than income tax credits. Revelt and Train (1998) compare the impact of zero interest loans and rebates and conclude that loans have a much larger impact on purchases of efficient refrigerators than rebates.

Finally, the use of guarantees, whereby governments or energy providers share the costs and risk but also the benefits from future savings related to energy efficient renovations can improve energy efficiency by reducing the perceived risk of the investment (Fischbacher, Schudy, and Teyssier 2015).

3.3 Provision of Information

Information programs can be divided into two broad categories. On the one hand are energy audit, product labelling, energy performance certificates and hard information interventions which disclose energy saving information and benefits related to energy-efficient appliances and investments. On the other are interventions (such as feedback, peer comparison, goal setting, default setting, focus on losses, manipulation of the metric and the scale, translation of the metrics) that are classified as nudges, because they act as low cost motivational and persuasion strategies. To design this type of interventions, increasingly guidance from psychologists and behavioural scientists is called for.

Information programs tend not only to overcome information problems, but they also address many behavioural barriers to energy efficiency. By guiding consumers in the decision process, information programs lower the cognitive costs of energy decision making and address **bounded rationality**. Information programs that provide feedback on own energy consumption are designed to address **rational inattention**. To address **bounded rationality**, feedback can also focus on peer comparisons through information on neighbors' energy consumption. Goal setting and commitment programs are nudging tools that intend to address high **temporal discounting**, **present bias, reference dependence**. Programs which change the default setting address the **status quo bias**. Messages that focus on losses instead of gains should tackle **reference dependence**. Messages that make future returns less uncertain can address **risk preferences. Moral suasion** tools can be designed to leverage **pro-environmental preferences**. Manipulation of the metric and the scale in the case of fuel economy helps addressing **bounded rationality. Bounded rationality** is also addressed by providing multiple translations of energy-efficiency metrics.

3.3.1 Audits

Information programs are a purely informational tool and a follow-up action is critical to realizing the energy efficiency gains. For example, **audits** consist in recommendations for example for attic insulation, sealing of windows and doors, lighting, heating and cooling improvements and replacement of appliances. Audits are tailored and highly personalized information. Audits can improve energy efficiency because homeowners may not be aware that their homes are inefficient and chose to follow some of the recommendations of the auditors. Moreover, by providing information to tenants, energy audits can help alleviating the information asymmetries between landlords and tenants. Frondel and Vance (2013) analyse the effect of home energy audit on investment in home renovations and find that on average audit increases energy efficiency investments. However, the authors find strong heterogeneous responses, with some households investing less as a result of the energy audit. This finding does not imply that for some households energy use increases as a follow-up of the energy audit. Taking advantage of coaching from auditors, some households may have decided to save energy through behavioural changes rather than through retrofitting investments. Alberini and Towe (2015), for example find that participation in the home energy audit program reduces energy use. A similar effect is found for heat pump rebate. However, Allcott and Greenstone (2017) report that the benefits of auditing are inferior to costs.

3.3.2 Labelling and hard information interventions

A growing number of studies have analysed the impact of **Energy Star** and hard **information** interventions which disclose energy saving information. The evidence is mixed, and eventually depends on the empirical approach adopted, with some papers using artefactual field experiments and other natural field experiments. Ward et al. (2011) apply a contingent choice experiment and confirm a positive influence of Energy Star label on consumer preferences for refrigerators. Houde (2014) uses quasi-experimental approach and find that consumers rely heavily on Energy Star label when purchasing refrigerators. Moreover, some consumers over-rely on the binary label which acts as a substitute for relevant energy information such as actual energy savings. Allcott and Taubinsky (2015) analyse the impact of a program that provides consumers with information about cost savings from compact fluorescent lightbulbs compared to incandescent ones. While in the artefactual field experiment, they find that information provision increases the market for efficient lightbulbs, they find no effect of information disclosure in the natural field experiment. Kallbekken, Sælen, and Hermansen (2013) test the effect of providing information which makes lifetime operating costs more salient to consumers at the point of purchase as well as training of sales staff. The combined information and training treatments lead consumers to purchase more energy-efficient tumble driers but no effect on fridge-freezers sales. However, in this study the authors employ a non-random control group. Allcott and Sweeney (2016) find that information about energy cost savings of Energy Star water heaters and about customer rebates provided by sales agents is ineffective at increasing demand for these energy efficient products. In this paper lack of awareness and cost savings information are not the primary obstacles to energy efficiency at least in this context, as consumers make an informed decision to not purchase the products. In Allcott and Greenstone (2017) hard information on the private and social benefits of investments that could follow-up a home energy audit did not influence the participation to the audit program. In this analysis only price interventions, in the form of audit subsidies, increased take-up of the program.

While artefactual field experiments suggest that the provision of information improves energy efficiency choices, natural field experiments seem to indicate that imperfect information and inattention are a minimal barrier to energy efficiency. In these last papers, a large shares of consumers might still prefer energy inefficient products even after being powerfully informed. It should be noted however that in natural field experiments, the (store) environment provides the control group with information on different energy efficient technologies, including electricity use. The availability of this information to the control group may have reduced the effectiveness of the information treatment.

The limited effect of information disclosure could be to a second reason, namely the way the information is presented. Heinzle (2012) uses a choice-based conjoint analysis to understand the relative importance of timeframe and format in which information about energy consumption is presented. The author concludes that framing information in terms of operating cost rather than physical measurement, such as “watts,” is more effective in influencing consumer behaviour, but only when framed over the lifetime of a product. Davis and Metcalf (2016) find that enhanced label with local electricity costs lead to better choices in a hypothetical framework. Tailored energy guide labels produce larger gains than non-tailored ones. Newell and Siikamäki (2014) using as well data from a stated choice experiment conclude that information content and label style strongly influence the valuation of water heater. In particular, they compare various elements of information labels and find that simple details on the economic value of energy saving is the most effective piece of information for cost-effective energy efficiency decisions.

3.3.3 Nudges

Some interventions aim at providing easily accessible **feedback** on the quantity of energy used through various technological means, such as in-home monitors, computers, mobile phones and/or other portable displays. Feedback can address **rational inattention** because it makes consumers aware of their energy usage or its impacts and it directs attention to a specific goal. A large number of rigorous studies exists on the effects of feedback which tends to confirm its positive role on energy conservation. Meta analyses have also been performed, to assess not only if feedback works (Corinna Fischer 2008; McKerracher and Torriti 2013), but also how it works best and which factors moderate its effectiveness. Karlin, Zinger, and Ford (2015) review 42 articles published between 1976 and 2010 and conclude that feedback has a positive effect on energy conservation. Moreover the effectiveness is maximized if feedback is delivered via computer, if the feedback duration is either less than three months or more than a year and if the feedback is combined with a goal intervention.

Some recent studies have tried to analyse why feedback influences energy-use behaviour and conclude that in-home-displays help consumers improving the decision making process in case of high-prices, whereas they are less likely to make prices more salient (Jessoe and Rapson 2014; Lynham et al. 2016).

Interestingly, Goodhew et al. (2015) find that thermal images of heat losses in homes motivate households to reduce energy use and take energy-saving measures more than a carbon footprint audit. Thermal images provide vivid information which is easy to process. Moreover, they provide personalised information, that directs toward the specific measures one could implement to prevent heat losses. Thaler and Sunstein (2008) report that proving simple but vivid signal of energy consumption through light bulbs that change colour at different energy prices are effective in reducing energy consumption. Interventions should be designed to provide vivid signals and recall energy saving actions that are easily available in consumers' memories (Frederiks, Stenner, and Hobman 2015).

Given that social norms can effectively induce behavioural change, feedback programs that provide **descriptive normative messages** through **peer comparison** have been used to encourage energy conservation. Conforming to social norms is sometimes a mental shortcut that people use to address complexity in decision making. For this reason descriptive normative messages can address **bounded rationality**. Comparative feedback can induce energy conservation by evoking feeling of competition, social comparison, and social pressure or making salient a social norm in favour of energy conservation. To avoid boomerang effects, whereby households with below average use respond by increasing consumption, these conservation programs also employ injunctive norms which convey social approval through "smiley faces" for example. Allcott (2011a); Schultz et al. (2007); Costa and Kahn (2013); Ayres, Raseman, and Shih (2012) find that this type of intervention is successful in reducing residential energy use. However, a meta analysis of 30 different studies published between 1976 and 2013 compares the effectiveness of a variety of social influence approaches in energy conservation (Abrahamse and Steg 2013). The analysis concludes that peer comparison is less powerful than other social influence interventions, because it delivers the feedback in a fairly anonymous way. The most effective interventions are those where information is provided by block leaders, who are persons belonging to the same social network and make use of face-to-face interactions.

Commitment is another important nudge whereby people make a pledge or promise to engage in sustainable energy behaviour. This program should reduce impulsivity and encourage delayed gratification for investments that have immediate and larger costs and delayed rewards. The commitment can effectively induce a behavioural change because it may activate and strengthen a personal norm. A similar strategy is **goal setting**, which entails giving consumers a specific reference point, for instance to save energy by a certain amount. Goal setting proves to be effective in particular in combination with a commitment to save energy (Katzev and Johnson 1983), or with a feedback (McCalley and Midden 2002). Harding and Hsiaw (2014) find that a goal setting program which offers a menu of energy savings options with respect to annual electricity savings, attracts **present-biased** consumers **and consumers with limited self-control**. These consumers are aware of their need for a commitment to behave pro-environmentally. With no commitment, they will consume more electricity than ex ante preferred. The authors report substantial and persistent savings among consumers who commit to realistic goals, but no savings among consumers who chose very low or unrealistically high goals. Becker (1978) as well finds that too easy goals to reduce electricity are not effective. On the contrary households who had been given a relative difficult goal in combination with a feedback performed better in terms of energy conservation. The importance of combing tailored feedback with goal setting is also emphasized in Abrahamse et al. (2007). Goal setting programs address also **reference-dependent preferences**. Harding and Hsiaw (2014) document that people voluntary enrol in the goal program, setting personal conservation goals.

Given that people tend to stick to the **status quo**, the use of **default setting** that favours energy conservation could be an important nudge to promote pro-environmental behaviour. The default option to participate in pro-environmental program can be set to opt-out rather than opt-in. Pichert and Katsikopoulos (2008) find that people are more likely to choose a green source of energy if the green option is presented as the default rather than an alternative. Brown et al. (2013) report that by decreasing the default setting in office thermostats produces a reduction in the chosen temperature setting.

One intervention that can be effective in addressing **loss aversion** is the use of **loss-framed** rather than gain-framed messages. Manipulating the messages to focus on the costs of the less efficient behaviour rather than the benefits of the energy conservation activities, makes this type of loss-framed messages more salient, memorable and motivating (Frederiks, Stenner, and Hobman 2015). While research on framing has reached some stable conclusions in the health domain, findings in the environmental contexts have been less consistent. Various factors can moderate the effect of loss-framed messages. For example, loss-framed messages should be more effective if the targeted behaviour invokes some level of risk (Loroz 2007). More research is needed on the empirical examination of the effectiveness of loss- versus gain-framing in the energy efficiency domain.

Manipulation of information metrics can address **bounded rationality**. For example, information metrics that match the problem-solving processes have the greatest influence on consumer preferences and choices. This is because the decision making is less effortful if the problem representation matches the problem-solving processes. Camilleri and Larrick (2014) find that simply manipulating the metric (consumption of gas versus the cost of gas) and the scale (100 miles versus 15,000 miles versus 100,000 miles) on which fuel economy information is expressed, would shift preferences toward more fuel-efficient vehicles. Ungemach et al. (2017) find that providing multiple translations of energy-efficiency metrics could help guiding behaviour. The way a message is **framed** proves to be important not only to address bounded rationality, but also **environmental preferences**. Pelletier and Sharp (2008) report the importance of framing messages in terms of whether they serve intrinsic goals (i.e., health, well-being) rather than extrinsic goals (i.e., make or save money, comfort) in order to increase the level of self-determined motivation and thus induce pro-environmental behaviour.

Meta-analyses have also been conducted to compare performance of information and non-information interventions. For example, Abrahamse et al. (2005) review 38 different articles dating from 1977 to 2004 and compare the effectiveness of commitment, goal setting, provision of information (which are categorized as antecedent strategies, because they aim at influencing underlying behavioural determinants) with feedback and rewards (which are classified as consequence strategies, because behaviour is influenced by its positive or negative consequences). They conclude that information programs increase knowledge but this does not necessarily translate into behavioural changes or energy savings. Monetary rewards are successful in engaging consumer in energy conservation, but the effect is not persistent in time. Commitment programs have long-term effects and are more effective when made in public rather than private. Finally feedback reduces energy use in particular if it is provided frequently, through continuous electronic feedback for instance. Delmas, Fischlein, and Asensio (2013) is the most comprehensive meta-analysis of different types of interventions. These include feedback, energy savings tips, energy audits, financial incentives and peer comparisons. The authors report that real time feedback and home energy audits are drivers of conservation behaviour, while low level information strategies, such as energy savings tips and individual usage feedback are not. Peer comparisons do not produce energy saving, but this may be due to the fact that feedback proves to be effective if delivered in real time, and none of the studies in the meta-analysis considers real time peer comparisons. Moreover, social influence is maximized in face-to-face interactions, while social comparison interventions generally happen anonymously. Moreover, non-monetary, information-based strategies seem to be superior to economic incentives. Financial benefits from saving energy are often limited and thus provide too little incentive to conservation. Moreover, financial incentives can crowd out pro-social behaviour.

Appealing to economic rather than biospheric concerns could be ineffective in securing behaviour change, but it can also be counterproductive. Extrinsic rewards can sometimes crowd out' intrinsic motivation to act altruistically and consequently backfire and discourage the pro-environmental behaviour they are meant to encourage (Gneezy, Meier, and Rey-Biel 2011). Ito, Ida, and Tanaka (2015) evaluate how persistent are the effects of appealing to intrinsic versus and extrinsic motivations. The author finds that both moral suasion and economic incentives induce the desired conservative effects, but while the former exert diminishing effects, the latter produce persistent effects, which induced habit formation.

Information programs, even if they increase knowledge and awareness in general, they tend to encourage behavioural changes among people who strongly endorse biospheric (environmental) values. Information is effective when it resonates with people's central values (Steg, Perlaviciute, and van der Werff 2015). Targeting the policy interventions is therefore crucial in many domains, not only with respect to the financial programs discussed above. Given that informational interventions are perhaps ineffective in those who care less about the environment, they could still deliver beneficial effects if directed towards those who strongly care about the environment. This is because they make them more inclined to act on their values.

A widespread misconception in information campaigns is that people are primarily motivated by (economic) self-interest. On the contrary, it seems that people are motivated to maintain a favourable view of themselves (Ariely, Bracha, and Meier 2009), which can be achieved by acting green, for example. People prefer to see themselves as 'green' rather than 'greedy. Bolderdijk et al. (2013) find that participants in laboratory experiments anticipate more positive affect from complying with the biospheric than the economic appeal. Biospheric appeal evokes positive affect because it enables people to perceive compliance as morally good conduct. The way a person acts is influenced by how the person feels about acting. Taufik, Bolderdijk, and Steg (2016) confirm that the intention to act environmentally friendly is largely driven by the positive feeling about acting pro-environmentally and less so by the perceived benefits connected to this action. Therefore, to induce pro-environmental behaviour, information campaigns should stress the selfless, societal aspects of acting pro-environmentally and should resonate with people' feelings, instead of exclusively appealing to their calculations.

References

Abrahamse, Wokje, and Linda Steg. 2013. “Social Influence Approaches to Encourage Resource Conservation: A Meta-Analysis.” Global Environmental Change 23 (6): 1773–85. doi:10.1016/j.gloenvcha.2013.07.029.

Abrahamse, Wokje, Linda Steg, Charles Vlek, and Talib Rothengatter. 2005. “A Review of Intervention Studies Aimed at Household Energy Conservation.” Journal of Environmental Psychology 25 (3): 273–91. doi:10.1016/j.jenvp.2005.08.002.

———. 2007. “The Effect of Tailored Information, Goal Setting, and Tailored Feedback on Household Energy Use, Energy-Related Behaviors, and Behavioral Antecedents.” Journal of Environmental Psychology 27 (4): 265–76. doi:10.1016/j.jenvp.2007.08.002.

Alberini, Anna, Silvia Banfi, and Celine Ramseier. 2013. “Energy Efficiency Investments in the Home: Swiss Homeowners and Expectations about Future Energy Prices.” Energy Journal 34 (1): 49–86.

Alberini, Anna, and Charles Towe. 2015. “Information v. Energy Efficiency Incentives: Evidence from Residential Electricity Consumption in Maryland.” Energy Economics, Frontiers in the Economics of Energy Efficiency, 52, Supplement 1: S30–40. doi:10.1016/j.eneco.2015.08.013.

Allcott, Hunt. 2011a. “Social Norms and Energy Conservation.” Journal of Public Economics, Special Issue: The Role of Firms in Tax Systems, 95 (9–10): 1082–95. doi:10.1016/j.jpubeco.2011.03.003.

———. 2011b. “Consumers’ Perceptions and Misperceptions of Energy Costs.” American Economic Review 101 (3): 98–104. doi:10.1257/aer.101.3.98.

Allcott, Hunt, and Michael Greenstone. 2017. “Measuring the Welfare Effects of Residential Energy Efficiency Programs.” SSRN Scholarly Paper ID 2945603. Rochester, NY: Social Science Research Network. https://papers.ssrn.com/abstract=2945603.

Allcott, Hunt, Christopher Knittel, and Dmitry Taubinsky. 2015. “Tagging and Targeting of Energy Efficiency Subsidies.” American Economic Review 105 (5): 187–91.

Allcott, Hunt, Sendhil Mullainathan, and Dmitry Taubinsky. 2014. “Energy Policy with Externalities and Internalities.” Journal of Public Economics 112 (April): 72–88. doi:10.1016/j.jpubeco.2014.01.004.

Allcott, Hunt, and Richard L. Sweeney. 2016. “The Role of Sales Agents in Information Disclosure: Evidence from a Field Experiment.” Management Science 63 (1): 21–39. doi:10.1287/mnsc.2015.2327.

Allcott, Hunt, and Dmitry Taubinsky. 2015. “Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market.” American Economic Review 105 (8): 2501–38. doi:10.1257/aer.20131564.

Allcott, Hunt, and Nathan Wozny. 2014. “Gasoline Prices, Fuel Economy, and the Energy Paradox.” Review of Economics and Statistics 96 (5): 779–95. doi:10.1162/REST_a_00419.

Anderson, Soren T, and Richard G Newell. 2004. “Information Programs for Technology Adoption: The Case of Energy-Efficiency Audits.” Resource and Energy Economics 26 (1): 27–50. doi:10.1016/j.reseneeco.2003.07.001.

Ariely, Dan, Anat Bracha, and Stephan Meier. 2009. “Doing Good or Doing Well? Image Motivation and Monetary Incentives in Behaving Prosocially.” American Economic Review 99 (1): 544–555. doi:10.1257/aer.99.1.544.

Aroonruengsawat, Anin. 2012. "The Impact of State Level Building Codes on Residential Electricity Consumption." The Energy Journal 33 (1). doi:10.5547/ISSN0195-6574-EJ-Vol33-No1-2.

Austin, David, and Terry Dinan. 2005. "Clearing the Air: The Costs and Consequences of Higher CAFE Standards and Increased Gasoline Taxes." Journal of Environmental Economics and Management 50 (3): 562–82. doi:10.1016/j.jeem.2005.05.001.

Ayres, Ian, Sophie Raseman, and Alice Shih. 2012. "Evidence from Two Large Field Experiments That Peer Comparison Feedback Can Reduce Residential Energy Usage." Journal of Law, Economics, and Organization, August, ews020. doi:10.1093/jleo/ews020.

Becker, Lawrence J. 1978. "Joint Effect of Feedback and Goal Setting on Performance: A Field Study of Residential Energy Conservation." Journal of Applied Psychology 63 (4): 428–33. doi:10.1037/0021-9010.63.4.428.

Bertoldi, Paolo, Bettina Hirl, and Nicola Labanca. 2012. "Energy Efficiency Status Report 2012 - Electricity Consumption and Efficiency Trends in the EU-27." EUR - Scientific and Technical Research Reports. Publications Office of the European Union. JRC69638. http://publications.jrc.ec.europa.eu/repository/handle/111111111/26929.

Blumstein, Carl. 2010. "Program Evaluation and Incentives for Administrators of Energy-Efficiency Programs: Can Evaluation Solve the Principal/Agent Problem?" The Socio-Economic Transition towards a Hydrogen Economy - Findings from European Research, with Regular Papers 38 (10): 6232–39. doi:10.1016/j.enpol.2010.06.011.

Bolderdijk, J. W., L. Steg, E. S. Geller, P. K. Lehman, and T. Postmes. 2013. "Comparing the Effectiveness of Monetary versus Moral Motives in Environmental Campaigning." Nature Climate Change 3 (4): 413–16. doi:10.1038/nclimate1767.

Bollinger, Bryan, and Kenneth Gillingham. 2012. "Peer Effects in the Diffusion of Solar Photovoltaic Panels." Marketing Science 31 (6): 900–912. doi:10.1287/mksc.1120.0727.

Boomhower, Judson, and Lucas W. Davis. 2014. "A Credible Approach for Measuring Inframarginal Participation in Energy Efficiency Programs." Journal of Public Economics 113: 67–79. doi:10.1016/j.jpubeco.2014.03.009.

Bradford, David, Charles Courtemanche, Garth Heutel, Patrick McAlvanah, and Christopher Ruhm. 2014. "Time Preferences and Consumer Behavior." Working Paper 20320. National Bureau of Economic Research. doi:10.3386/w20320.

Brennan, Timothy J. 2007. "Consumer Preference Not to Choose: Methodological and Policy Implications." Energy Policy 35 (3): 1616–27. doi:10.1016/j.enpol.2006.04.023.

Brown, Zachary, Nick Johnstone, Ivan Haščič, Laura Vong, and Francis Barascud. 2013 "Testing the Effect of Defaults on the Thermostat Settings of OECD Employees." Energy Economics 39: 128–34. doi:10.1016/j.eneco.2013.04.011.

Bruderer Enzler, Heidi, Andreas Diekmann, and Reto Meyer. 2014. "Subjective Discount Rates in the General Population and Their Predictive Power for Energy Saving Behavior." Energy Policy 65 (February): 524–40. doi:10.1016/j.enpol.2013.10.049.

Busse, Meghan R., Christopher R. Knittel, and Florian Zettelmeyer. 2013. "Are Consumers Myopic? Evidence from New and Used Car Purchases." American Economic Review 103 (1): 220–56. doi:10.1257/aer.103.1.220.

Camilleri, Adrian R., and Richard P. Larrick. 2014. "Metric and Scale Design as Choice Architecture Tools." Journal of Public Policy & Marketing 33 (1): 108–25. doi:10.1509/jppm.12.151.

Cialdini, Robert B., and Melanie R. Trost. 1998. "Social Influence: Social Norms, Conformity and Compliance." In The Handbook of Social Psychology, Vols. 1-2, 4th Ed, edited by D. T. Gilbert, S. T. Fiske, and G. Lindzey, 151–92. New York, NY, US: McGraw-Hill.

Costa, Dora L., and Matthew E. Kahn. 2010. "Why Has California's Residential Electricity Consumption Been So Flat since the 1980s?: A Microeconometric Approach." Working Paper 15978. National Bureau of Economic Research. doi:10.3386/w15978.

———. 2011. "Electricity Consumption and Durable Housing: Understanding Cohort Effects." American Economic Review 101 (3): 88–92. doi:10.1257/aer.101.3.88.

———. 2013. "Energy Conservation 'nudges' and Environmentalist Ideology: Evidence from a Randomized Residential Electricity Field Experiment." Journal of the European Economic Association 11 (3): 680–702.

Datta, Souvik, and Sumeet Gulati. 2014. "Utility Rebates for ENERGY STAR Appliances: Are They Effective?" Journal of Environmental Economics and Management 68 (3): 480–506. doi:10.1016/j.jeem.2014.09.003.

Davis, Lucas W. 2008. "Durable Goods and Residential Demand for Energy and Water: Evidence from a Field Trial." The RAND Journal of Economics 39 (2): 530–46.

———. 2010. "Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances?" Working Paper 16114. National Bureau of Economic Research. doi:10.3386/w16114.

Davis, Lucas W., Alan Fuchs, and Paul Gertler. 2014. "Cash for Coolers: Evaluating a Large-Scale Appliance Replacement Program in Mexico." American Economic Journal: Economic Policy 6 (4): 207–38. doi:10.1257/pol.6.4.207.

Davis, Lucas W., and Gilbert E. Metcalf. 2016. "Does Better Information Lead to Better Choices? Evidence from Energy-Efficiency Labels." Journal of the Association of Environmental and Resource Economists 3 (3): 589–625. doi:10.1086/686252.

Delmas, Magali A., Miriam Fischlein, and Omar I. Asensio. 2013. "Information Strategies and Energy Conservation Behavior: A Meta-Analysis of Experimental Studies from 1975 to 2012." Energy Policy 61: 729–39. doi:10.1016/j.enpol.2013.05.109.

Di Maria, Corrado, Susana Ferreira, and Emiliya Lazarova. 2010. "Shedding Light on the Light Bulb Puzzle: The Role of Attitudes and Perceptions in the Adoption of Energy Efficient Light Bulbs." Scottish Journal of Political Economy 57 (1): 48–67. doi:10.1111/j.1467-9485.2009.00506.x.

Dunlap, Riley E., J. Keith Grieneeks, and Milton Rokeach. 1983. "Human Values and pro-Environmental Behavior." In Energy and Material Resources: Attitudes, Values, and Public Policy, Boulder, CO: West view.

Dunlap, Riley E., and Kent D. Van Liere. 1978. "The 'New Environmental Paradigm.'" The Journal of Environmental Education 9 (4): 10–19. doi:10.1080/00958964.1978.10801875.

Dütschke, Elisabeth, and Alexandra-Gwyn Paetz. 2013. "Dynamic Electricity pricing—Which Programs Do Consumers Prefer?" Energy Policy 59: 226–34. doi:10.1016/j.enpol.2013.03.025.

Eichhammer, Wolfgang, Tobias Fleiter, Barbara Schlomann, Stefano Faberi, Michela Fioretto, Nicola Piccioni, S. Lechtenböhmer, A. Schüring, and Gustav Resch. 2009. "Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries." Final Report.

Ek, Kristina, and Patrik Söderholm. 2010. "The Devil Is in the Details: Household Electricity Saving Behavior and the Role of Information." Energy Policy, Security, Prosperity and

Community – Towards a Common European Energy Policy? Special Section with Regular Papers, 38 (3): 1578–87. doi:10.1016/j.enpol.2009.11.041.

Erdem, Cumhur, İsmail Şentürk, and Türker Şimşek. 2010. "Identifying the Factors Affecting the Willingness to Pay for Fuel-Efficient Vehicles in Turkey: A Case of Hybrids." Energy Policy, The Role of Trust in Managing Uncertainties in the Transition to a Sustainable Energy Economy, Special Section with Regular Papers, 38 (6): 3038–43. doi:10.1016/j.enpol.2010.01.043.

Farsi, Mehdi. 2010. "Risk Aversion and Willingness to Pay for Energy Efficient Systems in Rental Apartments." Energy Policy, The Role of Trust in Managing Uncertainties in the Transition to a Sustainable Energy Economy, Special Section with Regular Papers, 38 (6): 3078–88. doi:10.1016/j.enpol.2010.01.048.

Filippini, Massimo, Lester C. Hunt, and Jelena Zorić. 2014. "Impact of Energy Policy Instruments on the Estimated Level of Underlying Energy Efficiency in the EU Residential Sector." Energy Policy 69: 73–81. doi:10.1016/j.enpol.2014.01.047.

Fischbacher, Urs, Simeon Schudy, and Sabrina Teyssier. 2015. "Heterogeneous Preferences and Investments in Energy Saving Measures." Munich Discussion Paper No. 2015-11. https://epub.ub.uni-muenchen.de/24894/.

Fischer, C., W. Harrington, and I. W. H. Parry. 2007. "Should Automobile Fuel Economy Standards Be Tightened?" Energy Journal 28(4): 1–29

Fischer, Corinna. 2008. "Feedback on Household Electricity Consumption: A Tool for Saving Energy?" Energy Efficiency 1 (1): 79–104. doi:10.1007/s12053-008-9009-7.

Frederiks, Elisha R., Karen Stenner, and Elizabeth V. Hobman. 2015. "Household Energy Use: Applying Behavioural Economics to Understand Consumer Decision-Making and Behaviour." Renewable and Sustainable Energy Reviews 41: 1385–94. doi:10.1016/j.rser.2014.09.026.

Frondel, Manuel, and Colin Vance. 2013. "Heterogeneity in the Effect of Home Energy Audits: Theory and Evidence." Environmental and Resource Economics 55 (3): 407–18. doi:10.1007/s10640-013-9632-4.

Galarraga, Ibon, Luis M. Abadie, and Steffen Kallbekken. 2016. "Designing Incentive Schemes for Promoting Energy-Efficient Appliances: A New Methodology and a Case Study for Spain." Energy Policy 90 (March): 24–36. doi:10.1016/j.enpol.2015.12.010.

Gallagher, Kelly Sims, and Erich Muehlegger. 2011. "Giving Green to Get Green? Incentives and Consumer Adoption of Hybrid Vehicle Technology." Journal of Environmental Economics and Management 61 (1): 1–15. doi:10.1016/j.jeem.2010.05.004.

Gerarden, Todd D., Richard G. Newell, and Robert N. Stavins. 2017. "Assessing the Energy-Efficiency Gap." Journal of Economic Literature. doi:10.3386/w20904.

Gillingham, Kenneth, Matthew Harding, and David Rapson. 2012. "Split Incentives in Residential Energy Consumption." The Energy Journal 33 (2). doi:10.5547/01956574.33.2.3.

Gillingham, Kenneth, Richard G. Newell, and Karen Palmer. 2009. "Energy Efficiency Economics and Policy." Annual Review of Resource Economics 1 (1): 597–620. doi:10.1146/annurev.resource.102308.124234.

Gillingham, Kenneth, and Karen Palmer. 2014. "Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence." Review of Environmental Economics and Policy, January, ret021. doi:10.1093/reep/ret021.

Gneezy, Uri, Stephan Meier, and Pedro Rey-Biel. 2011. "When and Why Incentives (Don't) Work to Modify Behavior." The Journal of Economic Perspectives 25 (4): 191–209.

Goodhew, Julie, Sabine Pahl, Tim Auburn, and Steve Goodhew. 2015. “Making Heat Visible: Promoting Energy Conservation Behaviors Through Thermal Imaging.” Environment and Behavior 47 (10): 1059–88. doi:10.1177/0013916514546218.

Greening, Lorna A., Alan H. Sanstad, and James E. McMahon. 1997. “Effects of Appliance Standards on Product Price and Attributes: An Hedonic Pricing Model.” Journal of Regulatory Economics 11 (2): 181–94. doi:10.1023/A:1007906300039.

Griskevicius, Vladas, Joshua M. Tybur, and Bram Van den Bergh. 2010. “Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation.” Journal of Personality and Social Psychology 98 (3): 392–404. doi:10.1037/a0017346.

Groot, Judith I. M. de, and Linda Steg. 2008. “Value Orientations to Explain Beliefs Related to Environmental Significant Behavior: How to Measure Egoistic, Altruistic, and Biospheric Value Orientations.” Environment and Behavior 40 (3): 330–54. doi:10.1177/0013916506297831.

Harding, Matthew, and Alice Hsiaw. 2014. “Goal Setting and Energy Conservation.” Journal of Economic Behavior & Organization 107, Part A (November): 209–27. doi:10.1016/j.jebo.2014.04.012.

Harding, Matthew, and David Rapson. 2017. “Do Voluntary Carbon Offsets Induce Energy Rebound? A Conservationist’s Dilemma.”

Hardisty, David J., and Elke U. Weber. 2009. “Discounting Future Green: Money versus the Environment.” Journal of Experimental Psychology. General 138 (3): 329–40. doi:10.1037/a0016433.

Hassett, Kevin A., and Gilbert E. Metcalf. 1995. “Energy Tax Credits and Residential Conservation Investment: Evidence from Panel Data.” Journal of Public Economics 57 (2): 201–17. doi:10.1016/0047-2727(94)01452-T.

Hausman, J. A. 1979. “Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables.” The Bell Journal of Economics, 33–54.

Heinzle, Stefanie Lena. 2012. “Disclosure of Energy Operating Cost Information: A Silver Bullet for Overcoming the Energy-Efficiency Gap?” Journal of Consumer Policy 35 (1): 43–64. doi:10.1007/s10603-012-9189-6.

Houde, Sébastien. 2014. “How Consumers Respond to Environmental Certification and the Value of Energy Information.” Working Paper 20019. National Bureau of Economic Research. doi:10.3386/w20019.

Houde, Sébastien, and Joseph E. Aldy. n.d. “Consumers’ Response to State Energy Efficient Appliance Rebate Programs.” American Economic Journal: Economic Policy (Forthcoming).

IPCC. 2014. Fifth Assessment Report - Impacts, Adaptation and Vulnerability. http://www.ipcc.ch/report/ar5/wg2/.

Ito, Koichiro, Takanori Ida, and Makoto Tanaka. 2015. “The Persistence of Moral Suasion and Economic Incentives: Field Experimental Evidence from Energy Demand.” Working Paper 20910. National Bureau of Economic Research. doi:10.3386/w20910.

Ito, Koichiro, and James M. Sallee. 2014. “The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel-Economy Standards.” NBER Working Paper 20500. National Bureau of Economic Research, Inc. https://ideas.repec.org/p/nbr/nberwo/20500.html.

Jacobsen, Grant D., and Matthew J. Kotchen. 2013. “Are Building Codes Effective at Saving Energy? Evidence from Residential Billing Data in Florida.” The Review of Economics and Statistics 95 (1): 34–49.

Jacobsen, Mark R. 2013. "Evaluating US Fuel Economy Standards in a Model with Producer and Household Heterogeneity." American Economic Journal: Economic Policy 5 (2): 148–87. doi:10.1257/pol.5.2.148.

Jaffe, A. B., and R. N. Stavins. 1994. "The Energy-Efficiency Gap What Does It Mean?" Energy Policy 22 (10): 804–810.

Jessoe, Katrina, and David Rapson. 2014. "Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use." American Economic Review 104 (4): 1417–38. doi:10.1257/aer.104.4.1417.

Kahn, M. E. 2007. "Do Greens Drive Hummers or Hybrids? Environmental Ideology as a Determinant of Consumer Choice." Journal of Environmental Economics and Management 54 (2): 129–145.

Kahneman, D., and A. Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." Econometrica: Journal of the Econometric Society, 263–291.

Kallbekken, Steffen, Håkon Sælen, and Erlend A. T. Hermansen. 2013. "Bridging the Energy Efficiency Gap: A Field Experiment on Lifetime Energy Costs and Household Appliances." Journal of Consumer Policy 36 (1): 1–16. doi:10.1007/s10603-012-9211-z.

Karlin, Beth, Joanne F. Zinger, and Rebecca Ford. 2015. "The Effects of Feedback on Energy Conservation: A Meta-Analysis." Psychological Bulletin. doi:10.1037/a0039650.

Katzev, Richard D., and Theodore R. Johnson. 1983. "A Social-Psychological Analysis of Residential Electricity Consumption: The Impact of Minimal Justification Techniques." Journal of Economic Psychology 3 (3): 267–84. doi:10.1016/0167-4870(83)90006-5.

Kőszegi, Botond, and Matthew Rabin. 2006. "A Model of Reference-Dependent Preferences." The Quarterly Journal of Economics 121 (4): 1133–65. doi:10.1093/qje/121.4.1133.

Kotchen, Matthew J., and Michael R. Moore. 2007. "Private Provision of Environmental Public Goods: Household Participation in Green-Electricity Programs." Journal of Environmental Economics and Management 53 (1): 1–16.

———. 2008. "Conservation: From Voluntary Restraint to a Voluntary Price Premium." Environmental and Resource Economics 40 (2): 195–215. doi:10.1007/s10640-007-9148-x.

Krishnamurthy, Chandra Kiran B., and Bengt Kristrom. 2015. "How Large Is the Owner-Renter Divide in Energy Efficient Technology? Evidence from an OECD Cross-Section." The Energy Journal 36 (4). doi:10.5547/01956574.36.4.ckri.

Laibson, David, and John A. List. 2015. "Principles of (Behavioral) Economics." American Economic Review 105 (5): 385–90. doi:10.1257/aer.p20151047.

Lange, Ian, Mirko Moro, and Laura Traynor. 2014. "Green Hypocrisy?: Environmental Attitudes and Residential Space Heating Expenditure." Ecological Economics 107 (November): 76–83. doi:10.1016/j.ecolecon.2014.07.021.

Levinson, Arik, and Scott Niemann. 2004. "Energy Use by Apartment Tenants When Landlords Pay for Utilities." Resource and Energy Economics 26 (1): 51–75. doi:10.1016/S0928-7655(03)00047-2.

Liebermann, Yehoshua, and Meyer Ungar. 1997. "Life Cycle Cost: An Individual Consumer's Perspective." Managerial and Decision Economics 18 (3): 227–34. doi:10.1002/(SICI)1099-1468(199705)18:3<227::AID-MDE807>3.0.CO;2-5.

———. 2002. "Efficiency of Consumer Intertemporal Choice under Life Cycle Cost Conditions." Journal of Economic Psychology 23 (6): 729–48. doi:10.1016/S0167-4870(02)00136-8.

Lynham, John, Kohei Nitta, Tatsuyoshi Saijo, and Nori Tarui. 2016. "Why Does Real-Time Information Reduce Energy Consumption?" Energy Economics 54 (February): 173–181. doi:10.1016/j.eneco.2015.11.007.

Maruejols, Lucie, and Denise Young. 2011. "Split Incentives and Energy Efficiency in Canadian Multi-Family Dwellings." Energy Policy 39 (6): 3655–68. doi:10.1016/j.enpol.2011.03.072.

McCalley, L. T. 2006. "From Motivation and Cognition Theories to Everyday Applications and Back Again: The Case of Product-Integrated Information and Feedback." Energy Policy, Reshaping Markets for the Benefit of Energy SavingReshaping Markets for the Benefit of Energy Saving, 34 (2): 129–37. doi:10.1016/j.enpol.2004.08.024.

McCalley, L. T, and Cees J. H Midden. 2002. "Energy Conservation through Product-Integrated Feedback: The Roles of Goal-Setting and Social Orientation." Journal of Economic Psychology 23 (5): 589–603. doi:10.1016/S0167-4870(02)00119-8.

McKerracher, Colin, and Jacopo Torriti. 2013. "Energy Consumption Feedback in Perspective: Integrating Australian Data to Meta-Analyses on in-Home Displays." Energy Efficiency 6 (2): 387–405. doi:10.1007/s12053-012-9169-3.

Melo, Conrado de, and Gilberto Jannuzzi. 2010. "Energy Efficiency Standards for Refrigerators in Brazil: A Methodology for Impact Evaluation." Energy Policy, Energy Efficiency Policies and Strategies with regular papers., 38 (11): 6545–50. doi:10.1016/j.enpol.2010.07.032.

Mills, Bradford F., and Joachim Schleich. 2010. "Why Don't Households See the Light?: Explaining the Diffusion of Compact Fluorescent Lamps." Resource and Energy Economics 32 (3): 363–78. doi:10.1016/j.reseneeco.2009.10.002.

Mills, Bradford, and Joachim Schleich. 2014. "Household Transitions to Energy Efficient Lighting." Energy Economics 46 (November): 151–60. doi:10.1016/j.eneco.2014.08.022.

Myers, Erica. 2015. "Asymmetric Information in Residential Rental Markets: Implications for the Energy Efficiency Gap." Energy Institute at Haas Working Paper 246. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.649.963&rep=rep1&type=pdf.

Nadel, Steve, and Kenneth Keating. 1991. "Engineering Estimates vs. Impact Evaluation Results: How Do They Compare and Why?" Research Report U915. American Council for an Energy-Efficient Economy. http://aceee.org/research-report/u915.

Newell, Richard G., and Juha Siikamäki. 2014. "Nudging Energy Efficiency Behavior: The Role of Information Labels." Journal of the Association of Environmental and Resource Economists 1 (4): 555–98. doi:10.1086/679281.

———. 2015. "Individual Time Preferences and Energy Efficiency." American Economic Review 105 (5): 196–200. doi:10.1257/aer.p20151010.

Palmer, Karen L., Margaret A. Walls, and Todd Gerarden. 2012. "Borrowing to Save Energy: An Assessment of Energy-Efficiency Financing Programs." Resources for the Future Report

Palmer, Karen, Margaret Walls, Hal Gordon, and Todd Gerarden. 2013. "Assessing the Energy-Efficiency Information Gap: Results from a Survey of Home Energy Auditors." Energy Efficiency 6 (2): 271–92. doi:10.1007/s12053-012-9178-2.

Papineau, Maya. 2013. "Energy Codes and the Landlord-Tenant Problem." Working Paper. Carleton University.

Parry, Ian W.H., David Evans, and Wallace E. Oates. 2014. "Are Energy Efficiency Standards Justified?" Journal of Environmental Economics and Management 67 (2): 104–25. doi:10.1016/j.jeem.2013.11.003.

Pelletier, Luc G., and Elizabeth Sharp. 2008. "Persuasive Communication and Proenvironmental Behaviours: How Message Tailoring and Message Framing Can Improve the Integration of Behaviours through Self-Determined Motivation." Canadian Psychology/Psychologie Canadienne 49 (3): 210–17. doi:10.1037/a0012755.

Percoco, Marco, and Peter Nijkamp. 2009. "Estimating Individual Rates of Discount: A Meta-Analysis." Applied Economics Letters 16 (12): 1235–39. doi:10.1080/13504850701367189.

Phillips, Yvonne. 2012. "Landlords versus Tenants: Information Asymmetry and Mismatched Preferences for Home Energy Efficiency." Energy Policy 45: 112–21. doi:10.1016/j.enpol.2012.01.067.

Pichert, Daniel, and Konstantinos V. Katsikopoulos. 2008. "Green Defaults: Information Presentation and pro-Environmental Behaviour." Journal of Environmental Psychology 28 (1): 63–73. doi:10.1016/j.jenvp.2007.09.004.

Poortinga, Wouter, and Nick F. Pidgeon. 2003. "Exploring the Dimensionality of Trust in Risk Regulation." Risk Analysis 23 (5): 961–72. doi:10.1111/1539-6924.00373.

Qiu, Yueming, Gregory Colson, and Carola Grebitus. 2014. "Risk Preferences and Purchase of Energy-Efficient Technologies in the Residential Sector." Ecological Economics 107 (November): 216–29. doi:10.1016/j.ecolecon.2014.09.002.

Ramos, Ana, Xavier Labandeira, and Andreas Löschel. 2016. "Pro-Environmental Households and Energy Efficiency in Spain." Environmental and Resource Economics 63 (2): 367–93. doi:10.1007/s10640-015-9899-8.

Revelt, D., and K. Train. 1998. "Mixed Logit with Repeated Choices: Households' Choices of Appliance Efficiency Level." Review of Economics and Statistics 80 (4): 647–657.

Sallee, James M. 2014. "Rational Inattention and Energy Efficiency." The Journal of Law and Economics 57 (3): 781–820. doi:10.1086/676964.

Sallee, James M., Sarah E. West, and Wei Fan. 2016. "Do Consumers Recognize the Value of Fuel Economy? Evidence from Used Car Prices and Gasoline Price Fluctuations." Journal of Public Economics 135 (March): 61–73. doi:10.1016/j.jpubeco.2016.01.003.

Samuelson, W., and R. Zeckhauser. 1988. "Status Quo Bias in Decision Making." Journal of Risk and Uncertainty 1 (1): 7–59.

Schleich, Joachim, Xavier Gassmann, Corinne Faure, and Thomas Meissner. 2016. "Making the Implicit Explicit: A Look inside the Implicit Discount Rate." Energy Policy 97: 321–31. doi:10.1016/j.enpol.2016.07.044.

Schultz, P. Wesley, Jessica M. Nolan, Robert B. Cialdini, Noah J. Goldstein, and Vladas Griskevicius. 2007. "The Constructive, Destructive, and Reconstructive Power of Social Norms." Psychological Science 18 (5): 429–34. doi:10.1111/j.1467-9280.2007.01917.x.

Schwartz, Shalom. 1992. "Universal in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 Countries." In Advances in Experimental Social Psychology, San Diego: Academic Press. https://publications.hse.ru/en/chapters/67067657.

Sexton, Steven E. 2011. "Conspicuous Conservation: The Prius Effect and Willingness to Pay for Environmental Bona Fides." http://works.bepress.com/sexton/11.

Simon, Herbert A. 1955. "A Behavioral Model of Rational Choice." The Quarterly Journal of Economics 69 (1): 99–118. doi:10.2307/1884852.

Steg, Linda, Jan Willem Bolderdijk, Kees Keizer, and Goda Perlaviciute. 2014. "An Integrated Framework for Encouraging Pro-Environmental Behaviour: The Role of Values, Situational

Factors and Goals." Journal of Environmental Psychology 38: 104–15. doi:10.1016/j.jenvp.2014.01.002.

Steg, Linda, and J. I. M. De Groot. 2012. "Environmental values." In The Oxford handbook of environmental and conservation psychology. Oxford University Press.

Steg, Linda, Goda Perlaviciute, and Ellen van der Werff. 2015. "Understanding the Human Dimensions of a Sustainable Energy Transition." Frontiers in Psychology 6 (June). doi:10.3389/fpsyg.2015.00805.

Tao, Jing, and Suiran Yu. 2011. "Implementation of Energy Efficiency Standards of Household Refrigerator/Freezer in China: Potential Environmental and Economic Impacts." Applied Energy 88 (5): 1890–1905. doi:10.1016/j.apenergy.2010.11.015.

Taufik, Danny, Jan Willem Bolderdijk, and Linda Steg. 2016. "Going Green? The Relative Importance of Feelings over Calculation in Driving Environmental Intent in the Netherlands and the United States." Energy Research & Social Science 22: 52–62. doi:10.1016/j.erss.2016.08.012.

Thaler, R. H., and C. R. Sunstein. 2008. Nudge: Improving Decisions about Health, Wealth, and Happiness. Yale University Press.

Train, Kenneth. 1985. "Discount Rates in Consumers' Energy-Related Decisions: A Review of the Literature." Energy 10 (12): 1243–53. doi:10.1016/0360-5442(85)90135-5.

Tsvetanov, Tsvetan, and Kathleen Segerson. 2014. "The Welfare Effects of Energy Efficiency Standards When Choice Sets Matter." Journal of the Association of Environmental and Resource Economists 1 (1/2): 233–71. doi:10.1086/676036.

Tversky, A., and D. Kahneman. 1974. "Judgment under Uncertainty: Heuristics and Biases." Science (New York, N.Y.) 185 (4157): 1124–31. doi:10.1126/science.185.4157.1124.

Ungemach, Christoph, Adrian R. Camilleri, Eric J. Johnson, Richard P. Larrick, and Elke U. Weber. 2017. "Translated Attributes as Choice Architecture: Aligning Objectives and Choices Through Decision Signposts." Management Science, March. doi:10.1287/mnsc.2016.2703.

Wagner, Katherine. 2016. "Environmental Preferences and Consumer Behavior." Economics Letters 149: 1–4. doi:10.1016/j.econlet.2016.09.028.

Ward, David O., Christopher D. Clark, Kimberly L. Jensen, Steven T. Yen, and Clifford S. Russell. 2011. "Factors Influencing Willingness-to-Pay for the ENERGY STAR® Label." Energy Policy 39 (3): 1450–58. doi:10.1016/j.enpol.2010.12.017.

Weber, Bethany J., and Gretchen B. Chapman. 2005. "Playing for Peanuts: Why Is Risk Seeking More Common for Low-Stakes Gambles?" Organizational Behavior and Human Decision Processes 97 (1): 31–46. doi:10.1016/j.obhdp.2005.03.001.

Werff, Ellen van der, Linda Steg, and Kees Keizer. 2013. "The Value of Environmental Self-Identity: The Relationship between Biospheric Values, Environmental Self-Identity and Environmental Preferences, Intentions and Behaviour." Journal of Environmental Psychology 34: 55–63. doi:10.1016/j.jenvp.2012.12.006.

Wilson, Charlie, and Hadi Dowlatabadi. 2007. "Models of Decision Making and Residential Energy Use." Annual Review of Environment and Resources 32 (1): 169–203. doi:10.1146/annurev.energy.32.053006.141137.