CONSEED

CONSumer Energy Efficiency Decision making

UNDERSTANDING CONSUMER DECISION MAKING IN THE CONTEXT OF ENERGY EFFICIENCY

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Executive Summary

World energy consumption is expected to grow by 30-50% over the next 25 years, bringing with it increased local air pollution and greenhouse gas emissions, increased fossil fuel consumption and higher energy prices. Enhancing the efficiency with which the economy uses energy to deliver services such as transport, refrigeration, cooking or space heating and cooling can play a very relevant role in reducing the cost and environmental damages associated with energy use. The importance of energy efficiency (EE) measures and technologies is highlighted by the Intergovernmental Panel on Climate Change (IPCC), which forecasts significant investments in EE to help limit the increase in global temperature to 2ºC (IPCC, 2014).

The general aim of the CONSEED Project is to examine the interaction of different consumers with existing EE policies aimed at influencing consumer decisions at the point of sale and to make policy recommendations based on the empirical evidence collected. This report delivers the findings of WP1 of the CONSEED project, which reviews existing, ongoing and new research on factors influencing decision-making by consumers related to energy for different sectors (appliances, buildings and cars) and for specified consumer groups (households, services, agriculture and industry).

Founded on an extensive literature review of 164 papers, this deliverable reviews **the main reasons for the EE gap**, the reasons why consumers tend to fail to account for all the expected costs of their purchase and heavily discount future or undervalue future energy savings. These are grouped as: **(a) informational failures** which include *asymmetry and imperfect information*, *hidden costs* and *transaction costs;* **(b)** other **market failures**, including *externalities*, *low energy prices*, *slowness of technological adoption*, *capital market failures* and the *principal-agent problem* and **(c) behavioural failures** such as *inattention*, *inertia*, and suboptimal decisions sometimes arising from cognitive biases and heuristics, Other factors such as issues related to *differences in discount rates* and *myopia* are also discussed in the deliverable.

The relevant literature proposes several **policy instruments** for preventing the EE gap which are implemented by governments. They include **energy labelling**, **taxation, subsidy schemes and rebates** or **energy audits**. **Depending on the type of failure that is to be addressed different instruments are suggested**. For instance, energy labelling seeks to avoid informational and behavioural failures. The existing evidence shows a positive WTP for most EE labelled goods such as appliances, vehicles and properties, but less remarkable one for commercial buildings. It is generally acknowledged that the effectiveness of labels will depend on their design, on the trust that consumers place on them and on the amount and quality of information that they provide.

In addition, the deliverable **identifies factors that affect decision-making** by consumers regarding the purchase of appliances, transport and properties in the household, service, industry and agriculture sectors. These include **behavioural factors**, **socio-economic characteristics** and **policy incentives**. Finally, the deliverable **presents the foundations for the theoretical model which will underpin the empirical analysis** in later work packages.

1. Introduction and background

World energy consumption is expected to grow by 30-50% over the next 25 years, bringing with it increased local air pollution and greenhouse gas emissions, increased fossil fuel consumption and higher energy prices (IEA, 2016; IEF, 2015) . Enhancing the efficiency with which the economy uses energy to deliver services such as transport, refrigeration, cooking, space heating and cooling can play a highly relevant role in reducing the cost and environmental damage associated with energy use (Gerarden et al., 2015a). The importance of energy efficiency (EE) measures and technologies is highlighted by the Intergovernmental Panel on Climate Change (IPCC), which recommends significant investments in EE in order to limit the increase in global temperature to 2ºC (IPCC, 2014). In particular, it envisages global investments in EE in buildings, transportation and industry growing by $336 billion per annum from 2010 to 2029 (IPCC, 2014). The European Commission (EC) also identifies EE as the fastest, most cost-effective way of reducing CO_2 emissions (European Commission, 2011; IEA, 2015). Furthermore, the EU 20-20-20 policy package aims to reduce energy consumption by 20% by 2020. In particular, for the residential sector, the goal is 27% energy saving by 2020 and 40% by 2030.

However, with no regulation in place, the diffusion of EE technologies is slower than would be socially optimal (Jaffe and Stavins, 1994b). That is, although EE has economic benefits and environmental advantages (e.g. reduction in carbon emissions and other pollutant emissions), there is underinvestment (Linares and Labandeira, 2010). Indeed, it is observed that households and businesses invest less in EE than is privately rational (Jaffe et al., 2004; Gerarden et al., 2015). In a rational investment decision consumers account for all the expected costs and returns of the investment, including initial planning, purchase, use, resale and disposal of the durable good or service. In the case of EE investments and EE goods, consumers often fail to account for all these expected costs and heavily discount future energy savings (Train, 1985) or undervalue future savings (Allcott and Wozny, 2013). This is the so-called *energy efficiency gap* or *energy efficiency paradox* (Jaffe and Stavins, 1994b). That is, investments in EE which appear to be highly beneficial are not actually carried out. Some authors suggest that almost 40% of the potential energy savings worldwide are not achieved (IEA, 2007).

The overall aim of the CONSEED Project is to **examine the interaction of different consumers with existing EE policies aimed at influencing consumer decisions at the point of sale and make policy recommendations based on the empirical evidence collected**. This report delivers the findings of WP1 of the CONSEED project. The aim of WP1 is to review existing, ongoing and new research on factors influencing decision-making by consumers related to energy, especially EE labelling for different sectors (appliances, buildings and cars) and for specified consumer groups (households, services, agriculture and industry).

The report is structured as follows: Section 2 explores the literature surrounding the EE gap and the existing policy measures addressing this gap; Section 3 presents the theoretical framework which will underpin the empirical analysis in future work packages. Section 4 provides an in-depth analysis of the literature on the role of labelling in investment decisions in different sectors (households, services, agriculture and industry) and product categories (appliances, buildings and cars).

2. Understanding the energy efficiency gap

The relevant literature points to several mechanisms which explain the energy efficiency paradox, which have been classified by Fredericks et al. (2015a), Linares and Labandeira (2010) and Ramos et al. (2015) as: (i) informational failures; (ii) other market failures; and (iii) behavioural failures. Although informational failures are market failures, the distinction is made in Table 1 so as to reflect the different policies used to correct them (Section 2.1). These mechanisms[1] are summarised in Table 1.

Table 1: Types of failure that explain the EE gap (adapted from Ramos et al., 2015).

	Informational failures	Other market failures	Behavioural failures
Lower-than-efficient energy prices		X	
Hidden and transaction costs	X		
Uncertainty*	X		X
Decision-making heuristics and biases			X
Slowness of technology adoption		X	
Principal agent problem*	X	X	
Capital market imperfections		X	
Divergence with social discount rates*	X	X	X
Asymmetric and/or incomplete information	X		

* Depending on the problem faced, these factors are considered as different failures

(i) **Informational failures**: Information plays a very important role in the decision-making process and may explain apparently non-rational decisions. This includes *asymmetry and imperfect information*, *hidden costs* and *transaction costs*. It is widely agreed that imperfect information leads consumers to non-optimal choices (Allcott and Sweeney, 2015; Labandeira et al., 2012; Phillips, 2012). A lack of information or asymmetry of information related to the energy consumption of durable goods is a clear example of *imperfect and asymmetric information*. Consumers need to know how much energy a good consumes in order to appreciate future energy savings. *Hidden and transaction costs* can be another example of informational failures (Ramos et al., 2015). Transaction costs, such as search costs associated with gathering and assimilating information regarding product quality, the cost of specification and tendering, bargaining and negotiation costs or the cost of legal advice, could create deviations from non-optimal outcomes (Sorrell, 2004). These costs, which are relevant especially for household, independently or combined with behavioural failures, could lead to lower investment in EE.

[1] Other highly interesting issues related to investments in EE worth exploring include the rebound effect (i.e. increases in consumption following improvements in energy efficiency due to lower cost of energy services), which is often connected to EE gap literature. Such issues are considered to lie outside the scope of this review.

(ii) **Other market failures.** Market failures include issues such as *externalities*, *low energy prices*, *slowness of technological adoption*, *capital market failures* and the *principal-agent problem* (Linares and Labandeira, 2010; Ramos et al., 2015). With regard to *externalities*, from one side there are external costs that are not internalised in energy prices; on the other side, there are also multiple benefits associated to EE (see Ryan and Campbell, 2012). For instance, when the regulation of the electricity market results in *energy prices* that are lower than the marginal costs, the decision-making process is distorted. Then low energy prices do not act as an essential driver for EE investments. Barriers to *technology adoption*[2] also play an important role in consumer decision-making and EE investments (Michelsen and Madlener, 2016). In prospective technology studies, the diffusion of new energy-related technologies may be overstated (Linares and Labandeira, 2010), while other studies show that the slow processes of technology adoption of technologies could explain the EE gap (Jaffe and Stavins, 1994b).

With regards to *capital market failures*, potential adopters may simply lack access to the capital needed to undertake EE investments. Train (1985) suggests that consumers in lower income segments have a higher implicit discount rate (i.e. they value future benefits with a large markdown) because of low access to capital. This prevents them from investing in EE. Furthermore, *principal-agent problems* arise when one party makes a decision relating to energy use but another party bears the cost or enjoys the benefits of that decision. For example, in the case of housing rental contracts, the landlord may decide the type of heating system while the tenant chooses how to use the heating. These situations often result in lower EE investment (Gillingham et al., 2006). A survey in New Zealand shows that tenants are willing to pay higher rents in order to improve the EE of houses but landlords are not investing in EE (Phillips, 2012).

(iii) **Behavioural failures**. We consider *inattention*, *cognitive biases and heuristics*[3] (Frederiks et al., 2015b). *Inattention* to future energy costs has clear implications for under-investments in EE. The level of inattention can vary from one individual and decision environment to another (Gerarden et al., 2015). *Decision making heuristics* suggest that individuals are constrained by cognitive limitations and/or bounded rationality which may prevent them from trading-off higher investment costs against lower future energy costs (Gillingham et al., 2009). Moreover, this constraint leads consumers to place more value on initial costs (for more details see Table A.1).
Due to the uncertainty contained in investment decisions, the rationality of decision-making leads buyers to think in terms of expected payoffs. This rationality often violates the neoclassical assumptions relative to the preferences of consumers under uncertainty, i.e. those of expected utility theory. This occurs particularly when a reference point of the expected payoff of the investment outcome influences the consumer (Kahneman, 1994). In other words, the decline in

[2] For example, the current limitations on switching from fossil fuel to an innovative, renewable-based residential heating system is a barrier to technology adoption. Barriers may consist of high initial installation costs and the financial risks connected to uncertainty regarding energy prices.

[3] See Table A.1 in the Annex for a detailed description of behavioural failures.

consumer utility from a relative loss is much larger than the increase in utility from an equivalent relative gain (Tversky and Kahneman, 1981). When the reference point is zero, consumers are said to be loss averse. Greene et al. (2008) and Green (2011) illustrate the role of loss aversion in the EE gap in the context of vehicles. Consumers face several uncertainties at the time of investment: future energy prices, energy reductions and expected level of use. The expected return on purchases might even be negative in a context of uncertainty on prices. Loss-averse individuals who weight such potential negative payoffs heavily may not purchase the more expensive EE vehicle. Loss aversion has been widely studied in other environments, but there is little empirical evidence on the impacts of reference points on EE decision-making and investments.

Apart from all the factors pointed out above, there are some that can also be considered under more than one failure category (e.g. *divergence of private and social discount rates*, *uncertainty* and the *principal-agent problem*). Divergence between *social discount rates*[4] and private discount rates affect all social decisions, particularly EE investment policies. The divergence of discount rates reveals that an EE may not be privately desired for several reasons, such as hidden cost and low prices as mentioned above, despite being socially desirable. A policy for compulsory EE investment may thus not be welfare improving for private individuals. Public intervention is thus justified when there are clear market failures and in the cases where welfare improvements can be achieved (Linares and Labandeira, 2010).

Other factors that can contribute to the EE gap are *myopia* (Busse et al., 2013; Cohen et al., 2017; T. D. Gerarden et al., 2015) *and uncertainty* (Greene, 2011). *Consumer myopia* is observed when the willingness to pay for a good is not affected by changes in the expected future costs of using it. Under myopia, avoided future costs of energy may not be perceived as a benefit. This results in under-investment in EE goods. Concerning *uncertainty*, Greene (2011) shows that uncertainty about fuel and electricity prices, combined with the loss aversion of buyers, results in decision-making bias. In this context, uncertainty can be considered as an informational failure. There are some factors (e.g. changes in EE legislation, myopia, hidden costs) that further increase *uncertainty* among consumers and lead to other behavioural failures (Ramos et al., 2015). For instance, uncertainty could be a consequence of frequent changes in policy regulations leading to mistrust among consumers. Therefore, uncertainty can be present in both behavioural and informational failures. The level of uncertainty is also driven by the regulatory environment and the information available on goods. Finally, from a methodological point of view, uncertainty generates several biases which influence results and interpretations (for more details see Table A.1 in the Annex).

2.1. Policy measures addressing the Energy Efficiency Gap

Many policy alternatives have been explored to address the aforementioned failures (Gibbons and Gwin, 2004; Gillingham et al., 2006). They include the optimal taxation of externalities, discriminatory taxation, pricing schemes, tradable permits, subsidies and green and white certificates (Bye and Bruvoll, 2008). An

[4] Rambaud and Muñoz Torrecillas (2006) describe the social discount rate as "the discount rate used by the society to give relative weight to social consumption or income accruing at different points in time".

optimal combination of subsidies and taxes may also encourage consumers to buy EE durable goods (Galarraga et al., 2016a; Markandya et al., 2009).

Table 2 presents some policy instruments implemented to address the EE gap. These instruments include feedback (Asensio and Delmas, 2016; Gans et al., 2013), audits (Frondel and Vance, 2013; Palmer et al., 2013) and energy certificates (Fuerst et al., 2016).

Table 2: Information policy instruments (Source: Own work based on Ramos et al., 2015, Gillingham et al., 2009 and Ryan et al., 2011)

Factors that affect the EE gap	**Policy instruments**
Lower-than-efficient energy prices	Real-time pricing, market pricing
Hidden and transaction costs	Certificates, feedbacks, audits
Uncertainty	Certificates, audits
Decision-making heuristics and biases	Certificates, feedbacks, audits
Slowness of technology adoption	R&D programmes; R&D incentives
Principal agent problem	Certificates
Capital market imperfections	Financing/loan/grant programmes
Divergence with social discount rates	Financing programmes
Asymmetric and/or incomplete information	Certificates, feedbacks, audits
Myopia	Information programmes

Feedback is a useful instrument for overcoming informational failures (e.g. incomplete information, information asymmetry) and behavioural failures such as consumers' beliefs about energy consumption or aversion to uncertainty. Feedback tools, such as information about energy consumption, can help consumers to reduce energy consumption, provided this feedback is effective and consumers react to informational signals such as price. For example, smart meters provide consumers with real-time information on their energy consumption as well as recommendations on saving energy (Asensio and Delmas, 2016). Authors who have analysed the effect of smart meters have observed electricity reductions of 6% and 7% when flat-rate tariffs are replaced by Time-of-Use (TOU) or Real-Time Tariffs (Faruqui et al., 2010, Gans et al., 2013, respectively). Energy bills can also be helpful in giving feedback to consumers by showing their own consumption and comparing it to that of similar consumers. This is a way of using social peer pressure to promote EE behaviour (DellaVigna, 2007).

Similarly, energy audits may help to inform and control the energy consumption of a household or a firm. Abrahamse et al. (2005) carry out a review of five studies analysing energy audits and find heterogeneous results: some of them find a decrease in electricity consumption but others show no significant change.

The most widely used instruments for dealing with market, informational and behavioural failures are energy labels. An energy-efficiency label is designed to highlight the EE of a good and consequently reduce the information gap (Galarraga et al., 2016b): it is a trustworthy logo that informs consumers about the attributes of a product and its life-cycle – the production, consumption and waste phases (Galarraga et al., 2016b). Energy labels describe first and foremost the energy characteristics of a product (future energy use and cost) but can also give information on the use of other resources (like water) and provide consumers with the information that they need to make optimal decisions. Labels can be considered as a hybrid instrument because they force the market to engage in a continual improvement process (the so-called 'dynamic efficiency').[5]

Wiel and Mcmahon (2003) draw a distinction between different types of labels: endorsement labels, comparative labels and information-only labels. Endorsement labels are used to distinguish between efficient goods and non-efficient ones, without detailing energy savings. Comparative labels enable consumers to compare similar products using discrete categories or a continuous scale. In the case of the car labelling Directive, Germany, Spain and the Netherlands have adopted a relative classification approach, rating vehicles in comparison to a weighted average of other vehicles within a certain vehicle segment. Information-only labels give detailed information on products (see Figure 1).

Many empirical studies which analyse the effectiveness of energy labels (Amecke, 2012; Banerjee and Solomon, 2003; Brounen and Kok, 2011; Codagnone et al., 2016; Kok and Jennen, 2012; Sammer and Wüstenhagen, 2006) find that the success of a label depends on the format, the information given, its colour, its size and the credibility of the institution that sponsors the campaign, among other factors.

Even though labels give a great deal of information, it is widely acknowledged that some informational failures may remain (such as aversion to uncertainty, inattention, etc.), so labelling schemes are sometimes combined with other policies such as subsidies, taxes, incentives schemes, etc. Examples of the literature that addresses the impact of these instruments include Revelt and Train (1998), Datta and Gulati (2014), Markandya et al. (2009) and Galarraga et al. (2016b).

2.2. EU labelling

Different legislations and regulations are in force in the EU depending on the product category. On the one hand, the EU Energy Labelling Directive (2010/30/EU) requires energy labels to be displayed on energy-related appliances at the point of sale.[6] On the other hand, the Directive on the Energy Performance of Buildings (Directive 2010/31/EU)[7] requires Member States to establish a certificate displaying the energy performance of buildings. Moreover, the car labelling Directive displays CO_2-

[5] Dynamic efficiency is the situation in which where it is possible to improve one generation of goods, without making the rest of the generations worse off.

[6] Directive 92/75/EC of the European Parliament and the Council of 22 September 1992 on household appliances, recast into Directive 2010/30/EU of 19 May 2010 (http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32010L0030).

[7] Directive 2002/91/EC of the European Parliament and the Council of 16 December 2002 on energy performance of buildings, recast into Directive 2010/31/EU of 19 May 2010 (http://eur-lex.europa.eu/legal-content/ES/TXT/?uri=celex%3A32010L0031).

emission (Directive 1999/94/CE)[8]. There is also a separate labelling for tyres.[9] For commercial and office equipment, the EU Energy Star programme (Directive 2012/27/EU)[10] provides a voluntary energy labelling scheme for equipment including computers, servers, displays, imaging equipment and uninterruptible power supplies. This type of products should cope with Minimum Energy Performance Standards (MEPS), typically set under Ecodesign Directive (2009/125/EC), which means that products not meeting the MEPS cannot be placed on the market.

The level of efficiency of an energy-consuming appliance is rated using a colour-coded and letter scale (see Figure 1). Labels also give other useful information to customers, depending on the appliance (e.g. energy consumption, water consumption and noise level). This information must also be displayed in catalogues and included by online retailers on their websites.

The Energy Performance of Buildings Directive (EPBD) (Directive 2010/31/EC) is the main EU policy instrument for improving the energy performance of buildings, taking into account cost-effectiveness and local conditions and requirements. The EPBD ensures that when buildings are reconstructed, sold or rented an Energy Performance Certificate (EPC) is made available to the owner, or by the owner to the prospective buyer or tenant. The EPC shows an EE rating for the energy performance of a home rated from A to G, similar to the ratings currently applied to appliances (Figure 2). In addition, EPCs must include recommendations for cost-effective improvement options to raise the rating of buildings. The recast of the EPBD in 2010 (Directive 2010/31/EU) clarifies certain points, promotes the role of the public sector and reinforces the role of EPCs by requiring publication of the EPC at the time of advertising a building for sale or rental rather than at the time of signing a purchase agreement or rental contract. Finally, the EC has designed a new package with an extensive set of legislative proposals, including a new indicator for smart buildings and some provisions that should enhance the current EPC in order to achieve the 30% of energy efficiency target (REHVA, 2016).

Most car labelling systems for light-duty vehicles are intended to provide clear, accessible information to enable consumers to compare the fuel performance of similar vehicles. This is the case of the European labelling scheme as implemented in Spain, The Netherlands or Germany. In the EU, this scheme is regulated by European Directive 1999/94/CE (European Commission, 2000), which requires Member States to impose a labelling system for light-duty vehicles that shows the absolute level of CO_2 emissions and the fuel consumption of each new car when it is sold. This Directive also recommends the use of a voluntary label (Figure 3) with colour-differentiated efficiency (fuel and CO_2) classes (from A to G) to facilitate comparisons between vehicles of the same size. A survey in 2004 showed that most Member States viewed the labelling directive as underperforming at that time. In May 2016, the EC conducted an

[8] Directive 1999/94/CE of the European Parliament and the Council of 13 December 1999 on CO_2 emissions for vehicles (http://eur-lex.europa.eu/legal-content/FR/TXT/?uri=CELEX%3A31999L0094).

[9] Regulation (EC) Nº 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters (http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficient-products/tyres)

[10] Directive 2012/27/EU of the European Parliament and the Council of 25 October 2012 on office equipment and buildings (http://eur-lex.europa.eu/legal-content/FR/TXT/?uri=CELEX%3A31999L0094).

appraisal of the directive. It concluded that the label is a relevant tool as it improves the awareness on fuel savings and CO_2 emissions. More particularly, the EC reports that the colour-coded EU energy efficiency label, used in 14 Member States[11], seems to increase the effectiveness of the directive.

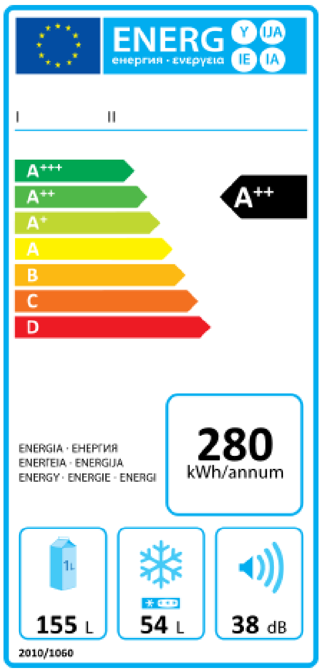


Figure 1: Energy efficient labelling for appliances (fridge).

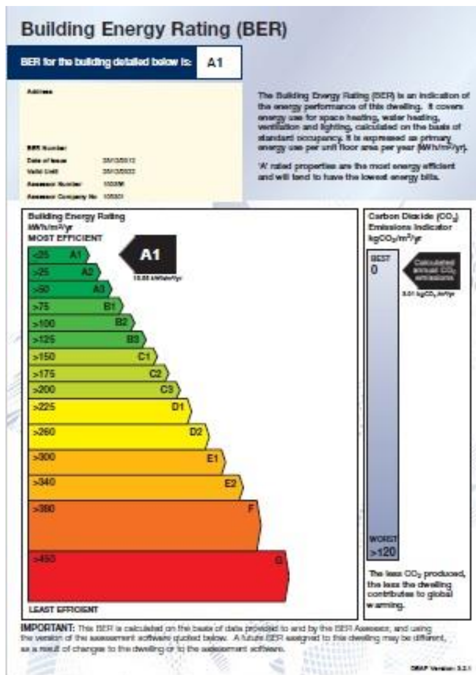


Figure 2: Energy efficient labelling for buildings (BER certificate)

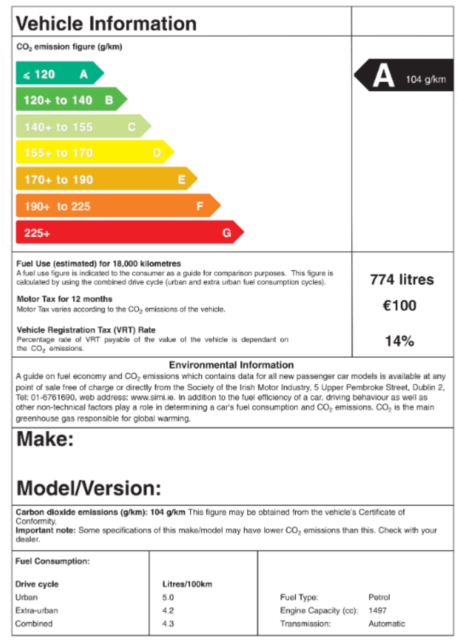


Figure 3:Energy-efficient labelling for cars - Voluntary version of the labelling

In 2012, the Commission reviewed the 2009 Ecodesign Directive and concluded that a revision of legislation was not required but that some aspects of the 2010 Energy Labelling Directive could be reviewed in the future. This review was published in July 2015 and highlighted that the Energy Labelling Directive had been effective in improving the EE of energy durable goods. However, a revision of legislation was required for the EU to continue meeting the same objectives. The new regulation was accepted on January 2017 but is not formally adopted yet. Once this new regulation enters into force, Directive 2010/30/EU will be abrogated. The proposed regulation would restore the original A to G energy label scale and, over time, abolish the A+, A++ and A+++ categories, while retaining the same green to red colour scheme for EE level. Existing labels would be tested by the Commission within five years to ensure their quality and effectiveness. Moreover, energy labels will be rescaled every 10 years to stimulate more advances in efficiency.

[11] https://ec.europa.eu/clima/policies/transport/vehicles/labelling_en

3. A theoretical model for energy efficiency investment decisions

The above discussion can be incorporated into a general theoretical framework. In this regard, CONSEED seeks to follow the model proposed by Allcott and Greenstone (2012), which describes an agent's choice between two goods (one efficient and one inefficient) for two time periods (investment occurs in period one and energy is consumed in period two). The model is general enough to capture investment decisions by consumers (utility maximisers) and firms (profit maximisers) for all technologies (appliances, property, transport and machinery) and sectors (household, services, agriculture and industry) explored by CONSEED, and is applicable to both comparisons between two prospective energy-consuming goods and those between an agent's existing good and a new, more efficient good.

In the CONSEED model (adopted from Allcott and Greenstone (2012)), the agent (either a consumer or a firm) chooses between an efficient good (denoted by 1), with energy intensity e_1, and an energy inefficient good (denoted by 0), with energy intensity e_0 ($e_0 > e_1$). Energy intensity can be thought of as the energy used by one unit of energy services, for example, kWh per hour of lighting or litres of fuel per kilometre of driving. The agent will choose the more efficient good if:

$$\frac{\mathrm{p}\,\mathrm{m_i}\,(e_0 - e_1)}{(1+r)} - \sigma > I \qquad (1)$$

where p is the price of a unit of energy, $\mathrm{m_i}$ is the agent-specific quantity of energy services and r is the risk-adjusted discount rate between the two periods (in period 1 the agent chooses the capital investment, whereas in period 2 the consumer uses the good and incurs the energy cost). σ and I are the unobserved net opportunity/utility cost and incremental investment costs of the more efficient good, respectively. The agent will choose the energy-efficient good if the willingness-to-pay (equal to the discounted energy cost savings net of any unobserved costs – left-hand-side of Equation 1) exceeds the incremental investment cost (right-hand-side).

To allow for the EE gap or 'investment inefficiencies' (Allcott and Greenstone, 2012), energy savings are scaled by parameter γ ($0 < \gamma < 1$) , which is equivalent to the implied discount rate:

$$\frac{\gamma\ p\, m_i\,(e_0 - e_1)}{(1+r)} - \sigma > I \qquad (2)$$

For the following discussion, we extend this model by disaggregating net costs into costs (c) and benefits (b) and allow these and the scaling parameter to be agent-specific to account for agent heterogeneity (in this general framework we ignore the possibility that prices may also vary per agent):

$$\frac{\gamma_i\ p\, m_i\,(e_0 - e_1)}{(1+r)} - c_i + b_i > I \qquad (3)$$

Much of the discussion in Section 2 above can be incorporated into this general framework. It is clear from Equation 3 that choosing the more EE technology involves more than comparing energy savings to incremented investment costs. Unobserved adoption or transaction costs (c_i) are likely to play a major role in the investment decision, and if unaccounted for will inflate estimates of the EE gap. Potential adopters must learn how a new technology fits into existing household routines (high search costs are also discussed in Hausman and Joskow (1982)) and, post-adoption, there may be qualitative deficiencies embedded in more efficient technologies (Jaffe and Stavins, 1994a). For example, in transport there may be a disutility associated with expected changes in fuelling (charging) and driving behaviour for potential adopters of electric vehicles. Even with a seemingly homogenous technology such as lighting, there may be differences in the quality of the lighting services provided by contemporary technologies. There are, however, also many unobserved benefits associated with improving EE (b_i). For example, improving insulation in property also enhances occupant comfort and future resale value (Hyland et al., 2013). There may even be 'warm glow' (Andreoni, 1990) motives given the perceived negative environmental and societal consequences of energy consumption. For businesses, EE investments can be used to boost corporate image and increase sales. For households, there may be equivalent status effects, particularly for visible technologies such as cars and solar panels. Such costs and benefits, as described in Equation 3, are agent-specific and are probably heavily influenced by demographics, environmental attitudes and culture.

A number of market failures are discussed in Section 2 which may slow the adoption of more energy-efficient technologies. For example, if energy prices in Equation 3 (p) are lower than marginal cost (perhaps as a result of government incentives for generators or non-internalised environmental impacts), the cost savings ($pm_i\,(e_0\text{-}e_1)$) and incentives to invest in EE will be diminished. Furthermore, there may be capital market imperfections which prevent some segments of the population from accessing capital at the risk-adjusted discount rate (Allcott and Greenstone, 2012).

Section 2 also highlights a number of potential behavioural failures which may widen the EE gap ($\gamma < 1$). Hyperbolic discounting leading to 'present bias' or 'time-inconsistency' in decision-making (Frederick et al., 2002; Laibson, 1997; Loewenstein and Prelec, 1992) has obvious implications for the valuation of future energy savings. High uncertainty regarding energy prices and savings (Sutherland, 1991) and the irreversible nature of efficiency investment (Hassett and Metcalf, 1993) may also lead to higher implicit discount rates. Furthermore, 'Prospect Theory' (Kahneman and Tversky, 1984, 1979; Tversky and Kahneman, 1981) suggests that the value change associated with a loss is significantly higher than for an equivalent gain ('loss aversion'), that choices are driven by context (framing effects) and that decision-makers overweigh certain outcomes (certainty effect). This theory helps explain why decision-makers may reject an actuarially favourable (but perceived as riskier) alternative and are reluctant to deviate from their status quo ('status quo bias') (Samuelson and Zeckhauser, 1988).

A standard market failure which may lead to the undervaluation of energy savings is imperfect or asymmetric information (Jaffe and Stavins, 1994b). For example, the EE gap may simply be due to the fact that agents are unaware of the energy intensity of different goods or, perhaps more importantly, the energy intensity of their existing appliances. There may also be asymmetric information problems between buyers and sellers of goods at the point of sale – a salesperson's commission may be unrelated to the efficiency of the appliances that he/she sells (Carroll et al., 2016b). Principal-agent problems may also be a driver of underinvestment. For example, if landlords cannot convey the EE of their property to renters (assuming that renters will pay more for higher efficiency) there is no incentive to invest (Carroll et al., 2016a). Given this range of informational deficiencies, it is not surprising that independent EE labelling of technologies has been a key policy to date.

There are numerous other informational deficiencies which may widen the EE gap or the perceived costs of investment. For example, agents may be unaware of their own energy demand (m_i) or even of the price of energy, and therefore unable to form energy cost expectations. Underinvestment in EE could also be due to biased, inflated perceptions of costs, possibly due to lack of experience (electric cars, for example). Furthermore, information on the benefits of EE may be acquired through an agent's network – a positive adoption externality – which may be an important driver for the dissemination of new energy-saving technologies.

In WP4, we explore whether the EE gap is specifically related to missing information on future energy costs. EU EE labelling provides a range of comparative non-monetary indicators, but deriving an energy cost forecast is not a straightforward exercise – an agent must combine non-monetary information with information (and expectations) on energy prices, level of use and duration of investment. In this regard, there is evidence that households make substantial errors when converting non-monetary information into energy cost expectations (Heinzle, 2012, Allcott, 2011). The theory of bounded rationality (Simon, 1959) may also be relevant here: it suggests that while decision-makers are fundamentally rational they may lack the cognitive abilities to process and incorporate all the information available.

A high implied discount rate may also be the result of 'inattention' by agents to future energy costs (Allcott and Greenstone, 2012) and a focus on upfront investment costs. For example, Kurani and Turrentine (2004) find that car owners in the US do not keep track of past expenditure and are therefore unlikely to have 'the basic building blocks of knowledge assumed by the model of economically rational decision-making' (p. 1213). Allcott (2011) presents similar findings and shows that 40% of respondents did not think about fuel costs when buying their last vehicle (and 35% did consider fuel costs but did not do any calculations). Sallee (2013) suggests that such inattention is not necessarily irrational behaviour when there is little variation in energy costs within product groups and there are high investment transaction costs associated with calculating and comparing models ('rational inattention').

The theoretical framework as described here will enable CONSEED to capture a wide variety of factors which influence investment decisions. Subsequent work packages will populate this framework with data collected from focus groups, consumer surveys, field trials and discrete choice experiments for various agents.

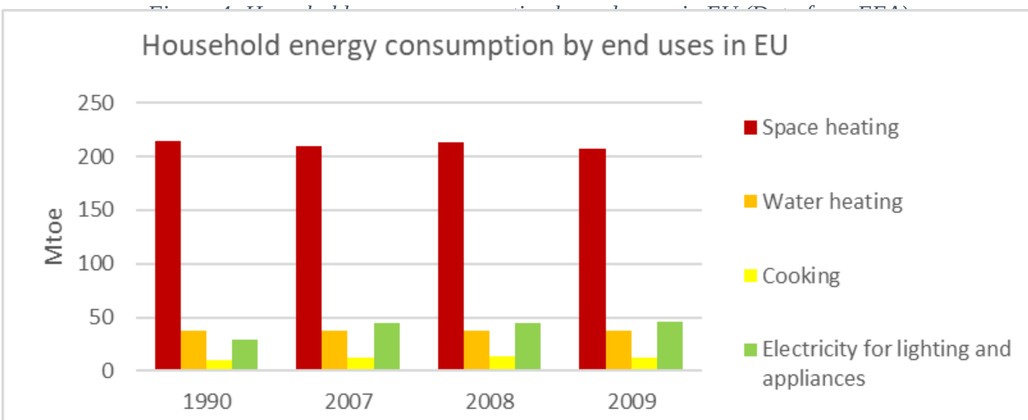
4. Review of the literature

A comprehensive literature review has been carried out in support of the modelling work within the CONSEED project. The aim of this review is to identify common factors that affect consumer purchasing decision-making in the household, service, industry and agriculture sectors. Accordingly, a total of 164 papers were reviewed between January and May 2017, 87.2% of which were peer-reviewed journal articles and 12.8% grey literature (4.9% books, encyclopaedias and reports; 7.9% working papers). A total of 102 papers were found for the household sector (48 for appliances, 20 for properties, 34 for transport); 18 for the service sector (10 for properties, 8 for transport); 7 for the industry sector and 8 for the agriculture sector. Keywords related to behavioural and policy aspects were used for all the sectors under review (e.g. loss aversion, uncertainty, tax, subsidy) on SciVerse, Scopus, Web of Knowledge and Science Direct. The findings were selected taking relevance (i.e. number of citations) into account and with no restriction on years, although preference was given to more recent papers. A summary of the studies included for the present literature review is available in Table A.3 of the Appendix.

4.1. Household sector

The household sector is a substantial consumer of energy in all countries (Eurostat, 2016) and therefore a focus for efforts to reduce energy consumption. Figure 3 shows household energy consumption by end uses in the EU. A significant reduction since 1990 can be seen in the energy used for space heating, while household energy consumption by appliances increased significantly from 1990 to 2009.

This of course opens up many questions with respect to whether the EE gap continues to play a major role, what other explanations there may be and what the role of the policy instruments designed to address this should be.



The main factors that affect consumer purchasing decisions regarding household appliances, properties and vehicles are reviewed below.

- **Appliances**

Two groups of papers on appliances in the household sector can be found. The **first group** explore the impact and effectiveness of EE policies, while the **second group** review the overall factors which affect the decision-making process (e.g. uncertainty, personal preferences and attitudes).

With respect to the **first group**, most research has focused on the effectiveness of energy certificates and labels. As mentioned in subsection 2.1, labels are commonly used to address the EE gap in the form of information asymmetry and imperfect information situations at the point of sale (Banerjee and Solomon, 2003; Carroll et al., 2016b; Heinzle and Wüstenhagen, 2012). For instance, Shen and Saijo (2009) find a significant WTP for high-efficiency refrigerators and air conditioners, with the figure being higher for the former than for the latter.

Several studies have focused on the best way of providing information in labels. For example, Kallbekken et al. (2013) run a field experiment with two product categories (fridge-freezers and tumble driers) to test the role of providing monetary energy cost information through labels and through sales staff training. The results show a decrease in the average energy use of tumble driers sold of 4.9% for the combined treatment and 3.4% for the staff training treatment. A similar field experiment is carried out by Allcott and Sweeney (2015), who find that information and sales incentives needs to be treated jointly if they are to influence consumer purchases.

Heinzle (2012) conducts a discrete choice experiment and finds that consumers will pay a higher price premium for televisions when ten-year monetary costs are displayed but a lower price when one-year cost information is displayed (compared to non-monetary EE information). Using an online field experiment for washing machines, Deutsch (2010) finds a small but significant reduction in energy use (0.8%) when consumers receive additional information on life cycle cost. In the UK, DECC (2014) finds a reduction of 0.7% in the average annual energy consumption of washer-dryers when lifetime energy cost information is given to customers. However, Min et al. (2014) show that providing estimated annual energy costs has no effect on consumers' decision making for the purchase of lightbulbs. Similarly, Allcott and Knittel (2017) find that running cost information has no effect on car purchases in the US.

The review also covers studies of how labels influence consumer behaviour (Panzone, 2013; Sammer and Wüstenhagen, 2006) and how this can be used to overcome market barriers. In a case study for Switzerland, Sammer and Wüstenhagen (2006) found that, for washing machines, brands are more important than energy efficiency, but that a price premium of up to 30% was found for labelled appliances. Sanchez et al. (2008) review all the product categories tagged with the US labelling system, while Davis (2011) studies the landlord-tenant problem considering data from different households with US ENERGY STAR appliances. Davis (2011) shows that renters tend to invest less in energy-efficient appliances such as refrigerators, clothes washers and dishwashers.

Other studies focus on policy incentives such as subsidies, rebates and taxes (Datta and Filippini, 2016; Datta and Gulati, 2014; Gans et al., 2013; Panzone, 2013). Datta and Filippini (2016) estimate an increase in the sales share of household US ENERGY STAR appliances by 3.3 to 6.6% due to rebate policies. Panzone (2013) shows that a tax for elastic non-efficient energy-using products (lightbulbs and refrigerators) can be more effective to promote EE than a subsidy for elastic efficient energy using products (washing machine and TVs).

Galarraga et al. (2013) explore the use of three alternative policy instruments: subsidies, taxes, and a combination of the two. They propose an optimal combination of a tax and a subsidy as the best way to boost purchases of EE appliances. Galarraga et al. (2016b) further explore the optimal use of taxes and subsidies and propose a new methodology that makes it possible to find the combination of taxes and subsidies that minimises deadweight loss under various policy goals and constraints for dishwashers, refrigerators and washing machines.

Finally, other studies estimate consumers' WTP for efficient appliances (Allcott and Taubinsky, 2015; Banfi et al., 2008; Galarraga et al., 2011a, 2011b). Galarraga et al. (2011a) estimate a price premium of 15.6% for high EE dishwashers compared to those with the same characteristics but lower EE levels. Moreover, Heinzle and Wüstenhagen (2012) show that consumers have a higher WTP for appliances rated according to the A-G scale than for those with the A+++-D scale.

In the **second group** of papers, behavioural factors and different aspects of the decision-making process are reviewed. Most of these papers seek to understand consumer preferences (Abrahamse et al., 2005; Faruqui et al., 2010; Hirst and Brown, 1990) and the implied discount rate regarding the purchase of EE appliances (Frederiks et al., 2015b; Heinzle and Wüstenhagen, 2012; Liu et al., 2016; Shen and Saijo, 2009; Tong et al., 2016).

Behavioural economics has tried to address the fact that consumers sometimes respond in unexpected and non-rational ways to different rewards, sanctions or even high prices intended to promote sustainable behaviour. Blasch et al. (2016) estimate the probability of making rational choices and test what information may lead consumers to make optimal decisions. Their study also shows that individuals with knowledge of energy issues and energy investments tend to buy more energy-efficient appliances. Davis and Metcalf (2014) find that consumers tend to invest more in EE in those US states where energy prices are higher. Allcott and Taubinsky (2015) show that subsidies for energy-efficient lightbulbs increase welfare. Finally, it is worth pointing out that Sarkis (2017) makes a theoretical comparison between the planned behaviour theory and the value belief norm theory models and concludes that the first model can be better for understanding the consumer EE behaviours.

Household energy behaviour is a key factor that impacts energy consumption, efficiency and conservation. Smart meters help households to understand how much energy appliances consume (Gans et al., 2013; Tong et al., 2016). Asensio and Delmas (2016) run a field experiment with smart meters and two treatments: the first treatment group received information on cost savings (e.g. "*last week, you used -- % more/less electricity than your efficient neighbours*"), while the second treatment group received information on health issues ("*you are adding/avoiding -- pounds of air pollutants, which contribute to known health impacts such as childhood asthma and cancer*"). After 9 months of control and 100 days of treatment, they conclude that health-related information could change behavioural patterns in the long run. However, cost savings information was able to change behaviour very fast (in short-term), while in the long run they return to the same non-energy saving behaviour.

There are many behavioural factors that affect decision-making processes (Lillemo, 2014; Liu et al., 2016; Zhou and Yang, 2016). Lillemo (2014) shows that people tend to procrastinate (postpone plans or tasks) and avoid behaviour that could save energy: she proposes that energy-saving behaviour be promoted through information campaigns.

Social norms are another important behavioural and psychological factor. Liu et al. (2016) run a field experiment to analyse the effect of social norms on energy consumption in a public building. Their results suggest that social norms can positively influence energy-efficient use of heating and cooling at a university. Moreover, personal beliefs and attitudes can also affect energy consumption. Ramos et al. (2016) show that households with eco-friendly behaviour tend to invest more in energy-efficient appliances and have habits that improve energy savings.

Other papers in the review focus on energy consumption, price elasticities and potential savings. Their findings are not related only to household appliances but also to other sectors and product categories (Dale and Fujita, 2008; Galarraga et al., 2011; Götz and Tholen, 2016; Halvorsen and Larsen, 2001; Khanna et al., 2016; Labandeira et al., 2005, 2012; Rahman, 2017; Schmidt and Weigt, 2013).

Regarding the effect of socio-demographic characteristics and dwelling attributes, Jones and Lomas (2015) find that high electricity consumption in UK households is related to a combination of socio-economic characteristics of occupants (e.g. number of family members, age of household members) and dwelling characteristics (e.g. age of the dwelling, number of bedrooms). In order to help to implement effective policies to change energy behaviour, Jones et al. (2015) carry out a literature review of empirical studies analysing different factors that affect electricity consumption (e.g. number of occupants, family composition, age of the representative of the household, dwelling type).

- **Properties**

With respect to the effects of EE ratings on residential property prices and rents, the literature does not explore the pre/post effects of providing EE information, but primarily the cross-sectional effects of EE improvements once a labelling system is in place.

Most studies use hedonic regression techniques applied to historical sales data. In general, house buyers value EE, with higher ratings leading to higher prices. For example, in The Netherlands, Brounen and Kok (2011) show that buildings certified as "Green" receive a 3.7% sales premium while Chegut et al. (2016) show that A-rated properties in the affordable housing market receive a 6.3% premium (relative to C-rated). Hyland et al. (2013) also find a positive sales effect in Ireland, and show that each upwards step in the Building Energy Rating (BER) scale leads to a 1.3% increase in sales price, with properties in the highest A-rated category receiving a 9.3% premium relative to the median category. Stanley et al. (2016) report similar sales premiums for the Dublin market in Ireland. Significant sales premiums are also observed in England (Fuerst et al., 2015), Wales (Fuerst et al., 2016) and Denmark (Jensen et al., 2016).[12] In Spain, de Ayala et al. (2016) apply the hedonic-price technique and observe that more EE dwellings have a price-premium between 5.4% and 9.8% compared to those with the same characteristics but lower EE level.

Studies employing survey data are less supportive of a link between EE and property values. For example, Murphy (2014) finds that only 10% of respondents in the Netherlands said that EE ratings influence their

[12] In Denmark, the effects were only observed after June 2010, when it became mandatory to display certificates.

buying decision. Amecke (2012) also finds that ratings are less effective, with respondents suggesting that ratings are not helpful for understanding the financial implications of efficiency improvements and that EE is only a minor criterion when purchasing a dwelling.

For the rental market, studies generally show a premium, although smaller in magnitude. In Germany, Cajias and Piazolo (2012) show that a one percent increase in a building's energy consumption leads to a 0.08% decline in rents. Furthermore, in a multi-region analysis, the EC (DG Energy) (2013) finds that EE improvements are associated with a 4.4% rent increase in Austria (for a one letter improvement: D-rating to C-rating, for example) and a 3.2% increase in Belgium (for a 100 CPEB[13] point increase). In Ireland, Hyland et al. (2013) find that each BER improvement raises rents by 0.5%. Using a discrete choice experiment, Carroll et al. (2016a) also find that Irish renters value EE improvements, but that this relationship mainly holds for efficiency improvements at the lower end of the efficiency scale (i.e. improving the least efficient properties).

- **Vehicles**

Like the other markets reviewed here, the market for cars appears to contain an EE gap, meaning that consumers place less weight on running costs than expected utility maximisation would predict (Greene, 2010). However, in other respects the decision to purchase a car is quite different from, for example, the decision to buy a refrigerator. Vast resources are spent by automakers to affect the decision. The auto industry's advertisement spending in 2015 accounted for 20% of the top 100 companies' total ad spending, more than any other business category. EE information schemes therefore face strong competition to influence consumers. Although there are few studies that focus specifically on labelling, several of them suggest that including monetary information might be useful.

The EE gap in general, and for cars in particular, has been explained by a combination of uncertainty and loss aversion (Greene, 2010, 2011) – i.e. the tendency to give more weight to a potential loss than to a potential gain. Although other market failures also appear to be present, Greene (2010) finds that those two factors suffice to explain the failure to adopt fuel-efficient cars. The value of future fuel savings is inherently uncertain, because it depends on future fuel prices and how far cars are driven. Their explanation implies that policies targeting purchasing prices are more effective than policies targeting energy prices; and that improved information (for example more accurate fuel efficiency ratings) can help to narrow the EE gap.

Other studies indicate that car buyers do not calculate running costs at all. In a survey of 57 Californian households few mentioned fuel economy when discussing past vehicle purchases, and no one had ever estimated the present value of fuel savings when choosing a car (Kurani and Turrentine, 2004). Similarly, focus groups in the UK reveal that little effort is expended on comparing fuel efficiency in purchasing decisions (Boardman et al., 2000).

[13] The energy efficiency of properties is measured by a CPEB score or EPC.

Several studies find that car purchasing decisions have two stages: type followed by vehicle, and that fuel economy and environmental effects come into play at stage two (Boardman et al., 2000; Codagnone et al., 2016; Mueller and de Haan, 2009; Noblet et al., 2006).

Unlike for other products, EE is not universally viewed as a desirable characteristic for cars, because until recently consumers did not face the prospect of paying more for vehicles with higher fuel efficiency. Many think it can only be achieved by compromising performance and safety (Boardman et al., 2000), and luxury car owners are even disdainful of fuel efficiency (Kurani and Turrentine, 2004).

The choice of engine technology greatly affects energy efficiency, because electric engines generally reduce energy consumption substantially relative to internal combustion engines, as measured both in physical and monetary units. The motivations of people who own electric vehicles (EVs) and hybrids seem to vary from country to country. The motivations of hybrid owners in California are to protect the environment, to own advanced technology and to be part of the future (Kurani and Turrentine, 2004). None of them are strongly interested in saving money on fuel. In contrast, financial benefits are the most important reason for 67% of Norwegians owning an EV (EV Norway, 2016)[14], which is unsurprising given the uniquely generous subsidies to EVs in Norway.

Because EVs are recent additions to the market, an interesting question is how experience with such vehicles will affect attitudes and demand. Two different studies have surveyed respondents before and after giving them access to an EV for three months. Franke et al. (2012) find that the sample share intending to buy an EV drops from 64% to 51%, and Jensen et al. (2014) find a drop from 31% to 17%. The main reason appears to be that experience leads to greater concern about driving range. Some respondents expressed surprise that the EV is not able to drive the range claimed by the manufacturer (Jensen et al., 2014). It should be noted that the vehicles tested are now outdated. As there are no factory built EVs available, Jensen et al (2014) used conventional cars with retrofitted electric engines at the start of the project, and these had many problems. More recent data indicate that the effect of experience is no longer negative. A survey of Norwegian EV owners conducted in 2016 (EV Norway, 2016) finds that 97% are satisfied or very satisfied with driving an EV, and that 86% would choose an EV or plug-in EV if they were to buy a new car (only 3.5% would buy a fossil-fuel-powered car). However, this survey does not provide pre-experience figures for comparison.

Several studies indicate that including running costs on labels is helpful to consumers (Boardman et al., 2000; Codagnone et al., 2016; Raimund, 1999). Results from a combined laboratory and online experiment show that labels focused on fuel economy and running costs are better understood and more effectively support pro-environmental behaviour than labels that state only information on CO_2 emissions (Codagnone et al., 2016).

If the label is to show a model's costs compared to other models, respondents appear to prefer comparisons with cars of the same size (measured by length times width) rather than with all cars

[14] https://elbil.no/english/ (accessed 4.18.17).

(Boardman et al., 2000; Raimund, 1999). This is in line with the finding that fuel efficiency is considered at stage two in the purchasing decision.

Information on fuel consumption is greatly facilitated if car salesmen refer to it in the sale situation, so training for sales staff should be provided (Raimund, 1999). However, it should be noted that consumers undertake considerable research before entering the showroom. This is a major difference between buying a car and an appliance. Nevertheless, the choice of car is often affected by the experience in the showroom (Boardman et al., 2000).

There is some evidence that vehicles labelled as efficient attract a price premium. Vehicles labelled A or B are found to attract a premium of around 6% over vehicles with lower-ranking but otherwise similar characteristics in the Spanish market (Galarraga et al., 2014). In the Swiss market, an A-rated car appears to attract a 5-11% price premium over a B-rated vehicle, in addition to the effect of fuel economy *per se* (Alberini et al., 2014).

4.2. Service sector

Energy consumption has increased in most sectors, but particularly in the service sector. The service sector was responsible for 13.3% of total energy consumption in the EU-28 in 2014 (Eurostat, 2016). Between 1990 and 2007 electricity consumption increased by 21.1%, at a rate of 1.1% per annum. This was due to high demand for electrical goods (appliances), information and communication technology (computers, photocopiers, etc.) and other high consuming goods (air conditioning) (EEA, Electricity Consumption, 2006).

The main factors that affect consumer purchasing decisions regarding properties and vehicles in the service sector are analysed below. Note that there seems to be a gap in the literature regarding how purchasing decisions are made with respect to appliances in the service sector, where further research could be beneficial.

- **Buildings**

There are few studies which focus specifically on the service sector, but there is a large body of literature exploring the effects of energy labels/certificates on commercial real estate rents and prices. As with the residential property sector, these studies predominantly use hedonic regression techniques to control for a range of property and location characteristics (with some methodological extensions, e.g. panel data techniques employed by Das et al. (2011) and the propensity score weighting techniques employed by Eichholtz et al. (2013) and Chegut et al. (2014)).

In the US commercial property market, studies generally find large, statistically significant price premiums associated with higher EE ratings (Energy Star or LEED certification). An early example is given by Eichholtz et al. (2010) who, using a sample of 1,813 properties from the CoStar database between 2004 and 2007, show that sales prices for certified buildings are 16% higher. Fuerst and McAllister (2011a) find even higher premiums of 25% for LEED and 26% for Energy Star (using a larger sample of 6,157 transactions from 1999 to 2008). Numerous other examples from US literature show similar effects, including Wiley et al. (2010) (an extra $30/ft2 for Energy Star and $130/ft2 for LEED), Eichholtz et al. (2013) (13% for Energy Star and 11% for LEED) and Das and Wiley (2014) (16% for Energy Star and 11% for LEED). Das and Wiley (2014) also show that premiums increase with property size but decrease with property age, and that certified properties reach higher premiums during periods of limited development and high vacancy. Robinson and McAllister (2015) find different size interaction effects and show that premiums tend to be higher for smaller, lower value buildings (and not significant for higher value properties).

Outside the US, results also suggest an efficiency premium, but not universally so. For example, in the UK, Fuerst and McAllister (2011b) do not find that EPC improvements or BREEAM certification leads to higher sales prices (N = 708), but Chegut et al. (2014) find an 18-24% BREEAM premium in the London area. Chegut et al. (2014) also show that the marginal effect of green building certification decreases when more green buildings come on the market at a given location. In Sweden, Bonde and Song (2013) also find no significant price effects for improved efficiency (as measured by the EPC). However, in Australia, Newell et al. (2014) observe a 9.4% premium for the 5-star NABERS certification and a 11.8% premium for the Green Star rating scheme.

A rental premium is also observed in previous studies. In the US, significant rental premiums are observed in Eichholtz et al. (2010) (3%), Wiley et al. (2010) (15-17% for LEED and 7-8.6% for Energy Star), Fuerst and McAllister (2011b) (5 and 4%, respectively), Eichholtz et al. (2013) (6 and 2%) and Das and Wiley (2014) (11 and 16%). Das et al. (2011) find that the green premium is counter-cyclical: it is positive and significant in down-markets, but substantially reduced in up-markets. In the UK, most studies also find a rental premium, with the exception of Fuerst and McAllister (2011b). Fuerst et al. (2013) find that the most efficient buildings receive a 12% premium (this result appears to be driven by the youngest cohort of state-of-the-art, energy-efficient buildings). In the London office market, Chegut et al. (2014) find large premiums for BREEAM certification (20%). Fuerst and van de Wetering (2015) find similar results in the UK (23-26%). In the Netherlands, Kok and Jennen (2012) observe a 6.5% rental premium (EPC A-C compared to D or lower). Different results are observed in Australia, with Newell et al. (2014) finding significant rental premiums but Gabe and Rehm (2014) finding no significant effects.

- **Transport**

The literature on the transport sector includes 11 papers which focus mainly on public transport and on transport mode. The studies focusing on public transport explore the consequences of introducing free bus tickets and travel cards on public transport. Bachman and Katzev (1982) carry out a field experiment and conclude that tickets can positively influence public transport-related preferences. Bresson et al. (2004) concludes that the downward trend in public transport is due to the increase in car use but that this will become less significant over time since the growth of the car stock is decelerating.

Thøgersen and Møller (2008) run an experiment that seeks to understand car use habits, and find that although promotion of a free one-month travel card can increase the use of public transport among car drivers during the promotion period, in the long run (four months after the experiment) people participating in the experiment do not use public transport more than control subjects. Finally, Kaklamanou et al. (2015) study a possible scale to measure endorsement of compensatory green beliefs (CGB), and conclude that endorsement of CGB is negatively correlated with pro-environmental behaviour, concern for climate change, education level and age.

With regard to the transport sector, Graus and Worrell (2008) analyse the principal-agent problem in transport in the case of company car leasing in the Netherlands (11% of cars are classified as company cars, accounting for 21% of the Netherlands' energy consumption). The results show an increase of 1 to 7% in fuel use in passenger cars, suggesting that that there is a potential way of reducing energy consumption by company cars, so policies for improving EE are needed (e.g. revised tax system).

Shiftan et al. (2012) conduct a survey in Israel on employees who use company cars and employees who use private cars in order to analyse travel behaviour. This experiment finds that 92% of drivers who have a company car use it as their main form of commuting, thus suggesting that an increase in taxation of companies and employers' policies could promote transport modes other than passenger cars. Bamberg et al. (2003) test the theory of planned behaviour related to travel modes. Based on a theoretical study, they show that travel choice is a reasoned decision which could be affected by various factors, such as changes in attitudes, subjective norms and perception of behavioural control. They show that past travel choices and behaviour could help to predict future travel choices and behaviour.

4.3. Industry sector

Most research in this sector has focused on household appliances and, to some extent, on services and transport and their investments in EE services/appliances. Even though the EE gap is well recognised, cost-efficient measures are seldom implemented in practice. The barriers to investments in improving EE include long payback periods, lack of profitability, lack of personnel, risk of production disruption and lack of time or commitment. Abadie et al. (2012) analyse EE investment decisions for SMEs in the US using probit models to better understand these barriers. Some large consumers, for example the iron and steel industry, account for a significant proportion of fossil fuel and electricity production. On the other hand, SMEs are struggling with high investment costs in combination with long-term benefits, lack of capital for investment, external pressures, lack of time and, in some cases, lack of people who can take responsibility for EE investments.

These findings have been explored in studies in various countries around Europe. Hrovatin et al. (2016) analyse EE and environmental investments in Slovenian manufacturing firms. Based on their findings, there is less likely to be an EE gap in large enterprises (LEs), which implies that policy measures should primarily target SMEs. LEs which face international competition and high energy costs may see EE investments as a means of decreasing production costs and thereby improving their competitive positions in the market. Additionally, the results of the study show that economic and financial crises reduce the likelihood of clean technology investments, but not of EE investments.

An empirical investigation (multiple case study approach) of 71 Italian manufacturing SMEs highlights the importance of allowances or public financing for EE interventions, and that of external pressures such as increases in energy prices and the introduction or increasing of fees on both resources consumed and emissions of pollutants (Cagno and Trianni, 2013). In Spain, econometric analysis shows that companies and large consumers of electricity are not affected by variations in electricity prices, with demand elasticities very close to zero. Inelastic demand by companies and LEs in the short term may be due to the fact that changing production systems would entail high costs (Labandeira et al., 2012).

Cross-sectional data analysis from SMEs which participated in a German energy audit programme between 2008 and 2010 indicate that high investment costs combined with a lack of capital slow the adoption of EE measures, even if those measures are deemed profitable (Fleiter et al., 2012). Similarly, interviews with representatives of Swedish industrial firms indicate that EE seems to be an important issue for firms, but that lack of time, lack of people with proper education in areas related to energy issues and low profitability appear to be the most important factors for the low level of adoption of EE investments (Johansson, 2015; Nehler and Rasmussen, 2016).

In conclusion, the literature seems to suggest that there is less likely to be an EE gap in LEs, which implies that policy measures should primarily target SMEs. Profitability appears to be one of the most important factors for making an investment, since it is difficult to meet payoff requirements with energy cost savings alone. In order to increase the number of investments in EE measures, companies are advised to allow for longer payback periods and, if possible, to establish some sort of fund for EE investments. Furthermore, financial support, such as investment subsidies, soft loans, public funds and guarantees, may increase investment in EE and should be promoted through regulatory policies

4.4. Agriculture sector

The agri-food chain accounts for 30% of the world's energy consumption and produces about 20% of the world's greenhouse gas emissions (FAO, 2011). The continued reliance of food supply chains on conventional, non-renewable oil and gas flows for production, processing and transportation activities will lead to greater business risks, especially when unpredictable price spikes are considered. EE in agriculture has received little attention – except for energy use in greenhouses – and is still in need of a coherent metric (Blancard and Martin, 2014). However, the energy used, and thus the potential for energy saving, in agriculture is considerable, especially when indirect energy use is considered (see AGREE, www.agree.aua.gr[15]). Referring to the prospects of energy saving in agriculture, AGREE concludes somewhat optimistically that "*As a result of the current views on energy efficiency in agriculture, implementing energy efficiency measures will mostly be considered by farmers based on the opportunities they see to save money, favouring low cost investment technology solutions that can be easily implemented*."

[15] The objective of the AGREE (**AGR**iculture & **E**nergy **E**fficiency) project is to put energy efficiency in agriculture on the research agenda based on its short and long term potential and the associated economic and ecological effects.

However, energy conservation efforts at farm level may fall short of the socially optimal level due to market failures such as externalities, cost information asymmetry, high implicit discount rates and moral hazards as epitomized in the on-going contrast between ‘dumb’ and ‘clairvoyant’ farmers (Schneider et al., 2000). There is thus increasing interest in understanding the processes that shape farmers’ attitudes towards EE at farm level.

Insights gained could be used to address a range of policy questions on the determinants of investing in EE equipment and the provision of appropriate information. To that end, extensive empirical research into how farmers perceive EE is still needed to identify a set of guiding principles for government intervention. This section reports on a recent web-based review on behavioural aspects of EE decision making in agriculture. The review seeks to shed light on questions which are directly relevant for understanding the past record of (not) adopting EE investments while informing the design of future eco-labelling policies for European farmers.

The bulk of EE studies in farming relate to the agronomic/technological potential for energy savings (Jokiniemi et al., 2016; Schneider et al., 2000). Little in the way of published research on behavioural aspects of EE in agriculture. The number of *explicit* references to EE decision-making is low. The issue is often not the focus of a paper but must be inferred from knowledge of farmers’ behavioural traits on choosing renewable energy and participating in conservation schemes.

Bailey et al. (2008) use a mail survey to understand the desire and ability of farmers in Nova Scotia to implement EE and renewable energy options. The most important of their research objectives for the purposes of the present review was to determine what factors influence the implementation of energy-efficient investments. The EE options most widely adopted were behaviour, insulation, and lighting. Few farms used renewable energy options. Approximately 78% of farmers indicated an interest in implementing EE and renewable energy options. Interest increased with farm size. Beef, fur and grain/forage farmers were significantly less likely to be interested in implementing energy options than dairy, hog/poultry, sheep/livestock, fruit/vegetable and greenhouse farmers. This may be due to budgetary constraints or limited knowledge. Farmers concerned about power and equipment reliability were less likely to be interested in implementing options. Farmers concerned about the environment were more likely to be interested in implementing options. Current use of certain EE technologies, such as efficient lighting, influenced interest in implementation. The authors also note that promoting energy conservation may be challenging due to an aging population of farmers, with many close to retirement. However, education and income are factors that suggest openness to energy conservation behaviour.

Small and medium-sized enterprises in the agri-food business are potentially a considerable source of EE. Hertel M & K Menrad (2016) focus on the process of decision-making and develop a model which explains the influence of the attitudes of managers and of social, environmental and external factors on the adoption of energy-efficient technology. The model is based on the theory of reasoned action (TRA) and the theory of planned behaviour (TPB). The authors rely on an energy dataset from the German horticultural sector and data collected via a personal survey of 104 managers of SMEs conducted through face to face interviews. The results show that the manager’s attitude and the social environment have a significant influence on intention to adopt EE technology. However, there is no evidence for a correlation between the intended and actual adoption of technology. This finding clearly stresses the importance of personal and social factors in the adoption process of energy-efficient technology at SMEs in the German horticultural sector. The authors conclude that further studies could focus on the situation of specific companies and on differences in the personalities of company managers so as to work out the main factors influencing the adoption of technology.

Eco-labelling is quite highly developed in farming, but only for food labelling and not for EE (see http://www.ecolabelindex.com/ecolabels/). Consequently, there is no published research on energy labelling in agriculture either. It might be useful at this stage to refer to a critical review by Van Amstel et al. (2008) concerning five food labels in the Netherlands and dealing with the reliability of their information. The study is based on desktop research of relevant material and reports and 17 in-depth interviews. The main conclusions are that efforts to make labels as reliable as possible are partly failing; eco-labels do not provide enough information to narrow the information gap; eco-labels do however have sufficient institutional guarantees to enforce producer compliance through compulsory and optional standards. The main disadvantages include: (i) environmental labelling does not guarantee that the quality of the environment will improve through the production process; (ii) there is insufficient communication about producer compliance; and (iii) recommendations in labelling cannot be enforced by inspections and sanctions.

In a similar problem setting, Manhoudt et al. (2002) compare four Dutch environmental certification schemes for agricultural food crops, analysing their methodology and the completeness of their criteria on five aspects: pesticide use, nutrient use, water management, energy and consumption of materials and habitat management. The analysis shows a varied pattern but even the most stringent ones largely neglect the aspects of energy consumption. Despite the fact that the study includes EE as an explicit goal in its evaluation, the authors go no further because "(t)here are no legislative restrictions on energy consumption." (p. 274). The authors conclude that growing consumer awareness of the environmental impact of agriculture means that guidelines should be developed on an international level.

Li et al. (2013) study farmers' behaviour in adopting solar technologies. Based on the theory of planned behaviour, the study examines nine factors related to farmers' willingness. A survey was conducted in rural China with 465 participants. Using binary logistic regression, it is shown that farmers' willingness is positively and significantly impacted by quality of life, government commitments and the assessments of neighbours/friends. Factors with negative and significant impacts included additional monthly out-of-pocket expenses and switching costs. The remaining four factors (i.e. durability, popularity, timing and local solar market maturity) had no significant impacts.

The issue of EE in agriculture is well documented from the agronomic and technological viewpoints, but not from the behavioural viewpoint. Our review of EE decision-making in agriculture shows how little relevant research has been done. Nevertheless, in an attempt at a tentative, preliminary stock-taking of the studies discussed above, we identify the following points to be taken into consideration in the development of the CONSEED model: (i) farmers' socio-economic characteristics, i.e. age, income and education level, play a role; (ii) energy cost information is not always apparent; more information certainly needs to be provided; and (iii) farmers' attitudes, norms, beliefs and values towards the environment and sustainable lifestyles play a role in the adoption of renewables and EE.

5. Conclusions

The importance of EE measures and technologies is highlighted by the IPCC, which recommends significant investments in EE in order to limit the increase in global temperature. Although investment in EE has economic benefits and environmental advantages, there is underinvestment in it. Indeed, it is observed that households and businesses invest less in EE than is privately rational. In the case of EE investments and EE goods, consumers often fail to account for all the expected costs and tend to discount future energy savings or undervalue future savings. This is the so-called *energy efficiency gap* or *energy efficiency paradox*.

There are various energy policies intended to prevent the EE paradox (e.g. taxes, subsidies, rebate programmes) which seek to monitor energy consumption and reduce CO_2 emissions. Even though these policies have been running for several years, they are not as efficient as they should be due to several failures (informational failures, other market failures and behavioural failures) that prevent consumers and firms from making optimal decisions regarding EE purchases. Informational failures, including information asymmetry, imperfect information situations, and uncertainty are significant in an EE purchase context.

Informational policies aim to provide valuable information about energy consumption and the level of efficiency of a product in an effort to encourage decision-makers to make optimal decisions. Such policies involve energy labels, energy audits and feedback programmes. All these policies have been developed in recent years, but the most common is that of energy labelling systems. Currently, there are several directives in force for different products (Directive 2010/30/EU for appliances; Directive 2010/31/EU for buildings; Directive 1999/94/CE for cars; Directive 2012/27/EU for commercial and office equipment, etc.). Labels currently give a range of information about the energy consumption of products. The level of EE is rated using a colour and letter coded scale. Labels also give other useful information to customers, depending on the product category (e.g. energy consumption, water consumption and noise level).

To bring to light the different factors that affect the effectiveness of policies, and particularly of labelling, a review has been undertaken of various sectors (households, services, industry, agriculture) and product categories (appliances, properties, vehicles and machinery). Socio-economic characteristics and the design of labels (the way in which information is provided, how visually striking labels are) seems to be key points for the effectiveness of energy labels.

In the household sector, on the one hand, the number of members in each household and their income level are crucial in the decision-making process for various product categories (appliances, properties, transport). On the other hand, several studies show that providing monetary energy cost information through labels is more efficient than giving energy consumption information alone, so a policy change is proposed in the current labelling system. Regarding properties, significant price-premiums of between 3.7% and 9.8% for homes rated as highly energy-efficient are found compared to similar homes with lower EE levels.

In the case of transport and vehicles, the review shows two directions: first, EE is not universally viewed as a relevant characteristic for cars; and second, most studies are focused on EVs. In EVs, striking financial benefits and incentives have been developed by some countries in Europe, such as Norway, which could point the way for other countries from a policy perspective.

In the service sector, energy consumption has increased by 21.1% in recent years. In this situation, EE takes on an important role in reducing energy consumption. An in-depth review has been conducted for two products: buildings and transport. In the case of buildings, most articles study the premium for efficient properties. For sales prices, this amount can be as much as 25% in LEED certified buildings and 26% in Energy Star rated ones. In the case of rented properties, the price premiums range from 5% to 20% depending on the study, the type of label and the country studied. In the case of transport, most articles study the mode of transport, focusing on public transport, travel mode habits, etc. No references have been found for appliances in the service sector, so this is an interesting field to develop in the CONSEED project.

The review conducted for industry shows that a lack of time and a lack of interest by the relevant people are among the most significant factors in explaining the low level of adoption of EE measures. This suggests that other kinds of motivational policies could perhaps be applied to boost EE in industry.

Regarding agriculture, there is literature on eco-labelling for food but not for EE purchases. The CONSEED project is thus an opportunity to generate new evidence for EE machinery and appliance purchases in the agriculture and service sectors.

References

Abadie, L.M., Ortiz, R.A., Galarraga, I., 2012. Determinants of energy efficiency investments in the US. Energy Policy 45, 551–566. doi:10.1016/j.enpol.2012.03.002

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T., 2005. A review of intervention studies aimed at household energy conservation. J. Environ. Psychol. 25, 273–291. doi:10.1016/j.jenvp.2005.08.002

Alberini, A., Bareit, M., Filippini, M., 2014. Does the Swiss Car Market Reward Fuel Efficient Cars? Evidence from Hedonic Pricing Regressions, Matching and a Regression Discontinuity Design. doi:10.2139/ssrn.2380034

Allcott, H., 2011. Consumers' Perceptions and Misperceptions of Energy Costs. Am. Econ. Rev. 101, 98–104. doi:10.1257/aer.101.3.98

Allcott, H., Greenstone, M., 2012. Is There an Energy Efficiency Gap? J. Econ. Perspect. 26, 3–28. doi:10.1257/jep.26.1.3

Allcott, H., Sweeney, R., 2015. Can retailers inform consumers about energy costs? Evidence from a field experiment, in: E2e. Working Paper 008.

Allcott, H., Taubinsky, D., 2015. Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market. Am. Econ. Rev. 105, 2501–2538. doi:10.1257/aer.20131564

Allcott, H., Wozny, N., 2013. Gasoline Prices, Fuel Economy, and the Energy Paradox. Rev. Econ. Stat. 96, 779–795. doi:10.1162/REST_a_00419

Amecke, H., 2012. The impact of energy performance certificates: A survey of German home owners. Energy Policy 46, 4–14. doi:10.1016/j.enpol.2012.01.064

Andreoni, J., 1990. Impure Altruism and Donations to Public Goods: A Theory of Warm-Glow Giving. Econ. J. 100, 464–477. doi:10.2307/2234133

Asensio, O.I., Delmas, M.A., 2016. The dynamics of behavior change: Evidence from energy conservation. J. Econ. Behav. Organ. 126, Part A, 196–212. doi:10.1016/j.jebo.2016.03.012

Bachman, W., Katzev, R., 1982. The effects of non-contingent free bus tickets and personal commitment on urban bus ridership. Transp. Res. Part Gen. 16, 103–108. doi:10.1016/0191-2607(82)90002-4

Bailey, J.A., Gordon, R., Burton, D., Yiridoe, E.K., 2008. Factors which influence Nova Scotia farmers in implementing energy efficiency and renewable energy measures. Energy 33, 1369–1377. doi:10.1016/j.e nergy.2008.05.004

Bamberg, S., Ajzen, I., Schmidt, P., 2003. Choice of Travel Mode in the Theory of Planned Behavior: The Roles of Past Behavior, Habit, and Reasoned Action. Basic Appl. Soc. Psychol. 25, 175–187. doi:10.1207/S15324834BASP2503_01

Banerjee, A., Solomon, B.D., 2003. Eco-labeling for energy efficiency and sustainability: a meta-evaluation of US programs. Energy Policy 31, 109–123. doi:10.1016/S0301-4215(02)00012-5

Banfi, S., Farsi, M., Filippini, M., Jakob, M., 2008. Willingness to pay for energy-saving measures in residential buildings. Energy Econ. 30, 503–516. doi:10.1016/j.eneco.2006.06.001

Blancard, S., Martin, E., 2014. Energy efficiency measurement in agriculture with imprecise energy content information. Energy Policy 66, 198–208. doi:10.1016/j.enpol.2013.10.071

Blasch, J.E., Filippini, M., Kumar, N., 2016. Boundedly rational consumers, energy and investment literacy, and the display of information on household appliances.

Boardman, B., Banks, N., Kirby, H.R., Keay-Bright, S., Hutton, B.J., Stradling, S.G., 2000. Choosing Cleaner Cars: The Role Of Labels And Guides - Executive Summary Of The Final Report On Vehicle Environmental Rating Schemes. TRI Rec. 001012.

Bonde, M., Song, H., 2013. Is energy performance capitalized in office building appraisals? Prop. Manag. 31, 200–215. doi:10.1108/02637471311321450

Bresson, G., Dargay, J., Madre, J.-L., Pirotte, A., 2004. Economic and structural determinants of the demand for public transport: an analysis on a panel of French urban areas using shrinkage estimators. Transp. Res. Part Policy Pract. 38, 269–285. doi:10.1016/j.tra.2003.11.002

Brounen, D., Kok, N., 2011. On the economics of energy labels in the housing market. J. Environ. Econ. Manag. 62, 166–179. doi:10.1016/j.jeem.2010.11.006

Busse, M.R., Knittel, C.R., Zettelmeyer, F., 2013. Are Consumers Myopic? Evidence from New and Used Car Purchases. Am. Econ. Rev. 103, 220–256. doi:10.1257/aer.103.1.220

Bye, T., Bruvoll, A., 2008. Multiple instruments to change energy behaviour: The emperor’s new clothes? Energy Effic. 1, 373–386. doi:10.1007/s12053-008-9023-9

Cagno, E., Trianni, A., 2013. Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises. Appl. Energy 104, 276–285. doi:10.1016/j.apenergy.2012.10.053

Cajias, M., Piazolo, D., 2012. Green Performs Better: Energy Efficiency and Financial Return on Buildings. SSRN Electron. J. doi:10.2139/ssrn.2186036

Carroll, J., Aravena, C., Denny, E., 2016a. Low energy efficiency in rental properties: Asymmetric information or low willingness-to-pay? Energy Policy 96, 617–629. doi:10.1016/j.enpol.2016.06.019

Carroll, J., Denny, E., Lyons, S., 2016b. The Effects of Energy Cost Labelling on Appliance Purchasing Decisions: Trial Results from Ireland. J. Consum. Policy 39, 23–40. doi:10.1007/s10603-015-9306-4

Chegut, A., Eichholtz, P., Holtermans, R., 2016. Energy efficiency and economic value in affordable housing. Energy Policy 97, 39–49. doi:10.1016/j.enpol.2016.06.043

Chegut, A., Eichholtz, P., Kok, N., 2014. Supply, Demand and the Value of Green Buildings. Urban Stud. 51, 22–43. doi:10.1177/0042098013484526

Codagnone, C., Veltri, G.A., Bogliacino, F., Lupiáñez-Villanueva, F., Gaskell, G., Ivchenko, A., Ortoleva, P., Mureddu, F., 2016. Labels as nudges? An experimental study of car eco-labels. Econ. Polit. 33, 403–432. doi:10.1007/s40888-016-0042-2

Cohen, F., Glachant, M., Söderberg, M., 2017. Consumer myopia, imperfect competition and the energy efficiency gap: Evidence from the UK refrigerator market. Eur. Econ. Rev. 93, 1–23. doi:10.1016/j.euroecorev.2017.01.004

Dale, Fujita, 2008. An Analysis of the Price Elasticity of Demand for Household Appliances.

Das, P., Tidwell, A., Ziobrowski, A., 2011. Dynamics of Green Rentals over Market Cycles : Evidence from Commercial Office Properties in San Francisco and Washington DC. J. Sustain. Real Estate 3, 1–22. doi:10.5555/jsre.3.1.00560483t235v797

Das, P., Wiley, J.A., 2014. Determinants of premia for energy-efficient design in the office market. J. Prop. Res. 31, 64–86. doi:10.1080/09599916.2013.788543

Datta, S., Filippini, M., 2016. Analysing the impact of ENERGY STAR rebate policies in the US. Energy Effic. 9, 677–698. doi:10.1007/s12053-015-9386-7

Datta, S., Gulati, S., 2014. Utility rebates for ENERGY STAR appliances: Are they effective? J. Environ. Econ. Manag. 68, 480–506. doi:10.1016/j.jeem.2014.09.003

Davis, L.W., 2011. Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances? NBER Chapters 301–316.

Davis, L.W., Metcalf, G.E., 2014. Does Better Information Lead to Better Choices? Evidence from Energy-Efficiency Labels. doi:10.3386/w20720

de Ayala, A., Galarraga, I., Spadaro, J.V., 2016. The price of energy efficiency in the Spanish housing market. Energy Policy 94, 16–24. doi:10.1016/j.enpol.2016.03.032

DellaVigna, S., 2007. Psychology and Economics: Evidence from the Field. doi:10.3386/w13420

Eichholtz, P., Kok, N., Quigley, J.M., 2013. The Economics of Green Building. Berkeley Program Hous. Urban Policy.

Eichholtz, P., Kok, N., Quigley, J.M., 2010. Doing Well by Doing Good? Green Office Buildings. Am. Econ. Rev. 100, 2492–2509. doi:10.1257/aer.100.5.2492

European Commission, 2011. Communication from the commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions. European Commission, Brussels.

Faruqui, A., Sergici, S., Sharif, A., 2010. The impact of informational feedback on energy consumption—A survey of the experimental evidence. Energy, Demand Response Resources: the US and International ExperienceDemand Response Resources: the US and International Experience 35, 1598–1608. doi:10.1016/j.energy.2009.07.042

Fleiter, T., Schleich, J., Ravivanpong, P., 2012. Adoption of energy-efficiency measures in SMEs—An empirical analysis based on energy audit data from Germany. Energy Policy, Renewable Energy in China 51, 863–875. doi:10.1016/j.enpol.2012.09.041

Franke, Bühler, Crocon, 2012. Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior.

Frederick, S., Loewenstein, G., O'Donoghue, T., 2002. Time Discounting and Time Preference: A Critical Review. J. Econ. Lit. 40, 351–401. doi:10.1257/002205102320161311

Frederiks, E.R., Stenner, K., Hobman, E.V., 2015a. Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renew. Sustain. Energy Rev. 41, 1385–1394. doi:10.1016/j.rser.2014.09.026

Frederiks, E.R., Stenner, K., Hobman, E.V., 2015b. Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renew. Sustain. Energy Rev. 41, 1385–1394. doi:10.1016/j.rser.2014.09.026

Frondel, M., Vance, C., 2013. Heterogeneity in the Effect of Home Energy Audits: Theory and Evidence. Environ. Resour. Econ. 55, 407–418. doi:10.1007/s10640-013-9632-4

Fuerst, F., McAllister, P., 2011a. The impact of Energy Performance Certificates on the rental and capital values of commercial property assets. Energy Policy, Sustainability of biofuels 39, 6608–6614. doi:10.1016/j.enpol.2011.08.005

Fuerst, F., McAllister, P., Nanda, A., Wyatt, P., 2016. Energy performance ratings and house prices in Wales: An empirical study. Energy Policy 92, 20–33. doi:10.1016/j.enpol.2016.01.024

Fuerst, F., McAllister, P., Nanda, A., Wyatt, P., 2015. Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. Energy Econ. 48, 145–156. doi:10.1016/j.eneco.2014.12.012

Fuerst, F., McAllister, P.M., 2011b. Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Property Values. doi:10.2139/ssrn.1140409

Fuerst, F., Wetering, J. van de, 2015. How does environmental efficiency impact on the rents of commercial offices in the UK? J. Prop. Res. 32, 193–216. doi:10.1080/09599916.2015.1047399

Fuerst, F., Wetering, J. van de, Wyatt, P., 2013. Is intrinsic energy efficiency reflected in the pricing of office leases? Build. Res. Inf. 41, 373–383. doi:10.1080/09613218.2013.780229

Galarraga, I., Abadie, L.M., Ansuategi, A., 2013. Efficiency, effectiveness and implementation feasibility of energy efficiency rebates: The "Renove" plan in Spain. Energy Econ., Supplement Issue: Fifth Atlantic Workshop in Energy and Environmental Economics 40, Supplement 1, S98–S107. doi:10.1016/j.eneco.2013.09.012

Galarraga, I., Abadie, L.M., Kallbekken, S., 2016a. Designing incentive schemes for promoting energy-efficient appliances: A new methodology and a case study for Spain. Energy Policy 90, 24–36. doi:10.1016/j.enpol.2015.12.010

Galarraga, I., Abadie, L.M., Kallbekken, S., 2016b. Designing incentive schemes for promoting energy-efficient appliances: A new methodology and a case study for Spain. Energy Policy 90, 24–36. doi:10.1016/j.enpol.2015.12.010

Galarraga, I., González-Eguino, M., Markandya, A., 2011a. Willingness to pay and price elasticities of demand for energy-efficient appliances: Combining the hedonic approach and demand systems. Energy Econ., Supplemental Issue: Fourth Atlantic Workshop in Energy and Environmental Economics 33, Supplement 1, S66–S74. doi:10.1016/j.eneco.2011.07.028

Galarraga, I., Heres, D.R., Gonzalez-Eguino, M., 2011b. Price premium for high-efficiency refrigerators and calculation of price-elasticities for close-substitutes: a methodology using hedonic pricing and demand systems. J. Clean. Prod. 19, 2075–2081. doi:10.1016/j.jclepro.2011.06.025

Galarraga, I., Ramos, A., Lucas, J., Labandeira, -., 2014. The price of energy efficiency in the Spanish car market. Transp. Policy 36, 272–282. doi:10.1016/j.tranpol.2014.09.003

Gans, W., Alberini, A., Longo, A., 2013. Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland. Energy Econ. 36, 729–743. doi:10.1016/j.eneco.2012.11.022

Gerarden, T.D., Newell, R.G., Stavins, R.N., 2015a. Assessing the Energy-Efficiency Gap (No. w20904). National Bureau of Economic Research.

Gerarden, T.D., Newell, R.G., Stavins, R.N., Stowe, R.C., 2015b. An Assessment of the Energy-Efficiency Gap and its Implications for Climate-Change Policy. doi:10.3386/w20905

Gibbons, Gwin, 2004. History of conservation measures for energy. Encycl. Energy 1, 649–659.

Gillingham, K., Newell, R., Palmer, K., 2006. Energy Efficiency Policies: A Retrospective Examination. Annu. Rev. Environ. Resour. 31, 161–192. doi:10.1146/annurev.energy.31.020105.100157

Gillingham, K., Newell, R.G., Palmer, K., 2009. Energy Efficiency Economics and Policy. doi:10.3386/w15031

Götz, T., Tholen, L., 2016. Stock Model Based Bottom-up Accounting for Washing Machines: Worldwide Energy, Water and Greenhouse Gas Saving Potentials 2010–2030. Tenside Surfactants Deterg. 53, 410–416. doi:10.3139/113.110460

Graeme Newell, John MacFarlane, Roger Walker, 2014. Assessing energy rating premiums in the performance of green office buildings in Australia. J. Prop. Invest. Finance 32, 352–370. doi:10.1108/JPIF-10-2013-0061

Greene, D.L., 2011. Uncertainty, loss aversion, and markets for energy efficiency. Energy Econ., Special Issue on The Economics of Technologies to Combat Global Warming 33, 608–616. doi:10.1016/j.eneco.2010.08.009

Greene, D.L., 2010. How Consumers Value Fuel Economy: A Literature Review. Environmental Protection Agency

Greene, D.L., German, J., Delucchi, M.A., 2008. Fuel Economy: The Case for Market Failure, in: Cannon, J.S., Sperling, D. (Eds.), Reducing Climate Impacts in the Transportation Sector. Springer Netherlands, pp. 181–205. doi:10.1007/978-1-4020-6979-6_11

Halvorsen, B., Larsen, B.M., 2001. The flexibility of household electricity demand over time. Resour. Energy Econ. 23, 1–18. doi:10.1016/S0928-7655(00)00035--

Hassett, K.A., Metcalf, G.E., 1993. Energy conservation investment. Energy Policy 21, 710–716. doi:10.1016/0301-4215(93)90294-P

Hausman, J., Joskow, P., 1982. Evaluating the Costs and Benefits of Appliance Efficiency Standards. Am. Econ. Rev. 72, 220–25.

Heinzle, S.L., Wüstenhagen, R., 2012. Dynamic Adjustment of Eco-labeling Schemes and Consumer Choice – the Revision of the EU Energy Label as a Missed Opportunity? Bus. Strategy Environ. 21, 60–70. doi:10.1002/bse.722

Hertel, M., Menrad, K., 2016. Adoption of energy-efficient technologies in German SMEs of the horticultural sector—the moderating role of personal and social factors. Energy Effic. 9, 791–806. doi:10.1007/s12053-015-9400-0

Hirst, E., Brown, M., 1990. Closing the efficiency gap: barriers to the efficient use of energy. Resour. Conserv. Recycl. 3, 267–281. doi:10.1016/0921-3449(90)90023-W

Hrovatin, N., Dolšak, N., Zorić, J., 2016. Factors impacting investments in energy efficiency and clean technologies: empirical evidence from Slovenian manufacturing firms. J. Clean. Prod. 127, 475–486. doi:10.1016/j.jclepro.2016.04.039

Hyland, M., Lyons, R.C., Lyons, S., 2013. The value of domestic building energy efficiency — evidence from Ireland. Energy Econ. 40, 943–952. doi:10.1016/j.eneco.2013.07.020

IEA, 2016. International Energy Outlook 2016-World energy demand and economc outlook - Energy Information Administration [WWW Document]. URL https://www.eia.gov/outlooks/ieo/world.php (accessed 6.19.17).

IEA, 2015. Publication: Energy Efficiency Market Report 2015 [WWW Document]. URL https://www.iea.org/publications/freepublications/publication/energy-efficiency-market-report-2015-.html (accessed 6.20.17).

IEA, 2007. Mind the Gap. OECD Publishing, Paris. doi:10.1787/9789264038950-en

IEF, 2015. Energy Outlooks | International Energy Forum [WWW Document]. URL https://www.ief.org/resources/energy-outlooks.aspx (accessed 6.19.17).

IPCC, 2014. Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jaffe, A.B, Newell, R.G, Stavins, R.N, 2004. Economics of energy efficiency. Encyclopedia of Energy 2, 79e90.

Jaffe, Stavins, 1994a. The energy-efficiency gap What does it mean? Energy Policy, Markets for energy efficiency 22, 804–810. doi:10.1016/0301-4215(94)90138-4

Jaffe, Stavins, R., 1994b. The energy paradox and the diffusion of conservation technology. Resour. Energy Econ. 16, 91–122.

Jensen, A.F., Cherchi, E., Ortúzar, J. de D., 2014. A long panel survey to elicit variation in preferences and attitudes in the choice of electric vehicles. Transportation 41, 973–993. doi:10.1007/s11116-014-9517-6

Jensen, O.M., Hansen, A.R., Kragh, J., 2016. Market response to the public display of energy performance rating at property sales. Energy Policy 93, 229–235. doi:10.1016/j.enpol.2016.02.029

Jeremy Gabe, Michael Rehm, 2014. Do tenants pay energy efficiency rent premiums? J. Prop. Invest. Finance 32, 333–351. doi:10.1108/JPIF-09-2013-0058

Johansson, M.T., 2015. Improved energy efficiency within the Swedish steel industry—the importance of energy management and networking. Energy Effic. 8, 713–744. doi:10.1007/s12053-014-9317-z

Jokiniemi, T., Suokannas, A., Ahokas, J., 2016. Energy consumption in agriculture transportation operations. Eng. Agric. Environ. Food 9, 171–178. doi:10.1016/j.eaef.2015.11.001

Jones, R.V., Fuertes, A., Lomas, K.J., 2015. The socio-economic, dwelling and appliance related factors affecting electricity consumption in domestic buildings. Renew. Sustain. Energy Rev. 43, 901–917. doi:10.1016/j.rser.2014.11.084

Jones, R.V., Lomas, K.J., 2015. Determinants of high electrical energy demand in UK homes: Socio-economic and dwelling characteristics. Energy Build. 101, 24–34. doi:10.1016/j.enbuild.2015.04.052

Kahneman, D., 1994. New Challenges to the Rationality Assumption. J. Institutional Theor. Econ. JITE Z. Für Gesamte Staatswiss. 150, 18–36.

Kahneman, D., Tversky, A., 1984. Choices, Values, and Frames. Cambridge University Press.

Kahneman, D., Tversky, A., 1979. Prospect Theory: An Analysis of Decision under Risk. Econometrica 47, 263–291. doi:10.2307/1914185

Kaklamanou, D., Jones, C.R., Webb, T.L., Walker, S.R., 2015. Using Public Transport Can Make Up for Flying Abroad on Holiday: Compensatory Green Beliefs and Environmentally Significant Behavior. Environ. Behav. 47, 184–204. doi:10.1177/0013916513488784

Kallbekken, S., Sælen, H., Hermansen, E.A.T., 2013. Bridging the Energy Efficiency Gap: A Field Experiment on Lifetime Energy Costs and Household Appliances. J. Consum. Policy 36, 1–16. doi:10.1007/s10603-012-9211-z

Khanna, N.Z., Guo, J., Zheng, -., 2016. Effects of demand side management on Chinese household electricity consumption: Empirical findings from Chinese household survey. Energy Policy 95, 113–125. doi:10.1016/j.enpol.2016.04.049

Kok, N., Jennen, M., 2012. The impact of energy labels and accessibility on office rents. Energy Policy 46, 489–497. doi:10.1016/j.enpol.2012.04.015

Kurani, K., Turrentine, T., 2004. Automobile Buyer Decisions about Fuel Economy and Fuel Efficiency. Inst. Transp. Stud.

Labandeira, -., Labeaga, J.M., López-Otero, -., 2012. Estimation of elasticity price of electricity with incomplete information. Energy Econ. 34, 627–633. doi:10.1016/j.eneco.2011.03.008

Labandeira, -., Labeaga, J.M., Rodríguez, M., 2005. A Residential Energy Demand System for Spain. Work. Pap.

Laibson, D., 1997. Golden Eggs and Hyperbolic Discounting. Q. J. Econ. 112, 443–478. doi:10.1162/003355397555253

Li, -., Li, H., Wang, -., 2013. Farmers' willingness to convert traditional houses to solar houses in rural areas: A survey of 465 households in Chongqing, China. Energy Policy 63, 882–886. doi:10.1016/j.enpol.2013.09.004

Lillemo, S.C., 2014. Measuring the effect of procrastination and environmental awareness on households' energy-saving behaviours: An empirical approach. Energy Policy 66, 249–256. doi:10.1016/j.enpol.2013.10.077

Linares, P., Labandeira, -., 2010. Energy Efficiency: Economics and Policy. J. Econ. Surv. 24, 573–592. doi:10.1111/j.1467-6419.2009.00609.x

Liu, Y., Veríssimo, D., Farhidi, F., 2016. Using social norm to promote energy conservation in a public building. Energy Build. 133, 32–36. doi:10.1016/j.enbuild.2016.09.041

Loewenstein, G., Prelec, D., 1992. Anomalies in Intertemporal Choice: Evidence and an Interpretation. Q. J. Econ. 107, 573–597. doi:10.2307/2118482

Manhoudt, A.G.E., van de Ven, G.W.J., Udo de Haes, H.A., de Snoo, G.R., 2002. Environmental labelling in The Netherlands: a framework for integrated farming. J. Environ. Manage. 65, 269–283. doi:10.1006/jema.2002.0548

Markandya, A., Ortiz, R.A., Mudgal, S., Tinetti, B., 2009. Analysis of tax incentives for energy-efficient durables in the EU. Energy Policy 37, 5662–5674. doi:10.1016/j.enpol.2009.08.031

Michelsen, C.C., Madlener, R., 2016. Switching from fossil fuel to renewables in residential heating systems: An empirical study of homeowners' decisions in Germany. Energy Policy 89, 95–105. doi:10.1016/j.enpol.2015.11.018

Mueller, M.G., de Haan, P., 2009. How much do incentives affect car purchase? Agent-based microsimulation of consumer choice of new cars--Part I: Model structure, simulation of bounded rationality, and model validation. Energy Policy 37, 1072–1082.

Murphy, L., 2014. The influence of the Energy Performance Certificate: The Dutch case. Energy Policy 67, 664–672. doi:10.1016/j.enpol.2013.11.054

Nehler, T., Rasmussen, J., 2016. How do firms consider non-energy benefits? Empirical findings on energy-efficiency investments in Swedish industry. J. Clean. Prod. 113, 472–482. doi:10.1016/j.jclepro.2015.11.070

Newell, R.G., Siikamäki, J.V., 2013. Nudging Energy Efficiency Behavior: The Role of Information Labels (Working Paper No. 19224). National Bureau of Economic Research. doi:10.3386/w19224

Noblet, C.L., Teisl, M.F., Rubin, J., 2006. Factors affecting consumer assessment of eco-labeled vehicles. Transp. Res. Part Transp. Environ. 11, 422–431. doi:10.1016/j.trd.2006.08.002

Palmer, K., Walls, M., Gordon, H., Gerarden, T., 2013. Assessing the energy-efficiency information gap: results from a survey of home energy auditors. Energy Effic. 6, 271–292. doi:10.1007/s12053-012-9178-2

Panzone, L.A., 2013. Saving money vs investing money: Do energy ratings influence consumer demand for energy efficient goods? Energy Econ. 38, 51–63. doi:10.1016/j.eneco.2013.03.002

Phillips, Y., 2012. Landlords versus tenants: Information asymmetry and mismatched preferences for home energy efficiency. Energy Policy 45, 112–121. doi:10.1016/j.enpol.2012.01.067

Rahman, L. etal, 2017. Energy Consumption Analysis Based on Energy Efficiency Approach: A Case of Suburban Area (PDF Download Available). ResearchGate. doi:http://dx.doi.org/10.1051/matecconf/20178702003

Raimund, 1999. Energy Efficiency of Passenger Cars: Labelling and its Impact on Fuel Efficiency and CO2-Reduction — ECEEE.

Rambaud, S.C., Muñoz Torrecillas, M.J., 2006. Social discount rate: A revision (PDF Download Available). ResearchGate.

Ramos, A., Gago, A., Labandeira, -., Linares, P., 2015. The role of information for energy efficiency in the residential sector. Energy Econ., Frontiers in the Economics of Energy Efficiency 52, Supplement 1, S17–S29. doi:10.1016/j.eneco.2015.08.022

Ramos, A., Labandeira, -., Löschel, A., 2016. Pro-environmental Households and Energy Efficiency in Spain. Environ. Resour. Econ. 63, 367–393. doi:10.1007/s10640-015-9899-8

REHVA, 2016. “Clean Energy” package with revised EPBD released : REHVA [WWW Document]. URL http://www.rehva.eu/news/news-single/article/clean-energy-package-with-revised-epbd-released.html (accessed 6.21.17).

Revelt, D., Train, K., 1998. Mixed Logit with Repeated Choices: Households’ Choices of Appliance Efficiency Level. Rev. Econ. Stat. 80, 647–657. doi:10.1162/003465398557735

Robinson, McAllister, 2015. Heterogeneous Price Premiums in Sustainable Real Estate? An Investigation of the Relation between Value and Price Premiums (PDF Download Available). ResearchGate.

Ryan, Campbell, 2012. Insight publications: Spreading the Net: the Multiple Benefits of Energy Efficiency Improvements. IEA.

Sallee, J.M., 2013. Rational Inattention and Energy Efficiency (Working Paper No. 19545). National Bureau of Economic Research. doi:10.3386/w19545

Sammer, K., Wüstenhagen, R., 2006. The influence of eco-labelling on consumer behaviour – results of a discrete choice analysis for washing machines. Bus. Strategy Environ. 15, 185–199. doi:10.1002/bse.522

Samuelson, W., Zeckhauser, R., 1988. Status quo bias in decision making. J. Risk Uncertain. 1, 7–59. doi:10.1007/BF00055564

Sanchez, M.C., Brown, R.E., Webber, C., Homan, G.K., 2008. Savings estimates for the United States Environmental Protection Agency's ENERGY STAR voluntary product labeling program. Energy Policy 36, 2098–2108. doi:10.1016/j.enpol.2008.02.021

Sarkis Jr., A.M., 2017. A comparative study of theoretical behaviour change models predicting empirical evidence for residential energy conservation behaviours. J. Clean. Prod. 141, 526–537. doi:10.1016/j.jclepro.2016.09.067

Schmidt, S., Weigt, H., 2013. A Review on Energy Consumption from a Socio-Economic Perspective: Reduction through Energy Efficiency and Beyond. Work. Pap.

Schneider, S.H., Easterling, W.E., Mearns, L.O., 2000. Adaptation: Sensitivity to Natural Variability, Agent Assumptions and Dynamic Climate Changes. Clim. Change 45, 203–221. doi:10.1023/A:1005657421149

Shen, J., Saijo, T., 2009. Does an energy efficiency label alter consumers' purchasing decisions? A latent class approach based on a stated choice experiment in Shanghai. J. Environ. Manage. 90, 3561–3573. doi:10.1016/j.jenvman.2009.06.010

Shiftan, Y., Albert, G., Keinan, T., 2012. The impact of company-car taxation policy on travel behavior. Transp. Policy 19, 139–146. doi:10.1016/j.tranpol.2011.09.001

Sorrell, S., 2004. The Economics of Energy Efficiency: Barriers to Cost-effective Investment. Edward Elgar.

Stanley, S., Lyons, R.C., Lyons, S., 2016. The price effect of building energy ratings in the Dublin residential market. Energy Effic. 9, 875–885. doi:10.1007/s12053-015-9396-5

Tong, -., Li, R., Li, F., Kang, C., 2016. Cross-domain feature selection and coding for household energy behavior. Energy 107, 9–16. doi:10.1016/j.energy.2016.03.135

Train, K., 1985. Discount rates in consumers' energy-related decisions: A review of the literature. Energy 10, 1243–1253. doi:10.1016/0360-5442(85)90135-5

Tversky, A., Kahneman, D., 1981. The framing of decisions and the psychology of choice. Science 211, 453–458. doi:10.1126/science.7455683

van Amstel, M., Driessen, P., Glasbergen, P., 2008. Eco-labeling and information asymmetry: a comparison of five eco-labels in the Netherlands. J. Clean. Prod. 16, 263–276. doi:10.1016/j.jclepro.2006.07.039

Wiel, S., McMahon, J.E., 2003. Governments should implement energy-efficiency standards and labels—cautiously. Energy Policy 31, 1403–1415. doi:10.1016/S0301-4215(02)00199-4

Wiley, J.A., Benefield, J.D., Johnson, K.H., 2010. Green Design and the Market for Commercial Office Space. J. Real Estate Finance Econ. 41, 228–243. doi:10.1007/s11146-008-9142-2

Zhou, K., Yang, S., 2016. Understanding household energy consumption behavior: The contribution of energy big data analytics. Renew. Sustain. Energy Rev. 56, 810–819. doi:10.1016/j.rser.2015.12.001

Annex: Supporting material

Table A.1: Explanation of behavioural failures (Source: Ramos et al., 2015)

Type	Behavioural failure	Explanation
Deviations from rational theory of choice	Framing	The way in which a problem is framed impacts the final decision
	Preference reversal	There may be differences between values and choices which result in a reversal of preferences
	Preference intransitivity	Preferences may not be consistent, and may be formed on the spot, resulting in the final decision.
	Independence of irrelevant alternatives	Alternatives that should be irrelevant become very important for the final decision
	Endowment or “status quo” effect	Tendency to value more what we have, or the starting situation
	Gambling and insurance	Partly based on the starting or reference point, people have different attitudes towards risk depending on its magnitude and starting point
	Sunk cost fallacy	People consider sunk costs in their decisions, even though they should not, sometimes based on self-discipline or stability of decisions
	Mental accounting	People allocate different expenses to different categories, as a way of dealing with complexity in budgeting
	Dynamic inconsistency	Preferences change when decisions come closer
	Limited attention	People are not able to use all the information available due to time/effort constraints
	The paradox of choice	More options result in less utility (maybe because of greater regret)
	Emotions	Emotions, altruism & social norms may have a significant effect on decisions
Biases when dealing with uncertainty	Representativeness	People look for internally-consistent stories, even if they go against probabilities. The same applies when people extrapolate small samples to larger ones.
	Availability	People make judgments about the probability of events by how easy it is to think of examples
	Anchoring	Estimations are biased by the number initially provided
	Gambler’s fallacy	Based on misconceptions of randomness, people are unable to estimate the likelihood of random sequences
	Selection bias	When the sample selected is not random, the results will be biased
	Aversion to uncertainty	People assign a lower utility to results the probability of which is not known

Table A.2: Most important variables in EE modelling for household appliances

Explanatory variables		Number of papers	Example of papers
Socio Demographic		32	Allcott and Taubinsky (2015)
Product characteristics	Technical	41	Jones et al. (2015)
	Price	17	Shen and Saijo (2009)
Geographical distinction (including climate conditions)		26	Sammer and Wüstenhagen (2006)
Policy	Tax Subsidy Rebates	19	Datta and Filippini (2016)
	Label	31	Newell and Siikamäki (2013)
	Others	3	Galarraga et al. (2013)
Behaviour	Role of information	23	Kallbekken et al. (2013)
	Decision, choice, preference	19	Heinzle and Wüstenhagen (2012)
	Attitude	16	Frederiks et al. (2015b)
Others (Sectoral aspects, consumer need, etc.)		4	Michelsen and Madlener (2016)

Table A.3: Description of studies reviewed

Reference	Sector and product category	Study year	Country	Data and methodology
Abadie et al. (2012)	Industry	2011	USA	Available data, Net present value and Real options
Abrahamse et al. (2005)	HH	-	-	Review
Alberini et al. (2014)	HH; Transport	2010-2011	Switzerland	Data available, Hedonic regression
Allcott and Sweeney (2015)	HH; Appliances	2012-2013	USA	Field experiment
Allcott and Taubinsky (2015)	HH; Appliances	-	USA	Field experiment
Allcott and Wozny (2013)	HH	2008	USA	Survey
Amecke (2012)	HH; Property	2009	Germany	Survey
Asensio and Delmas (2016)	HH; Appliances	2011-2012	USA	Field experiment
Bachman et al. (1982)	Services; Transport	-	USA	Field experiment
Bailey et al. (2008)	Agriculture	2004	Nova Scotia	Survey
Bamberg et al. (2003)	Services; Transport	1994-1995	Germany	Survey
Banerjee and Salomon (2003)	HH; Appliances Services; office equipment	1979-2001	USA	Meta-evaluation of USA policies
Banfi et al. (2008)	HH; Appliances	2003	Switzerland	Survey (telephone), discrete choice model
Blancard and Martin (2014)	Agriculture	2007	France	Data Envelopment Analysis approach
Blasch et al. (2016)	HH; Appliances	2015	Switzerland	Choice experiment
Boardman et al. (2000)	HH; Transport	-	UK	Report, Review, Labelling
Bonde et al. (2013)	HH; Property	2003-2010	Sweden	Econometric approach
Bresson et al. (2004)	Services; Transport	1975-1995	France	Panel data, fixed effects
Brounen and Kok (2011)	HH; Property	2008-2009	Netherlands	Logit model
Cagno and Trianni (2012)	Industry	-	Italy	Regression modelling

Reference	Sector and product category	Study year	Country	Data and methodology
Cajias and Piazolo (2012)	HH; Energy consumption	2008-2010	Germany	Quantile regression
Carroll et al. (2016a)	HH; Property	2014	Ireland	Choice experiment
Carroll et al. (2016b)	HH; Appliances	2013	Ireland	Field experiment
Chegut et al. (2014)	HH; Property	1999-2009	UK	Hedonic model (ex-post)
Chegut et al. (2016)	HH; Property	2008-2013	Netherlands	Hedonic real estate valuation framework
Codagnone, C. et al (2016)	HH; Transport	2012-2013	UK	Lab experiment
Dale and Fujita (2008)	HH; Appliances	1980-2002	USA	Price elasticities
Das and Wiley (2014)	Services; Property	2004-2011	USA	Hedonic model
Das et al. (2011)	Services; Property	2007-2010	USA	Hedonic model
Datta and Filippini (2015)	HH; Appliances	2001-2005	USA	Non-linear methods, Diff in Diff
Datta and Gulati (2011)	HH; Appliances	2001-2006	USA	Econometric modelling
Davis (2009)	HH; Appliances	2005	USA	Survey data
Davis and Metcalf (2015)	HH; Appliances	2014	USA	Discrete choice experiment
de Ayala et al. (2016)	HH; Property	2013	Spain	Hedonic model
Eicholtz et al. (2013)	Services; Property	2007-2009	USA	Data available, Hedonic model
Eicholtz et al. (2010)	Services; Property	2004-2007	USA	Data available, Hedonic model
Faruqui et al. (2010)	HH	-	Multi	Survey
Fleiter et al. (2012)	Industry	2008-2010	Germany	Survey
Franke et al. (2012)	HH; Transport	-	Germany	Field experiment
Fuerst and van de Wetering (2015)	Services; Property	2006-2010	UK	Data available, Hedonic model
Fuerst et al. (2013)	Services; Property	2008-2010	UK	CoStar data, Hedonic model
Fuerst and McAllister (2011a)	HH; Property	2011	UK	Portfolio Analysis Service data, hedonic model

Reference	Sector and product category	Study year	Country	Data and methodology
Fuerst, McAllister (2011b)	HH; Property	-	USA	CoStar database, Hedonic model
Fuerst et al. (2016)	HH; Property	2003- 2014	Wales	Datasets from several sources, Hedonic model
Gabe and Rohm (2014)	Services; Property	-	Australia	NABERS data, Hedonic model
Galarraga et al. (2013)	HH; Appliances	2008-2009	Spain	Data collected, DWL
Galarraga et al.(2016)	HH; Appliances	January 2012	Spain	Data collected, DWL
Galarraga et al. (2011a)	HH; Appliances	December 2009	Spain	Data collected, Hedonic model + Quantity Based Demand System
Galarraga et al. (2011b)	HH; Appliances	December 2009	Spain	Data collected, Hedonic model
Galarraga and Markandya (2003)	HH; Transport	1996-1997	Hungary	Data available, AIDS model
Galarraga et al. (2014)	HH; Transport	Sep-Nov 2012	Spain	Data collected, Hedonic model
Gans et al. (2013)	HH; Appliances	1990-2009	N. Ireland	Natural experiment
Götz and Tholen (2016)	HH; Appliances	2010-2030	Global	Data available, Bottom-up model
Greene (2011)	HH; Transport	2004	USA	National Research Council data,
Greene et al. (2009)	HH; Transport	-	-	Review
Halvorsen and Larsen (2001)	HH; Appliances	1975-1994	Norway	Survey of Consumer Expenditure, Discrete continuous approach
Hann et al. (2007)	HH; Transport	2004	Switzerland	Survey
Haq and Weiss (2016)	HH; Transport	1999-2015	EU	Review
Heinzle and Wüstenhagen (2012)	HH; Appliances	2009	Germany	Quasi field experiment, Hierarchical Bayesian model
Helter and Menrad (2016)	Agriculture	2011	Germany	Survey, partial least square approach
Hirst and Brown (1990)	HH; EE gap	-	USA	Review
Holland et al. (2016)	HH; Transport	2011 and 2014	USA	Available data, discrete choice experiment
Hrovatin et al. (2016)	Industry	2005-2011	Slovenia	Available data, econometric model

Reference	Sector and product category	Study year	Country	Data and methodology
Hylland et al. (2013)	HH; Property	2008-2012	Ireland	Available data (from draft.ie), hedonic model
Jaffe and Stavins (1994)	HH	-	-	Review
Jaffe et al. (2004)	HH	-	-	Encyclopaedia
Jakob (2006)	HH; Property	2003	Switzerland	Survey, Cost-benefit analysis
Jensen et al. (2016)	HH; Property	2007-2011	Denmark	Available data, Regression
Jensen et al. (2014)	HH; Transport	-	Denmark	Survey, State Choice experiment
Johansson (2014)	Industry	2012	Sweden	Qualitative research method, In/deep interviews
Jokiniewi et al. (2010)	Agriculture	-	Finland	Estimates on fuel consumption
Jones et al. (2015)	HH; Appliances	-	-	Review
Jones and Lomas (2015)	HH; Appliances	2009-2010	UK	Survey (face-to-face), Odds ratio
Kaklamanou et al. (2015)	Services; Transport	-	UK	Survey (on-line), Regression model
Kalbekken et al. (2013)	HH; Appliances	2009	Norway	Field experiment
Khanna et al. (2016)	HH; Appliances	2012	China	Survey data (China Residential Energy Consumption Survey data), Electricity demand model
Kok and Jennen (2012)	Services; Property	2005-2010	Netherlands	Data available (CoStar), Hedonic model
Kurani and Turrentine (2004)	HH; Transport	2003	USA	Interviews
Labandeira et al. (2012)	HH Industry	2005-2007	Spain	Data available (Iberdrola), New approach to estimate the electricity demand
Labandeira et al. (2005)	HH Industry	1973-1995	Spain	Data available, Demand model (Almost Ideal Model)
Li et al. (2016)	Agriculture	2013	China	Survey (online), Econometric approach
Lillemo (2014)	HH; Appliances	2010	Norway	Survey, Econometric approach

Reference	Sector and product category	Study year	Country	Data and methodology
Linares and Labandeira (2010)	HH; Policy	-	-	Review
Liu et al. (2016)	HH; Appliances	2010	USA	Field experiment
Manhoudt et al. (2002)	Agriculture	-	Netherlands	Comparative study
Markandya et al. (2009)	HH; Appliances	-	Europe	Data from retailers, Partial equation approach
Michelsen and Madlener (2016)	HH; Appliances	2009-2010	Germany	Survey, Regression model
Min J et al (2014)	HH; Appliances	-	USA	Experiment, Conjoint analysis
Mueller and De Haan (2009)	HH; Transport	2005	Switzerland	Survey, Agent based simulation
Murphy (2013)	HH; Property	2008-2011	Netherlands	Survey
Nehler and Rasmusen (2015)	Industry	2013-2014	Sweden	Qualitative in-depth semi-structured interviews
Neij, L et al. (2009)	HH; Appliances	-	-	Review
Newell et al. (2014)	Services; Property	-	Australia	Data available, Hedonic model
Newell and Siikamäki (2013)	HH; Appliances	-	USA	Lab experiment
Noblet et al. (2006)	HH; Transport	2004-2005	USA	Survey, Empirical model of individual’s choice
Palmer et al. (2013)	HH; Appliances	2011	USA	Survey
Panzone (2013)	HH; Appliances	2010-2012	UK	Data from retailers, AIDS
Phillips (2012)	HH; Appliances	-	New Zealand	Survey, Hedonic model
Rahman et al. (2017)	HH	3 months (-)	Malaysia	Survey
Ramos et al. (2016)	HH; Appliances	2008	Spain	Data available, Discrete choice experiment
Robinson and McAllister (2015)	Services; Property	2001-2011	USA	Data available (CoStar), Hedonic and quantile regression
Salle (2013)	HH; appliances and transport	-	USA	Heuristic model
Sammer and Wüstenhagen (2016)	HH; Appliances	2004	Switzerland	Survey, Discrete choice experiment

Reference	Sector and product category	Study year	Country	Data and methodology
Sanchez et al. (2008)	HH; Appliances and Property	2002-2015	USA	Review
Sarkis (2017)	HH; Appliances	-	-	Review
Schmidt and Weigt (2013)	HH	-	-	Review
Schneider et al. (2000)	Agriculture	1983-1992	USA	Theoretical paper
Shen and Saijo (2009)	HH; Appliances	2012	China	Survey (choice), Hedonic model
Shiftan et al. (2012)	Service; Transport	2008-2011	Israel	Survey
Stanley et al. (2016)	HH; Property	2009-2014	Ireland	Data available, Hedonic model
Thøgersen and Moller (2008)	Services; Transport	-	Denmark	Field experiment
Tong et al. (2016)	HH; Appliances	2009-2010	Ireland	Survey
Train (1985)	HH	-	-	Review
Van Amstel et al. (2008)	Agriculture; Policy	-	Netherlands	Review
Wiley et al. (2010)	HH; Property	2008	USA	Data available (CoStar), Hedonic model
Zhou and Yang (2016)	HH; Appliances	-	China	Survey, Big data approach

Abbreviations used in the table:
- AIDS: Almost Ideal Demand System
- DWL: Dead weight loss
- HH: Household