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- A critical overview of literature and energy efficiency policies in EU and Sweden

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Executive summary

A rather large literature argue that firms and households do not improve energy efficiency by investing in new technology despite that is cost-effective to do so. If this is the case people would be able to reduce their energy bills and spend their money on more pleasurable things. We argue that the so-called energy efficiency gap to some extent is a numerical artifact that can be explained by heterogeneity within the frames of rational choice not captured in the calculations of average cost-effectiveness of various measures to improve energy efficiency. In this paper we have reviewed the theoretical and empirical literature on the energy efficiency gap and provided a rational for policy makers to act on improving energy efficiency. By eliminating market failures, welfare can be improved in a broad sense, including both environmental quality and material welfare. Social 'nudges' are an example of policy instruments which does not directly target any market failure in energy markets, but still may have a significant impact on energy use. As social 'nudges' do not restrict choices available to consumers such 'nudges' can be considered as least-cost instruments, given they have persistent and desirable effects on energy demand.

Sammanfattning

Flera studier har pekat på att hushåll inte vidtar energieffektiviseringsåtgärder trots att de är lönsamma. Om så är fallet betyder det att hushållen skulle kunna minska sina energikostnader och använda pengarna till andra nyttiggörande saker. Enligt detta resonemang finns en betydande potential för energipolitiska åtgärder att simultant effektivisera energianvändningen och samhällsekonomin. I den här rapporten redogör vi för olika anledningar till varför beräkningar av ekonomiska potentialer är felaktiga och varför det så kallade energieffektiviseringsgapet är en teoretisk konstruktion. Den främsta invändningen är att beräkningar av enskilda åtgärders genomsnittliga lönsamhet vanligtvis inte beaktar alla de omständigheter som underligger hushålls konsumtions- och investeringsbeslut. Dessa omständigheter är situationsspecifika och beror bland annat på hushållens tycke och smak och deras preferenser för risk och resursfördelning över tid.

I den här rapporten presenteras samtidigt argument till varför det faktiskt kan finnas ett energieffektiviseringsgap och varför det behövs en aktiv energipolitik. Utgångspunkten är att marknadskrafterna av olika anledningar inte förmår att fördela samhällets resurser optimalt, det vill säga det förekommer olika typer av marknadsmisslyckanden. Genom att eliminera marknadsmisslyckanden ökar välfärden i samhället i bred mening, där både miljökvalitet och materiell välfärd inkluderas. Vi redogör även för forskning inom beteendeekonomi och relaterar den till energiområdet.

1 Introduction

There has for a long time been a debate in the energy economics literature about the potential to cost-effectively reduce energy demand by investing more in energy efficient technologies. The debate started in the 1970s when studies on peoples' real choices on electrical appliances found that people seem to discount energy savings at rates far above interest rates in the capital markets (Hausman 1979). Since then a vast number of papers in economics have replicated the result of high implied discount rates (Train 1985; Frederick *et al.* 2002; DEFRA 2010). This result has also been found in bottom-up analysis by engineers calculating negative life cycle cost for many different technical measures to improve energy efficiency. Today there are a vast number of studies suggesting that the potential to cost-effectively increase energy efficiency is substantial and that this potential will not be realised without political interventions. As an example, it has been suggested that the EU, by adopting cost-effective technologies can reach its energy efficiency target to reduce energy demand by 20 percent by 2020 (Fraunhofer ISI 2009; Ecofys 2010). A similar potential has been suggested for the U.S. (McKinsey & CO 2009). This puzzle of an untapped potential is commonly referred to as the *energy efficiency gap*. Economists have typically taken the sceptical view on these huge untapped energy savings arguing that firms and households must have good reasons for not investing in seemingly cost-effective technologies and, as a result, engineer's calculations of cost-effectiveness must be incorrect. A number of papers in the economic literature have taken a more positive view trying to bridge the energy efficiency gap by explaining why calculations are faulty and why the market fails to deliver an economically efficient outcome regarding energy use (e.g. see Jaffe and Stavins (1994); Sanstad and Howarth (1994); Brown (2001); Sanstad *et al.* (2006); Tietenberg (2009); Gillingham *et al.* (2009); Linares and Labandeira (2010); Allcott and Greenstone (2012); Gillingham and Palmer (2014)).

Although the debate sometimes seems to repeat itself endlessly, recently more attention has been given to incomplete information and behavioural anomalies in energy economics (see e.g. Sanstad and Howarth (1994); Sanstad *et al.* (2006); Tietenberg (2009); Allcott and Greenstone (2012); Gillingham and Palmer (2014)). If firms and households do not have appropriate information the market solution will most likely not be at the social optimum. Inefficiencies may also arise, if firms and households cannot use information effectively due to cognitive limitations or if under some circumstances they act seemingly irrational. Incomplete information and behavioural anomalies may strengthen or change the conventional wisdom in the economics literature that economic and market-based policy instruments, such as carbon pricing and taxes, are effective and fundamental in least-cost strategies of eliminating economic inefficiencies caused by externalities. The increased attention given to incomplete information and behavioural anomalies has increased the interest for non-price policy instruments such as standards and measures to inform firms and households.

In the process of designing the optimal mix of policy instruments, it is important to assess the severity of individual market failures and identify how they effectively can be addressed by policy makers. In this paper we contribute to the policy oriented literature on energy efficiency by reviewing the literature concerning informational failures and behavioural anomalies in the context of household energy demand. If market fails to deliver efficiency because of incomplete information or behavioural anomalies the problem likely applies to a wider range of energy demand issues. Accordingly, we take a more holistic view focusing on inefficiencies in energy demand rather than focusing only on the energy efficiency gap. Thus, we extend the frame of the analysis by including inefficiencies in the use of the current capital stock and inefficiencies regardless of their direction, i.e. energy demand can be either too high or too low compared to what is economically efficient.

In this paper, we review the broad literature related to energy inefficiency issues to answer the following key questions:

- What traditional or/and behavioural economic theories can explain the seemingly inefficient use of energy in households?
- What non-price policy instruments are effective and cost-effective in achieving energy efficiency targets?
- Can information alluding to social norms be an effective and cost-effective policy measure to reduce energy use?

The purpose of this paper is to reflect on these key questions and present a critical analysis of current policies for improving energy efficiency in the EU and, as a special case, in Sweden. The Swedish case is interesting for several reasons. Sweden introduced a carbon tax already in 1991 and is seen as a forerunner in climate policy. In 2008 a national target for energy efficiency was introduced and the structure of energy taxes was adjusted to cost-effectively fulfil this target. Many other types of policy measures have been adopted in Sweden after the oil crises in the 1970s to decrease emissions and improve the security of energy supply. Still, Sweden is a relatively energy intensive economy reflecting a cold climate, large distances, a energy intensive production and a historical abundance of cheap electricity. Hence, there are lessons to be learned from these experiences in order to sharpen future policies.

The outline of this paper is as follows. In section 2 we give a quick review of the literature bridging the energy efficiency gap with neoclassical theory. In section 3 we review literature on behavioural anomalies in energy related choices. In section 4 we discuss and review empirical evidence about the effectiveness and efficiency of energy efficiency policies, with a focus on policies in Sweden and the rest of EU.

2 The energy efficiency gap – The neoclassical view

We define the energy efficiency gap on the basis of rational investment theory and simple calculations of cost-effectiveness based on minimization of life-cycle costs. The gap is equivalent to the reduction in energy use that would occur if all cost-effective investments in energy efficiency where realised, i.e. the gap is the difference between possible and actual cost-effective investments in energy efficient technologies. The mere existence of a persistent gap implies that there are market barriers to investments in energy efficiency. Indeed, there are many market barriers, but not all of them should be eliminated by policy interventions. Economists typically want to sort market barriers into two categories: market failures and other market barriers (Jaffe and Stavins (1994); Brown (2001); Sanstad *et al.* (2006); Linares and Labandeira (2010); Allcott and Greenstone (2012); and Gillingham and Palmer (2014)). The presence of market imperfections drives a wedge between the market solution and the outcome that would be socially optimal. The basic problem is that firms and households fail to make decisions that are socially optimal when prices fail to signal the true resource scarcity or when information is incomplete or when people act irrationally. To increase market efficiency and enhance welfare well-targeted policy instruments are needed to eliminate or alleviate these market failures. However, if policy instruments are costly to use, it may not be welfare enhancing to eliminate market failures, i.e. in cases where costs outweigh benefits.

Here below, we discuss a series of barriers that appears in discussions relating to the energy efficiency gap. The list of barriers is not exhaustive, but includes those we see as essential: (1) scarce resources; (2) transaction costs, hidden costs and preferences; (3) incomplete information; and (4) inattention. One aim of this review is to highlight that some market barriers are natural features of efficient markets and not market failures.

2.1 Scarce resources and discount rates

The greatest market barrier, but also the strongest driver, for investments in energy efficiency is resource scarcity. Choices must be made whenever there are scarce resources. Choices imply opportunity costs which sometimes makes decision making difficult. People simply need to prioritise - buying a new boiler or going on a well needed vacation abroad.

Regardless of how investments are funded there will be a capital cost that needs to be covered. At a minimum, the energy savings must cover instalments and the cost of interest (or the return on risk-free financial investments). Swedish banks today offer loans to energy efficiency projects at 6 percent interest rate without demanding collateral and offer mortgages with a five year fixed interest rate of 3,5 percent. Further, the average annual real return on Swedish and American stocks during the period of 1912-2009 have been estimated to be approximately 5 and 7 percent respectively (Nyberg and Vaihekoski 2014). These numbers serve as a reasonable starting point (minimum) when thinking about households' discount rates. How people choose to discount future utility is, of course, up to individuals and ultimately depends on the valuation of their alternative uses of financial resources, e.g., other investments or consumption possibilities.

The empirical studies on investments in household appliances and heating systems suggest that households discount at even higher rates, on average 15-25 percent, and that discount rates are inversely related to income (Hausman (1979); Dubin and McFadden (1984); Train (1985); DEFRA (2010)). Even if the implicit discount rates mentioned above seem high they are in line with some intertemporal choices observed in credit markets (Jaffe and Stavins (1994); Allcott and Greenstone (2012)). However, the literature shows a large variation and actually one study on the choice of refrigerators found implicit discount rates in the range of 45-300 percent, which clearly is not the rates observed in the regular capital markets (Gately 1980).

The empirical studies on implicit discount rates typically rely on revealed preferences and the results from these studies can either be interpreted as true discount rates or as consumers' choices being influenced by market failures or behavioural failures. These studies have been criticised on methodological grounds for not being able to isolate the discount rates from the influence of other factors such as functionalities, size and appearance (Sanstad *et al.* (2006); Allcott and Greenstone (2012)). Some recent studies address these problems by controlling for product fixed effects using panel data to test whether fuel economy is correctly priced on the market for new and old cars (Allcott and Wozny (2013); Busse *et al.* (2013); and Sallee *et al.* (2009)). The results from these studies show small or negligible inefficiencies, i.e., consumers correctly value fuel economy.[3] Another method to control for personal and product fixed effects has been to study hypothetical choices. The results from studies based on hypothetical choices point at lower implicit discount rates ranging between 12-19 percent (Kooreman 1996).

[3] Greene (2011) review the litrature on valuation of fuel economy and find inconclusive results regarding whether there are biased beliefs.

One reason why households discount future energy savings at relatively high rates is that they demand a risk-premium as such investments are typically illiquid, irreversible and expected returns are subject to genuine uncertainties, e.g., uncertainties about future energy prices (Hassett and Metcalf 1993; Kooreman 1996). Uncertainties about product attributes such as performance and risks may also contribute to high implicit discount rates (Kooreman and Steerneman 1998). For example, extra insulation to unheated attics is associated with a higher risk for damp and mould damages which may incur large unintended health and property damages in the future. Thus, it is likely that people require substantial risk premium to invest in energy efficiency measures that is associated with such risks.

Capital rationing is a popular argument for governmental action in the literature on the energy efficiency gap (Schleich and Gruber 2008). Market failures on capital markets make financial resources scarcer or more abundant than they ought to be. However, the extent to which liquidity constraints (as a market failure) impede investments in energy efficiency "has yet to be established empirically"(Gillingham *et al.* 2009). A fact that often is overlooked in the literature on the energy efficiency gap is that lenders not only consider the projects at hand when they decide on offering loans, but also consider households' risk of default. A household or firm with low credit worthiness (e.g., due to high indebtedness levels) is not likely to be offered a loan at a low interest rate regardless of the project's cost-effectiveness. Thus, some cost-effective investments cannot be realised not due to market failures in the credit market but due to an economically justifiable scarcity of financial resources. We will come back to credit markets below.

To sum up, potentially there is a large heterogeneity among the individuals regarding discount rates, which may be 20 percent or even higher. Hence, the average values of cost-effectiveness may be associated with an asymmetric distribution explaining parts of the bottom-up calculated energy efficiency gap which is based on assumptions about the average discount rate. This means that some investments will not be realised because they are not truly cost-effective considering that some households, usually poor households, may apply high discount rates.

2.2 Transaction costs, hidden costs and preferences

Life-cycle calculations of cost-effectiveness typically focus on investment costs and discounted annual energy cost savings. Thus, these calculations neglect a range of direct and indirect costs that firms and households considers when making their investment decisions. These costs can be categorised into transaction costs, hidden costs and preferences. Transaction costs are typically defined as the incurred costs in the process of finding a trading partner and making a trade. This definition includes costs of finding an acceptable trading partner and costs related to negotiation, monitoring and implementation. On the housing market people spend time searching for the perfect object, when they find it they typically need to employ an expert to survey the building and possibly have to pay excise duty and pay for mortgage deed. The seller typically needs to employ a broker, clean and style the house for prospective buyers, empty the house and pay capital tax on profits. Obviously, transaction costs are substantial on the housing market. There may also be substantial transaction costs for investments in energy efficiency. Typically the buyer needs information about products and services, needs to find a credible trading partner, needs to negotiate prices and possibly employ an expert to survey the work, or consult, before investment decisions are made.

In theoretical models in economics, it is often assumed that there are no transaction costs. It is important to note, however, that transaction costs are actual costs, but that they usually do not alter economic policy reasoning. Of course, the transaction costs must be taken into account when theory becomes empiricism.

It is difficult to conceptually define transaction costs as they can be associated with any market failure or with effort costs due to behavioural aspects of bounded computational abilities. For example, Sanstad and Howarth (1994) point out that *transaction costs* can be viewed as part of problems related to imperfect and asymmetric information. However, in the end what matters is whether specific policy interventions to deal with transaction costs simultaneously can improve energy efficiency and social welfare. High transaction costs can obstruct the market from reaching an economically efficiency outcome and the government can in some cases cost-effectively reduce transaction costs by enforcing standards, labelling or by providing information to the public.

Sometimes the process of improving energy efficiency may impose frictions to the daily business causing large opportunity costs. For example, firms may not be able to accept or complete orders as usual and as a result loose customers. Households may not be able to use their facilities which increase frictions in their daily life. There may also be tax-issues, e.g. if value enhancing investments are made by house owners this may incur costs in terms of capital and real estate taxes. These are hidden costs that can be important on the margin. There may however be hidden benefits as well, e.g., longer time intervals between changing of light bulbs or higher comfort due to reduced variation in indoor temperature.

When there are more variables to consider than only energy efficiency and upfront costs, it becomes more difficult to decide whether or not an investment is cost-effective from the consumers' perspective. For example, when converting the heating system in a house from direct electric heaters to a centralized hot-water system, one typically need to attach the water pipes to the walls, which may be conceived as a visual defect possibly affecting the attractiveness of the house. Another example is that the colour temperature and colour rendition of different light bulb technologies may differ. If people dislike any attribute that are correlated with highly energy efficient appliances or installations, it constitutes a cost to them. When preferences play an important role, it is difficult to argue that people act irrationally when in fact it may all be a matter of taste.

2.3 Incomplete information and institutional hinders

It seems to be a fact that some energy efficiency measures are not being realised despite that they are highly profitable and have a short payback time. Obviously, this is not in line with the standard economic concept of rational behaviour. However, choices are based upon available information at the time of decision. A precondition for an objective rational choice is that the decision maker has a complete set of information. Markets provide the necessary incentives for sellers to share information about their outstanding products and to many consumers the problem may appear to be overprovision of information (e.g. annoyingly frequent commercials on media). However, information needed for energy efficiency is often context-dependent due to consumer heterogeneity, which may impede private information sharing (e.g., commercials) or the effects of information sharing (Tietenberg 2009). Incomplete information about available products and services, investment costs, energy savings and other attributes may be a significant obstacle to investments in cost-effective energy efficiency. However, incomplete information can also be a driver for cost-ineffective investments. People may act on messages on increased risks without having any information about the level of the risk, leading to ineffective behaviour, e.g., too much insurance. It has been shown that consumers' willingness to pay for insurances is more sensitive to salient risks (e.g., risk of cancer, plane crash or terrorism) than to increases of risk in general

(Johnson *et al.* 1993). Transferred to the energy sector this could mean that occasionally high energy prices or alarming media coverage on peak-oil or environmental concerns may accentuate cost-ineffective investments in energy efficiency.

Asymmetric information is one type of incomplete information that occurs when one part of an agreement knows more about the product than the counterpart does. There are two types of asymmetric information that fosters bad incentives and thus inhibits the market from reaching an efficient outcome: moral hazard and adverse selection. *Moral hazard* occurs when the actions of one part of an agreement is not observable to the counterpart. For example, moral hazard exists when water and energy costs are included in the rent. In such cases tenants have low incentives to save energy. *Adverse selection* occurs when one part, typically the buyer, of a potential agreement has incomplete information about the product at sale, e.g., incomplete information regarding the energy-efficiency of a building. Under such circumstances the buyer may not be willing to pay a premium for buildings which is said to have a higher energy-efficiency. If the seller believes that buyers are not willing to pay a premium, she will stop selling houses with high energy performance (Akerlof 1970). Problems related to asymmetric information are commonly addressed with policy instrument, such as minimum standards, eco-labelling and third-party certification.

There may also be organizational problems that lead to misplaced incentives, e.g. split-incentives, which may be closely related to the problem of asymmetric information and moral hazard. In the landlord-tenant context, the problem may be that the landlord determines the degree of energy efficiency, but the energy bill is paid by the tenants. Under these conditions the landlord has incentives to minimize investment costs rather than minimising life-cycle costs (or maximising cost-effectiveness). This may result in badly insulated buildings and cheap appliances with low energy performance. Another example of misplaced incentives is rental contracts where heat is included in the rents, which is the case in Sweden. Such contracts imply that tenants have weak incentives to save energy by lowering indoor temperature. On the other hand, given that heat is included in the rents, landlords ought to have strong incentives to invest in insulation or control equipment regulating the indoor temperature. If landlords use the later strategy, they may solve the problem of tenants wasting energy, but may create utility losses for some households who cannot optimize their indoor comfort.

As hinted above, incomplete information also may be a barrier to efficiency in credit markets. Potential borrowers usually have more information about projects and risk of bankruptcy than lenders have, which can lead to adverse selection and credit rationing (Stiglitz and Weiss 1981). Incomplete information on behalf of lenders gives them incentives to offer loans at relatively high interest rates which only will attract borrowers with risky projects. Potential borrowers with low-risk and low-return projects will leave the credit market since their projects are not cost-effective at the offered interest rates. However, it has been shown that lenders can screen the borrowers riskiness by simultaneously deciding on collaterals and interest rates. Under the assumption that low-risk borrowers can raise collateral to distinguish themselves from high-risk borrowers it has been proven that asymmetric information will not result in credit rationing (Bester 1985). A Swedish bank, Swedbank, exemplifies how lenders screen the market to distinguish different types of households in the energy efficiency context. Swedbank offers an "energy efficiency loan" that currently is offered at an interest rate just under 6 percent with no collateral needed. Swedbank currently also offers mortgage at 3.5 percent interest rate.

There are also other barriers to energy efficiency that can be classified as institutional hinders. First, there may be laws and standards (such as building regulations) that prevent the uptake of energy efficient technology, e.g. rules concerning minimum air flow or radiation from radon. In Sweden it has been suggested that energy use would increase with 5 TWh if all single-family houses would comply with the building codes for new buildings concerning minimum air flow (Boverket 2009). Second, there may also be rent controls impeding investments in buildings. Sweden has for a long time used rent control as a means of social policy, which distorts incentives on the tenancy market. Rent control is expected to hamper investments in buildings as landlords cannot freely adjust rents to reap all benefits from their investments. Regarding energy efficiency, things may be different as such investments typically lower the operating cost of the building. Little is known about to what extent rent controls affect investments in improved energy efficiency.

Finally, energy pricing practices may be a barrier to an efficient use of energy. Today electricity is not subject to marginal pricing, but rather to average pricing, and the energy bill is usually paid 1-12 times per year. Further, some countries have direct or indirect price regulations that restrict peak-prices. The current practices may contribute to inattentiveness as volatility in prices is avoided and information about how energy use affects the energy bill is limited. Resent research has shown that real time pricing and real time information on electricity use can be powerful instruments to increase energy efficiency (Allcott 2011a; Gans *et al.* 2013). However, although a more effective pricing of electricity may increase households' attention to energy issues it may on average lower the price of electricity and, therefore, reduce incentives for improving energy efficiency.

2.4 Inattention

Consumer theory builds on the idea that consumers buy goods and services that compose of many attributes (Lancaster 1966). Individuals have preferences for attributes, meaning that a fruit is valued on the basis of its colour, shape and taste. Some attributes are more important than others, e.g. taste is likely to be more important than shape in the example above. Energy efficiency is sometimes an important attribute deserving greater attention, in other cases it's not. As noted in Sanstad *et al.* (2006), the focus on implied discount rates may be misleading in many cases as the energy savings are too small to care about due to relatively high transaction costs of observing, and gathering information about all attributes of products. This is referred to as rational inattention (Sims 2003; Houde 2013; Sallee 2013). Sallee (2013) argue that rational inattention is quite likely for automobiles and home appliances as inattention is a function of price variation, variation in the differentiation of products in other dimensions than energy efficiency and the effort cost of paying attention. It could further be expected that the more we intend to use appliance or the higher our expectations are on energy prices the more attention we will pay to energy performance as the operating costs then become more important.

Even if individuals rationally ignore small cost-effective energy savings, these savings may be substantial in the aggregate (Sanstad *et al.* 2006). This argument could, as an example, rationalise technology standards on homogeneous products or services (e.g. energy performance of standby function) even in cases where the transaction costs of gathering information about energy performance is fairly small. The argument is closely related to the problem with adverse selection.

Some argue that energy efficiency is an attribute that people really care about but fail to consider in their investment decisions, which tend to focus too much on the upfront cost. Accordingly, some people will regret their investments when (if) they realise the product have bad energy performance (Greene 2011). We will come back to this aspect of inattention in Section 3.

3 Behavioural anomalies in energy related choices

Research on behavioural economics have pointed at several behavioural biases that are claimed to systematically violate the assumption of rational consumers, which is a basic assumption in economic theory and modelling (see e.g. review by Kahneman (2003); DellaVigna (2009)). These findings may have a substantial descriptive and normative impact on policy making in a spectrum of policy areas, such as marketing, financial trading, savings, insurance business, health care, social policy and macroeconomic policy. Behavioural anomalies have recently received more attention in environmental and energy economics challenging old practice (see, for example, reviews and reflections in Shogren and Taylor (2008); Smith and Moore (2010); Gsottbauer and van den Bergh (2011); Greene (2011); Metcalfe and Dolan (2012)). In this section we give a brief review of some of the most discussed behavioural anomalies that we can relate to energy consumption. Similar analysis can be found in: Sanstad and Howarth (1994); Sanstad *et al.* (2006); Tietenberg (2009); Allcott and Greenstone (2012); and Gillingham and Palmer (2014).

In neoclassical economics consumers are represented by a representative individual who is commonly referred to as *homo economicus*. This person has stable preferences, behaves rationally, is fully informed and maximises utility in pure self-interest. The use of *homo economicus* in choice theory have been criticised by psychologists saying that it will result in faulty predictions about human decision making. It has been argued that people make most choices intuitively, placing little or no analytical effort into the decision process, and simplifies decision making by applying heuristics - consumers satisfies rather than optimise (Simon 1955). An extensive literature on human decision making stresses a number of behaviour anomalies that deviates from the assumptions underlying rational choice as manifested in standard economic theories, for example assumptions relating to utility maximization, self-interest, expected utility and discounted utility (see e.g. the compilation by Kahneman and Tversky (2000)).[4] Still, behavioural anomalies do not necessarily imply that people systematically make incorrect decisions (as being subjectively irrational), they may imply that standard theories are wrong, for example about individuals' utility functions and should, therefore, be corrected. From a behavioural perspective, anomalies are often descriptive rather than normative, i.e. behavioural anomalies explains why observed behaviour deviates from that predicted by rational choice theory.

It should be stressed that *homo economicus* is a social construct, rather than a universal description of individual decision making, formed by repeated activity in exchange markets where bad decisions are punished and good decisions awarded (Becker 1962; Arrow 1983; Chu and Chu 1990; Bowles 1998; Shogren and Taylor 2008). Results from field experiments suggest that the influence of behaviour anomalies in real markets is less pronounced compared to the findings in laboratory experiments and that experience from one market can be transferred to other markets or situations (Cherry *et al.* 2003; List 2003, 2004; Cherry and Shogren 2007; List 2007). Some authors underpin that the critic against neo-classical theory does not imply that reality is characterised by chaos and randomness but rather by a behavioural distribution with more or less irrational (unpredicted) behaviour in its tails (Becker 1962; Smith 1991; Shogren and Taylor 2008).

[4] Levitt and List (2007) scrutinises the evicence of behavioural anomalies and stresses that most evicence comes from labaratory experiments on students. They argue that the labaratory enviroment is likely to differ from real choice situations and that morality plays a large role in how people behave, e.g., people behave differently if they believe their actions will be scrutinized. They stress the need for verifying lab-results in field experiments.

Some anomalies imply that markets may fail to deliver a socially efficient outcome even in absence of traditional markets failures such as externalities and incomplete competition. It has been suggested that the government may have a role to play in alleviating the effects of so-called behavioural failures (Loewenstein and Haisley 2008; Shogren and Taylor 2008; Gsottbauer and van den Bergh 2011). Shogren and Taylor (2008) argue that a normative approach is necessary if we expect that '*repeated market experience pushes people toward more rational behaviour*'. They also argue that the presence of behavioural anomalies may strengthen or weaken the effectiveness of previously praised policy instruments, e.g. economic policy instruments, which are based on rational choice theory. Shogren (2012) argue that behavioural insights may play a role in environmental policy if they, filtered through an economic lens, qualify as part of the least cost strategy to protect environmental values. A similar argument has been used to motivate market interventions to increase energy efficiency efforts in society (see e.g. Allcott and Mullainathan (2010); Allcott (2011b); Metcalfe and Dolan (2012); Allcott *et al.* (2014)). Some argue that behavioural biases can be addressed with 'nudges' that pushes peoples' behaviour in a pro-social direction without restricting the choices available to them (Thaler and Sunstein 2008).[5]

Even if the rational-choice theory has been heavily criticised, it is still most often used as the guiding light in search for a social optimum. This can be seen in the context of the energy efficiency gap, which some refer to as the *energy efficiency paradox* (DeCanio 1998). The paradox can only be understood in the context of rational choice - households and firms do not undertake cost-effective investments as predicted by the theory. If this objective rationality is the role model to follow, both market failures and behavioural failures have to be addressed by policy makers. Below we give a brief review of behavioural anomalies that are commonly referred to in behavioural economics. We do this in four subsections describing: (1) reference dependence; (2) inattention due to bounded rationality; (3) limited self-interest (social norms, moral, fairness, status seeking and habits); and (4) anomalies in intertemporal choices.

3.1 Reference dependence

In neoclassical economics utility is associated with final outcomes of different choices. This means, among other things, that choices under uncertainty are based on assessments of expected utility derived from possible outcomes that are linear in gains (increased utility) and losses (decreased utility). Behavioural studies on both risky and riskless choices have found that utility is reference dependent what really matter are gains and losses relative to a reference point (Kahneman and Tversky 2000). It has been found that people are loss averse, i.e., a person's disutility from a loss out-weights utility from a gain of equal size, and that the sensitivity to gains and losses decreases with the absolute size of the stakes, meaning that a person is risk adverse concerning gains but risk seeking concerning losses. Thus, to be descriptively realistic, losses should be given a higher weight than gains in expected utility models. As a rule of thumb, losses should be double-counted (DellaVigna 2009). In this sense loss aversion can be included in the neo-classical model to improve its ability to predict

[5] Policies addressing behavioural failures are referred to as libertarian, soft, light or asymmetric paternalism in the literature. (Loewenstein and Haisley 2008) discuss different welfare measures and conclude that 'light paternalistic policies should only be put into play when welfare judgements tend to be relatively straightforward'. They label this approach as an 'imperfect but pragmatic approach'. According to this approach it is important to define what behaviour that really is pro-social, which must be considered to be a difficult task.

the outcome of decision making. However, it has been argued that, if consumer preferences are context dependent and reference points are changing, loss aversion may cause people to make choices that are bad for themselves (Tversky and Simonson 1993; Kahneman 1994; Greene 2011). For example, if people adapt their preferences to new circumstances, this means that ex-ante expectations are not consistent with the ex-post experience, e.g. people may habituate to a new technology, a noise or a smell. Preference adaptation has been used as an argument for using alternative welfare measures, such as experience utility, not relying on revealed preferences (Kahneman *et al.* 1997).[6]

Several studies argue that people attach too much weight to small probabilities in risky choices, i.e. people overstate small risks (e.g. Kahneman and Tversky (1979), Tversky and Kahneman (1992), Tversky and Fox (1995), Mason *et al.* (2005)). In the context of a referendum on phasing-out old nuclear power plants (or building new plants), the misperception of risks may lead to more yes-votes (no-votes) than predicted by rational choice theory. In the context of energy efficiency the misperception of risks may hinder that certain types of measures are undertaken, e.g. measures to improve a building's insulation (which may incur a risk of future damp and mould problems).

Reference dependence and loss aversion are associated with a number of well-known behavioural biases: endowment effect, status quo bias and framing effects. The endowment effect refers to results found in experiments showing that people seem to attach an instant sentimental value to goods as they fall in their possession (Kahneman et al. 1991). This creates a difference between buying and selling prices, i.e. an individual asks for more when selling a good than she would be willing to pay to acquire the same good. The status quo bias refers to the findings that people tend to stick to the status quo option when having the chance to do so. The status quo bias has been explained by other factors than loss aversion such as transaction costs, cost of thinking, psychological commitment to prior choices, omission bias and regret avoidance (Loomes and Sugden 1982; Spranca *et al.* 1991; Tversky and Kahneman 1991; Korobkin 1997). The status quo bias may, as an example, explain the high share (around 20 percent) of Swedish households that stick to their default electricity agreement although it is highly unfavourable (on average 30 percent above market prices).[7]

As reference dependence tends to bias decisions toward the familiar and the status quo it is expected to work in the direction of delaying investments in new technology and, thereby, slow down improvements of energy efficiency. At the same time reference dependence creates opportunities for designing innovative policy measures utilizing framing effects.

3.2 Inattention due to bounded rationality and framing effects

It is a common argument for policy intervention that consumers due to different reasons do not pay attention to energy efficiency when buying energy using products (Bull 2012). Previously, we argued that, since it may be costly to gather information and make difficult calculations, people may rationalise decisions by not paying attention to attributes that most likely will not change their final choice (Sims 2003; Sallee 2013). However, psychologists argue that our cognitive ability is limited and that the brain activates different schemes

[6] Loewenstein and Haisley (2008) review and reflect upon different welfare measures. They argue that preference adaptation is not only problematic for welfare measures based on revealed preferences, but also for experience utility. For example, a person that has a chronic disease may adapt hedonically to her physical status and report the same level of happiness as others, but at the same time state that she is willing to trade expected lifetime against full physical capability.

[7] DN 2013-11-06 (http://www.dn.se/ekonomi/en-av-sex-betalar-dyrt-for-usla-elavtal/)

(mental representations) in order to categorise new information and associate external stimulus to knowledge from our previous experiences. Thus, the choices we make may depend on which scheme being activated. In a typical choice between several products different attributes competes for our attention. The winning attributes are those that are perceptually salient as they are highly accessible in the mental process. Physical salience, expectations and immediate consequences have been pointed out as important determinants of accessibility (Kahneman 2003). When we buy a washing machine, appearance and price are salient attributes, whereas loudness, washing performance and energy and water efficiency may be less salient. If this is the case, we will focus too much on price and appearance forgetting about other attributes that can turn out to be important when we start using the chosen machine.

The cognitive bias of inattention is closely related to other biases found in the behavioural literature, such as preferences for salient attributes and preferences for the familiar (DellaVigna 2009). Habitual behaviour is also associated with selective attention. The more we face the same situation, respond to it in the same way and face a satisfactory outcome the higher will the accessibility be of a habitual mental representation (Verplanken *et al.* 1998; Steg and Vlek 2009). This means that people will have a hard time changing their behaviour when faced with new information about a more efficient response to the repeated situation. Regarding energy, habitual behaviour could result in inattention and insensitivity to higher energy prices.

We have found no empirical evidence regarding energy use in the literature on cognitive inattention. However, some evidence has been found for less complex choices. DellaVigna (2009) review the empirical literature and report evidence for inattention to shipping costs on Ebay, sales taxes in the U.S. and financial news. These are probably not examples of rational inattention as information was available and consumers did not have to involve any difficult calculation. Kahneman (2003) suggest that problems related to salience can be addressed with deliberate attention, which is a popular instrument in both the EU and the U.S., where eco-labelling is applied to increase the salience of energy efficiency.

Framing effects refer to the fact that peoples' decisions are influenced by how choices are presented (or framed). People tend to passively accept the formulations presented to them and therefor framing may change the relative salience and accessibility of different attributes, making one choice more likely than another (Kahneman 2003). It has been found that reference points are of great relevance as they decide what is to be considered as gains and losses (Tversky and Kahneman 1986). It matters which option is assigned to be the status quo and also that peoples' preferences over two options can be affected by inclusion of a third option (Tversky and Simonson 1993). Furthermore, framing may evoke different emotions which may influence choices (DellaVigna 2009). There are several well-cited anecdotic evidences on framing effects and the status quo bias. In some European countries the default option is that people agree to donate organs upon their death, whereas in other countries the default option is that people do not agree to donate organs. The major share of the population sticks to the default option, and hence, the acceptance rate for organ donation differs substantially across European countries. Another example often referred to is traffic insurances with full or limited right to sue (Johnson *et al.* 1993).

Framing effects may be relevant in the context of energy efficiency. Maybe it influences consumers' choices if the benefits from improved energy efficiency are framed in terms of losses from not improving energy efficiency? Maybe it matters if the Eco-mode on appliances being the status quo instead of having to be actively chosen? Maybe it matters if household appliances, cars and buildings with high energy performance are labelled as pro-social options (e.g. green)? Maybe it matters if people are exposed to information about other peoples' choices? These are all examples of potential 'nudges' which only reframe choices without restricting possibilities. If they have persistent and desirable effects on energy demand, such 'nudges' surely are least-cost instruments. To what degree 'nudges' have persistent effects on energy use is, of course, an empirical question that has to be carefully tested. Studies relying on survey data on stated choices have found that loss aversion, monetisation of efficiency and social norms have a profound effect on decisions relating to energy efficiency (see e.g. Ek and Söderholm (2010) and Bull (2012)).

3.3 Limited self-interest, ethics and social norms

Social norms and moral issues are the key in behavioural research, but have not been widely addressed in the economic literature, which mainly concerns economic efficiency. Ethics is implicitly included in the neoclassical welfare theory, as morality affects the relationship between consumption of goods and the utility people receive. For example, a company may be severely punished by the market if it is associated with unethical activities such as child labour or environmental damages. The moral context of some actions can be further integrated or explicitly included in the utility function to, for example, reflect preferences for equality or fairness and moral utility reflecting warm glow from charitable giving or disutility from social pressure (see e.g., Levitt and List (2007); and DellaVigna *et al.* (2012)). Conceptually, individual i's choice of action (*a*) affects her utility (*U*) both through a wealth effect (*W*) and a moral effect (*M*) in line with:

$$U_i(a,v,n,s) = W_i(a,v) + M_i(a,v,n,s) \quad (1)$$

This function says that the moral effect is a function of the stakes (*v*) and how the individual imagines that her action will be scrutinised (*s*). The moral effect is also a function of social norms (*n*), which may be associated with fairness issues, feelings of social responsibility and an obligation to act in a perceived pro-social manner. For example, it can be assumed that more attention is given to the wealth effect when stakes are larger and that individuals are more likely to comply with social norms if they believe that their behaviour will be observed and judged.

Morality plays and important role in human decision making as it helps to explain why some people act even in cases where the action demands time and effort but have an infinitely small payoff, e.g. vote in political elections or referendums or act to curb climate change. Social norms may play a significant role in policies for improving energy efficiency. In a recent study on American households it was found that individual households' demand for electricity is sensitive to information about how much electricity other similar households use (Allcott 2011b). The study found that the demand for electricity on average dropped by two percent in households exposed to information about their relative consumption.[8] One interpretation of these results is that consumers with relatively high use of energy become aware of their relatively bad behaviour and undertake what they perceive as pro-social actions. However, the results can also be interpreted in terms of new information about technologies where actions are taken in pure self-interest, e.g. consumers with relatively high use of energy may become aware of cost-effective opportunities to save energy. Of course, the result may be a combination of the two.

[8] Since the households where also exposed to energy saving tips the results must be causously interpreted as the tips may confound with the results concerning social norms. However, Metcalf and Dolan (2014) adresses the problem with cofunded effects by isolating the effect of peer comparisons from other effects. They find a significant reduction in energy use among households in the U.K. that were provided with comparative information.

3.4 Anomalies in intertemporal choice

Varying time-preferences (hyperbolic discounting)

In the standard expected utility framework the future stream of costs and revenues are discounted exponentially at a constant interest rate. The results from a vast number of behavioural laboratory experiments stress that people have a declining rate of time-preferences, meaning that the discount rate monotonically decreases with the time horizon (Frederick *et al.* 2002). Hyperbolic discounting may result in preference reversals and time-inconsistent behaviour, e.g. a person favours € 10 today over € 15 next week, but favours €15 in one year and one week over € 10 in one year. Models assuming hyperbolic discounting have been used to study problems of erroneous decisions caused by intertemporal myopia and bounded will-power (self-control problems), such as decisions influenced by habits, addiction and procrastination. Hyperbolic discounting households has also been used as an explanation to why people save money in illiquid retirement funds at the same time as they hold high-interest credit-card debt (Laibson *et al.* 2003). The generalisation of the experimental findings of hyperbolic discounting is still disputed.[9]

Hyperbolic discounting may to some degree explain the energy efficiency gap if it leads to time-inconsistent behaviour in terms of procrastination of investments in energy efficiency. The potential problem seems to be more likely for investments where one option is to stay in an inactive status quo and where transaction costs to change may be substantial, e.g., weatherisation. Otherwise, applying hyperbolic rather than exponential discounting has an ambiguous effect on the net present value of investments in energy efficiency as the effect is determined by the hyperbolic discount function and its relation to exponential discounting.

Magnitude effect and Loss aversion

It has been found in experiments that people´s patience increases with the size of the stakes. People not willing to wait 1 year for a 10 percent return of €10 may be willing to wait for a 10 percent return of €100 (Frederick et al. 2002).[10] The result has been applied to explain the high implicit discount rate estimates concerning energy efficient appliances, which often have a long stream of small-stake returns. Implicit discount rates are usually found to be lower for major decisions relating to savings and intertemporal substitution between work and leisure (Loewenstein and Prelec 1992). Further, gains have been found to be discounted at a higher rate than losses, which also may help to explain the energy efficiency gap (Frederick et al. 2002).

[9] The experimental methology have been heaily criticized and few field experiments exist (Harrison and Lau 2005). A recent field experiment does not find strong support for hyperbolic discounting in general (Andersen *et al.* 2013). After reviewing the previous literature it is found that the existing evidence for hyperbolic discounting mainly is based on experiments on students. The study further finds some support for the hypothesis that students are biased toward instant gratification and are not representative for the general population. Another study test whether the discounting process differs between individuals (in this case students) (Coller *et al.* 2012). The results show that roughly half of the subjects in the experiment seemed to apply quasi-hyperbolic discounting and the other half exponential discounting.

[10] A recent field experiment study find support for the magnitude effect, but also find that it is much smaller compared to findings in preious laboratory experiments (Andersen *et al.* 2013).

3.5 Summary on review of behavioural anomalies

Our review of research in behavioural economics suggests that there exist a broad literature providing evidence on behavioural anomalies in human decision making. However, these evidences are largely based on analyses of constructed, real or hypothetical, choices that don't necessarily say anything about real choices in real markets. The evidence on behavioural anomalies has yet to be validated in well-designed field experiments or natural experiments.

Based on our review, we conclude that behavioural anomalies may explain parts of the energy efficiency gap and that there is a potential to use behavioural research to improve existing instruments and create new and innovative instruments in order to improve welfare. We also believe that bounded rationality in certain circumstances can justify market interventions in order to reduce transaction costs and make energy performance more accessible to consumers. Innovative instruments that exploit behavioural anomalies are undoubtedly cost-effective if they create socio-economic values without restricting the choice-sets to households or cause disutility in terms of distress or regret. To what extent such instruments have a lasting effect on energy use is ultimately an empirical question. Social norms depend on institutional, cultural, historical and economic factors and innovative policy instruments must therefore be studied at the national or the local level.

4 Energy efficiency policies in Europe and Sweden

Climate and energy policy is high upon the political agenda in both the EU and Sweden. Above we presented a rational for policy makers to act on energy efficiency. In this section we describe general features of some policies in EU and Sweden designed to reduce households' use of energy, and discuss specific policy instruments with respect to their effectiveness and cost-effectiveness.

In Table 1 we give a schematic view of potential policy instruments that are roughly categorised by how they affect household energy use. First, we separate these policies by whether they are monetary or mainly information-based (or non-monetary). Second, we make a distinction between monetary measures on basis of whether they have a *direct or indirect effect* on energy prices. These monetary policy measures can also be categorised as *market-based* or *command-and-control* instruments, respectively. The information-based instruments is separated by whether they deal with incomplete information issues or designed to change households' priorities by framing, for example by alluding to social norms such as conformity and reciprocity. Furthermore, we categorise policy tools by whether or not they directly affect incentives for improving energy efficiency through *capital investments*.

Naturally, it is not always clear in which category policy instruments belong. For example, an energy efficiency obligation system (white certificates) theoretically is a price instrument that usually is financed by end consumers through a premium on their electricity price. In this regard white certificates schemes are quite similar to cap-and-trade schemes applied in other fields of environmental economics. However, white certificates have a second redistributive objective not to target real energy flows but rather bottom-up calculated energy savings and, therefore, is similar to a subsidy programme for investments in energy efficient technology financed by "earmarking" revenues from taxing energy. There are similar classification issues with other policy instruments, to which we will come back to below.

Table 1. A selected list of EE policies categorized by whether they (*i*) affect the capital stock through investments in energy efficiency; and (*ii*) are monetary.

<table>
<tr><th></th><th colspan="2">Monetary</th><th colspan="2">Non-monetary</th></tr>
<tr><td></td><td>Direct effect on prices</td><td>Indirect effect on prices</td><td>Incomplete information</td><td>Social ‘nudges’</td></tr>
<tr><td>Behavioural (for given capital stock)</td><td rowspan="2">Energy tax;
CO2 tax;
Emissions trading;
(Tradable) white certificates.</td><td>Incentivised energy rationing</td><td rowspan="2">Individual metering and debiting;
Eco-labelling;
Standards;
Certification;
Energy audits;
Providing public information (advices);
Energy performance contracting (EPC).</td><td>Default options;
Peer comparisons.</td></tr>
<tr><td>Capital/investment</td><td>Subsidies;
Soft loans
(Standards)</td><td>Peer comparisons;
Framing.</td></tr>
</table>

Although we try to overview all relevant policies for stimulating energy efficiency our primary focus is on the policy tools that aim at increasing households’ attention by alluding to social norms (see the last column of Table 1). These instruments could be labelled as innovative or behavioural policy instruments, but to be more specific we call them social ‘nudges’. Social ‘nudges’ stands out from all other policy instruments as they do not affect households’ monetary costs for energy or investments in energy efficiency and do not directly solve any market failure. Social ‘nudges’ simply reframe decisions such that people may choose to change their behaviour without being forced to it or economically incentivized.

In this section we scan the literature for the range of policy instruments that are both effective[11] in practice and economically efficient[12]. For our purpose to assess the effectiveness of the main policy instruments we selected a few *ex-post* studies. We selected these studies based on our subjective opinion on their scientific credibility. Although the attempt was made to cover as many policies and country cases as possible, the number of policies in the selected countries (most EU member states and Norway) is limited due to space and time limits. Another limitation is that there are few scientifically rigorous ex-post studies for European policies, which makes it difficult to assess the economic efficiency of the analysed policy instruments in the European context.

As it is difficult to disentangle *behavioural issues* from informational and other *market failures* empirically (Gillingham *et al.* 2009), we structure this section by the sets of specific policy tools that is said to “correct” for market or/and behavioural issues. Several policy databases were used to overview energy efficiency policies:

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[11] The effective policy instrument can be considered the measure that is politically and administratively easy to implement and achieves the energy conservation targets but does not consider the social cost related to its implementation.

[12] By the term of “economically efficient policy” we mean least cost policy instruments that help to address certain market failures or some behavioural issues in order to enhance social welfare.

- MURE database which describes policy measures for energy efficiency in the EU-countries;
- National Energy Efficiency Action Plans (NEEAPs);
- Other publically accessible sources, such as IEA database or ERGEG reports.

4.1 Market-based instruments: energy taxes and white certificates

EU and Swedish policies

Market-based policy instruments have been extensively used to promote energy efficiency ambitions in the European countries. In practice, there are two common market-based instruments to promote energy efficiency: energy related taxes and energy efficiency obligation schemes (or so-called white certificates). Energy taxes and tradable energy efficiency obligation systems can, under some conditions, achieve similar energy reductions. But as white certificate schemes typically does not target real energy flows, such an instrument will, in a profound way, differ from standard tax policies leading to the question which policy is the better one.

An energy tax implies that a fixed premium is added to the prices of certain fuels or electricity. In Sweden, this premium is based on the energy content of different energy carriers and also carbon content as regards fossil fuels.[13] The Swedish tax structure is designed to steer energy use and production in order to cost-effectively attain policy targets for GHG-emissions, renewable energy and energy efficiency. As tax levels differ between sectors the Swedish tax-structure is not truly cost-effective. In theory, market-based policy instruments are cost-effective only if they equalise marginal costs of, e.g., energy savings among different energy users. Few EU member states apply unilateral energy-carbon taxes. Energy taxes, including carbon taxes, are usually higher for households than for energy intensive firms. The wide range of carbon-energy tax rates are mostly determined by political issues with potentially detrimental effects on competitiveness of some sectors.

The Energy taxation directive (2003/96/EC) specifies minimum levels of energy taxes. In Table 2 we compare the Swedish tax rates to the EU minimum levels. Apparently tax levels in Sweden deviate substantially from the EU minimum levels, except from the electricity tax on energy intensive industries.

Table 2. Examples of energy taxes in Sweden and EU minimum tax rates according to the energy taxation directive.

Energy type	Tax rates EU minimum (Öre/kWh)	Tax rates Sweden (Öre/kWh)
Leaded petrol	39,94	61,8
Diesel	29,07	51,5*
Electricity (commercial use)	0,43	0,5-29,3
Electricity (non-commercial)	0,86	19,4-29,3

**The energy tax on diesel depends on environmental status and an average is presented in the table.*

[13] Diesel being an exemption as it has a substantially lower tax per kWh compared to petrol. The Swedish government has annonched that they aim to step-by-step close this gap in the future.

To what extent energy taxes affect energy use depends on the price elasticity of energy demand. If the elasticity is small, the potential to reduce energy use with modest price premiums is limited. It is widely acknowledged that energy demand is inelastic (elasticity of demand is below unity), more so in the short term (for a review of empirical estimates see e.g. Lijesen (2007)). This implies that energy use is important to households and, therefore, the opportunity cost of reducing energy use is high. However, a recent study Jessoe and Rapson (2014) use data from a field experiment to test whether information provision stimulates demand response to energy prices. They find that information provided by real time displays increases the price elasticity of electricity demand which may imply that energy consumers do not pay attention to energy prices due to high transaction costs. This result is interesting in light of a growing number of consumers having access to real-time feedback on their electricity price and consumption.

In contrast to energy taxes, energy efficiency obligation systems in practise introduce a quantity target for bottom-up calculated energy savings translated to tradable certificates, which determine a market price on energy savings. There are only a few countries, namely France, Italy, Denmark, Poland, and UK (see Table 5), that have introduced energy efficiency obligation system schemes. However, energy efficiency obligation systems have an expressed status in the energy efficiency directive (directive 2012/27/EU) and, therefore, more EU member states are expected to introduce such schemes in the future. The directive stipulates that each member state should take measures to accomplish annual energy savings amounting to 1,5 percent of final energy consumption, excluding energy used in the EU ETS, as an average for the period 2011-2013. The annual savings target should be aggregated into a target for cumulative energy savings for the period 2014-2020. The directive also stipulates that the cumulative target should be achieved by an energy efficiency obligation system, but also allows for alternative strategies.[14]

Rational and empirical evidence

Empirically comparing energy taxes to energy efficiency obligation systems and different designs of the later in order to rank them in terms of cost-effectiveness is not a simple task. Such a comparison must be based on a reliable baseline scenario and counterfactual data which is difficult to observe empirically as countries differ in their ambitions, in design of energy efficiency targets and in how they measure energy savings. Using a partial equilibrium model Quirion and Giraudet (2009) find that tradable white certificate scheme entails an higher overall cost than an energy tax, mainly because the scheme does not provide the optimal incentives for households to reduce their consumption of energy. They also find that the difference in costs increases with the elasticity of demand for energy use.

Energy related taxes and energy efficiency obligation systems have also been compared in other dimensions. Mundaca (2007) estimates transaction costs through a questionnaire distributed to energy suppliers and through interviews. The study finds that perceived transaction costs represented 10 percent of investment costs for lighting measures and 30 percent for insulation measures. These figures are quite significant and most likely higher than transaction costs incurred by energy taxes. Bertoldi *et al.* (2010) analyse experience with tradable white certificates in EU.). They conclude that supplier obligations and white certificate schemes were generally successful by delivering larger savings than originally expected, and, in some cases, at cost below what policy makers had anticipated. However, the unavailability of reliable counterfactual data, different energy efficiency target

[14] Sweden has choosen the later strategy.

ambitions and other differences across countries make it very difficult to empirical evaluate the effectiveness and cost-effectiveness of white certificates. This is an area of policy evaluation that deserves more attention in the future.

4.2 Soft loans

EU and Swedish policies

Subsidised loans in terms of lower interest rates or loan guarantees are quite widespread in the EU (see Table 5), Germany and France being two examples. In Germany, the administrative burden of providing soft loans is dedicated to a government-owned development bank (KfW bank) which offers subsidised low-interest loans to promote energy-efficient retrofits of residential buildings. In France, an interest-free loan known as the "the eco-loan" has been introduced.to promote energy efficiency measures in existing residential buildings. The loans are intended to reduce energy consumption by installing new energy effective equipment and improved insulation. The administrative burden is assigned to high-street banks.

Rational and empirical evidence

Financial resources are needed to finance investments and, therefore, capital markets play an important role in policies for improving energy efficiency. If credit markets do not function efficiently it may contribute to underinvestment in measures to improve energy efficiency. Credit rationing can be viewed as a supply side problem. However, as we discussed in the previous section, it is important to emphasise the fact, which often is overlooked in the literature, that some cost-effective investments will not be realised due to objective financial resource scarcity of individuals with high credit risk profiles. Higher credit risk profile can be seen as a proxy for individual discount rate, meaning that individuals with higher credit risk profiles have higher corresponding discount rates and are less willing to implement costly energy efficient investments not because of some credit market failures but due to their individual characteristics.

The market failure in credit markets argument is often used in the literature, but sparsely supported by empirical evidence on its existence and extent. However, financial institutions in developed countries can usually assess the household/project risk levels quite well by using the wide availability of credit scores and credit histories. The lack of empirical studies signals that the problem may be small in developed economies. Leicester and Stoye (2013) points at the limited role (if any) of credit related failures. They study characteristics of residential buildings in the U.K. and conclude that low-income households and those with low educational attainment, who are more likely to be subject to credit constraints, are not less likely to have loft insulation, wall insulation or full double glazing than high-income households.

Both in the EU and the U.S. credit issues have been addressed by different financing facilitating programmes (including grants). In some cases there are mixed objectives, such as facilitating credit rationing *and* having social justice objectives *and/or* promotion of preferred energy efficient technologies at the same time. The multiple objectives of credit policies make empirical evaluation of their cost-effectiveness difficult.

4.3 Technology standards and subsidies

EU and Swedish policies

One of the most widely used non-price policies for combating market barriers to energy efficiency is technological standards and different types of subsidies for improving energy performance of buildings and household appliances.

Table 3 overviews the mandatory standards for buildings, heating systems and electric appliances in EU member states. According to the MURE2 database, the dominant measures addressing energy use in residential buildings are energy efficiency standards. The European Directive on Energy Performance of Buildings (EPBD), which came into force in its first version in 2001, has been a driving force for implementation of national standards. The current version of the directive requires that all new buildings should be "nearly zero-energy buildings" by the end of 2020.

In Sweden building codes has a long history, being introduced in the 1970's. The Swedish building code is a rather detailed code specifying minimum standards for overall energy performance in terms of energy use per m^2 and wall insulation. The code (energy use per m^2) is stricter for houses heated with electricity (and geothermal energy) and for houses in the southern part of Sweden (reflecting that the northern part is colder). The code also specifies a maximum power restriction for houses heated with electricity.

The EU Ecodesign Directive relates to standards for energy performances of energy using products, such as light bulbs, washing machines and computers. The new minimum standards means that producers of certain energy using products are obliged to reduce the energy consumption and negative environmental impacts of their products.

Rational and empirical evidence

From a general economic theory perspective, standards and subsidies can be seen as similar types of policy measures dealing with investment inefficiencies. Standard imposes a shadow cost on regulated products (e.g. energy using appliances) by making the presumably cheaper alternatives unavailable to consumers and, therefore, work just like an explicit product subsidy. However, it should be noted that in practice subsidies and standards address different types of market failures and behavioural issues and that the social cost of these policy measure may differ. In general, standards are commonly used to correct for incomplete information issues, such as inattention or asymmetric information, while subsidies are usually justified by policymakers as a proper tool to deal with credit constraints and positive technology externalities.

There is a large literature on the underlying policy rationale and the economic logic of technology-based energy efficiency regulations, including building codes (see review in Sanstad *et al.* (2006)). Standards are usually not considered a "first-best" solution to informational failures, but, can under some conditions, still be welfare improving, where other policy options are limited (Leland 1979). Most studies analysing the effects of energy efficiency standards on welfare assume away behavioural issues what leads to the conclusion that standards are considered as a "second-best" policy (Gillingham and Palmer 2014). A few recent studies show that, in some circumstances, when consumers are sufficiently homogeneous, standards or subsidies for energy intensive durable goods can be justified as a "first-best" policy to deal with investment inefficiencies caused by informational and behavioural issues (Allcott and Taubinsky 2013; Allcott *et al.* 2014).

While standards as command-and-control measures are relatively easy to implement and may be quite effective in energy conservation, they raise some economic concerns, as they force all consumers into higher cost investments and reduce the number of available alternatives on the market. Technology standards are attractive from a political point of view as they do not involve direct fiscal transfers through the public budgets and because the social cost of the policy implementation is "hidden" (see more Sanstad *et al.* (2006). The political attractiveness of standards is not only related to their hidden social cost but also to the opportunity for policymakers to use them as a measure to achieve multiple policy objectives, such as promoting more energy/CO2 efficient technologies and products.

The empirical literature is scarce on studies evaluating the cost-effectiveness of energy performance standards, especially in the European context. Aroonruengsawat et al. (2012) study the effects of a minimum standard in the construction sector and find, using panel data for 48 US states from 1970-2006, that the states that adopted building codes have experienced detectable decreases in per capita residential electricity consumption ranging from 0.3-5 percent in the year of 2006. However, the authors refrain from the discussion on the cost-effectiveness of the policy measure calling for "future research (...) to assess the costs of these building codes and compare them to the derived benefits."

Improved energy efficiency of residential buildings has also commonly been addressed by a number of direct or indirect subsidies. So-called "demand-side management" programs usually include direct subsidies or tax incentives to encourage demand for energy efficient products or installations, such as insulation, appliances with high energy performance, heat pumps etc. Allcott and Greenstone (2012) overview and reflect upon the cost-effectiveness of such programs. They single out the study by Arimura *et al.* (2011) as "the most advanced estimate in this literature" finding that the cost-effectiveness of "demand-side management" programs in the U.S. between 1992 and 2006 amounted to approximately $0.05per kWh which, according to Allcott and Greenstone (2012), is "barely profitable at a discount rate of 5 percent". Palmer *et al.* (2012) conclude that "actual estimates of energy savings from financing programs, using energy bills before and after retrofits and comparing programmes participants to a control group, have not been conducted". The lack of adequate *ex-post* research on the actual subsidy/standard effectiveness and economic efficiency makes it difficult to evaluate this policy set and its applicability for countries like Sweden.

Residential subsidies have historically been extensively used in Sweden, but have lost their popularity after the last programmes ended in 2008-2010 (Kiss *et al.* 2010). Among other things subsidies has aimed at stimulating energy efficient windows, solar and bio-fuel heating and conversion from direct electric heating. During the period of 2005-2008 there was a programme for increasing energy efficiency in buildings used for "public" activities.[15] Owners of such properties could apply for a tax reduction amounting to 30 percent of the investment cost. The programme was evaluated by the responsible authority, Boverket, in 2009 and the results pointed at a noticeable share of free riders. Control calculations showed that 50–67 of the measures supported by the programme were profitable even without the support. In a follow-up survey 53 percent of the property owners stated that they would have done the investment even without any financial support (Boverket, 2009). The programme was further evaluated in Broberg *et al.* (2009) who found that the underlying motives for the programme were unclear and that the support per KWh saved differed between different types of energy efficiency measures and, on average, amounted to SEK 0.18-0.78, where installation of heat

[15] In this context "public" means places where large groups of people reside, e.g., publiclly or prively owned multi-apartment buildingsm, sport centers, churches, schools or bus stations.

pumps was the cheapest measure and ventilation measures, the most expensive. The evaluation also showed that the marginal support per kWh ranged between SEK 0,94-8.03.[16] The evaluation concluded that the programme failed in cost-effectiveness (when compared to alternative policy measures).

4.4 Informational measures: labelling, certification and audits

European and Swedish policies

Providing households with information on energy efficiency through labels, certification or mandatory audits can help mitigating energy inefficiencies caused by information asymmetries and other behavioural issues. As informational issues are interlinked and difficult to disentangle from cognitive limitations, we overview the policy approaches to deal with them as one set of informational policy tools.

Many EU member states have introduced programmes with the objective to inform the public on energy performances of household appliances, cars and buildings. Mandatory energy labelling policies are one of the most prominent legislative information-based measures in Europe following implementation of the Energy Labelling directive (2010/30/EC) and the Energy Performance Directive for Buildings (2010/31/EC). Energy labels for electric appliances and energy performance certification of buildings are established in all EU member states.

Information campaigns in various forms have also been commonly used in EU member states to inform households about measures to improve energy efficiency. Most of the national programmes use all kind of media channels, such as print or internet, to promote more energy efficient choices among households. Some European countries also have legislations that oblige utility companies to provide households with detailed information on their energy use. Measures based on detailed information are closely related to the diffusion of smart metering and billing. Advanced meters and monthly billing of electricity is common in Sweden, but not in the EU as a whole. According to the ERGEG report (2010), most households received *yearly* electricity bills in Austria, Belgium, Czech Republic, Denmark, Germany, Luxembourg and the Netherlands in 2010. An interesting example is Lithuania which has quite a unique electricity billing system. Commonly, households do not receive electricity bills, instead they themselves have to read their electricity meter readings, state the relevant price of electricity, according their contract, calculate their payment, fill the special forms provided by the electricity suppliers and pay the calculated amounts on monthly basis. The electricity providers do regular checks to reconcile payments and electricity consumption. The system forces households to keep track of their electricity (and gas) consumption and costs on monthly basis, which likely leads to low inattentiveness levels when it comes to energy consumption and its price/costs. However, it raises the question whether this additional number-filling burden on households is overall beneficial for them and the society.

Another strand of policy measures designed to deal with incomplete information and inattention are energy audits, energy performance certification and advice services. Although audits and advice services are available in most EU countries, they differ in size and design. For instance, Finland is an example of a country with a long tradition of providing energy audits (including subsides for the audits) and advices to households. Sweden has taken a different route focusing mainly on public energy and climate advisors on the municipality level that can be contacted by households and small and medium sized firms free of charge.

[16] Marginal values refere to the most expensive (per kWh) measure receiving financial support.

The aim of the advisors is to mediate objective and technology-neutral information concerning energy efficiency options (N2013/5035/E). Following the implementation of the directive of energy performance of buildings, all Swedish home owners are obliged to make an energy performance certification available upon sale of single-dwelling homes.[17] Large firms have been able to apply for energy audit checks since 2010.

In recent years Sweden has introduced the subsidy programmes to urge municipalities to strategically work with energy efficiency; and the networks have been established to increase the knowledge base through information sharing. For example, BeLok and HyLok are two network programmes unifying bodies from the public sector and the construction sector with property and tenancy owners.

Rational and empirical evidence

As mentioned above market failures of asymmetric information and misaligned incentives of landlords and tenants may lead to over-consumption of energy, and it is widely used to justify, not only hard policies, such as building codes and products standards, but also soft policies such as energy performance certification, eco-labelling and audits. However, the lack of controlled field experiment studies leads to the situation where "the empirical evidence on the extent of realised principal-agent issues is remarkably limited" (Gillingham *et al.* 2012). Although, the empirical studies usually find that there are substantial differences across homeowners and tenants when it comes to electric appliance choices (e.g. Davis (2010); Krishnamurthy and Kriström (2013)) or insulation (e.g. Gillingham *et al.* (2012); Leicester and Stoye (2013); Krishnamurthy and Kriström (2013)), these differences are not hard evidence for significant energy inefficiency and misaligned incentives in the rental market. These differences can exist for other unobserved reasons, such as different preferences.

Product energy efficiency labels are widely used as a policy tool to guide the consumer choices of electric appliances and other energy consuming products. However, Newell and Siikamäki (2013) point that "surprisingly little is known about how consumers and firms respond to such programmes". One of few analyses, which has focused specifically on labelling programmes, is a recent study done by Houde (2013). He examines the welfare effects of "Energy Star" certification of refrigerators and finds that the programme is cost-effective. Another study by Min *et al.* (2014), based on lab experiments, find that providing operating cost information through labels induces stronger preferences for bulbs with longer lifetime and lower energy consumption.

The empirical literature on the impact of the energy performance certificates (EPC) in the private housing market is so far scarce too. Brounen and Kok (2011) find that EPC ratings capitalise into the price of dwellings in the Dutch market. Similar studies in Sweden find inconclusive results (Högberg 2013; Cerin *et al.* 2014). However, these studies do not perform any "before and after test" and, therefore, cannot say anything about whether EPC have affected the capitalisation of energy performance into housing prices. Amecke (2012) finds that purchasers of owner-occupied dwellings in Germany incorporate EPC information in their purchasing decisions and find somewhat limited effect on household behaviour. Another study by Kjaerbye (2009) about the impact of the Danish Labelling Scheme (which served as a blueprint for the EPC) on energy consumption in existing single-family houses found no significant impact on energy savings.

[17] A energy performance certification must also be avaliable when houses are rented out or new houses constructed.

Providing the public with information in the form of advice could be a mean to address informational failures by reducing transaction costs. There are very few studies with the focus on the effect of providing such information to energy users; therefore, there is little empirical evidence that energy consumption is reduced by providing household-level generic advice on its own. Advice can be delivered through various means (e.g. by post, internet or RTD), and in combination with other information. A recent study commissioned by Ofgem (Raw and Ross 2011) explores energy efficiency advice effects (supplying information with other type of information through various media channels) on energy consumption of households in the UK. The study finds that an effect of energy efficiency advice was not always seen and, when it was seen, the reduction in annual consumption was up to 5 percent. Meanwhile, Delmas et al. (2013) meta-analysis (156 studies) results show that strategies providing individualised audits and consulting have even higher average effect on energy conservation and are comparatively more effective than informational strategies that provide historical, peer comparison energy feedback or other type of information feedback. However, in general, individualised audits and consulting have much higher implementation costs.

The diffusion of advanced or smart metering and billing pave the way for innovative informational policy measures. One such measure correcting for incomplete information (mainly inattentiveness) in residential energy consumption is to simply provide real time information to households. Recent reviews by Ehrhardt-Martinez et al. (2010) and Darby (2006) on information feedback effects on residential electricity consumption indicate a wide range of electricity saving potentials. For example, Gans et al. (2013) find that the provision of real time information on energy consumption can be associated with a decline in electricity consumption of 11–17 percent in the Northern Ireland. However, Brandon and Lewis (1999) indicate that the effect of providing information on energy consumption can also have the opposite effect than expected. While high and medium energy users might decrease their energy consumption, low energy users are likely to increase their consumption (a “boomerang” effect). A recent study by Nilsson et al. (2014) finds no significant differences in energy use between their control and treatment groups. However, the study suffers from a very small sample and non-representative sample issues.

As mentioned above ethics and social norms can also play a significant role in policies for improving energy efficiency. A recent influential study by Allcott (2011b) finds that individual households’ demand for electricity is sensitive to information about how much electricity other similar households use. The substantial social norms effects on residential energy users were confirmed for the case of London residents in Dolan and Metcalfe (2013). Delmas *et al.* (2013) overview over 30 experimental studies on social comparisons (which were implemented in the last 30 years) and find high average effect (11 percent). This effect gets even higher when private social comparison information becomes publicly available. Delmas and Lessem (2014) find that the effect can reach 20 percent reduction in electricity use for heating and cooling in the U.S. It is worth to mention that the effect of providing information depends on how it is provided. For example, Dolan and Metcalfe (2013) found that information alluding to social norms did work when provided by printed letters, but not when the same information was provided through emails. It also matters who receives information. Costa and Kahn (2013) find that the environmental ‘nudges’ are much more effective with political liberals than with conservatives. The authors suggest that energy conservation ‘nudges’ may be more effective if targeted to specific individuals/communities. These results are somewhat in line with the results of Ek and Söderholm (2010), studying household electricity saving behaviour and the role of information. They also find that household heterogeneity, namely, environmental attitudes and social interactions are important determinants of electricity saving activities within Swedish households.

Table 3 Standards for buildings, heating systems and electric appliances

	AU	BEL	BG	CZ	DK	EST	FIN	FRA	GER	GRE	HUN	IRL	ITA	LV	LT	NLD	NOR	PL	POR	RO	SK	SLO	SPA	SWE	UK	EU
Mandatory Standards for Buildings																										
Energy Performance and/or thermal insulation standards	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Regulation for Heating Systems and hot water systems																										
Minimum efficiency standards for boilers	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Mandatory use of solar thermal energy in buildings	-	-	-	-	-	-	-	-	-	y	-	-	y	-	-	-	-	-	y	-	-	y	y	-	-	-
Maximum indoor temperature limit(s)	-	-	-	-	-	-	-	y	-	-	-	-	y	-	-	-	-	-	-	y	y	-	y	-	-	y
Mandatory Standards for Electrical Appliances																										
Minimum efficiency standards for electrical appliances	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Mandatory measures for efficient lighting	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y

Source: mostly based on MURE2 database

Table 4 Information measures

	AU	BEL	BG	CZ	DK	EST	FIN	FRA	GER	GRE	HUN	IRL	ITA	LV	LT	NLD	NOR	PL	POR	RO	SK	SLO	SPA	SWE	UK	EU
Labelling																										
Mandatory labelling of heating equipment	-	y	-	-	-	-	y	y	-	-	-	-	y	-	-	-	-	-	-	y	y	y	y	-	-	-
Mandatory energy labelling of electrical appliances	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Mandatory energy performance certificates for buildings	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Information and audit																										
Information campaigns	y	y	-	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Monthly bills as most common practice*	-	-	-	-	-	y	-	-	-	-	y	-	-	y	-	-	-	-	-	y	-	-	y	-	-	-
Energy advise and audit programmes	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	-	-	-	y	-	y	y	-

Source: mostly based on MURE2 database or NEEAPs

* *According to ERGEG report (2010)*

Table 5 Other measures

	AU	BEL	BG	CZ	DK	EST	FIN	FRA	GER	GRE	HUN	IRL	ITA	LV	LT	NLD	NOR	PL	POR	RO	SK	SLO	SPA	SWE	UK	EU
Grants / Subsidies/Tax exemptions																										
For investments in *new* buildings exceeding building regulation	y	y	-	y	-	-	-	y	y	-	-	y	-	-	-	-	y	-	-	-	-	y	y	y	y	-
For investments in energy efficient building renovation	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	-
For the purchase of more efficient boilers	y	y	-	y	-	-	y	y	-	-	-	-	y	-	y	-	-	y	-	-	-	y	y	-	y	-
For the purchase of highly efficient electrical appliances	-	y	-	-	-	-	-	-	-	-	-	-	y	-	-	-	-	-	y	-	y	y	y	-	y	-
Soft loans																										
	y	y	y	y	-	y	-	y	y	y	-	-	y	-	y	-	y	y	y	y	y	y	-	-	-	-
price instruments																										
Tax on energy	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Tradable white certificates	-	-	-	-	y	-	-	y	-	-	-	-	y	-	-	-	-	y	-	-	-	-	-	-	y	-

Source: mostly based on MURE2 database or NEEAPs

Table 6. Type of inefficiency, policy tools and their potential effects (selected)

	Theories explaining EE gap	Policy toolkit	Policy effect potential range on electricity conservation?	Source
Market failures	**Imperfect information (split incentives issue)**	Insulation incentives EE appliance incentives	1-2% (US) "substantial" (11 OECD countries) 0% (Australia) and 0.5% (US) "substantially larger" (11 OECD countries)	Allcott and Greenstone (2012); Gillingham *et al.* (2012); Krishnamurthy and Kriström (2013); Wood *et al.* (2012); Davis (2010); Krishnamurthy and Kriström (2013)
Market failures	**Credit constraints**	Interest rate subsidies; Loan guarantee programmes	"relatively minor" (in developed countries); "limited role" (UK)	Palmer *et al.* (2012); Leicester and Stoye (2013)
Market failures	**Energy market design failures (e.g. average-cost pricing)**	Price instruments; Better market design	Dynamic el pricing: 0-7% and electricity pricing with RT* 8-22% (US); "low value" of real time price elasticity (the Netherlands)	Jessoe and Rapson (2014); Lijesen (2007)
Behavioural issues and other market barriers	**Ethics, social norms and reference dependence**	Social comparisons;	2% (US), 6% (UK), 11% (meta-analysis)	Allcott (2011b); Dolan and Metcalfe (2013); Delmas *et al.* (2013)
Behavioural issues and other market barriers	**Bounded computational capabilities and Inattentiveness ("salience effect")**	More detailed information; Better appliance labelling; Standards; Financial incentives (subsidies) for more energy efficient durables.	3.8-12% depending on feedback type (including RT*, meta-analysis) 11-17% (UK); 11% (RT* feedback, meta-analysis) Substantial welfare gain of "Energy star" label: 87 $ per fridge (US) "No significant impact" (housing, Denmark) 0.3-5% electricity savings for building standards (US); 1-2% of energy use (US)	Ehrhardt-Martinez *et al.* (2010); Gans *et al.* (2013) Delmas *et al.* (2013); Houde (2013); Kjaerbye (2009) Aroonruengsawat *et al.* (2012); Arimura *et al.* (2011)
Behavioural issues and other market barriers	**Transaction (search) and other costs**	Energy Efficiency Advice	0-5% (UK); 13.5% (meta-analysis)	Raw and Ross (2011); Delmas *et al.* (2013);

Note: there might be substantial differences in the potential policy effect estimates between the studies done in different countries due to different economic, social and regulatory environments;

* *RT is abbreviation for real time visualisation*

5 Discussion and conclusions

A rather large literature argue that firms and households do not improve energy efficiency by investing in new technology despite that it is cost-effective to do so. If this wasn't the case people would be able to reduce their energy bills and spend their money on more pleasurable things. We argue that the so-called energy efficiency gap is a numerical artefact that to some extent can be explained by heterogeneity within the frames of efficient markets. In this paper we have provided a rational for policy makers to act on improving energy efficiency. From the economic standpoint we may be using too much energy or invest too little in energy efficiency technology given there are market failures, such as negative externalities or incomplete information. By eliminating these market failures, welfare can be improved in a broad sense, including both environmental quality and other welfare.

We reviewed the literature on behavioural anomalies, which suggest that people systematically deviate from the behaviour predicted by the rational choice theory, and reflected upon its relevance in energy markets. From this review we conclude that behavioural aspects can partly explain the energy efficiency gap and that social 'nudges' may be used to change households' behaviour without restricting the choices available to them. In the light of bounded rationality policy makers can play a role in cost-effectively reducing transaction costs and make energy efficiency a more salient attribute of energy using products. There is a wide literature in the field of behavioural economics providing evidence on behavioural biases that can be explored by policy makers. These evidences are mostly based on experiments involving hypothetical or real choices leaving us with the question whether or not the same biases exist in real markets.

Also in this paper we reviewed the main energy efficiency policies in the EU and Sweden, discussed these policies from the theoretical perspective and surveyed the literature for empirical evidence on their effectiveness and cost-effectiveness. From this review we conclude that there is a large number of instruments targeting energy efficiency and that an economic rational can be found for almost any policy instrument. However, policy instruments differ in terms of effectiveness and cost-effectiveness. Ex-post studies on the effectiveness and cost-effectiveness of individual policy measures are sparse, in particular studies evaluating the economic efficiency aspect. We argue that policy instruments should target existing rather than potential market failures and that policy instruments should be designed to cost-effectively eliminate these failures. We acknowledge that it is difficult to create proper policy instruments to cope with inefficiencies, when the underlying problems are not general but rather unevenly distributed among final energy users. So, although there are profitable actions that will not be undertaken by households or energy service companies, they can be difficult or expensive to remedy through inadequate political interventions.

Social 'nudges' differ from all other policy instruments as they do not directly target any market failure. Since social 'nudges' do not restrict choices available to consumers but rather change the framing of choice situations, they do not cause any obvious market distortion. If social 'nudges' have persistent and desirable effects on energy demand, such 'nudges' surely are least-cost instruments. To what degree 'nudges' have persistent effects on energy use is, of course, an empirical question that has to be carefully tested on a national basis as the results are expected to be sensitive to institutional, cultural, historical, political and economic contexts. Well-designed field experiments are needed to address this question. Empirical evidences from the U.S. and the U.K. suggest that households respond to comparative information by significantly reducing their energy use. Compared to traditional policy instruments, such as energy taxes, peer comparisons come out favourably.

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