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Summary

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Keywords: Energy Efficiency, Energy Policy, Behavioural Economics

JEL Classification: D9, Q4, Q48

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Internal and external barriers to energy efficiency: made-to-measure policy interventions

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Abstract

This paper has two objectives. First it provides a correlation between internal and external barriers to energy efficiency and consumer behaviour related to two domains. It evaluates behaviour related to energy curtailment, which represents routine, repetitive effort to decrease consumption on a day-to-day basis. It also considers behaviour related to investments, which are one time actions such as purchasing new energy efficiency technologies.. Second, it assesses the effectiveness of the different interventions and programs in addressing the two types of barriers (internal and external) with the aim of informing the policy debate. By assessing the value of a large number of interventions, this paper is one of the first that combines in a unified framework the main findings of different disciplines, from economics to psychology.

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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. The European Council endorsed three targets, with one being a binding commitment to improve energy efficiency by at least 27 percent by the year 2030. 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 to ensure that the new target is met.

Energy efficiency can deliver a wide 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 cutting energy bills, implying higher disposable income and improved competitiveness. To improve energy efficiency, regulatory approaches, economic instruments and information measures have been extensively applied, along with substantial public resources being invested in research and development for energy-efficient technologies.

However, the ability to increase energy efficiency depends not only on the availability of cheap technologies or on policy interventions, but to a large extent also on the behavioural choices of users. The evidence is that agents underinvest in energy-efficient technologies with adoption rate of households and firms being too low. The concept of "private energy-efficiency gap" also called "energy paradox" describes precisely the fact that some energy-efficient technologies are not adopted despite the savings they entail (Gerarden et al., 2017).[1] The low level of investment in energy efficiency technologies translates into high implicit discount rates. A discount rate reflects the trade-off between upfront capital costs and operating costs that occurs over a longer period and it is an indication of how consumers value future benefits from current investments.

The existing literature has largely searched the explanations for such underinvestment and correlated high implicit discount rates (Jaffe and Stavins, 1994). By reviewing all the existing empirical evidence, the current paper provides a correlation between the different barriers to energy efficiency and consumer behaviour related to two domains. The first domain is behaviour related to energy curtailment, which represents routine, repetitive effort to decrease consumption on a day-to-day basis. The second is behaviour related to investments, which are one time actions such as purchasing new energy efficiency technologies and modifying a building or house.

While some types of barriers are well known and their implications for energy efficiency documented, barriers that pertain to preferences and irrational behaviour are less studied. A full understanding of the exact impacts of the latter on energy efficiency is still limited (Gillingham et al., 2009). The paper also assesses the effectiveness of the different policy interventions and programs in addressing

[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.

the different barriers. In particular, it investigates the efficacy of the existing "nudges" approaches, which are low cost motivational and persuasion strategies. Finally, the paper reviews the penetration of behavioural sciences principles into this type of programs. This paper is one of the first that combines in a unified framework the main findings of different disciplines, from economics to psychology.

The remainder of the paper is organized as follows. Section 2 presents the empirical evidence of the impact of the barriers on adoption and energy use. Section 3 describes the different policies available in the energy efficiency domain and discusses their relevance in addressing the barriers to energy efficiency. Section 4 concludes the paper.

2. Empirical evidence of the impact of barriers on behaviour

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 (high) implicit discount rates.[2] These factors, which have been classified as internal and external barriers, explain the low adoption behaviour in the domain of energy efficiency. Internal barriers have to do with factors that cannot be changed or are difficult to change, because they relate to preferences and behaviour. On the contrary, external barriers cover factors that can be more easily changed.[3] I apply the same framework throughout this paper, because of its clarity and completeness. Moreover, the same type of barriers are found to influence both investment and energy use.

2.1 Internal barriers and adoption or energy use

According to Schleich et al. (2016), internal barriers to energy efficiency are related to **preferences** and predictable **(ir)rational behaviour**. These factors are labelled "behavioural explanations" for the energy efficiency gap in the taxonomy provided by Gerarden et al. (2017).

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 explaining the variation in energy efficient behaviour as individuals differ in their time, risk and pro-environmental preferences (Table 1).

2.1.1 Preferences

Time preferences are reflected in time discounting, namely how the consumers value the future relative to the present. Time preferences describe 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 and for this reason they are labelled present-oriented. In the context of energy efficient choices,

[2] See also Gerarden et al. (2017) for a similar taxonomy.

[3] 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 et al., 2017) .

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.

Table 1: 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
	Present bias and myopia
	Status Quo Bias

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

The literature has typically elicited time preferences from actual energy-saving behaviour. Only few studies measure individual discount rates first 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. They set up a choice experiment and use alternative product models and different labelling treatments to elicit individual discount rates. They 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. 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 et al. (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. Bruderer Enzler et al. (2014) relate discount rates to various energy saving behaviours. They find mixed results, with low discount rates being correlated with only some of the behaviours considered.

Given that some degree of uncertainty surrounds the benefits of an energy efficiency investment, due to uncertain prospects of future cost savings or uncertain technology performance, **preferences related to risk** are another internal barrier typically influencing investments.[4] Risk preferences vary among individuals, but, most importantly, the same person can change her love and aversion for risk, depending on what is at 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 et al. (2014) apply the same two-step approach described above, whereby risk preferences are first elicited through hypothetical

[4] Interestingly, there is a correlation between risk and time preferences. Typically, high risk aversion is associated with low discounting (Sutter et al., 2013; Rodriguez-Lara and Ponti, 2017).

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 homes or purchase energy efficient appliances. Fischbacher et al. (2015) elicit risk attitudes using an experimentally-validated risk questionnaire and confirm larger renovations among more risk takers. Erdem et al. (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) analyses consumers' preferences for energy saving systems and how they are influenced by risk. The author concludes that risk attitude affects consumers' behaviour regarding enhanced insulation and ventilation.

Pro-environmental preferences are a third factor affecting behaviour in the energy domain. Some people may decide to purchase energy efficient appliances or curtail energy use, even though these decisions are associated with higher (monetary and non-monetary) costs in the short run. People may choose to act pro-environmentally because they want to protect the environment and value environmental quality more than their personal comfort. Values are antecedents of environmental preferences, intentions, and behaviour and 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 et al., 1983). Individuals endorse four different values: hedonic, egoistic, altruistic and biospheric (Steg and De Groot, 2012).

While altruistic and biospheric values are positively correlated with pro-environmental behaviour, hedonic and egoistic values constrain pro-environmental behaviours (Steg et al., 2014). Persons who strongly endorse altruistic values adopt behaviours 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).

Persons with strong egoistic values adopt a behaviour taking into consideration 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 or curtail consumption, if these are too costly in terms of personal comfort. Egoistic and hedonic values typically limit pro environmental behaviours, because of the trade-offs between resources/comfort and the environment.

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 consumer behaviour in energy efficiency. The evidence is mixed for two reasons. First, because different approaches have been used to elicit preferences, with some papers measuring environmental preferences through attitudes and other papers through effective behaviour. Second, because papers measure different types of energy efficient behaviour. Some behaviours are more difficult and demanding than others, and some behaviours are private rather than visible.

There are a number of papers that find a positive correlation between energy efficiency and pro-environmental attitudes, measured through stated preferences. For example, Fischbacher et al. (2015) 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. Di Maria et al. (2010) find that environmentalists are more likely to use energy-efficient light bulbs. Environmentalists are also more likely to participate in green-electricity programs (Kotchen and Moore, 2007; 2008), sign up for a carbon offsetting program (Harding and Rapson, 2017), implement electricity saving activities (Ek and Söderholm, 2010) and choose the most sustainable though most expensive products (van der Werff, et al., 2013).

On the contrary, studies that measure environmental preference through actual behaviour find an opposite result. Lange et al. (2014) find that only environmental behaviour is correlated with environment-friendly heating, while attitudes and perceptions are not. Similarly, Ramos et al. (2016) report that eco-friendly behaviours, elicited from environmental policy activism and recycling actions, are positively correlated with both energy efficiency investments in the dwelling and daily energy-saving habits. On the contrary, environmental attitudes are not. The authors notice that measures of environmental attitudes elicited through stated preferences may not reflect true environmental preferences because of 'compliance/social desirability bias'. This bias arises when respondents tend to manifest a higher propensity to be pro-environment due to the influence of social norms. This may explain why these last papers find that pro-environmental attitudes do not translate into actual investment in energy efficiency or energy-saving actions.

The second reason for a mixed evidence 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 other people such as neighbours. Other actions, such as investment in solar panel or purchase of hybrid cars are visible to others. In the case of green conspicuous products, the investment may be undertaken because of prestige and not by the desire to behave pro-environmentally. The adoption of green products is believed to enhance social status, particularly when it is costly, as it signals to others the availability of sufficient resources to make altruistic sacrifices (Griskevicius et al. , 2010). This evidence has been largely confirmed in the case of green cars and solar panels (Kahn 2007; Bollinger and Gillingham, 2012).

Moreover, Sexton and Sexton (2014) find that consumption of conspicuous green products confers social status that is higher, the greater the strength of environmental preferences of one's peers. In this case, social approval rather than strong biospheric values may drive the environmental behaviour. Social aspects are important in the context 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 preferences can be influenced by the willingness to conform to pro-environmental social norms, because people tend to do what is socially approved. This consideration has important policy implications. First, 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, it provides a guide to policy makers in the selection of products for subsidies. Policies should target investments that are less conspicuous in place of those that confer a status benefit.

2.1.2 (Ir)rational behaviour

Behavioural economics has drawn attention to numerous cases where individuals behave differently from the expectations of the neoclassical economic theories. Consumer behaviour is complex and rarely consistent with the assumption of fully rational agents. It should be noted that behavioural economics amends rather than rejects the traditional economic assumptions. For example, behavioural economics assumes that people *try* to choose their best feasible option, and this is simply a variant of the optimization assumption (Laibson and List, 2015). For this reason, rather than labelling these behaviours as failures, it is now common to refer to "behavioural explanations" for the energy efficiency gap (Gerarden et al., 2017).

In the taxonomy provided by Schleich et al. (2016) these behavioural explanations are called (ir)rational behaviour. Many behavioural explanations exist, but the most powerful and pervasive ones to influence energy usage and investment are: 1. Reference-dependence and non-linear probability weighting; 2. Rational inattention; 3. Bounded rationality; 4. Present bias and myopia; 5. Status quo bias (Table 1).

Research in psychology has recognized that people tend to strongly prefer avoiding losses to achieving gains and therefore weight losses more heavily than equal-sized gains. This implies that simply framing a decision as a choice between losses rather than a choice between gains can reverse preferences, everything else equal (Wilson and Dowlatabadi, 2007). This phenomenon is called **loss aversion** or **reference dependence** because individuals evaluate the benefits and costs of a decision relative to a reference point. This insight 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 by risk aversion only, in prospect theory it is jointly determined by risk aversion, loss aversion and non-linear probability weighting.

Loss aversion, reference dependence and non-linear probability weighting have implications for energy efficient choices, in particular in the context of energy use. 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 for 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.

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.** Given that consumers are less attentive to operating costs compared to purchase prices, rational inattention can lead to low investment in energy efficient products. Allcott (2011a) confirms that vehicle buyers make their decisions without considering fuel costs. Busse et al. (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 et al. (2016), on the contrary, report that future fuel costs are not undervalued. Rational inattention may also have an impact on energy conservation. Cohen et al. (2017) find that consumers underestimate future energy savings by 35%. Because of this underestimation they increase energy use.

It should be noted that the use of limited attention when choosing among different durable goods could be the result of a rational choice. A proper valuation of energy efficiency requires time and effort which may not be justified when consumers have strong preferences regarding other product attributes (Sallee, 2014).

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). By satisficing, the required effort is reduced. In this respect, the apparent irrational behaviour could derive not from too little information, but from people being unable to process all available information, because of cognitive constraints.

Another heuristic is the use of trust in decision-making (Poortinga and Pidgeon, 2003). Trustworthiness is driven by competence-based attributes of peers, such as apparent expertise and experience, and integrity-based attributes, such as perceived openness, honesty, and concern for others.

Camilleri and Larrick (2014) find that, given bounded rationality, the decision making is less effortful if the problem representation matches the problem-solving processes. For example, information on fuel consumption rather than fuel costs and the use of a more comprehensive mileage scale increase preferences toward fuel efficient vehicles. Ungemach et al. (2017) confirm that people often apply simple heuristics when choosing between cars and they are influenced by highly correlated attributes, rather than their meaning. Providing multiple translations of energy efficiency metrics could help guiding behaviour.

Present bias and myopia are other behavioural explanations for the energy efficiency gap. Present bias refers to a situation where a discount rate is not constant and changes over time.[5] A constant rate of discounting allows for consistent intertemporal decisions. However, behavioural economics and psychology reject the assumption that agents have a constant rate of discounting. Individuals appear to discount the future at a much higher rate in the short than in the long term. As the future gets closer, individuals display reversals of preferences. This behaviour has been formalized through a (quasi) hyperbolic time discounting function.

Individuals also display **myopia**, i.e. a lack of foresight. Future (and past) pleasure is valued on a diminished scale compared to present pleasure. This is because, the further into the future an event, the more imprecisely the agent is able to estimate the utility she derives from it. The model of myopia predicts reversals of preferences similar to the ones predicted by theories of present bias. Myopia is therefore able to explain why individuals are extremely short-sighted when their decisions have environmental consequences. The future receives very little weight, not because individuals do not care about the environment, but because of the high uncertainty regarding the future utility derived from undertaking pro-environmental behaviours. The tendency to be short-sighted often leads to procrastination.

A test on the impacts of present bias and myopia on energy use 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.

Another individual behaviour that has implications for energy efficient choices is the **status quo bias**, also called the endowment effect. Agents tend to stick to the default setting and display preferences for the current state. Decisions are postponed and this confers inertia to the decision process.[6] Moreover, the status quo and the default option tend to be favoured because individuals display an anchoring bias,

[5]On the contrary, time preferences discussed in Section 2.1.1 indicate whether a person has a high or low discount rate.

[6] According to Samuelson and Zeckhauser (1988), there are three main explanations for the status quo bias: transition costs and/or uncertainty; cognitive misperceptions; psychological commitment stemming from misperceived sunk costs, regret avoidance, or a drive for consistency.

whereby 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. The status quo bias can be reinforced by uncertainty. Alberini et al. (2013) report that individuals tend to prefer the status quo of no renovation in case of future energy-price uncertainty.

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 are less salient, and this due to rational inattention. It could also be that investment costs are evaluated as a loss and are weighted more than gains, because of 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.[7]

2.2 External barriers and adoption or energy use

According to Schleich et al. (2016), external barriers are factors external to the decision maker and mainly depend on institutional settings. For this reason they are also called "market failure explanations" (Gerarden et al., 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.

Table 2: External Barriers to energy efficiency

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

Source: Schleich et al. (2016)

Table 2 reports the different sources of external barriers. One is **capital market failures**, such as liquidity constraints, as some agents do not have access to capital to invest in energy efficiency technologies (Berry, 1984; Gillingham et al., 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. This happens even if expected future savings are higher than the costs. Palmer et al. (2012) document that lenders may not offer loans for energy efficiency investments because of credit risk, high transaction costs, and asymmetric information.

[7] For this reason, the papers that find evidence of rational inattention, provide also evidence of myopia (Busse et al., 2013; Allcott and Wozny, 2014).

Another external barrier is represented by **information problems**. If consumers lack information on product availability and energy efficient attributes, such as potential savings, they tend to invest less in energy efficiency technologies. To test the importance of lack of information on investment and energy use, the existing literature has analysed if a policy intervention, such as the provision of information, has any impact on consumer choice. Except for few contributions (Filippini et al., 2014; Allcott and Sweeney, 2016; Allcott and Greenstone, 2017), the empirical findings confirm that lack of relevant information leads to underinvestment in energy efficiency (Kallbekken et al., 2013; Newell and Siikamäki, 2014; Allcott and Taubinsky, 2015; Davis and Metcalf, 2016; Houde, 2017).

Not only **lack of information,** but also **asymmetric information** combined with split incentives between a principal (for example the landlord) and an agent (tenant) represent barriers to energy efficiency. It is difficult and expensive for the principal to verify what the agent is doing. An actor may be unconvinced about the energy efficient attributes of a product or a house. Moreover, the principal and the agent have conflicting goals, preferences and incentives.

Given asymmetric information and split incentives, the literature has reached some robust conclusions. First, the ownership status of a house influences investment in profitable energy efficiency technologies. Gillingham et al. (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 owning the residence does not significantly influence the adoption of energy-saving compact fluorescent lamps.

Second, energy efficiency investment also depends on the type of payment regime between the landlord and the tenant. 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 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 unlabelled buildings, constructed under an energy code, are associated with significant rent and selling price premiums. This finding is consistent with little asymmetric information.

Third, the type of **payment regimes** also impacts energy use. In particular, utility-included rents contribute to lower effort in energy conservation of tenants. Elinder et al. (2017) report that households who were subject to a change from having electricity consumption-included rents to having to pay the market price for their consumption, reduced consumption by 25 percent. 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 borne by the landlord. They also find that the higher costs of the energy used do not translate in proportionally 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.

As a third external barrier to energy efficiency, Schleich et al. (2016) consider **financial** and **technological risks**. 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 the uncertainty related to the actual as compared to the expected energy savings. Risks are also connected to the fluctuations in fuel prices and to 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.

As in the case of the different behavioural anomalies, the distinction between external and internal barriers is often more theoretical than practical. In many circumstances it is difficult to disentangle one barrier from the other. For example, lack of information can be the consequence of inattention or constraints in assessing available information. At the same time, it is classified as an external barrier to energy efficiency if it results from an effective discrepancy between the information available to the agents involved in a transaction. Newell and Siikamäki (2014) is one of the few attempts to disentangle the effect of imperfect information from alternative explanations linked to consumer behaviour, such as not constant discounting. The authors 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

Policies and interventions are introduced to overcome external and internal barriers. However, a broadly held view is that a substantial portion of the potential benefits of energy efficiency is still uncaptured, as the effectiveness of policies can be improved. The objective of this section is to present the existing policies and interventions, relate them to the specific barrier and discuss their effectiveness.

Three types of policy instruments have been used to influence energy efficiency by addressing both internal and external barriers. Information-based instruments, regulatory instruments and economic and financial programs.

Informational instruments are intended to influence consumers' behaviour by disclosing crucial information about potential savings for example, through energy audits, labelling, energy performance certificates and information campaigns. Within this group of instruments are included persuasion strategies also called "nudges", which represent well-crafted interventions that provide for example feedback, peer comparisons, injunctive norms, or that manipulate the default setting and the information metrics.

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 meet. Products that do not satisfy such standards are removed from the market.

Finally, **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 energy-efficient investments. Rebates, tax credits and tax deductions encourage energy efficiency actions by reducing the cost to make the investments. Taxes are also a financial instrument that contributes to energy efficiency by increasing the relative prices of less efficient products. Table 3 provides a correspondence between the different barriers and policy options available.

3.1 Provision of Information

Information programs can be divided into two broad categories. On the one hand energy audit, product labelling, energy performance certificates, feedback and hard information interventions disclose energy saving information and benefits related to energy-efficient appliances and investments. On the other hand, 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", act as low cost motivational and persuasion strategies. To design this second type of interventions, increased guidance from psychologists and behavioural scientists is called for.

Almost all the information programs listed above not only help to overcome information barriers, but also address many behavioural barriers to energy efficiency. By guiding consumers in the decision process, they lower the cognitive costs of energy decision-making and address **bounded rationality**. Moreover, information programs that provide feedback on own energy consumption are designed to address **rational inattention** because they make consumers aware of their consumption and potential impacts. To address **bounded rationality**, feedback can also focus on peer comparison through information on neighbours' energy consumption. Goal setting and commitment programs are nudging tools that intend to address high **temporal discounting**, **present bias** and **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.

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

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

Information programs are a purely informational tool and the realization of energy efficiency gains crucially depends on a follow-up action. For example, **audits** are tailored and highly personalized information and consist in recommendations for attic insulation, sealing of windows and doors, lighting, heating and cooling improvements and replacement of appliances. They can improve energy efficiency because homeowners may not be aware that their homes are inefficient and choose 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 audits on investment in home renovations and find that on average audits increase energy efficiency investments. However, the authors find strong heterogeneous responses, with some households investing less as a result of the energy audit. Taking advantage of coaching from auditors, some households may have decided to reduce energy use through behavioural changes rather than retrofitting investments. Alberini and Towe (2015), for example find that participation in the home energy audit program reduces energy use. However, Allcott and Greenstone (2017) report that the benefits of auditing are inferior to costs.

A growing number of studies have analysed the impact of hard information interventions which disclose energy saving information of products, through for example energy labelling.[8] The evidence is mixed, and eventually depends on the empirical approach adopted, with some papers using artefactual field experiments and other natural field experiments.[9] Ward et al. (2011) apply a contingent choice experiment and confirm a positive influence of Energy Star label on consumer preferences for refrigerators. Houde (2017) uses a quasi-experimental approach and finds that consumers rely on Energy Star label when purchasing refrigerators. However, some consumers over-rely on the binary label which acts as a substitute for more accurate, but complex, energy information such as actual energy savings.

Allcott and Taubinsky (2015) apply both approaches and 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. Allcott and Sweeney (2016) find that information provided by sales agents about energy savings and customer rebates is ineffective at increasing demand for energy efficient products. In Allcott and Greenstone (2017), hard information on the private and social benefits of investments that could followup a home energy audit did not influence the participation in the audit program. In this analysis only price interventions, in the form of audit subsidies, increased the take-up of the program. Kallbekken et al. (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. Combining information and training treatments leads consumers to purchasing more energy-efficient tumble driers but no effect on fridge-freezers sales.

While artefactual field experiments suggest that the provision of information improves energy efficient 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 share of consumers might still prefer energy inefficient products even after being powerfully informed. Consumers make an informed decision

[8] The US has adopted the Energy Star Program; in Europe the Regulation (EU) 2017/1369 of the European Parliament provides a framework for energy labelling that repeals the Directive 2010/30/EU.

[9] Choice experiments and computer-based experiments are artefactual field experiments because they do observe behaviour in an artefactual environment, as opposed to a naturally occurring environment.

not to purchase the energy efficient products. It should be noted however that in natural field experiments, the (store) environment provides the control group with information on different energy efficiency technologies, including electricity use. The availability of this information to the control group may have reduced the effectiveness of the information treatment.

A second important aspect when testing the effectiveness of information programs is the way in which the information is presented. Heinzle (2012) assesses the 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 if the information is presented over the lifetime of the product. Davis and Metcalf (2016) find that labels enhanced with local electricity costs information lead to more energy efficient choices. Tailored energy labels produce larger gains than non-tailored ones. Newell and Siikamäki (2014) conclude that information content and label style strongly influence the valuation of water heaters. In particular, they compare various elements of information labels and find that the economic value of energy saving is the most effective piece of information for energy efficient decisions.

Some information 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. A large number of rigorous studies exists on the effects of feedbacks. These studies confirm the positive correlation between the feedback and energy conservation. Meta analyses have been also used to assess if feedback works (Fischer, 2008; McKerracher and Torriti, 2013) and which factors moderate their effectiveness. Karlin et al. (2015) review 42 articles published between 1976 and 2010 and conclude that feedback has a positive effect on energy conservation. Its effectiveness is maximized if the 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 analysed the mechanisms behind the effectiveness of feedbacks and conclude that in-home-displays help consumers improve 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. 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. Given that people rely on a simple counting heuristic, vivid signals as well as interventions that make one recall energy saving actions that are easily available in memories are effective because they provide information which is easy to process (Frederiks et al., 2015).

Feedback programs that provide **descriptive normative messages** through peer comparison have been used to encourage energy conservation. This is because social norms can effectively induce behavioural change (Schultz et al., 2007). 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 feedbacks can induce energy conservation because they evoke social comparison and social pressure but also because they make 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” or “thumbs-up”.

Schultz et al. (2007), Ayres et al. (2012) and Costa and Kahn (2013) find that this type of intervention is successful in reducing residential energy use. However, Allcott and Rogers (2014) report that the effort in reducing electricity is not persistent and decays after some time. They document a pattern of action and backsliding, in which, after an initial reaction, consumers forget about the report and return to baseline consumption. In this respect, the report does not act by providing information but by drawing attention to energy use. Allcott (2011b) as well confirms that consumers react to the report not because their knowledge increases, but because the report increases the moral cost of energy use. A meta-analysis of 30 different studies published between 1976 and 2013 concludes that peer comparison is less powerful than other social influence interventions, because it delivers the feedback in a fairly anonymous way (Abrahamse and Steg, 2013). 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 investments that have immediate and larger costs but delayed rewards. A similar strategy is **goal setting**, which entails giving consumers a specific reference point, for instance to save energy by a certain amount. In this respect, goal setting programs address **reference-dependent preferences**. Harding and Hsiaw (2014) document that people voluntarily enrol in the goal program, setting personal conservation goals. The paper also finds 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 energy conservation among consumers who commit to realistic goals, but no savings among consumers who choose 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 relatively difficult goal in combination with a feedback performed better. Goal setting proves to be effective in particular in combination with tailored feedback (McCalley and Midden, 2002; Abrahamse et al., 2007).

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 programs 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. 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.

One intervention that can be effective in addressing **loss aversion** is the use of **loss-framed** rather than gain-framed messages. A message should focus on the costs of the less efficient behaviour rather than the benefits of the most efficient one. This manipulation makes the loss more salient, memorable and motivating (Frederiks et al., 2015). Dütschke and Paetz (2013) find that loss aversion has implications for energy tariff configurations. In their study, consumers prefer pricing programs characterized by lower spread of charges, so that they can avoid the risk of too high bills. While in the health domain the research on framing has reached some stable conclusions, findings in the environmental contexts have been less consistent. More research is needed on the empirical examination of the effectiveness of loss-versus gain-framing in the energy efficiency domain.

Manipulation of the 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 consumer behaviour.

The way a message is framed proves to be important in light of the different degrees of **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. Information programs, even if they are designed to increase knowledge and awareness in general, tend to encourage behavioural change among people who strongly endorse biospheric (environmental) values. Information is effective when it resonates with people's central values (Steg et al., 2015). Targeted policy interventions are therefore crucial in this context as well. Given that informational interventions are perhaps ineffective in those who care less about the environment, they should be directed towards those who strongly care about the environment. This is because they make consumers more inclined to act on their values. Taufik et al., (2016) find that the intention to act pro-environmentally 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's feelings, instead of exclusively appealing to their calculations.

3.2 Regulatory instruments

Standards are an important tool to improve energy efficiency because they lead to a ban on certain classes of products which do not meet certain efficiency standards. They can also impose stricter requirements for heating and cooling systems and for housing envelopes. By removing energy-inefficient products from the market, regulatory instruments are designed to address (**rational) inattention** to operating costs and to energy savings connected to energy-efficient products, bounded rationality and **present bias,** in particular lack of **self-control**. Moreover regulatory instruments such as standards or building codes are also justified by the presence of **imperfect information**.

Many papers document that stricter energy standards expedite the transitions towards more energy-efficient investments (Greening et al., 1997; Davis, 2008; de Melo and Jannuzzi, 2010; Costa and Kahn, 2010; 2011; Tao and Yu, 2011; Aroonruengsawat et al., 2012; Jacobsen and Kotchen, 2013; Mills and Schleich, 2014). However, calculations of the energy savings and welfare effects of stricter standards are often made without taking into account the welfare losses imposed by fewer available choices. Product standards impose a restriction on product choice and force behavioural change on those who gain little from energy efficiency. Allcott and Taubinsky (2015) find that **imperfect information** and rational **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 on 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) acknowledge 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. This paper indicates how important it 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. In the US, 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. Jacobsen (2013) confirms that gasoline taxes are more efficient than CAFE regulation. Moreover, examining both the new and used vehicle markets, the author finds that in the long-run, fuel economy standards are more regressive than expected as they generate larger proportional welfare losses to low-income households. Fischer et al. (2007) conclude as well that the efficiency rationale for raising fuel economy standards is weak.

In the context of fuel-economy, the inefficiency of standards is confirmed even in the presence of some behavioural anomalies. Parry et al. (2014) compare the welfare effects of energy efficiency standards and pricing policies in the case of misperceptions of energy costs due to 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 is designed conditional on product attributes rather than the target they wish to achieve.[10] Attribute-based policies tend to provide a less strict 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.

To summarize, efficiency standards are an inferior instrument compared to other policies, such as information programs or taxes, as they do 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 and efficient response to the market failures that standards tend to address.

3.3 Economic and financial instruments

Economic instruments are an important instrument for energy efficiency as they make investments more attractive by lowering upfront costs or by changing the relative price compared to less efficient products. 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 individuals.

Economic incentives are primarily designed to address **capital market failures**. Moreover, Blumstein (2010) reports that some individuals choose to make energy efficiency investments because their awareness has been raised by the existence of the incentive schemes. In this respect, economic incentives may address an **information problem**. If subsidies, grants and loans are given directly to installers, they reduce information barriers, as installers may have a commercial approach to promoting energy efficiency. Rebates, tax credits and tax deductions 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**,

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

bounded rationality and **rational inattention**. This is because in case of present bias and rational inattention, product subsidies and taxes can divert purchases towards the most efficient appliances. Finally guarantees address **risk preferences** as well as **financial and technological risks**.

Just like standards, product subsidies on efficient products or taxes on inefficient products impose a relative shadow cost on less efficient products. This shadow cost means that consumers pay relatively less for more efficient products. While they are designed to overcome a similar barrier, 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 the price elasticity of energy demand is small. However, Wagner (2016) finds that environmental preferences shape the effectiveness 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 et al. (2016) find that in Spain a tax scheme on dishwashers, refrigerators and washing ensures greater energy savings than a subsidy scheme. In the presence of behavioural anomalies, however, subsidies for energy efficiency investments represent the optimal policy option. Hassett and Metcalf (1995) report that subsidies are much more effective than an equivalent tax in particular in 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 increase 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 et al. (2014) report that, if consumers undervalue energy costs because of **rational 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 achieving the highest energy conservation. From a welfare perspective, what matters is whether the consumers affected by the distortions are also affected by the policy interventions. If, from an institutional point of view, the eligibility of subsidies cannot be restricted to a specific group, targeted marketing at the groups most affected by the distortion could produce large gains (Allcott et al., 2015).

There are important concerns however with subsidies, tax deduction, tax credits and rebates. First, the literature has found that these policy instruments are associated with a rebound effect (Alberini et al., 2016), whereby potential savings are wiped out by changes in people's behaviour. Second, they encourage free-riding (Houde and Aldy, 2017). Third they need to be financed through, for example, distortionary taxes and finally they are often not cost-effective. Davis et al. (2014) evaluate a subsidy programme 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-saving estimates for residential retrofit programs are lower than 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 benefit from reduced energy does not compensate for the reduction in consumer utility, due to the higher taxes required 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.

Finally, the use of guarantees, whereby governments or energy providers share the costs and risks 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 et al., 2015).

Meta-analyses have been conducted to compare the performance of information and non-information interventions. For example, Abrahamse et al. (2005) review 38 different articles dating from 1977 to 2004 and conclude that information programs increase knowledge but this does not necessarily translate into behavioural changes or energy savings. Monetary rewards are successful in engaging consumers 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 et al. (2013) present 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 savings, 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 considered real time peer comparisons. Social influence is maximized in face-to-face interactions, while social comparison interventions generally happen anonymously (Abrahamse and Steg, 2013). Finally, in this analysis, non-monetary, information-based strategies are superior to economic incentives.

Gneezy et al. (2011) report that financial benefits from saving energy are often limited and thus provide fewer incentives to conservation. Ito et al. (2015) compare the effects of appealing to intrinsic versus extrinsic motivations. The authors find that both moral suasion and economic incentives induce the desired conservative effects, but while the former exerts diminishing effects, the latter produces persistent effects, leading to habit formation.

Appealing to economic rather than biospheric concerns not only could be ineffective in securing behaviour change, but also counterproductive. Extrinsic rewards can sometimes crowd out' intrinsic motivation to act pro-environmentally and consequently backfire and discourage the pro-environmental behaviour they are meant to encourage (Schwartz et al., 2015).

4. Summary and conclusions

Various barriers to the adoption of energy efficiency technologies have been identified. Some are classified as internal and other as external barriers. Internal barriers have to do with factors which cannot be changed or are difficult to change because they are related to preferences and predictable (ir)rational behaviour. On the contrary, external barriers capture underlying factors that limit the adoption of energy efficiency technologies but can be easily changed. Policy instruments have been introduced to address both types of barriers. Policy instruments are classified as regulatory instruments, economic and financial programs and information-based instruments. By assessing the effectiveness of the different types of policies against the barriers they aim to address, this paper is able to provide seven solid conclusions.

First, feedback is an effective way to influence behaviour related to energy use, in particular if the 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. While real time feedback induces energy conservation, a simple feedback on individual energy usage is not enough to influence behaviour. Feedback provided by vivid information, such as thermal images of heat losses, largely motivates households to reduce energy use. Moreover, feedback that provides peer comparison on energy use encourages energy conservation. There are other social influence approaches, such as interventions where the information is provided by block leaders, that prove to be effective because they deliver the feedback less anonymously.

Second, audits improve energy efficiency because they increase awareness of possible improvements but their benefits are found to be inferior to their costs imposed to the community.

Third, motivational and persuasion strategies such as commitment and goals setting, default options that favour energy conservation, loss-framed messages, messages framed in terms of intrinsic goals and moral suasion are very effective in addressing the relevant bias and induce energy conservation.

Fourth, evidence regarding information programs such as product labelling is mixed and depends on the methodology used for the analysis. More research is needed to fully understand if labelling really improves energy efficient choices. Moreover, the effectiveness of the information programs is affected by the way in which the information is presented, with the timeframe, format and metrics being strong moderators of the effectiveness of this type of interventions.

Fifth, standards, information programs, subsidies and taxes are directed to the same types of market failures. However, standards are an inferior instrument compared to the other interventions because they do not influence behaviour by reducing the use of energy-using products and generate a welfare loss by limiting the available choices. Information programs, subsidies and taxes should be preferred because they represent a more direct and efficient response to the targeted market failures.

Sixth, taxes are a good solution because they are transparent, promote behavioural changes and take into consideration the heterogeneity of consumers. However they give rise to negative distributional effects. Moreover, in case of reference dependence, subsidies and tax credits are better than taxes. This is because people strongly prefer avoiding losses to achieving gains. The limitation of subsidies is that they produce a rebound effect, encourage free-riding and need a source of financing.

Finally, a crucial point emerging from this review is the importance of targeting the policies. For example, policies should target investments that are less conspicuous in place of those that confer a status benefit. People in search of social approval are willing to invest in the latter without any policy intervention. Moreover, while some interventions are ineffective among those who care less about the environment, they could still deliver substantial benefits if targeted towards those who strongly care about the environment. This is because they make them more inclined to act on their values. When the policy itself cannot be targeted, once can think of targeting a marketing campaign. For example, subsidies cannot be restricted to a specific group, but a marketing campaign can target the consumers that are mostly affected by the distortion that the subsidy aims to address.

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