Information failures and energy labelling in large purchase decisions

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Abstract

Not accounting for future energy costs is often cited as a barrier to the adoption of more efficient technologies. Numerous studies suggest that consumers are often uninformed of future energy use costs, particularly when making large purchase decisions such as homes or vehicles. Whether this can be corrected through information provision alone however remains unclear. This paper provides an overview of recent literature on labelling in energy efficiency adoption, focusing on energy efficiency information provision in two of the largest purchases households make – homes and vehicles. The literature suggests that while information failures are likely present, it can be difficult to fully correct these using simple information provision alone. Information failures also interact with other market failures, behavioural patterns and distributional issues. This underscores the need for policy measures in addition to labelling to encourage investments in efficiency.

Keywords: energy efficiency, market failures, information failures, framing, vehicle purchases, residential efficiency, labelling.

1. INTRODUCTION

The cleanest form of energy is the one that we do not use. Sometimes referred to as the *hidden fuel* since we can only observe it as the quantity of energy not used, improvements in *energy efficiency* have seen increased attention as a strategy to reduce greenhouse gas emissions. Perhaps they should be referred to as the *first fuel* (IEA, 2014).

It is useful to begin by providing a definition of energy efficiency. Fundamentally, the demand for energy can be viewed as a derived demand (Quigley, 1984). Consumers of energy typically do not demand primary (or even secondary)[1] energy itself but rather what that energy can do for them. In other words – consumers demand the *energy services* provided. For example, a consumer does not directly demand the kWh of electricity going into an electric light bulb, but rather the light coming from it. An improvement in energy efficiency can therefore be

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1 Primary energy typically refers to the resources captured directly from nature – for example crude oil, natural gas or solar energy. Secondary energy sources come from the transformation of primary energy sources – examples include electricity or petroleum products (OECD/IEA, 2004).

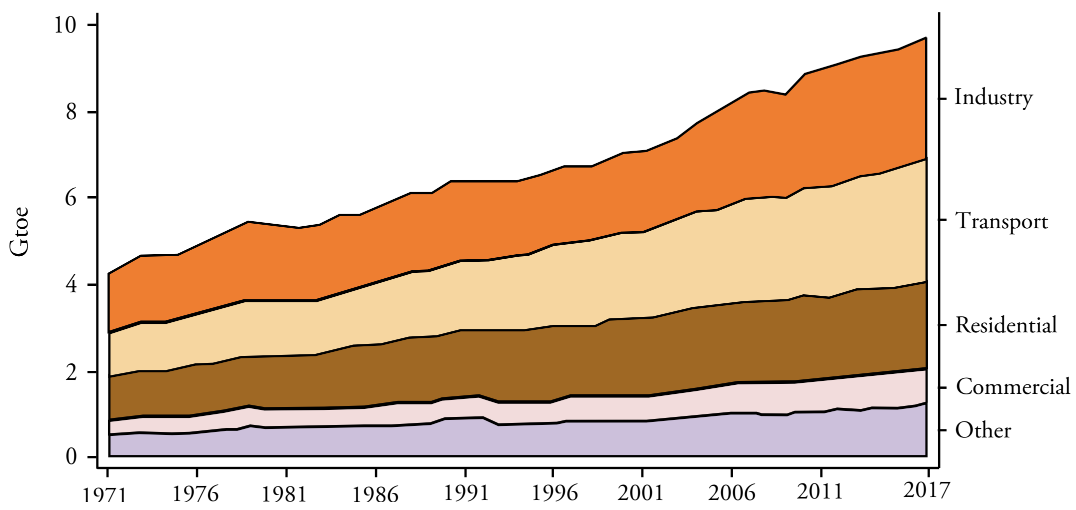
defined as obtaining the same (or better) levels of energy services, with less energy input. In our light bulb example, if we can obtain the same (or better) levels of light with less electrical input, this would be considered an improvement in efficiency.

It is also important to distinguish energy efficiency from energy conservation. As discussed in Linares and Labandeira (2010), energy conservation refers to an absolute reduction in energy demand. This can come from improvements in efficiency, or simply from a reduction in the energy services consumed. The distinction between energy efficiency and energy conservation is further exemplified by the fact that improvements in efficiency may not necessarily lead to proportional decreases in energy use. This is typically referred to as the rebound effect – a situation where more energy services are used as their per-unit cost decreases (Alberini *et al.,* 2016b; Gillingham *et al.,* 2013). Going back to our light bulb example, this would occur if a more energy efficient light bulb (being cheaper to operate) is left switched on for longer.

Notwithstanding limitations due to the rebound effect, the potential of energy efficiency in mitigating greenhouse gas emissions is non-trivial. IEA (2018) estimate that more than 40% of the emissions abatement required by 2040 to be in line with the Paris Agreement could be met by improvements in efficiency alone. Given that global energy demand has more than doubled in the last 50 years (figure 1),[2] and is projected to continue increasing (Smil, 2020)

Figure 1

Global final consumption of energy (gtoe) by sector



Note: "Other" includes agriculture, fishing, non-specified (other) and non-energy use.

Source: IEA (2020b).

2 According to the *World Energy Outlook* by the International Energy Agency (IEA), in 2017 global energy demand was projected to rise by a further 30% to 2040 – the equivalent of adding another China and India to today's global demand (IEA, 2017).

it seems likely that improvements in efficiency will play a key role in meeting future climate targets.

Two of the largest contributors to energy demand are the transport and residential sectors. Combined, they represent over 50% of total final global energy consumption. However, they also offer significant potential for improvements in efficiency from a household's perspective. In the residential sector, energy efficiency in buildings can be improved through the use of better building design, insulation materials, heating/cooling systems and appliances (IEA and UN, 2018). The transport sector offers efficiency gains which can be realised through modal shift (switching from private car to public transport), improvements in fuel economy, or a switch to alternative fuel technologies such as electric and hybrid-electric vehicles (SEAI, 2014).

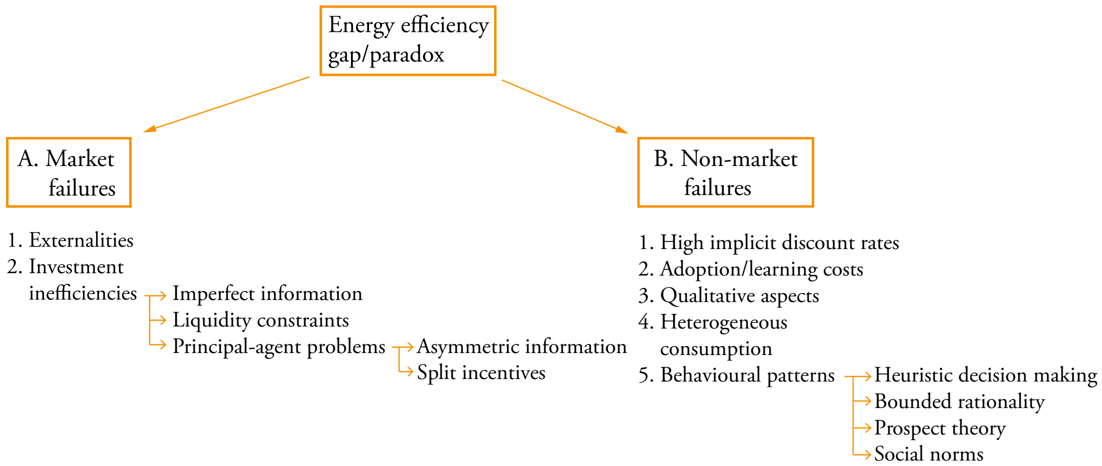
Moreover, many improvements in efficiency can be cost effective, in addition to delivering a range of other benefits for the consumer (Ryan and Campbell, 2012). These can include health and wellbeing improvements and asset value increases in the case of properties. While many engineering studies highlight a range of energy efficient technologies that provide an attractive return on investment (Gerarden *et al.,* 2015; Wada *et al.,* 2012), the uptake of energy efficient technologies seems to remain below their economic potential. This is typically referred to as the "Energy Efficiency Gap" – a wedge between the cost-minimising level of energy efficiency and the level actually realised (Allcott and Greenstone, 2012; Jaffe and Stavins, 1994).

The economics literature has produced various explanations for the existence of this gap. These can be broadly categorised into two groups: market failures and other non-market failure barriers (figure 2). Market failures refer to situations where market conditions provide an inefficient outcome. These can result from flaws such as unpriced externalities, imperfect information or principal-agent problems. For example, if energy prices are too low due to unpriced environmental externalities, this may discourage investment in efficient technologies by lengthening their payback periods. If consumers are not aware of (or have imperfect information on) the energy cost savings which can be made by adopting more efficient appliances, this can also clearly prevent adoption. Asymmetric information between buyers and sellers of energy-using durable goods can also lead consumers to make purchases with suboptimal levels of efficiency, with sellers of inefficient goods having an incentive to conceal this information (Akerlof, 1970).

Typically, the presence of market failures gives clear justification for government intervention which can improve welfare (Baumol, 1972). Allcott and Greenstone (2012) categorise the market failures associated with energy efficiency in two broad sub-types: externalities and investment inefficiencies. The authors argue that government intervention in the form of subsidies or mandates for energy efficiency is only justified in cases where the market failure is not the result of unpriced environmental externalities, and cannot be fully addressed directly (for example by providing information to imperfectly informed consumers).[3]

Figure 2

Explanations for the energy efficiency gap



Sources: Allcott and Greenstone (2012), Gillingham *et al.* (2009).

Non-market failure explanations as per Jaffe and Stavins (1994) include high implicit discount rates, unpriced costs of adoption (such as learning costs), qualitative technological aspects, and heterogeneity in energy consumption. High implicit discount rates indicate that individuals may overly discount future benefits relative to the higher upfront purchase price of more efficient appliances. In a seminal work in the field, Hausman (1979) investigates how individuals trade-off of increased capital costs associated with more efficient air conditioners against lower future usage costs.[4] Individuals were found to behave as though they would require a return on investment of 20% in order to purchase a more efficient air-conditioner. Some authors have argued however that such high implied discount rates may not be irrational due to the uncertain nature of future benefits, and the irreversibility of efficiency investment decisions (Hassett and Metcalf, 1993). It is therefore unclear as to whether or not high implicit discount rates in of themselves are justification for government intervention.

Adoption or learning costs more generally occur when consumers need to consider efficiency differences between appliances, their own usage patterns, and how these may translate into

3 The authors argue that if energy use externalities are the only market failure, the social optimum will be obtained using Pigouvian taxes (or equivalent cap and trade programs) and not with other forms of intervention. If investment inefficiencies exist however, the first-best policy is to address the inefficiency directly – for example by providing information to imperfectly informed consumers. If these direct interventions are not fully effective and investment inefficiencies remain, only then is there rationale for policies that subsidise or mandate energy efficiency.

4 The idea of myopia with respect to future usage prices can be traced at least all the way back to Pigou, who commented on a “defective telescopic faculty” when it comes to future benefits (Hausman, 1979; Pigou, 1920, p. 25).

future monetary savings. There is a transaction cost associated with collecting this information and transforming it into an energy use forecast. Individuals may be unable or unwilling to carry out substantial research if the cost savings between energy-using goods are perceived as minimal, or of lesser importance than other product attributes (de Ayala *et al.,* 2020). Qualitative aspects, such as the appearance or other perceived functionality of an energy-using durable good may also prevent investments in efficiency if more efficient appliances are perceived to be of lower quality (Jaffe and Stavins, 1994). Heterogenous consumption might also imply that some individuals (particularly those with very low or irregular consumption patterns) will not benefit as much as median or mean consumers from investments in efficiency (Sekar *et al.,* 2019). Heavy users on the other hand may benefit much more.

The behavioural economics literature has yielded further non-market failure reasons for lower than expected investment levels in efficiency. Gillingham *et al.* (2009) include concepts such as bounded rationality, heuristic decision making and prospect theory as further barriers. Boundedly rational consumers may not be able to take all attributes of a purchase into account in complex trade-offs and time-limited decision contexts (Simon, 1979) and may experience information overload or a high cognitive load (Jacoby *et al.,* 1974). This may lead to heuristic decision making, whereby "rules of thumb" are used by consumers to simplify the decision process (Van Den Broek and Walker, 2019). Prospect theory suggests that individuals may overweight potential losses when compared to gains (Kahneman and Tversky, 1979), and may therefore place lower weight on potential future gains from efficiency investment when compared to the initial cost outlay. Social norms can also impact investments in efficiency through comparisons with other individuals. Social information may allow people to "fit in", avoid social disapproval, or seek social esteem (Farrow *et al.,* 2017). For example, Allcott (2011a) finds that providing social norm information in the form of relative electricity consumption (compared to neighbours) significantly reduces energy use among treated households.

These behavioural patterns can be influenced by altering the choice architecture consumers are faced with or by providing better or more targeted information. However, it is not as clear if these barriers in of themselves justify government intervention due to ethical concerns (Sunstein, 2015). Government interventions which "nudge" towards sustainable energy consumption may however be justified on the grounds that the energy system is "massively architectured" to begin with (Kasperbauer, 2017), and choices are being made in an environment where individuals are already strongly influenced by external factors.

A key theme which emerges from the framework in figure 2 is the importance of information in both market and non-market failure explanations to the energy efficiency gap. While imperfect information (or the absence of information) on energy cost savings associated with more efficient appliances is considered a market failure in its own right, it also interacts with other market and behavioural failures. For example, asymmetric information (which is one class of imperfect information) can interact with split-incentives in landlord-tenant relationships. Information asymmetries occur when one party in a contractual arrangement holds more information than the other party. Split-incentives can be defined as a goal conflict between the two parties. If tenants cannot observe the efficiency of the property, and are also responsible for energy bills (as is commonly the case in many rental arrangements), this may lead to a disincentive for landlords to invest in efficiency. Information failures are also clearly a factor in many of the behavioural explanations listed above, such as learning costs and bounded rationality which can stem from unclear or difficult to understand information.

Information failures can therefore ultimately lead to increased energy consumption. Ramos *et al.* (2015) discuss the implications of information interventions on efficiency investment and energy use more broadly, including the role of feedback and smart-metering on energy consumption. Solà *et al.* (2020) focus on the policy instruments which aim to alleviate the energy-efficiency gap, including non-information interventions such as standards and price instruments. Alberini (2018) highlights that there are many challenges when attempting to empirically estimate the effects of information and other policies on household energy use directly, which can include significant data limitations such as measurement error in estimating energy demand functions, response stickiness to excise taxes of fuels and energy inputs, salience, and rebound effects. The focus of this review paper is narrower in scope. We explore the role of information provision on the adoption of household efficiency measures, rather than on energy use. We focus specifically on two large purchase decisions – housing and vehicles – and discuss the role of efficiency labelling in both settings.

2. RESIDENTIAL ENERGY EFFICIENCY

2.1. Property purchases

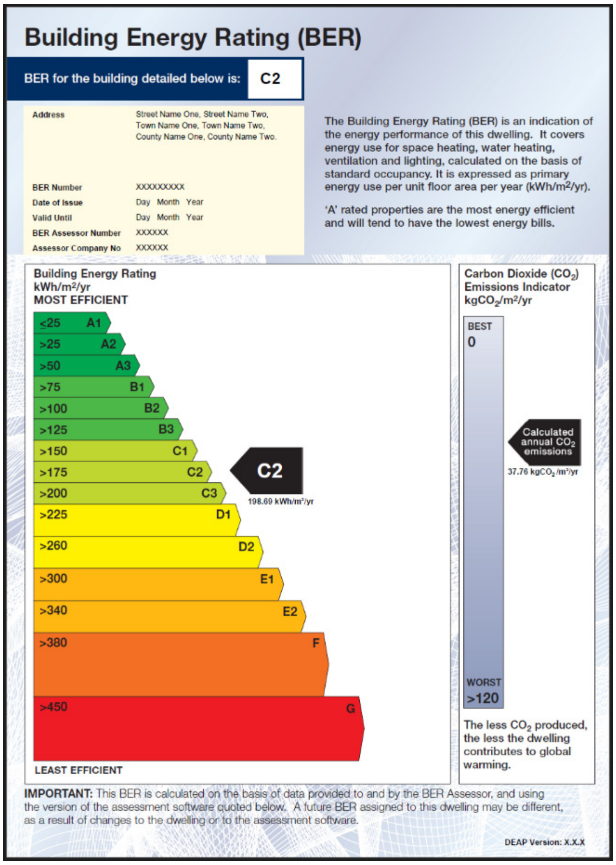
We begin by discussing the role of efficiency information in what is often the largest single purchase consumers make in their lifetime – their home. A central question in the literature is whether energy efficiency is capitalized in property prices. Numerous studies find a positive relationship between efficiency and sales values (Aydin *et al.,* 2020; Brounen and Kok, 2011; Cajias and Piazolo, 2013; de Ayala *et al.,* 2016; Fuerst *et al.,* 2015; Galvin, 2023). Since prospective buyers cannot directly observe the efficiency of a property (for example insulation levels or airtightness) in the absence of standardized labels, consumers may purchase properties with suboptimal levels of efficiency. This in part motivates the disclosure of energy performance certificates (EPC) in many countries in the European Union. Article 7 of the 2002 EU directive on the Energy Performance of Buildings (Directive 2002/91/EC, 2002) sets out the need for member states to adopt energy performance certificates which are to be displayed at the point of sale or lease of a property. In the Republic of Ireland, these are known as the Building Energy Rating (BER) and similar to other member states are based on a detailed engineering assessment of the dwelling (BPIE, 2014).

The assessment includes the measurement of wall, roof and floor dimensions, window and door sizes and orientation, as well as construction type and insulation, ventilation and airtightness features, the system for heat supply (including renewable sources), heat distribution and controls and the type of lighting (SEAI, 2013a). BERs are conducted by registered assessors and are valid for a period of 10 years. It is mandatory to provide a BER label (panel [b]) of figure 3) on the advertisements of properties offered for sale or rent across all media including in newspapers, magazines, brochures, leaflets, advertising notices, vehicle advertising, radio, television, internet (including apps and social media) and direct mail (SEAI, 2013b). The legislation mandating this came into effect on the 9th of January 2013 (*S.I. No. 243 of 2012*).

Figure 3

Example Building Energy Rating (BER) certificate and advertising labels

(a) BER certificate



(b) BER labels to be displayed with advertisement

Source: Sustainable Energy Authority of Ireland (www.seai.ie).

Multiple studies have found a positive relationship between a better BER rating and higher sales premiums. For example, using a Heckman selection model and advertisement data, Hyland *et al.* (2013) find that efficiency premiums are higher for properties advertised for sale (9% premium for an A-rating relative to a D-rating) than for rent (2% premium). Similarly, Stanley *et al.* (2016) also find a sales premium of 1% for each improvement in the alphanumeric BER grade, controlling for a wide range of property and location characteristics. A recent review of the European literature by Ou *et al.* (2025) presents similar findings across multiple European studies, with a one grade improvement in an energy performance certificate associated with a 1-3% price premium on average. In a review of international studies, Cespedes-Lopez *et al.* (2019) find that properties with a rating command a premium of 4.2% globally, relative to properties without a rating. However, the extent to which the BER itself (or other energy performance certificate) is responsible for correcting the information failure is unclear from these findings. The decision to advertise a rating (in cases where it is not mandatory) is likely correlated with other unobserved property or seller characteristics. Where advertised, better ratings may also be correlated with other unobservables, such as overall property quality. It is also difficult to gauge whether in the absence of such certificates, the efficiency of the property would not have been capitalized in sales prices to begin with. To address these identification issues, Frondel *et al.* (2020) examine the impact of transitioning from voluntary to mandatory EPC disclosure in the German market – and find that sellers of less-efficient properties revise their offer prices downwards post mandate. This suggests that energy performance certificates are communicating the inefficiency of low-rated properties to consumers, and are therefore increasing transparency in the market.

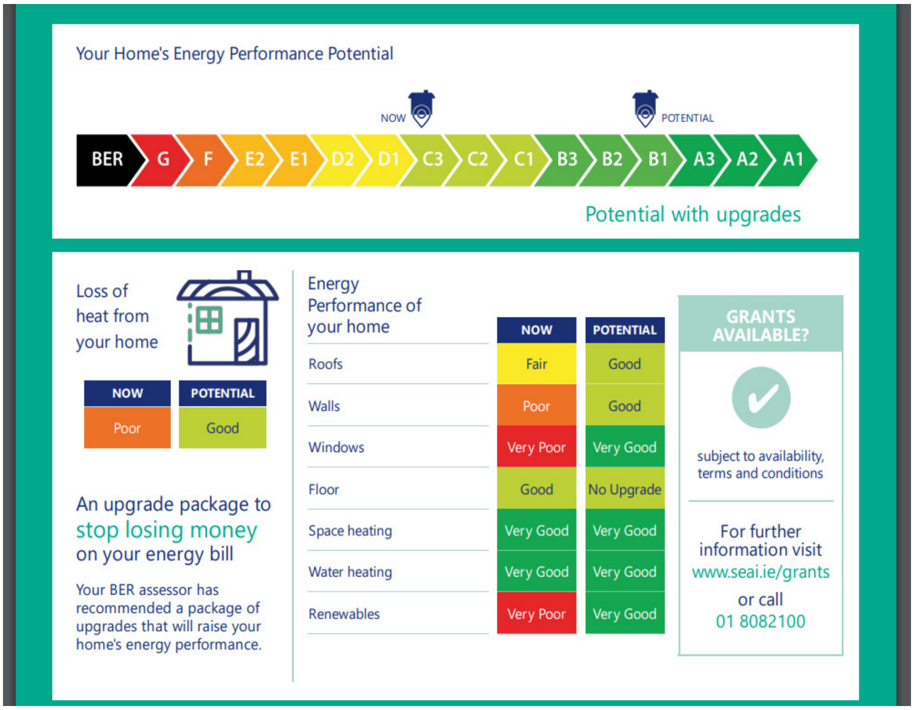
In a related vein, an area of further concern is how well energy performance certificates are understood by prospective purchasers. While the alpha-numeric colour coded scale used to display efficiency is designed to make it easy to assess relative differences between properties, how the rating can be translated into an energy cost forecast may not be obvious to buyers. Using a nationwide experiment, Carroll *et al.* (2024) find that providing monetary energy cost information (in the form of an energy cost forecast) in addition to the efficiency label in online advertising increases transaction sales premiums for efficiency and reduces the time it takes sell a property. This suggests consumers may be missing a key piece of information from the BER label – the monetary cost implications associated with the efficiency level of the property.

Further potential issues identified with the rating system come from the nature of threshold values used to determine which alpha-numeric grade category a rating falls into. Collins and Curtis (2018) find significant excess bunching (or grouping) of properties on the favourable side of threshold values post-retrofit, which may suggest strategic improvements in efficiency to reach a better grade. Since only the letter grade is advertised, this may mean that consumers should assume that within grades, the efficiency of the property is likely in the lower range of a band's kWh/m^2/yr values. This may also be applicable in other settings where a continuous efficiency measure is discretized to produce alpha-numeric grades. Other issues identified with energy performance certificates such as the BER is a potential lack of realism with respect to real-world consumption data (Coyne and Denny, 2021), which may be driven by prebound effects (households in less-efficient housing underheating their property) or rebound effects (households in more-efficient properties heating their homes to a higher temperature, for longer durations, or heating more rooms of the property). Meles *et al.* (2023) find that even controlling for set-point (thermostat) temperature and outside ambient temperature, implied energy savings by the BER are not fully realized in consumption data. While a standardized level of usage is necessary to provide an objective measure of efficiency, it has been found in other settings also that engineering estimates of efficiency improvements on consumption can be greater than realized benefits (Fowlie *et al.*, 2018; Levinson, 2016). This highlights the need to incorporate historical consumption data to improve a rating's accuracy.

Notwithstanding the limitations of energy performance certificates in communicating the efficiency of a property to potential buyers, there are also other benefits from this type of information which are in addition to correcting information asymmetries between buyers and sellers. The provision of publicly accessible efficiency data is important in guiding overall

Figure 4

Extract from BER advisory report



Source: Sustainable Energy Authority of Ireland (www.seai.ie).

policy and identifying disadvantaged areas (Ali *et al.,* 2021). Energy performance certificates also provide useful information to current property owners even if the property does not transact, which can guide retrofit decisions. In the Republic of Ireland, the BER assessment also includes an advisory report (figure 4) which identifies opportunities for improvements in efficiency through different measures, with estimated associated costs and information on grants and supports available. BER assessments must also be conducted prior to receiving government supports for retrofit in order to gauge the extent of improvement. Furthermore, energy performance certificates may also stimulate future investments in efficiency beyond what is already in place at the time of sale, since many purchasers of second-hand properties carry out renovation work post-purchase.

From a researcher perspective, the availability of efficiency data on properties also enables novel insights which can aid in further improving energy conservation, and the methodologies for measuring efficiency (BPIE, 2014). The communication and normalization of energy efficiency in the public discourse is also likely to draw further attention to efficiency improvements. The value of information provided by energy performance certificates is therefore likely to extend beyond the realm of simply correcting information asymmetries between buyers and sellers, and may have additional public good benefits.

2.2. Rental properties

Information asymmetries can also interact with other market failures. In the case of rental properties, the misalignment of incentives for efficiency investments or energy conservation is facilitated by information asymmetries. This misalignment of incentives is typically referred to as the *split-incentives or landlord-tenant* problem. It can be characterized as a principal-agent problem, since the party responsible for investment in efficiency or energy conservation (the principal) may not necessarily act in the interests of the other party (the agent) in the contractual arrangement (Eisenhardt, 1989). This can lead to an under-investment in energy efficiency by landlords or an over-consumption of energy by tenants, depending on which party is responsible for energy-related utility bills. Some authors have suggested that this may be a significant barrier to improving energy efficiency in residential properties. Murtishaw and Sathaye (2006) estimate that as much as 35% of primary residential energy use in the US may be affected by landlord-tenant problems. In the Netherlands, IEA (2007) find that up to 41% of the energy consumption for space heating in the residential sector might be affected by principal-agent issues, owing to a high proportion of rental properties. Homeownership rates have seen a decline in recent years across many Western countries (Billings and Soliman, 2023; Goodman and Mayer, 2018), and if this trend is to continue this will become an increasingly important barrier to efficiency investment and energy conservation.

Figure 5

Split-incentives problem

	Occupant owns dwelling	Occupant rents dwelling
Occupant pays for energy use	(1) No split-incentives	(2) Efficiency problem: asymmetric information leading to less insulation and efficient appliances
Occupant does not pay for energy use	(3) Both	(4) Usage problem: Over-use of energy due to moral hazard problem

Source: Adapted from Gillingham *et al.* (2012).

The above illustrates the split-incentives problem in the owner-occupant relationship. In case (1) there are no split incentives problems since the owner is also the occupier of the property and can decide to invest in efficiency or not, and therefore obtain the benefits in reduced energy bills (or not). Similarly, energy conservation efforts are also captured directly by the occupant, since the utility bill is also the responsibility of the occupant.

In case (2), the occupant rents their dwelling from another individual (or organization) however is responsible for energy utility bills. This is perhaps the most common type of rental arrangement, and may lead to under-investment in efficiency since landlords cannot benefit directly from efficiency investments. Such benefits accrue to the tenant. Where information problems can arise within this relationship is when tenants are not perfectly informed or cannot observe the efficiency of the dwelling prior to entering into a rental contract. Uninformed tenants may end-up paying high energy costs without the ability to change the efficiency of the property through, for example, insulation or heating system upgrade. Even in cases where tenants may have the option to purchase more efficient equipment, they may be unwilling to make these types of investments depending on planned tenancy duration, and also do not capture the benefits of increased property asset values associated with efficiency. There is therefore an incentive for landlords of inefficient properties to not-report efficiency information to prospective tenants. In the spirit of Akerlof's (1970) *market for lemons,* this may lead to a decline in the efficiency of the stock of rental properties available as a whole. Many studies find an efficiency difference between rental and non-rental properties which may be attributable to this form of asymmetric information, typically finding that rental properties are less likely to have efficiency measures such as insulation or efficient appliances (Gillingham *et al.,* 2012; Scott, 1997). Specifically for Ireland, findings from Petrov and Ryan (2021) suggest that rental properties have a lower BER rating overall when compared to similar non-rental counterparts.

In case (3) of figure 4 there is both the incentive to underinvest in efficiency and to over-consume energy. While rare, these cases can occur in collective heating arrangements where owners pay a fixed fee for utilities. Finally in Case (4), the split incentives problem is reversed. Here, the energy bills are the responsibility of the landlord, and tenants may pay a fixed fee for utility bills, or the utility bills are included as part of the overall fixed rent amount. In this instance there is an incentive for tenants to over-consumer energy if they face zero marginal cost with energy use. The information problem here is reversed – landlords may not be able to observe or control the usage patterns of the tenant, leading to a moral hazard problem. It has been documented that tenants with this type of heating arrangements tend to over-consume energy (Gillingham *et al.,* 2012; Levinson and Niemann, 2004).

The benefit of efficiency information in rental arrangements (particularly where tenants are responsible for energy bills) may also be higher than in purchase settings, due to potentially higher levels of exposure of the efficiency label. If tenure duration is shorter in rental accommodation than in owner-occupied properties, the label may be advertised and observed more often. Prospective tenants are also unlikely to conduct a detailed engineering assessment of the property as is commonly the case when a property is bought. Coupled with the incentives problems outlined above, there may be more value in efficiency information provision in the rental sector. Using stated preference methods Carroll *et al.* (2016a) find that tenants have significant willingness-to-pay for rental properties with a better BER which is in excess of the implied energy cost savings. Respondents also exhibit significant disutility with properties in the least efficient categories, and will pay significantly more for improvements at the lower end of the efficiency scale. When the energy savings associated with a more efficient rental property are presented as monetary amounts in Carroll *et al.* (2022) willingness to pay for efficiency improvements increases. As in the property sales domain, this again suggests that presenting energy cost savings as a monetary amount (rather than simply as an alphanumeric label) may further increase the demand for efficiency.

3. CAR PURCHASE CHOICES

A vehicle is typically the second-largest single purchase a household will make. Such purchases can also be made multiple times, offering substantial opportunities to communicate and invest in efficiency. Energy efficiency in the passenger car domain is typically referred to as fuel economy (or gas-mileage). As before, the demand for energy can be thought of as a derived demand, since consumers typically demand the energy service (car transportation) rather than the energy vector itself (gasoline or diesel). Improvements in fuel economy in turn are directly related to reductions in greenhouse gas emissions, which is one of the many externalities associated with passenger car use.[5]

5 Tail-pipe CO_2 emissions are only one of many external costs imposed on society when operating a passenger car. As per Parry *et al.* (2007) other associated costs include localised air pollution, congestion, noise, oil dependence and accident risk.

Many studies have attempted to estimate the degree to which consumers undervalue future fuel costs when making a new car purchase. Typically, a valuation ratio or parameter is estimated, which reflects the degree to which discounted future energy costs are internalized in purchase decisions. While earlier literature in the area suggests that the evidence for or against undervaluation of fuel economy is mixed (for reviews refer to Greene, 2010; Helfand and Wolverton, 2011), many recent studies have found that the valuation parameter is less that one (Allcott and Wozny, 2014; Gillingham *et al.,* 2021; Grigolon *et al.,* 2018; Leard *et al.,* 2023, 2020). This suggests that consumers may not be fully taking into account future car running costs when making a purchase decision.

The degree to which consumers undervalue fuel economy is unclear, with significant differences in findings across studies. Exploiting fuel price variation, Allcott and Wozny (2014) estimate a valuation ratio of 0.76 in the US, indicating that every $1 in discounted future fuel costs is valued at $0.76 in car transaction prices today. In contrast, Busse *et al.* (2013) do not find evidence of myopia with respect to future fuel costs, finding implicit discount rates for efficiency of similar magnitude to interest rates paid by buyers who borrow to finance their car purchase. In the EU Grigolon *et al.* (2018) find a more modest undervaluation (€0.91 for every €1), and suggest that fuel taxes may be more effective at reducing fuel usage than product taxes/subsidies, since they preferentially target high mileage users. Other more recent studies in the US such as Leard *et al.* (2023, 2020) find that the undervaluation of fuel economy may be higher (at $0.54 for every $1 in future fuel costs) due to higher valuation of other car attributes, such as acceleration and performance. Using a natural experiment (a re-statement of fuel economy labels), Gillingham *et al.* (2021) find that consumers value $1 in discounted future costs at only $0.16 - $0.39 cents in purchase prices, which suggests a larger degree of undervaluation. The fact that consumers changed their valuation of fuel economy (without any underlying change in the vehicles themselves) also illustrates that consumers do place a value on the fuel economy label itself.

While most of the above studies suggest that consumers do not fully take into account future energy cost associated with car use, the extent to which an additional information intervention can correct these errors and ultimately alter purchase choices is unclear. In stated preference settings it is found that consumers' preferences for fuel economy can be altered by providing additional information, particularly when this information is framed in monetary terms (Brazil *et al.,* 2019). The presentation of CO_2 information and its framing is also found to be effective in altering stated preferences towards less polluting vehicles (Daziano *et al.,* 2017; Wang *et al.,* 2021). What information is presented, its framing, and relative comparisons are also shown to be of importance in Codagnone *et al.* (2013). The presentation of running costs in particular appears to be an effective nudge. A more recent study conducted for the Directorate-General for Climate Action (European Commission *et al.,* 2021) suggests that presenting labels via online channels could have a large impact on the sales of new vehicles, and recommends the establishment of online comparison platforms. In a large 8,000 participant study conducted as part of the report it was found that the provision of running cost, air pollution and electric range bring about the most significant benefits.

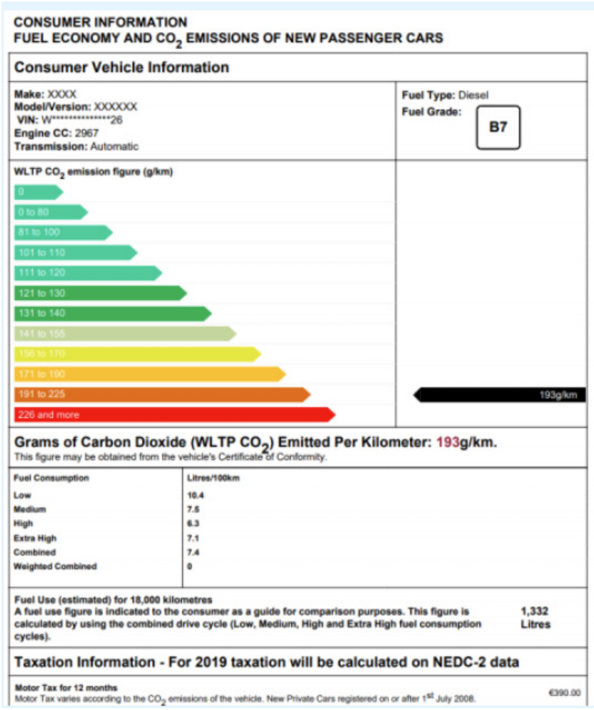
However, it has been found to be more difficult for labelling interventions to substantially influence purchase choices outside of hypothetical settings. In that regard, there is a paucity of experimental research which aims to actively provide energy cost information to consumers at the point of sale. Allcott and Knittel (2019) use a randomized experiment to provide energy use cost information to vehicle shoppers and do not find that this altered purchase choices towards more fuel-efficient vehicles, highlighting the difficulty in altering preferences in real-world applications. By contrast, when it comes to vehicle tax information, using a randomized information experiment in Switzerland Cerruti *et al.* (2023) find that providing information on the existence of fiscal incentives for fuel economy increases awareness and leads consumers to purchase more efficient vehicles.

As with property efficiency, many countries also mandate efficiency labels to be displayed on new vehicles offered for sale. Directive 1999/94/EC requires EU member states to ensure that consumers are informed about the fuel economy and CO_2 emissions of new passenger cars through labelling, however these are not uniform across countries (Haq and Weiss, 2016). These labels are typically based on fuel economy and emissions ratings from testing procedures to ensure vehicle compliance with environmental and safety regulations. Examples of these for Ireland, Switzerland and the US are presented in figure 6.

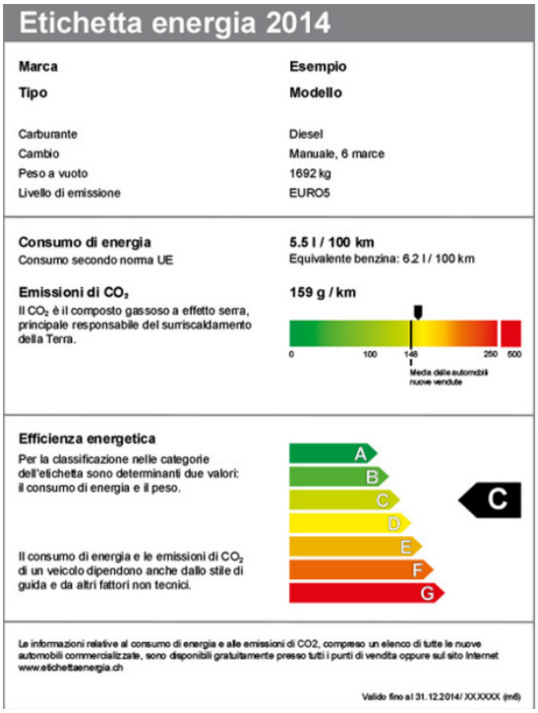
In Switzerland, Alberini *et al.* (2016a) find a significant price premium to more efficient cars, suggesting that consumers place a value on fuel economy. Again however, as in the property labelling domain, the issue is whether this is simply the effect of the underlying efficiency of the vehicle or as a result of labelling policy correcting information asymmetries. To address this, the authors use a regression discontinuity design and find that an A rated vehicle receives an excess price premium of 6-11% relative to almost identical vehicles which are just below the A threshold value. This illustrates that consumers place a value on the A certification itself, which is beyond the value of the underlying efficiency. Interestingly, this premium is absent for B or C rated vehicles, suggesting that there may be an asymmetric effect of labelling which favours the most efficient (A) categories. The authors suggest that one explanation for this could stem from consumer heterogeneity, with those that place the highest value on efficiency seeking out vehicles with the best rated fuel economy. This correlates with findings by Hahnel *et al.* (2015) where "green" labelled vehicles were preferred by respondents with high ecological motivation, even when presented with product information that contradicts the label's image.

Figure 6
Car fuel economy and CO_2 labels

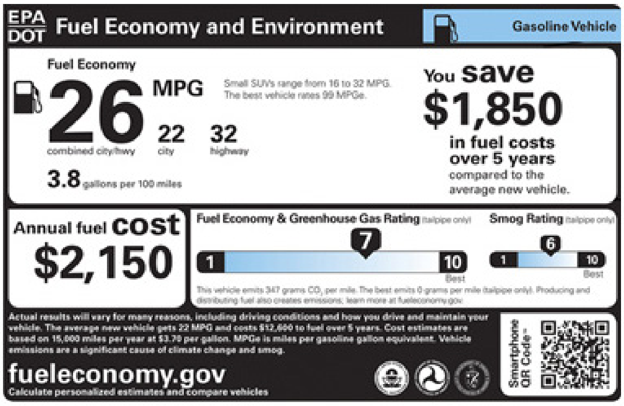
(a) Ireland



(b) Switzerland



(c) US EPA

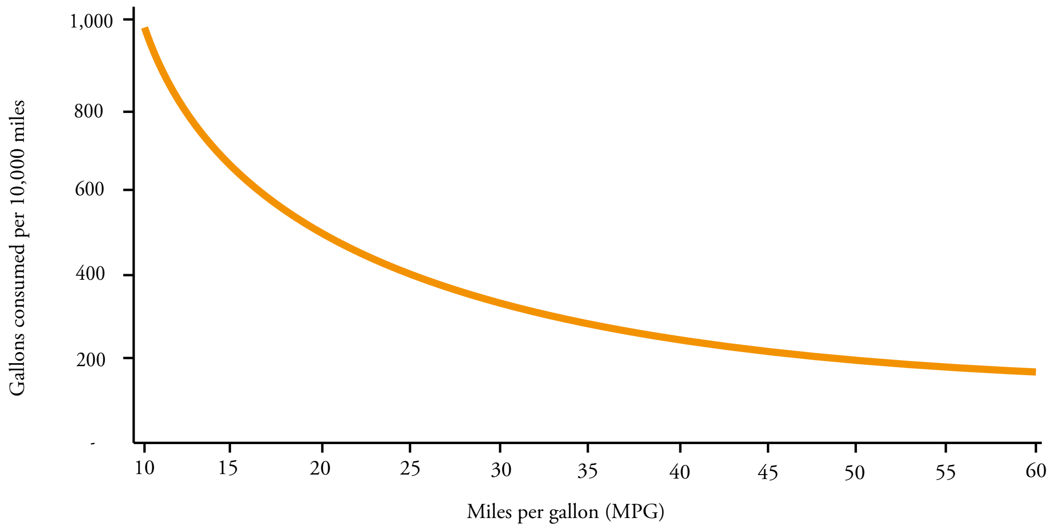


Notes: (a) Society of the Irish Motor Industry (SIMI, 2025), (b) Switzerland (Cerruti *et al.*, 2023) and (c) US Environmental Protection Agency (US EPA, 2024).

As with property efficiency labels, a further concern may be the extent to which consumers understand and internalize the fuel economy information contained in labels. Brazil and Caulfield (2017) use eye-tracking technology to test which aspects of the car label in Ireland attract the most attention. Most respondents focus their attention on the top of the colour coded rating (where the best performing vehicles are located), followed by the estimated annual fuel consumption of the car, its annual tax, and purchase tax rate. This may relate to the findings by Alberini *et al.* (2016a), whereby the "A" rating receives disproportionately more attention than the remaining grades. Other centres of attention found in Brazil and Caulfield (2017) correspond to the fuel consumption information at the bottom of the image and the details of the make and model of the car. This suggests that participants do pay attention to the fuel economy information in the label, however how well this fuel consumption information (in litres per 100km) is understood by consumers remains an area of concern. Turrentine and Kurani (2007) find in interviews that households do not analyse their fuel costs in a systematic way when making car or gasoline purchases. Using survey data in the US, Allcott (2011) also finds that American consumers devote little attention to fuel costs when purchasing vehicles.

In the US (panel [c] of figure 6), the top left quadrant of the car information label displays fuel economy in miles-per-gallon (MPG). Some studies find evidence of a MPG illusion (Larrick and Soll, 2008) whereby differences in fuel economy among higher MPG values are perceived

Figure 7
Miles per gallon (MPG) illusion



Note: "Figure illustrates the number of gallons of gasoline consumed per 10,000 miles driven at different MPG values (Larrick and Soll, 2008).

Source: Larrick and Soll (2008).

to have similar impacts on total fuel consumption as differences at lower MPG values. For example, the difference in total fuel consumption for a fixed driven distance between two cars rated at 11 MPG and 13 MPG is approximately the same as between two cars rated at 29 MPG and 49 MPG (Allcott, 2011b). This is illustrated in figure 7.

How the fuel economy/efficiency information is presented and understood by consumers is therefore of importance in facilitating comparisons between vehicles. Allcott (2011) argues that it is unclear whether the MPG illusion would influence consumers to purchase either vehicles with very low or very high fuel economy, since it should lead consumers to underestimate fuel economy differences in low MPG vehicles, and to overestimate the savings of the highest MPG vehicles. In Europe this should not be an issue since most labels display fuel economy as l/100km and therefore consumption scales linearly. However, the extent to which the l/100km metric is understood by European consumers and factored into future energy use forecasts is still unclear and warrants further future research.

4. DISCUSSION AND CONCLUSIONS

This paper discusses some of the issues around efficiency information provision in household purchase decisions. We focus our review on two of the largest purchases households typically make – housing and vehicles. Imperfect information is a likely barrier to efficiency investment in these settings, and therefore as per Allcott and Greenstone (2012) a first-best policy solution is to correct this by providing clear and easy to understand information. Information failures also interact with other market and non-market failure explanations to the energy efficiency gap, such as principal-agent problems and behavioural patterns. This suggests that there are potential multiple benefits of efficiency information provision beyond simply correcting information asymmetries between buyers and sellers.

In the property purchase domain, many studies find that more efficient properties are sold at a premium. Labelling has also been found to increase transparency in sales markets, particularly in the case of inefficient properties (Frondel *et al.,* 2020). There is therefore potential for labelling to improve welfare in property markets. This may be particularly true in the case of rental markets. Split-incentives problems and short tenure durations may mean that tenants are unable or unwilling to alter the efficiency of the property. If properties are let more often than they are sold, then the rating as an information measure may have greater exposure in rental markets – which could also mean greater value in information provision.

In the car purchase domain, many studies find that consumers undervalue efficiency (or fuel economy), and therefore labelling also has the potential to improve welfare. In stated preferences studies, it has been found that vehicle choice can be altered by additional monetary and emissions information provision. In revealed preference settings however, it appears to be more difficult to alter purchase choices simply through labelling at the point of sale. This may be due to preferences for other vehicle attributes (such as size or power), brand loyalty or due to timing in information provision. Consumers may conduct significant research on a vehicle of interest before going through with a purchase, therefore when the efficiency information is presented is likely important. Trust in emissions labelling in the car domain may be also of particular importance, given recent emissions scandals, and observed discrepancies between test results and on-road performance of vehicles (Tietge *et al.,* 2019).

Labelling may also have additional spillover benefits beyond correcting market failures at the individual level. Information from labelling may raise overall awareness of energy consumption and the role of efficiency in the public domain. This may lead to improvements in overall energy literacy. There may also be spillover effects into other domains, such as environmental awareness. In addition, labelling also provides important data which can be used in evaluating and guiding policy.

However, it is also important to understand the limits of information provision via labelling in altering purchase choices and delivering investments in efficiency. It is unclear whether efficiency information is fully understood by consumers, due to the complexity in calculating energy savings which include the need to understand and forecast energy prices and consumption. Monetary information provision (presenting efficiency information as €/$ bill savings) has been found to increase the demand for efficiency in multiple settings and research designs – highlighting a potential refinement to efficiency information provision. Monetary information however does not take into account the rebound effect or significant heterogeneity in usage patterns. Furthermore, efficiency measures may be subject to potential biases and errors in engineering estimates, and therefore need to be calibrated against real world consumption data where available.

It is also important to place the role of information provision within the context of other barriers, such as high up-front costs of more efficient purchases, principal-agent issues and uncertainty regarding future energy prices. For example, low-income households may be well aware of the benefits associated with efficiency improvements, however may not be able to realize these benefits due to prohibitively high upfront costs for investments in efficiency. Low-income households are also more likely to be in rental accommodation and therefore exposed to principal-agent issues. In these cases, it is clear that labelling alone may not encourage the adoption of more efficient appliances and therefore additional targeted supports or mandates for efficiency may be needed.

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