SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Fiscal Interventions to Change Energy Behaviour

A review of the literature

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Sustainable Energy Authority of Ireland
SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with Government, homeowners, businesses and communities to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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Preface

If Ireland is to meet its climate change obligations, we need fundamental changes in our energy system and our interactions with it. This calls for innovative approaches to transform us to a low-carbon society. Measures that encourage changes in our energy behaviour have the potential to substantially reduce greenhouse gas emissions.

Fiscal measures can be applied to incentivise or discourage certain behaviours. They are part of a wider package of government interventions being applied the world over to drive the sustainable energy transition. Examples of fiscal incentives are grants for retrofit actions, investment subsidies for energy-efficient equipment, low-interest loans, feed-in tariffs for renewable electricity, tax credits and tax exemptions. Fiscal disincentives include environmental taxes, levies and tolls.

The Government of Ireland already uses fiscal measures, as part of a wider policy package, to encourage pro-environmental behaviour. These include programmes and subsidies to encourage building retrofits, grants for low-emission vehicles, supports to encourage sustainable energy investment and reduce energy use in businesses, and a carbon tax to discourage the use of fossil fuels. The Government has acknowledged, via the *Climate Action Plan – To Tackle Climate Breakdown*, that additional measures are required to achieve the ambitious targets for 2030.

This report comprises a comprehensive review of international literature exploring the effectiveness of fiscal measures to change energy behaviour.

The evidence in this report will help inform the design and delivery of effective sustainable energy policies and measures to drive Ireland's low carbon imperative. SEAI is working with Government to ensure delivery of a comprehensive package of effective measures in this regard. As the policy package expands, we will continue to learn what works and how to further accelerate the transformation required.

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1. Introduction

1.1. Context

Climate change is now the greatest challenge of our generation and of future generations. Evidence of global warming as a result of increased greenhouse gas emissions and of its adverse effects on the climate and the environment is unequivocal, and human activity, in particular the burning of fossil fuels, has been identified as the dominant cause. In December 2015, a legally binding, international agreement was put in place to combat climate change (UNFCC, 2016). The Paris Agreement sets the goal of limiting global warming to well below 2 degrees Celsius with the ambition to limit temperature increase to 1.5 degrees. The EU's Nationally Determined Contribution under the Paris Agreement is to reduce greenhouse gas emissions by at least 40% by 2030 compared to 1990. As a party to the Paris Agreement, and in line with our EU obligations, Ireland is obliged to significantly reduce greenhouse gas emissions in the coming years. This will entail a transition to a more sustainable, low-carbon economy. Achieving this transition will require radical change in our national energy system and in our interactions with it.

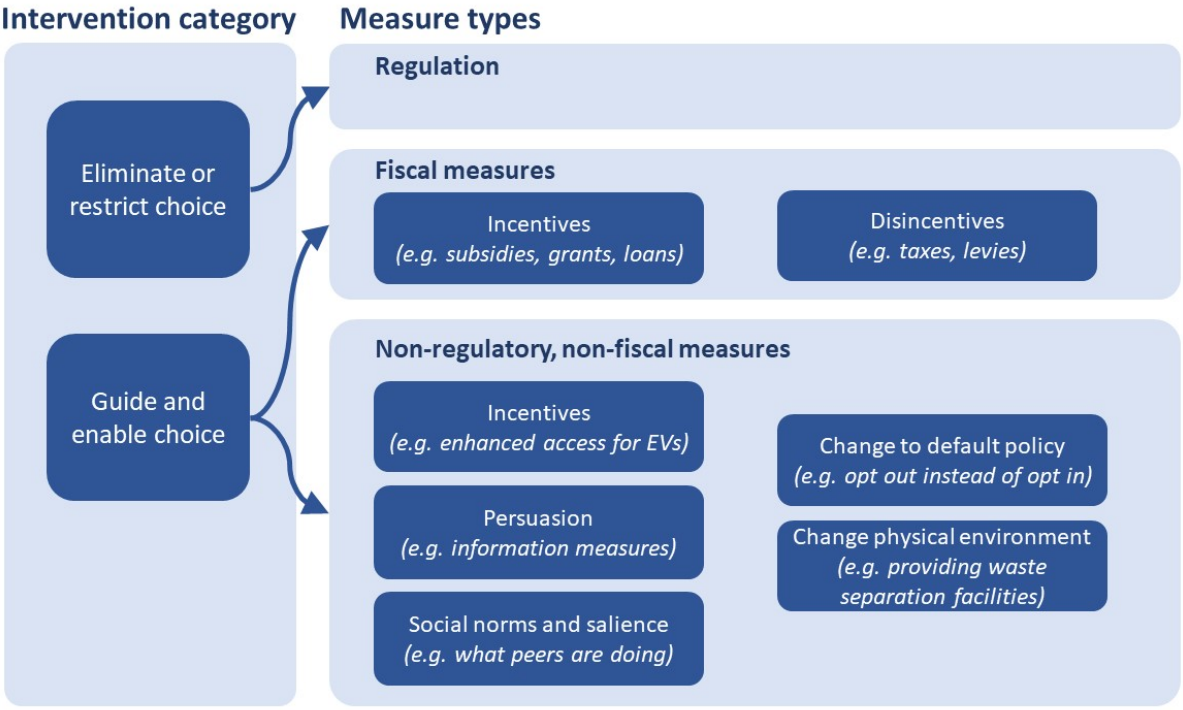
The Irish Government's response to the challenge of climate change and its plans for an energy transition are detailed in several high-level policy documents. Most recently, it has published the comprehensive All of Government Climate Action Plan (Government of Ireland, 2019a). The Climate Action Plan states that, by 2030, Ireland will need to have reduced non-ETS emissions by 30% relative to 2005. It commits to this reduction and details over 180 actions designed to meet that commitment. Key actions outlined in the Climate Action Plan to be completed by 2030 include: upgrading 500,000 existing homes to a B2 equivalent Building Energy Rating; installing 600,000 heat pumps in buildings; increasing the number of electric vehicles to 1 million and expanding the associated charging infrastructure. The Plan commits to increasing the share of electricity generated from renewable sources to 70% by 2030, to providing supports to homeowners to generate their own renewable electricity, and to discontinuing the use of coal and peat for the generation of electricity. It sets 5-year carbon budgets for sectors of the economy and establishes governance procedures for monitoring progress to targets. *Project Ireland 2040: National Planning Framework* is a strategic plan for the future growth and development of the country (Government of Ireland, 2018). It consolidates the Government's commitment to a transition to a low-carbon society by integrating climate change considerations into the planning process, promoting energy efficiency in buildings and systems, and supporting the sustainable rollout of renewable technologies. *The National Development Plan* sets out the investment priorities to underpin Project Ireland 2040: National Planning Framework (Government of Ireland, 2019b).

Yet, despite the enabling frameworks, Ireland already struggles to meet its existing international commitments. Binding targets for 2020 enacted in EU law in 2009 included a 16% renewable energy share, a national greenhouse gas emissions' reduction of 20% compared to 2005 (excluding the sector participating in the EU Emissions Trading Scheme), and a 20% improvement in energy efficiency. Ireland will fail to meet all three of these targets (EPA, 2019; SEAI, 2019). The *All of Government Climate Action Plan* acknowledges this and charts a pathway to 2030 that can bring Ireland back on track to achieve net zero emissions by 2050. While the Government must play a leading role in tackling climate change, our commitments can only be achieved through a concerted engagement by citizens, communities and civil society generally. Defining targets and putting in place supports to achieve them will not be sufficient to meet our obligations without changes in the behaviours and actions of each individual citizen or without the support of businesses. To this end, new and innovative instruments are needed to encourage pro-environmental behaviour and empower people to bring about the energy transition.

Irish people are ready for that transition. The findings of the 2017 Citizens' Assembly showed that Irish citizens want to place climate action at the centre of Irish policy-making and that people are prepared to do a lot more to avert the worst effects of climate change (Citizens' Assembly, 2018). The Citizens' Assembly identified a clear roadmap for climate action and made several recommendations for future policy. A special Joint Oireachtas Committee on Climate Action was established in 2018 to examine the recommendations. The All of Government Climate Action Plan acts on the recommendations of the Special Joint Oireachtas Committee. In its recent report, the Committee established that innovative financial measures are needed to assist citizens to transition to low-carbon lifestyles and that the existing framework of financial incentives should be reviewed and amended to ensure that a balanced, equitable and effective package of instruments is in place (Houses of the Oireachtas, 2019). By conducting a literature review of fiscal measures designed to change energy behaviour, this short report provides insights into potential opportunities for effective and innovative policy-making.

1.2. Focus of the review

Figure 1.1: Overview of behaviour change interventions for individuals. Adapted from House of Lords (2011)



Behavioural interventions can be categorised as those that restrict or eliminate choice and those that guide or enable choice (House of Lords, 2011). The restriction or elimination of choice is achieved mainly by regulatory measures that, for example, prohibit products or curtail certain behaviours. Measures that guide and enable choice, on the other hand, include both fiscal measures and non-fiscal, non-regulatory measures. Fiscal measures can be in the form of incentives that provide financial reward for changed behaviours (for example a grant, a soft loan or a rebate), or disincentives that make behaviours more costly (taxes and tariffs). Non-fiscal measures include non-monetary incentives and persuasive information measures to encourage more sustainable energy use. Such measures are often referred to as nudges.

Nudges are measures that alter people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives (Nordic Council of Ministers, 2016). Examples of nudges include: providing real-time information about current energy use requiring electricity consumers to opt out of a green electricity tariff rather than opt in and; measures that establish social norms such as sharing information with consumers about the typical consumption of their peers.

Table 1.1: A sample of existing fiscal measures in Ireland

Measure	Measure type	Behaviours / sectors targeted
Better Energy Homes Scheme	Grant	Encouraging homeowners to invest in a range of energy-efficient retrofits
Warmer Homes Scheme	Grant	Retrofits for homeowners in receipt of certain social welfare payments
Deep Retrofit Grant	Grant	Encouraging owners of older homes to invest in retrofits
Electric Vehicle Grant	Grant	Encouraging purchase of private and commercial electric vehicles
SEAI EXEED Certified Grant	Grant	Encouraging businesses to design energy efficiency into projects
Lighting Support Scheme	Grant	Encouraging small and medium-sized enterprises (SMEs) to invest in energy-efficient lighting
Sustainable Energy Communities	Grant	Encouraging communities to undertake projects that deliver community benefits
Home Energy Saving Loan	Soft loan	Encouraging homeowners to invest in retrofits
Home Renovation Incentive Tax Credit	Tax credit	Encouraging homeowners and landlords to invest in retrofits
Accelerated Capital Allowances	Tax relief	Supporting energy-efficient investments in business
Carbon tax	Tax	Reducing fossil fuel use across all sectors excluding fuel use covered by the EU emissions trading scheme
Motor tax based on CO2 emissions	Tax	Encouraging purchase of low-emission vehicles
Vehicle Registration Tax based on CO2 emissions	Tax	Encouraging purchase of low-emission vehicles

Ireland already has several significant fiscal measures in place to encourage energy-efficient and pro-environmental behaviour. For example, a suite of grant supports is available to homeowners under the Better Energy Homes Scheme to improve insulation, install heating controls and invest in renewable energy technology for their homes. The Warmer Homes Scheme aims to tackle fuel poverty by providing free energy upgrades to homeowners who qualify for certain social welfare payments. The Home Energy Saving Loan scheme makes low- interest loans available through credit unions for retrofits. The Home Renovation Incentive Scheme provides income tax credit to homeowners and landlords to the value of 13.5% of qualifying expenditure on their properties.

The Accelerated Capital Allowance Scheme is a tax incentive to encourage businesses to invest in energy-efficient equipment. The Sustainable Energy Communities Programme supports a community-oriented approach to building retrofits. Electric vehicle grants reduce the purchase price of electric vehicles for individuals and businesses. Carbon tax on fossil was introduced in 2009. The All of Government Climate Action Plan proposes successive increases in carbon tax to implement a rate of at least €80 per tonne by 2030 (Government of Ireland, 2019a). Many other fiscal incentives and disincentives exist, and these will need to be supplemented with new measures to meet the targets set in the Climate Action Plan.

A recent SEAI publication, *Changing energy behaviour – what works?,* examined international evidence of effective measures to encourage more sustainable energy behaviours (SEAI, 2018). The study covered all categories of behavioural intervention and recommended that a number of behavioural change measures should be trialled in Ireland. This report complements that research by focussing specifically on fiscal measures to change energy behaviours and examining the international evidence for effective policy-making. This report highlights insights extracted from the literature review that may prove useful when devising new fiscal measures to influence energy behaviour in Ireland.

2. Findings

2.1. Effective behavioural measures: Availability of evidence

Evidence helps policy-makers to make informed decisions. Evidence of the effectiveness of measures is provided by rigorous and scientific monitoring and evaluation of programmes. An extensive search of the academic literature and of grey literature sources was conducted in order to find evidence of the influence of fiscal interventions on energy behaviours. A large quantity of papers was examined and filtered for abstract review. A smaller number of the most relevant studies from the filtered results were selected for detailed review. Even at the filtering stage, it was evident that the number of studies evaluating relevant financial instruments was low. Most studies examined did not provide a scientific evaluation of the effectiveness of a particular instrument in changing energy behaviour. Some of the review studies in the literature confirm that this is indicative of a wider problem of lack of evaluations for measures implemented (Dougherty et al., 2015; Murphy, 2014). In Europe in particular, even in countries that would be considered exemplary in terms of their energy policy instruments, few programmes have any monitoring and evaluation that would enable them to be linked with effects (Murphy, 2014). Some papers examine aspects of behaviour and consider their implications for the design of instruments, some use outcomes of programmes to understand behaviours, while others evaluate the potential influence of proposed measures on behaviour. Comprehensive assessments of the direct and enduring impacts of fiscal measures are rare. Despite the large number of programmes implemented globally, little is known about the relative effectiveness of different types of fiscal measures. This is due to the absence of reliable evidence and the lack of consistent approaches to programme evaluation. This scarcity of evidence inhibits policymakers from learning from the experiences of others when formulating new programmes.

"Few programmes have any monitoring and evaluation that would enable them to be linked with effects."

The literature therefore presents an incomplete picture of the effectiveness of fiscal measures in changing energy behaviour. Consequently, this review doesn't attempt to compare fiscal instruments and determine which is most effective, based on the evidence found. Instead, it identifies the main themes of the papers examined and attempts to present the most useful information in them.

2.2. Monitoring and evaluation of measures

Monitoring and evaluation provide evidence of effective policymaking. Monitoring and evaluation can enable programme managers to optimise benefits of measures, understand the changing policy environment, adapt measures to changing circumstances, and demonstrate value for money. Evidence of success provided by monitoring and evaluation also helps to communicate the benefits of a programme and may assist others to replicate its achievements elsewhere.

Where evaluation of the effectiveness of financial measures is attempted in the literature, a wide variety of evaluation methods are applied. Ex-ante evaluations seek to assess the potential effectiveness of a proposed measure. Ex-post studies, on the other hand, attempt to determine the impact of an existing instrument or of a programme that is concluded. Many studies examined do not evaluate any particular measure but instead seek to understand human behaviour with respect to energy consumption or pro-environmental actions in order to design better, more effective policy measures.

Some ex-ante studies use engineering or stock models to predict consumer behaviour or consumption in response to a financial intervention (Brand et al., 2013; Simpson et al., 2016). More often, the ex-ante studies are based on a survey of stakeholders in the form of a structured questionnaire. Typically, contingent choice or stated preference surveys are used to assess consumers' willingness to pay or to change behaviour, or to determine their response to a measure (Andor et al., 2018; Collins and Curtis, 2018; Li et al., 2016; Olsthoorn et al., 2017). Many of these studies use the results of a stakeholder survey in an econometric model to assess overall impact of a proposed instrument (Baranzini and Carattini, 2017; Miu et al., 2018).

Ex-post evaluations are rarely built into programmes. Many of the ex-post evaluations in academic papers rely on national statistical data rather than real measurements collected by the programme administrators. Researchers attempt to assess the effectiveness of a measure by discerning trends or changes in statistical data rather than directly observing changed consumer behaviour (Borenstein, 2017; Jenn et al., 2018; Narassimhan and Johnson, 2018). Indeed, several ex-post evaluations don't appear to have any interaction with consumers or input from the administrators of relevant programmes.

The strongest programme evaluations are to be found for utility energy-efficiency programmes in North America. These ex-post evaluations use directly metered gas or electricity data to monitor the effects of an intervention. Characteristically, the evaluations are based on a *difference in difference* approach whereby consumption patterns of a treatment group of customers (participants in a programme) are compared to those of a control group (non-participating consumers) to measure impact (Cadmus Group Inc, 2016; NMR Group Inc., 2017). Evaluations of this type are generally scientific with a reasonably high level of confidence in the findings. Even with these types of evaluations, however, the persistence of savings is often not measured (Allcott and Rogers, 2014; Sussman and Chikumbo, 2016). Also, they generally cannot distinguish between changed habitual or curtailment behaviours (such as switching off lights) and one-off investment decisions (a new energy-efficient fridge for instance). These evaluations are typically supported by a survey of participating consumers and of programme administrators to better assess the qualitative aspects of the programme.

2.3. Understanding and targeting consumer behaviour

Many factors influence attitudes, motivations and behaviours of citizens with respect to energy consumption, including demographic factors such as age and gender, and socio-economic factors like education, wealth and income. A common thread in many studies examining the response of consumers to financial incentives is to explore the predictive value of these factors and consider implications for policy development (Aydin et al., 2017; Craig, 2018; Tanaka et al., 2017). For example, Craig and Allen (2014) find that political affiliation is a determinant of the engagement of consumers in pro-environmental behaviour in the south-east of the United States, with individuals to the left of the political spectrum more likely to participate in programmes and support the use of clean energy by utility companies. Aspara et al. (2017) assert that intelligence, and numerical intelligence in particular, has a positive effect on consumers' responsiveness to pro-environmental tax incentives, because it enables one to process the complex combination of pro-environmental benefits and economic benefits.

Segmenting and targeting consumer groups

Several studies examine the heterogeneity of consumer groups and define or stratify consumer segments. Generally, it is found that policies should differentiate between distinct consumer segments and, where possible, address the needs of each segment in a target group separately. These studies typically don't evaluate the effectiveness of measures but suggest how instruments might be designed in order to be more effective.

"Policies should differentiate between distinct consumer segments and address the needs of each segment in a target group separately."

Egmond et al. (2006a) describe how the diffusion of energy efficient technologies can be classified into an early market and a mainstream market in a target group. The early market comprises Innovators and Early Adopters, while the mainstream market is made up of Early and Late Majorities and Laggards. Diffusion of energy efficiency technology starts with the early market, followed by the mainstream market, and finishes with the Laggards. Innovators and Early Adopters are best influenced through knowledge transfer about innovative technology and products. Availability of subsidies is not a key influencing factor for this group and therefore they're responsible for substantial free rider effects. Financial instruments work best for the mainstream market if they're in the form of an up-front payment. Instead of choosing a generic *one-size-fits-all* intervention a more effective approach would be to choose instruments that fit the characteristics of the target group (Egmond et al., 2006b, 2006a).

When analysing Austrian homeowners' decisions to install a new alternative heating system rather than a fossil fuel system, Hecher et al. (2017) divide subjects into three groups: those in problem situations (as a result of a technical defect or dissatisfaction regarding the heating system); those in opportunity situations (as a result of a heating system replacement in the course of a building refurbishment, or the availability of specific subsidies) and; those looking at new builds. Financial incentives are most effective in influencing a decision to adopt an alternative heating system for those in problem situations. financial considerations are also important for the opportunity group but so too are convenience and access to expert information whereas most heating systems installed in new builds in Austria are alternative systems and therefore do not require intervention.

Sekar et al. (2019) analyse the heterogeneity in consumer usage patterns of domestic appliances in the USA. They examine the potential impact of energy-efficient appliances and find large variations in the potential for savings. They recommend that abatement programmes supporting the purchase of appliances should target high-use consumers to maximise savings and reduce abatement costs.

Investment behaviour versus curtailment behaviour

In households, energy-relevant decisions may be categorised as curtailment behaviours or investment behaviours. Curtailment behaviours, such as switching off lights or turning down heating levels, are performed frequently, are low or no-cost and achieve modest savings. Investment behaviours, for example insulating a home or purchasing an energy-efficient appliance, involve one-off decisions, require financial commitment and achieve high energy savings. Curtailment behaviour must be maintained for savings to persist whereas savings from investment behaviour are mostly enduring although levels of saving are influenced by behavioural factors. While curtailment behaviours are associated with personal norms, investment behaviours are linked with the expected consequences of those investment decisions, that is, costs versus financial and non-financial benefits (Kastner and Stern, 2015). Models used to analyse one type of behaviour are not necessarily relevant to the other and different policy options need to be explored for supporting each. Karlin et al. (2014) find that providing energy feedback, for example through energy bills, is effective in encouraging curtailment behaviour. The study also finds that concern about the environment has a greater influence on curtailment than on investment behaviour. Investment behaviour is best encouraged by overcoming relevant barriers such as cost and lack of information. It suggests maintenance behaviour as a third category of energy-related behaviour. Maintenance behaviour may lead to greater savings than curtailment behaviour, while still low-cost. Examples include servicing of boilers at appropriate intervals and regular control of thermostat settings.

"Models used to analyse one type of behaviour are not necessarily relevant to the other and different policy options need to be explored for supporting each."

Table 2.1: Primary attributes of investment and curtailment behaviours. Adapted from Karlin et al. (2014).

Attribute	Curtailment behaviour	Investment behaviour
Frequency	Repetitive/ daily/ habitual	Infrequent/ One-time
Cost	Low-cost/ no-cost	Requires financial commitment
Actions	Behaviour / habits/ practices	Technical/ structural/ purchases
Permanence	Reversible / non-durable	Long-term/ permanent/ durable
Lifestyle	Loss of amenities / comfort	No lifestyle change
Cognition	Conscious or sub-conscious/ little effort	Conscious/ requires effort
Impact	Small impact/ low savings	Higher impact/higher savings
Population	All	Often excludes renters/ low-income
Motivation	Saving energy/ moral	Consequential benefits /saving money

A study by Lavelle et al. (2015) categorises the two main strands of pro-environmental behaviour as habitual and occasional and finds little overlap between cohorts exhibiting each. People exhibiting habitual pro-environmental behaviour are more likely to be less well-off, suggesting that their behaviour may be due to financial necessity. Occasional pro-environmental behaviour, on the other hand, involves higher financial commitment and is displayed by more affluent individuals with higher incomes.

The report asserts that Irish retrofit schemes should be more sensitive to these socio-demographic differences. The influence of income on investment and curtailment behaviours is further explored by Umit et al. (2019) using survey data from several European countries. People on higher incomes were more likely to *report* that they save energy by investing in energy-efficient technologies than those on lower incomes[1]. Higher earners were also less likely to report that they engage in curtailment behaviour.

2.4. Investment behaviour in households

Investment behaviour typically involves one-off actions arising from conscious planning and decision-making. When making investment decisions that influence the energy efficiency of their dwellings, homeowners are not motivated by financial gain alone. Effective policy requires insight into the complex motivations for these investment decisions and an understanding of how measures can be designed to influence them.

Motivators and barriers to retrofitting

Fiscal measures designed to stimulate retrofits should consider the intrinsic motivations of householders to improve their homes. One of the perceived barriers to energy-efficiency investments in households is that costs are immediate while the benefits, in the form of energy savings, are accrued over a longer period of time. Yet, the motivation to save energy is often not the primary driver and the cost savings not the only benefit. Baumhof et al. (2018) surveyed owners of detached and semi-detached properties, undertaking retrofit actions, to determine the factors that led to their decisions and found that improvement in the appearance of the house and reduced building maintenance as a result of the interventions were the most important factors. Similarly, in Croatia, householders had a greater willingness to pay for measures that improved the aesthetics of the home, such as window replacement, than for less visible ones like heating or insulation (Matosović and Tomšić, 2018). A Danish study differentiates between householders who undertake retrofits out of necessity and those who do so for aesthetic or lifestyle reasons (Gram-Hanssen, 2014). While costs are important to both groups, payback times are only a consideration for the former. It recommends that, when providing advice on energy efficient retrofits to householders, energy professionals should be more aware of the non-economic aspects of the decision-making. A study analysing the Green Deal home improvement scheme in the UK attributes its low take-up partly to the assumption that households respond rationally to economic incentives and that the main barrier to action is a lack of capital. The Scheme failed to recognise the much greater aspirations that people have for themselves in their home, such as comfort, well-being and health (Rosenow and Eyre, 2016). By contrast, it has been found that in Irish households the decision to invest in an energy efficiency measure is determined mainly by the cost of investment and gains in energy savings, followed by comfort gains, and that environmental considerations were not very influential (Collins and Curtis, 2017)[2].

[1] Studies based on self-reported data can have significant limitations. Self-reporting can be subject to response bias, (that is, an individual's tendency to respond in a certain way), variations in the understanding of the questions being asked, and difficulties interpreting the strength of preference for chosen options due to the use of ordinal data in questionnaires.

[2] It should be noted that these findings are from a survey of homeowners. While surveys can be useful in understanding consumers' motivations for retrofitting, consumers may also be prone to confabulation. Confabulation describes the process by which people attempt to explain their decisions after the fact, which sometimes leads people to provide rationale for their behaviour which may not have actually influenced their original decision at the time.

Significant barriers to the adoption of renewable heating systems in German households are found to be technology-specific and not necessarily ones that can be overcome by providing financial incentives (Michelsen and Madlener, 2016). For instance, for wood heating systems there are concerns about the skills and the amount of work needed to operate them while for heat pumps, there are reservations about how they correspond to existing traditions and norms for heating systems. A separate study by the same authors finds that motivations for adoption of renewable heating systems differ between groups of homeowners (Michelsen and Madlener, 2013). It finds that house characteristics, such as dwelling size and energy standard, as well as household income, can predict levels of motivation. It recommends that rather than distributing financial incentives in an arbitrary way, a grant award should consider the variety of householders' motivations by awarding different grant sizes based on technology house characteristics (e.g. low-energy standard homes) and socio-demographic characteristics (e.g. low-income households, pensioners).

"Householders had a greater willingness to pay for measures that improved the aesthetics of the home, such as window replacement, than for less visible ones like heating or insulation."

Encouraging a whole-house approach to retrofits

The order of retrofit actions undertaken by householders can have a substantial impact on household energy consumption over a longer period (Simpson et al., 2016). Fiscal measures that support a whole-house approach to retrofits are likely to achieve higher efficiency gains and greater savings per Euro spent than instruments that support isolated interventions. An analysis of retrofits undertaken by Canadian households, subsequent to completion of home-energy audits, found that householders did respond to the multiple recommendations given to them, but that actions weren't necessarily done in the right order, thus significantly reducing the energy-saving potential (Hoicka and Parker, 2018). That report recommends that supporting instruments should facilitate an integrated, staged approach to retrofits to ensure that they are done in the correct sequence and that a longer timeframe be allowed to complete them.

A whole-house approach involves carrying out multiple measures at the same time. Typically, a technical assessment determines the optimal combination of the most appropriate measures, addressing both the fabric of the building and its energy systems, to achieve a significant improvement in the energy efficiency of the building. The whole-house approach is encouraged by the German *KfW* programme of support for construction and refurbishment of homes (Thomas et al., 2016a). The programme leverages the German government's excellent credit rating to provide low-cost loans, through high street banks, to householders for construction and for energy-efficient retrofits of homes that meet defined energy-efficiency criteria and substantially exceed minimum energy performance standards. In addition to the low interest rate, the householder can either get a grant for part of the total costs or a write-off of part of the total loan value. The level of grant or write-off depends on the level of energy efficiency achieved. The higher the energy efficiency the greater the amount. The operators of the programme recommend an energy consultant to assist in planning the intervention and provide support to the owner of the building throughout the process.

Clustering of whole house retrofits is becoming more common in Europe. Retrofits are undertaken simultaneously in many houses in the same neighbourhood. The approach lowers total costs by achieving economies of scale and enables the work to be completed very quickly. This clustering approach is exemplified by the Dutch *Energiesprong* programme (Energiesprong, 2019; Thomas et al., 2016b). The programme provides support for significant building retrofits that aim to dramatically improve energy efficiency. Buildings are addressed in clusters rather than individually and the whole-house method is used to address the building envelope, the energy sources and energy-using appliances.

Disruption to the occupants is minimised by tackling all interventions together and by completing the work in a short period. The aim is to create net zero energy homes. A building retrofit comes with a 30-year performance guarantee on both the indoor climate and the energy performance. Retrofits are funded by the reduced energy bills of the house. The household pays an *energy plan* and the landlord receives an on-going income to fund similar works to more homes. Whilst the programme was initiated in the Netherlands, it has been expanded to serve several other European countries. It uses the social housing sector in each market as the launching market for its solutions, with a view to extend to the private home-owner market. The All of Government Climate Action Plan proposes to group retrofits together to achieve economies of scale, leverage private finance, and ensure easy pay-back methods (Government of Ireland, 2019a). It cites the Energiesprong programme as an example of how this could be achieved.

Incentivising the purchase of energy-efficient domestic appliances

There are few fiscal incentives to encourage the purchase of domestic appliances in Europe. Preferred measures are more typically regulations that stipulate minimum efficiency levels and information measures in the form of labelling. Evidence from elsewhere indicates that financial incentives for appliances have had limited success. In the USA, domestic appliance rebate programmes have been estimated to increase the sales' share of Energy Star energy-efficient appliances by between 3.3 and 6.6 percentage points (Datta and Filippini, 2016). Other evidence suggests, however, that while consumers are prepared to pay more for Energy Star appliances, the availability of a rebate did not improve their willingness to pay for an appliance. Indeed, the very presence of a rebate meant that consumers were less likely to associate Energy Star certification with high product quality (Li et al., 2016). In Japan, consumers who purchased energy-efficient appliances under the *Home Appliance Eco-Point* Scheme earned points that could be exchanged for environmentally friendly products and services, or for vouchers. It was found that that the Scheme increased the stock of energy-efficient appliances but no overall change in electricity consumption could be discerned (Nakano and Washizu, 2017). A later study concludes that the carbon abatement costs associated with the Scheme were very high and that it had not been cost effective (Nishijima et al., 2019).

"Evidence indicates that financial incentives for appliances have had limited success."

Design of fiscal incentives for energy-efficiency investment

Fiscal incentives for investment behaviour are commonly in the form of an investment grant, a rebate, guaranteed payments (for instance a feed-in tariff), low-interest loan, or tax relief. In general, consumers appear to prefer discounts in the form of cash payments or discounts at the point of purchase. The design of an incentive, and the means by which the incentive is delivered, can influence levels of participation and thereby the effectiveness of a scheme. Irish householders are found to strongly prefer cash payment subsidies to indirect methods of financial support such as tax credits (Collins et al., 2018). That cash payment could be in the form of an upfront discount on the cost of the work or cash back once the work is complete. Financial incentives for the purchase of low or zero-emission vehicles are found to be more effective when paid upfront in the form of a grant, rebate, or a VAT or purchase tax exemption (Brand et al., 2013; Hardman et al., 2017). However, in Japan, it was found that the availability of a feed-in-tariff accelerates the decision of householders to invest in solar photovoltaic systems, but the availability of a subsidy does not (Tanaka et al., 2017).

"In general, consumers appear to prefer incentives in the form of cash payments or discounts at the point of purchase."

As evidence is scarce, it is not possible to compare the relative effectiveness of different fiscal measures in encouraging homeowners to retrofit their homes or install energy efficiency technologies. However, it is clear from the literature that programmes should be carefully designed to segment audience and be closely aligned to the benefits consumers care about, while reducing barriers to uptake as much as possible. These benefits and barriers are often unique to the behaviour change being encouraged; policies should therefore be carefully designed with this in mind.

2.5. Curtailment behaviour in households

Financial incentives are used widely to encourage households and individuals to invest in low-carbon technologies. However, effective financial incentives that support sustained curtailment behaviour and that deliver enduring savings are harder to find. Although investment subsidies can help overcome the high upfront costs of an energy-saving intervention or a renewable energy technology, they have no direct influence on consumers' behaviour after purchase. Policies that focus only on the uptake of a technology and ignore behaviour after uptake are not maximising savings that can be achieved (Bergman et al., 2009).

Field experiments have shown that consumers can respond positively to financial incentives to reduce energy (Mizobuchi and Takeuchi, 2013), but also that the positive influence of a reward can diminish once the incentive is removed (Abrahamse et al., 2005). A UK trial found that incentivising householders to reduce peak electricity demand can be effective but could be more successful if consumers could select from a variety of financial incentive mechanisms according to their preferences (Bradley et al., 2016). Eirgrid's Power Off andSave pilot programme rewarded consumers who agreed to reduce their electricity use in periods of high demand (Eirgrid & Electric Ireland, 2018). Participating consumers were requested to switch off appliances for about 30 minutes on ten occasions and were rewarded with up to €100 off their bill. Although a robust full-scale evaluation of the programme has not yet been carried out, preliminary results indicate that around 50% of participants responded to the requests resulting in a reduction of available load of between 9% and 17%. Bertoldi et al. (2013) outline a number of isolated programmes that have had some success in encouraging curtailment behaviour using financial incentives. A short programme in Ontario, Canada, offered a 10% rebate to residential and business customers who reduced their electricity use over the summer period by 10% relative to the previous year. 24% of businesses and 30% of households achieved enough savings to qualify for the rebate. A pilot programme in Trondheim, Norway, agreed a fixed price and electricity consumption profile with participating households. For electricity consumption above the agreed profile, households were required to pay a spot price per unit which was generally higher than the agreed price. For consumption below the agreed profile the supplier bought back the saved energy at the spot price. Savings achieved by the pilot were partly attributed to informing customers about their contract and making them aware of the potential to save money if they changed behaviour. Generally, however, non-financial measures such as information and feedback are more commonly applied to encourage curtailment behaviour. For a review of the evidence in this area, please see the SEAI report, Changing energy behaviour – what works? (SEAI, 2018).

Bertoldi et al. (2013) propose an energy savings feed-in tariff, financed through energy bills, that rewards energy consumers for reducing metered energy use below a baseline or target value. This novel approach could achieve enduring savings by maintaining the incentive to reduce energy every month and may be more successful in changing habits and encouraging sustained curtailment behaviour. This rewards' concept is combined with smart meters and applied in a new pilot programme in Germany called *Energieeinsparzähler*, or *Energy Savings Meter* (Weiss et al., 2017). With this government-supported scheme, a baseline energy use is calculated by the energy service provider for each participating consumer. Regular, detailed information on energy use is provided and savings below the baseline are rewarded. In the pilot scheme, 25% of the service provider's project development costs are supported with half of the funding conditional on achieved and verified savings.
This is a highly innovative scheme that uses advanced metering infrastructure, currently being rolled in several countries, to open up the residential and SME market to energy services and tap into new savings potentials.

2.6. Pro-environmental behaviour in businesses

Barriers to pro-environmental behaviour in businesses are well documented. In a study of UK SMEs, the main obstacles to reducing their impact on the environment included: the lack of funding; the high upfront costs of efficiency measures; lack of clear advice from state bodies; lack of specialist expertise and; the perception that return on investment in energy efficiency measures was too low (Baranova and Paterson, 2017). For businesses using leased premises there is the barrier of the *landlord-tenant dilemma* whereby the owner of the premises would not receive all the benefits of an investment in energy efficiency (Schlomann and Schleich, 2015). Additionally, there is often a low level of awareness among small businesses of financial instruments designed to save energy (Liu et al., 2014). Policies designed to encourage energy efficiency in businesses are typically designed to overcome these barriers. These include: establishment of voluntary agreements for larger companies; encouraging a market for energy services; provision of expertise; support for the establishment of energy management practices and; subsidies. Qualification for financial incentives is sometimes contingent on participation in programmes. For example, a significant aspect of a voluntary agreements' programme for industry in Denmark is the linking of the voluntary scheme with qualification for a CO_2 tax rebate to encourage businesses to cooperate (Johannsen, 2002). Government participation is an important factor in the success of voluntary agreements. The availability of incentives indicates the government's goodwill and commitment and incentives are perceived to compensate for costs foregone (Lee et al., 2016). Whilst we are aware of a number of studies that investigate the impact of subsidies on the uptake of energy-efficiency upgrades and lighting installations, they did not meet the inclusion criteria of our literature search and are therefore not described here.

"In most organisations, cost-effective investments in energy efficiency don't have strategic value and, as a result, the business case for energy efficiency doesn't feature in these organisations' investment decision-making processes."

By providing public funds to support programmes, the aim is to remove barriers, make improved energy efficiency more cost-effective and thereby increase the demand for energy-efficient technology (Backlund et al., 2012). This barrier-based approach to policy-making is challenged by some researchers (Biggart and Lutzenhiser, 2007; Mallaburn, 2018). It is well established that organisations don't necessarily behave rationally when barriers are removed and that cost-effective energy measures are not always implemented. One significant reason for this is that, in most organisations, cost-effective investments in energy efficiency don't have strategic value and, as a result, the business case for energy efficiency doesn't feature in these organisations' investment decision-making processes. Mallaburn (2018) describes how *salience*, that is, the propensity of an issue to be noticed and acted upon, works as part of the decision-making process for energy-efficiency investments. Issues first become salient during an early identification phase, possibly amplified by a sensitising event that distracts the organisation from its core business and allows it to focus on new opportunities. The salience of energy efficiency is generally greater in larger companies, in companies that deal with the public or that operate in environmentally sensitive fields, and in organisations where there are strong connections between energy teams and senior managers. The study argues that government policy should focus on companies where salience drivers are weak, develop policies that influence salience drivers, and support investments as they move along the decision-making process.

Organisations can also improve their energy performance by encouraging pro-environmental behaviours among employees. The extent to which financial incentives can achieve this is uncertain. In one study a framework of determinants for employee pro-environmental behaviour at the workplace was developed consisting of factors that act at individual, group, organisational and external levels (Young et al., 2015). It found that financial incentives provided to the employee could be effective at individual and group levels. However, a real-life experiment conducted among employees of a Dutch firm suggested otherwise (Handgraaf et al., 2013). It found that social rewards to encourage energy-efficient practices among employees produced better and longer-lasting results than monetary rewards. It concluded that concentrating on normative aspects of pro-social behaviour, both descriptive (telling people what other people do) and injunctive (what is commonly approved or disapproved), may be more effective than focussing on materialistic rewards.

2.7. Energy taxes and levies

As well as being a means of raising revenue for the state as efficiently as possible, taxes can be used to encourage behaviour change among individuals, households and businesses, and to pursue economic and social policy goals (Acheson and Lynch, 2017). A carbon tax attempts to address the negative effects of harmful environmental emissions associated with consumption of fossil fuels; it ensures that the fuel price paid by the consumer more accurately reflects the damage to the environment and the cost to society as a whole. A carbon tax also endeavours to influence energy-consumption behaviour and therefore its success should be assessed not just by the revenue it raises but also by its effectiveness in bringing about behavioural change.

"It is important that environmental taxes and levies be seen to be equitable in order to win acceptance among the public."

It is important that environmental taxes and levies be seen to be equitable in order to win acceptance among the public. One study highlighted the significance of communicating the benefits of a carbon tax to improve its acceptability to the public (Baranzini and Carattini, 2017). It found that the perceived positive environmental impacts and the potential of local co-benefits from revenues raised were the main drivers of acceptability among the public. It also found evidence that even renaming a carbon tax to a 'climate contribution' could improve its acceptability. In Germany, where the costs associated with renewable electricity generation are financed by a charge to consumers' bills, a stated preference study found that consumers are far more willing to pay a significant increase if the exemption from the charge, currently in place for energy-intensive industry, was removed (Andor et al., 2018). This suggests that the perceived fairness of taxes/levies is important for their public acceptability. In Ireland, the Citizens' Assembly indicated that people are willing to pay higher taxes on carbon-intensive activities, subject to the qualifications that revenue raised would be used to aid Ireland's transition to a low-carbon economy, that poorer households would not have to pay more, and that increases would be introduced over a number of years (Citizens' Assembly, 2018).

Carbon taxation is likely to play an important role in helping Ireland to achieve its climate ambition as outlined in the All of Government Climate Action Plan (Government of Ireland, 2019a). The setting of a clear trajectory to €80 per tonne in 2030 is likely to influence investment decisions over the time period. While there have been studies, based on macro-modelling the economy to estimate the impact of such changes on emissions in Ireland (Conefrey et al., 2013; de Bruin and Yakut, 2019; ESRI, 2019), there is little evidence available to directly link changes in carbon taxation to changes in behaviours.

This is not to say that carbon taxation does not impact on individuals' behaviours or choices, but it does show that few studies have attempted to provide a causal link between macro changes in a carbon tax and specific behaviours at the micro level. A comparative experiment in the UK emphasised the importance of making the carbon tax element of the energy price highly visible when designing policy, in order to maximise behavioural impact and ensure consumers don't just focus on the bottom line (Parag et al., 2011).The introduction of a revenue-neutral carbon tax in British Colombia, Canada, in 2008, was found to have reduced emissions from fuel by between 5% and 15% by 2015, relative to a counterfactual, with negligible adverse effects to the economy (Murray and Rivers, 2015). A review of the history of carbon tax in the Nordic countries, and of studies that examine its effectiveness, finds that, while the Danish CO_2 tax appears to be the most effective, the overall impact of carbon tax on energy behaviour is difficult to determine due to the wide variety of evaluation methods used in the different countries, and the significant differences in assumptions, approaches and results (Andersen, 2004).

"Making the carbon tax element of the energy price highly visible can maximise the behavioural impact."

In recent years, many governments have redesigned taxes to bring about a reduction in CO_2 emissions from passenger vehicles. A strong upfront price signal, in the form of a vehicle registration tax for instance, is more effective than a tax on fuel or on running costs due to consumers undervaluing long-term savings (Dineen et al., 2018). In 2008, Irish vehicle registration tax and annual motor tax changed from being related to engine size to being based on levels of CO_2 emissions. The purpose was to encourage consumers to purchase more efficient cars with lower emissions. The change resulted in consumers immediately switching from purchasing petrol to low-emission diesel vehicles rather than purchasing cars with smaller engines. Reductions in emissions arising from the change were modest and there was a considerable loss in Government revenue (Rogan et al., 2011). The impact that increased sales of diesel cars can have on air quality highlights the need to be mindful of the unintended consequences of interventions. Nevertheless, the experience demonstrates the significant and immediate impact a change in motor taxation policy can have on vehicle purchasing behaviour.

2.8. Financial measures and free riders

Free riding occurs when subsidies are paid to consumers who would have made the investment or purchased the technology even without the subsidy. Ignoring free riders when evaluating a financial measure leads to an overestimation of the cost-effectiveness of the measure and of the savings attributed to it. Free riding also represents wasted subsidies. Financial measures must be designed to minimise free riding.

Free riders can be difficult to identify. It is also likely that eliminating all free ridership may not be possible or may incur such administrative burden as to limit the overall effectiveness of the programme, which is undesirable. Free riding is usually assessed by surveying consumers and understanding their motivations for the interventions they've undertaken. Estimates of the extent of free riding in the literature vary substantially depending on subsidy levels, technologies used and the consumers targeted by the subsidy. In Ireland, the Better Energy Homes programme, run by SEAI, gives fixed cash grants for insulation and heating system upgrades. Recent analysis of the programme indicates that levels of free riding are low, with 8% of participants classed as free riders, and a further 7% partial free riders (SEAI and ESRI, 2018). Partial free riders are participants who would have undertaken upgrades if a lower grant was available. An analysis of a series of domestic retrofit subsidies in Croatia found that insulation and heating replacement incentives were without free riders but that the level of free riding for window replacements was 100% (Matosović and Tomšić, 2018). In the USA, evaluations of the effectiveness of utility energy-efficiency programmes commonly incorporate an assessment of free riders.
In a commercial demand side management programme in Maine, for instance, that incorporated a range of financial incentives, free riding and spillover effects were estimated by means of a survey of the programme participants. Based on their analysis, the evaluators reduced the calculated gross savings by 28% to account for the joint effects of free riding and spillover (Nexant Inc., 2017, 2016).

When designing financial measures, potential free riders should be excluded from the target consumer group, where possible. One interesting study differentiates between *strong* and *weak* free riders (Olsthoorn et al., 2017). Strong free riders are consumers that were planning to invest in a technology anyway, whereas weak free riders are consumers not originally planning to invest but who decided to do so after receiving information about an attractive technology. A stated-choice experiment conducted across several European countries distinguished weak free riders among the population by identifying those who opted to replace their heating system once total costs and total savings were presented to them without any subsidy option. While several studies assert that a combination of complementary measures can be more effective in encouraging consumers to adopt energy efficient technologies, this study advocates that rather than implementing subsidies and information programmes simultaneously, they could be introduced sequentially: firstly, information programmes providing details about costs and savings and, latterly, the subsidies. By introducing information measures first, the number of weak free riders may be reduced substantially[3].

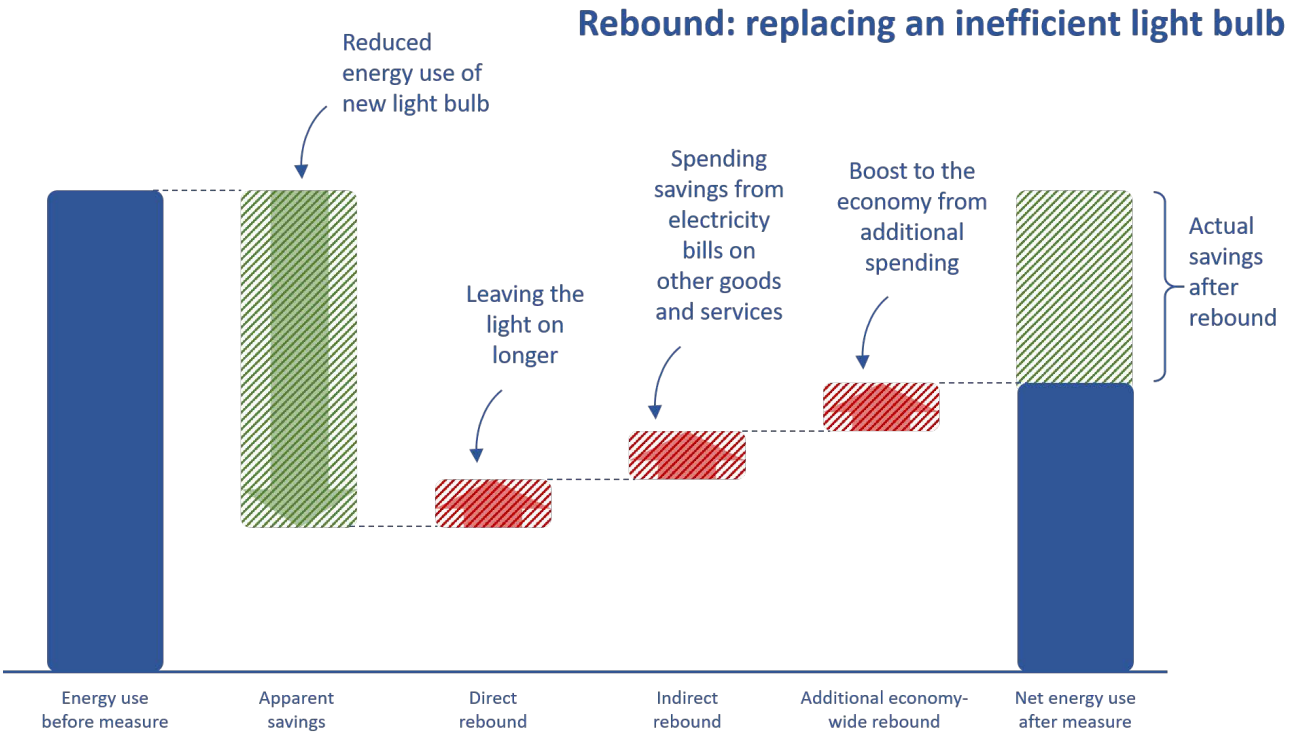
"To minimise free riding, information programmes could be introduced first, followed by subsidies."

[3] It is worth noting that these results are from a hypothetical choice experiment and so, while insightful, they may not be predictive of actual behaviour. A field experiment testing these findings should be conducted before relying on these insights for policy design.

2.9. Consumer behaviour and rebound

An important consideration when analysing consumer behaviour with respect to energy saving is *rebound*. Rebound is the increased demand for energy arising from an increase in energy efficiency. Improved energy efficiency reduces the cost of an energy service to the consumer, which in turn, increases the demand for that service (direct rebound). The cost savings provide the consumer with a greater means for consumption of other goods and services that require energy to produce (indirect rebound). The increased economic activity as a result of this expenditure serves to further increase demand for energy in the global economy (economy-wide effects). Savings arising from a subsidy programme to encourage more energy-efficient behaviour can be lower than expected as a result of rebound.

Figure 2.1: Illustration of the impact of rebound on apparent energy savings



Quantifying total rebound involves assessing the extent to which apparent energy savings must be reduced to give total energy savings, when the direct, indirect and economy-wide effects on all fuels are taken into account. Most studies examining rebound attempt to quantify direct rebound effects, typically by examining energy consumption before and after an intervention. Fewer try to assess total rebound including indirect or economy-wide effects across all fuel types. Indirect and economy-wide effects are typically estimated using econometric models that look at the distribution of expenditures and market adjustments after the change in energy expenditure, arising from the intervention. In the UK, residential sector rebound has been estimated to be modest for a variety of common interventions addressing domestic electricity and heating fuel use (0-32%) but larger for measures to reduce vehicle fuel use (25-65%) when all rebound effects are taken into account. Rebound is greater for low-income households as they spend their savings on more energy-intensive necessities such as food and drink (Chitnis et al., 2014).

"Rebound is greater for low-income households as they spend their savings on more energy-intensive necessities."

The rebound effect associated with a Dutch information and subsidy programme, that encouraged households to improve the efficiency of their homes by one or two points on a scale for building energy performance certification, has been estimated at 55%, with rebound increasing for households with lower income (Aydin et al., 2017). In Sweden, on the other hand, total rebound effects for energy-efficiency improvements in the home were found to be in the region of 5-15% (Nässén and Holmberg, 2009). In extreme cases, rebound could exceed 100%, that is, the gross savings from the measure are cancelled out by the resultant increase in energy consumption. This is known as *backfire*. While evidence of backfire in the literature is not convincing (Sorrell, 2009), the extent to which rebound may effect savings needs to be taken into account when considering the impact of behavioural responses on energy efficiency measures.

A related but distinct phenomenon, described in recent literature examining household energy consumption, is *prebound* (Hoffmann and Geissler, 2017; Sunikka-Blank and Galvin, 2012). It has been found that the calculated energy demand of a dwelling with poor energy performance tends to be higher than the actual energy consumption of the dwelling. Reasons may include inaccurate values used in engineering calculations, for instance, values used to determine the building's energy rating, and the consumption behaviour of the occupants. The poorer the thermal performance of a house, the more economically the occupants tend to behave with respect to their space heating. Prebound describes the overestimation of the potential savings of a particular intervention as a result of these effects. The impact of planned policies devised to improve the energy efficiency of the housing stock, for example large-scale national deep retrofit programmes, can be miscalculated if prebound effects are not considered. Prebound can be avoided by basing savings' predictions on measured data rather than on modelled results using standard values.

2.10. The need for complementary measures

Multiple barriers require multiple instruments. A number of studies point to the increased effectiveness of a comprehensive suite of diverse and synergistic measures to influence behaviours rather than a series of stand-alone measures designed in isolation. The most effective policy involves a combination of complementary measures of different types. Effective instrument packages may take into account the diversity in target groups, for example, levels of income or education, or may allow for market changes over time, such as the maturity and diffusion rate of an energy technology. A restrictive instrument may be strengthened by a complementary stimulative instrument. For instance, financial incentives for energy-efficient building interventions may be designed to assist homeowners to meet the regulatory requirements for building refurbishments (Murphy, 2014). Information measures are needed to complement subsidies to address the combined impediments of lack of awareness and the perception of prohibitive costs (Mahapatra and Gustavsson, 2009; Olsthoorn et al., 2017). An instrument package might encourage a *whole house approach* to building retrofits rather than a series of one-off interventions. While an individual measure may be effective in promoting the adoption of an energy-saving measure, a mixture of different instrument types may be needed to encourage sustained pro-environmental behaviour.

"The most effective policy involves a combination of complementary measures of different types."

Policies don't act in isolation but as part of complex policy architectures (Ürge-Vorsatz et al., 2007). This combination of interacting and complementary policy components makes it difficult to assess the effectiveness of individual instruments, disaggregate impacts and attribute savings to each. Monitoring and evaluation methods should therefore be designed to evaluate a complete package of complementary measures rather than single instruments, but they should also provide sufficient insights into the shortcomings of the package and help to identify what supplementary measures might be needed.

2.11. Limitations of financial measures in effecting behavioural change

Most of the studies in the literature attempt to provide insights into the effectiveness of financial measures or examine how behaviours are positively influenced by such measures. However, some warn about the limited capability of financial incentives to stimulate sustained pro-environmental behaviour. Frederiks et al. (2015) found that larger incentives or disincentives lead to greater behavioural responses but that the effects of financial incentives are often surprisingly short-lived and inconsistent, with behaviour reverting back to baseline levels upon removal of the reward. They point out that even when it is financially advantageous for consumers to avail of a technology or to change behaviour, many still don't act.

Therefore, the shortfall between people's behaviour and their environmental concerns is not explained by their pursuing material interests or extrinsic rewards, and the effectiveness of financial measures will be limited. Fleiß et al. (2017) warn that reliance on financial incentives may crowd out intrinsic motivations for pro-environmental behaviour, as beneficiaries may feel entitled to act less sustainably in other domains, having already *done their shar*e. Similarly, Karlin et al. (2014) describe how *single action bias* can occur when people respond to an issue such as climate change by taking a single action, and that that single action deters further actions in the future. They also indicate that focussing on several individual behaviours with separate measures can lead to information overload and diminished decision accuracy.

A concern in some studies is that subsidies are regressive as they tend to be availed of by wealthier consumers and in neighbourhoods with higher living standards. A Californian study found that the installation of photovoltaics in residences, and consequently the take-up of state supports, is heavily skewed towards the wealthy. This is due to the high installation costs and the tiered electricity tariff structure that makes solar more economically viable for higher consumption households (Borenstein, 2017). German research on the potential uptake of zero-emission vehicles suggests that more affluent households are more likely to benefit from subsidies as electric vehicles are often purchased as a second or third car (Rudolph, 2016).

"The effects of financial incentives are often surprisingly short-lived and inconsistent, with behaviour reverting back to baseline levels upon removal of the reward."

Table 2.2: Advantages and disadvantages of broad fiscal measure types

Measure category	Attributes	Advantages	Disadvantages
Grant	• Covers part of the cost of an intervention; requires additional co-financing; • Often combined with other financing mechanisms such as soft loans; and • Typically administered centrally by national administrator.	• Improves affordability of energy efficient retrofits; • Specific consumer groups can be targeted using eligibility criteria; and • Can be used to encourage demonstration projects or support new technologies that are not yet cost-effective.	• Can lead to cost inflation of interventions supported; • Can be regressive if affordability of interventions for different segments is not considered; and • Can create administrative burden for recipient if not well designed.
Soft loan	• Loan provided for particular interventions at low interest rate; • Typically delivered through existing credit institutions; and • Risk of bad debts often shared with lending institutions.	• Can be targeted at particular interventions; • Funds can be re-invested when the loan is repaid; and • Enables borrower to meet repayments with energy cost savings.	• Less suited to people on lower incomes or with poor credit rating.
Income tax relief	• House owner receives tax credit on income equal to a percentage of total retrofit costs for qualifying measures.	• Improves affordability of energy efficient retrofits; and • Can help to ensure retrofits are carried out in a tax-compliant manner.	• Excludes individuals not in receipt of regular taxable income; • Does not address barrier of high upfront costs; and • Reduces Government revenue.
Corporation tax relief	• Typically, in form of accelerated capital allowance for capital equipment • Deduction of full costs against taxable profits in one year	• Provides improved cash flow to companies • Can be designed to support new technologies and highest efficiency products	• Can involve high level of administration; • Reduces Government revenue; and • Only beneficial to companies currently in profit.
Carbon tax	• Tax applied to all fossil fuels at a level based on carbon content.	• Can reflect the social cost of consumption of fossil fuels; and • Provides revenue that can be used to finance climate mitigation measures.	• Regressive if not well targeted/well recycled; • Increased potential for carbon leakage and fuel tourism; and • Complex interaction with EU Emissions Trading Scheme.

3. Conclusion

The energy transition needed to meet Ireland's climate change obligations will require innovative policy measures to encourage more sustainable energy behaviour among citizens. This review has examined the scientific literature to find evidence on the effectiveness of fiscal measures to change energy behaviour. A significant finding is that, despite the broad scope of the review, relatively few studies have been identified that provide an assessment of the effectiveness of specific fiscal measures in changing energy behaviour using scientific methods. Instead, studies tend to examine and classify pro-environmental behaviour of individuals, households and businesses, and consider how this behaviour can be influenced by policy. Others conduct field experiments to try to determine what kinds of fiscal incentives could work. Hence, there is a lack of evidence in the literature that robustly demonstrates a causal link between fiscal instruments and energy-efficient behaviour globally.

Many of the studies that do attempt to measure the effects of implemented programmes, do so by discerning patterns in national statistics rather than by using more reliable feedback or data directly from programme participants and administrators. Rarely is a monitoring and evaluation procedure integrated into the programme. This may be attributable to the costs of undertaking such activities, the lack of required expertise, or the absence of standard approaches to policy evaluation. When putting programmes in place to change the energy behaviour of Irish consumers in the future, consideration should be given at the design stage to incorporating methods to assess the effectiveness of policy and programmes to contribute to the scientific literature on this subject.

Care should be taken to avoid a one-size-fits-all approach when putting in place financial measures. Financial measures will be more effective if they focus on segments of a target group that have been identified to respond best to price signals. Segmentation can help target hard-to-reach groups, minimise the undesired regressive effects of financial incentives, and maximise savings by focussing on segments where savings' potential is the greatest.

For many businesses, in particular small businesses, cost-effective energy-efficiency interventions are often not implemented because energy efficiency does not have strategic value. Energy-efficiency opportunities do not become salient as they are not part of an organisation's core business. Policies could target business sectors where salience of energy efficiency is weak and seek to influence salience drivers. Fiscal measures should support organisations once energy-efficiency investments are prioritised.

The All of Government Climate Action Plan sets out a target to upgrade 500,000 homes to a B2 Building Energy Rating standard by 2030 (Government of Ireland, 2019a). Achieving this standard for many of these homes will require extensive energy upgrades. Policies to encourage more ambitious whole-house approaches to retrofits are becoming increasingly popular internationally. Undertaking several retrofit actions simultaneously is more cost-effective and leads to greater savings than a series of one-off interventions. Providing incentives for isolated interventions will have limited impact on national targets. It may also lead the householder to undertake a sub-optimal sequence of actions and lower the energy savings' potential. European experience has shown that grouping retrofits in a neighbourhood or locality can reduce costs and accelerate the retrofit process through economies of scale. The All of Government Climate Action Plan proposes to promote similar area-based approaches to deep retrofits and to use existing community structures to engage homeowners.

Research indicates that fiscal measures in the form of taxes or levies must be perceived to be fair to gain widespread acceptance from the public. Academic research evaluating the success of carbon tax, for example, tends to focus on its impact on national emissions and on economic activity. Studies show that carbon tax has been successful in reducing greenhouse gas emissions. Further specific research is required, however, to explore the behavioural pathways by which people's energy behaviour changes as a result of a carbon tax. For example, are emissions reduced by choices to drive less or to buy more efficient vehicles and drive the same amount? Although taxation can be designed to have a significant impact on investment behaviour, its effect on curtailment behaviour is not yet well understood.

When estimating the impact of proposed fiscal measures, consideration should be given to factors that can lead to overestimation of potential savings. Rebound can have a significant effect. Robust monitoring and evaluation methods account for rebound by assessing its magnitude and applying appropriate correction factors to measured or metered savings. Free riding represents waste of public funds and savings achieved by free riders should not be attributed to programmes.

Finally, policymakers need to be aware of the limitations of fiscal measures. Curtailment behaviours brought about by the introduction of financial incentives have been shown to be short-lived with behaviours reverting to original after the incentive is removed. Investment actions are not triggered by the prospect of financial reward alone. Energy conservation behaviour and pro-environmental actions are elicited by a diverse set of motivators, and fiscal measures on their own cannot bring about a sustained change in behaviour. The All of Government Climate Action Plan presents an integrated framework of measures, incorporating subsidies, taxation measures, regulatory standards, such as the phasing out of fossil fuel boilers, and other non-fiscal measures to accelerate the necessary transition to a low-carbon society (Government of Ireland, 2019a). Encouraging citizens to bring about persistent savings requires this blend of complementary restrictive and enabling measures that take into account the diversity of people's motivations, behaviours and circumstances.

3.1. Key recommendations for policymakers

- Due to scarcity of evidence in the literature regarding the effectiveness of financial incentives, future programmes should be tested using pilot schemes before a broader rollout.

- Robust monitoring and evaluation should be built into programmes from the start so that they can be assessed whilst in operation and corrective actions can be undertaken when necessary. Ideally, monitoring and evaluation methods should record the experiences of programme participants, use measured data to assess changes in behaviour, and provide an opportunity for input from programme administrators.

- Behavioural instruments should differentiate between segments of a target group and be tailored to maximise the energy-saving potential in each segment. The method of segmentation will depend on the type of incentive and the technology supported. For households, this could, for instance, entail targeting specific income groups or dwelling types.

- In order to maximise value for money, free rider effects should be minimised through the design of financial incentives. This may be achieved by segmenting consumer groups and targeting only those groups likely to include lower levels of free riders, through a strengthening of eligibility requirements or a phased approach to the introduction of the incentive. Financial supports are less suited to technologies with high levels of free riders.

- Policies to encourage building retrofits should consider householders' intrinsic motivations to improve their homes; in particular, the desire to improve the aesthetics of the home. When promoting retrofit programmes, benefits such as comfort, well-being and building appearance should be highlighted as well as energy and cost savings.

- Fiscal measures should be designed to incentivise householders to undertake a more ambitious whole-house approach to retrofits. For example, enhanced subsidies could be made available for retrofit actions undertaken in a prescribed combination, or a minimum energy-performance level of a house could be a prerequisite for qualification for a renewable technology investment subsidy.

- In line with the proposals in the All of Government Climate Action Plan, policymakers should investigate programme models that can group deep retrofits together in a neighbourhood or locality to achieve economies of scale; the Dutch *Energiesprong* programme may provide insights. The research should examine how a core project focussing on social housing and housing agencies can be expanded to incorporate private homes in the locality.

- Consideration could be given to using the 2020 SEAI RD&D Funding Programme to develop a trial, exploring how advanced metering infrastructure could be used to encourage energy-saving behaviour in households and to provide innovative energy services to small consumers. The experience gained in the German pilot programme *Energy Saving Meter* may help inform this research.

Appendix: Literature review methodology

To compile this report, an extensive search of the international literature was conducted. The literature search encompassed all areas of energy behaviour, covering both investment decisions and more habitual pro-environmental behaviour. It covered all technologies and end-uses in both household and commercial sectors, including transport services and renewables.

In the first stage a search strategy was devised in line with the methodology outlined in DECC (2012), and five commonly used databases of peer-reviewed literature were identified. A list of inclusion and exclusion criteria was drawn up. Search strings were developed using keywords relevant to the research topic. The initial searches in all databases yielded large numbers of results. The search strategy was then refined using combinations of relevant phrases instead of words in the search strings. At this stage, databases that didn't accommodate the use of more complex search strings were excluded. After applying the refined search strings, it was evident that two of the selected databases, Scopus and Web of Science, would adequately cover all peer-reviewed literature relevant to the research topic. Once papers published before 1990 and papers not available in English were excluded, and after filtering out broad subject areas unlikely to have content relevant to the research question (for example, medicine, chemistry, etc.), the search yielded the following results:

- Scopus: 2,535 publications
- Web of Science: 2,234 publications

As journal publications are often represented in several databases, the search results included a significant number of duplicate entries. The results from the two databases were combined and a methodology to remove duplicates was developed. The combined database contained 3,456 unique results. 1,313 duplicates were removed.

The 3,456 peer-reviewed papers were filtered by reviewing the titles of each and excluding those that were not relevant to the research topic. After the title filtering process, 872 papers were selected for abstract review. Originally it had been planned to exclude all papers that didn't present measured or modelled results, papers that described measures proposed but not implemented, and studies that didn't address fiscal measures specifically. During the abstract review, it quickly became clear however, that the number of studies in the literature that evaluated and presented the results of a particular fiscal measure was very low. Consequently, these exclusion criteria were removed, and a qualitative review of the abstracts selected for a deeper analysis of all studies that were felt to be broadly pertinent to the research. Once studies covering least-developed and developing countries, according the United Nations classification[4] ,were excluded, 118 papers were selected for detailed review. A further 14 peer-reviewed papers were identified and analysed at later stages in the project.

A search of grey literature sources was conducted in parallel. A list of publicly accessible databases of grey literature was drawn up. It included resources from renowned research institutions, government bodies, and national and international non-governmental organisations. A manual search of these sources identified 28 reports and research papers for detailed analysis. To aid the analysis of all papers, a template was developed to classify studies, distil their outcomes and record and summarise the most relevant findings from each. The template with the summary of each of the studies reviewed in detail is available on request from SEAI.

During the research, a number of international experts in the areas of energy policy, energy efficiency and behavioural economics were consulted, and their feedback was taken into account in the identification and analysis of studies and the compilation of this report.

[4] https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects-2019/

Bibliography

Abrahamse, W, Steg, L, Vlek, C., and Rothengatter, T, (2005), 'A review of intervention studies aimed at household energy conservation'. *Journal of Environmental Psychology*, *25*(3), 273–291. https://doi.org/10.1016/j.jenvp.2005.08.002

Acheson, J, and Lynch, D, (2017),' Implications of behavioural economics for tax policy'. Available at: https://igees.gov.ie/wp-content/uploads/2014/01/Behavioural-Economics-and-Tax.pdf

Allcott, H, and Rogers, T, (2014), 'The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review*, *104*(10), 3003–3037. https://doi.org/10.1257/aer.104.10.3003

Andersen, M S, (2004), Vikings and virtues: A decade of CO2 taxation. *Climate Policy*, *4*(1), 13–24. https://doi.org/10.1080/14693062.2004.9685507

Andor, M. A., Frondel, M., & Sommer, S. (2018). Equity and the willingness to pay for green electricity in Germany. *Nature Energy*, *3*(10), 876–881. https://doi.org/10.1038/s41560-018-0233-x

Aspara, J., Luo, X., & Dhar, R. (2017). Effect of intelligence on consumers' responsiveness to a pro-environmental tax: Evidence from large-scale data on car acquisitions of male consumers. *Journal of Consumer Psychology*, *27*(4), 448–455. https://doi.org/10.1016/j.jcps.2017.03.002

Aydin, E., Kok, N., & Brounen, D. (2017). Energy efficiency and household behavior: the rebound effect in the residential sector. *RAND Journal of Economics*, *48*(3), 749–782. https://doi.org/10.1111/1756-2171.12190

Backlund, S., Thollander, P., Palm, J., & Ottosson, M. (2012). Extending the energy efficiency gap. *Renewable Energy in China*, *51*, 392–396. https://doi.org/10.1016/j.enpol.2012.08.042

Baranova, P., & Paterson, F. (2017). Environmental capabilities of small and medium sized enterprises: Towards transition to a low carbon economy in the East Midlands. *Local Economy*, *32*(8), 835–853. https://doi.org/10.1177/0269094217744494

Baranzini, A., & Carattini, S. (2017). Effectiveness, earmarking and labeling: testing the acceptability of carbon taxes with survey data. *Environmental Economics and Policy Studies*, *19*(1), 197–227. https://doi.org/10.1007/s10018-016-0144-7

Baumhof, R., Decker, T., Röder, H., & Menrad, K. (2018). Which factors determine the extent of house owners' energy-related refurbishment projects? A Motivation-Opportunity-Ability Approach. *Sustainable Cities and Society*, *36*, 33–41. https://doi.org/10.1016/j.scs.2017.09.025

Bergman, N., Hawkes, A., Brett, D. J. L., Baker, P., Barton, J., Blanchard, R., … Woodman, B. (2009). UK microgeneration. Part I: Policy and behavioural aspects. *Proceedings of Institution of Civil Engineers: Energy*, *162*(1), 23–36. https://doi.org/10.1680/ener.2009.162.1.23

Bertoldi, P., Rezessy, S., & Oikonomou, V. (2013). Rewarding energy savings rather than energy efficiency: Exploring the concept of a feed-in tariff for energy savings. *Energy Policy*, *56*, 526–535. https://doi.org/10.1016/j.enpol.2013.01.019

Biggart, N. W., & Lutzenhiser, L. (2007). Economic sociology and the social problem of energy inefficiency. *American Behavioral Scientist*, *50*(8), 1070–1087. https://doi.org/10.1177/0002764207299355

Borenstein, S. (2017). Private Net Benefits of Residential Solar PV: The Role of Electricity Tariffs, Tax Incentives, and Rebates. *Journal of the Association of Environmental and Resource Economists*, *4*(S1), S85–S122. https://doi.org/10.1086/691978

Bradley, P., Coke, A., & Leach, M. (2016). Financial incentive approaches for reducing peak electricity demand, experience from pilot trials with a UK energy provider. *Energy Policy*, *98*, 108–120. https://doi.org/10.1016/j.enpol.2016.07.022

Brand, C., Anable, J., & Tran, M. (2013). Accelerating the transformation to a low carbon passenger transport system: The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK. *Transportation Research Part A: Policy and Practice*, *49*, 132–148. https://doi.org/10.1016/j.tra.2013.01.010

Cadmus Group Inc. (2016). *Evaluation of Residential Customer Behavioral Savings Pilot (Vermont US)*. Cadmus Group Inc.

Chitnis, M., Sorrell, S., Druckman, A., Firth, S. K., & Jackson, T. (2014). Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups. *Ecological Economics*, *106*, 12–32. https://doi.org/10.1016/j.ecolecon.2014.07.003

Citizens' Assembly. (2018). *Third report and recommendations of the Citizens' Assembly. How the State can become a leader in tckling climate change.* Retrieved from https://www.citizensassembly.ie/en/How-the-State-can-make-Ireland-a-leader-in-tackling-climate-change/Final-Report-on-how-the-State-can-make-Ireland-a-leader-in-tackling-climate-change/Climate-Change-Report-Final.pdf

Collins, M., & Curtis, J. (2017). An examination of the abandonment of applications for energy efficiency retrofit grants in Ireland. *Energy Policy*, *100*, 260–270. https://doi.org/10.1016/j.enpol.2016.10.030

Collins, M., & Curtis, J. (2018). Rental tenants' willingness-to-pay for improved energy efficiency and payback periods for landlords. *Energy Efficiency*, *11*(8), 2033–2056. https://doi.org/10.1007/s12053-018-9668-y

Collins, M., Dempsey, S., & Curtis, J. (2018). Householder preferences for the design of an energy efficiency retrofit subsidy in Ireland. *Economic and Social Review*, *49*(2), 145–172. Retrieved from Scopus.

Conefrey, T., Fitz Gerald, J. D., Valeri, L. M., & Tol, R. S. J. (2013). The impact of a carbon tax on economic growth and carbon dioxide emissions in Ireland. *Journal of Environmental Planning and Management*, *56*(7), 934–952. https://doi.org/10.1080/09640568.2012.709467

Craig, C. A. (2018). Residential support for energy efficiency by utility organizations in the Southeast US. *Journal of Cleaner Production*, *177*, 89–100. https://doi.org/10.1016/j.jclepro.2017.12.189

Craig, C. A., & Allen, M. W. (2014). Enhanced understanding of energy ratepayers: Factors influencing perceptions of government energy efficiency subsidies and utility alternative energy use. *Energy Policy*, *66*, 224–233. https://doi.org/10.1016/j.enpol.2013.10.074

Datta, S., & Filippini, M. (2016). Analysing the impact of ENERGY STAR rebate policies in the US. *Energy Efficiency*, *9*(3), 677–698. https://doi.org/10.1007/s12053-015-9386-7

de Bruin, K., & Yakut, A. M. (2019). *Working Paper No. 619. The effects of an incremental increase in the Irish carbon tax towards 2030*. Retrieved from https://www.esri.ie/system/files/publications/WP619.pdf

DECC. (2012). *What Works in Changing Energy Using Behaviours in the Home? A Rapid Evidence Assessment*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69797/6921-what-works-in-changing-energyusing-behaviours-in-.pdf

Dineen, D., Ryan, L., & Ó Gallachóir, B. (2018). Vehicle tax policies and new passenger car CO2 performance in EU member states. *Climate Policy*, *18*(4), 396–412. https://doi.org/10.1080/14693062.2017.1294044

Dougherty, A., Henderson, C., Dwelley, A., Jayaraman, M., Vine, E., & Mazur-Stommen, S. (2015, May). *Energy Efficiency Behavioral Programs: Literature Review, Benchmarking Analysis, and Evaluation Guidelines*. Illume Advising, LLC.

Egmond, C., Jonkers, & Kok, G. (2006a). Target group segmentation makes sense: If one sheep leaps over the ditch, all the rest will follow. *Energy Policy*, *34*(17), 3115–3123. https://doi.org/10.1016/j.enpol.2005.06.002

Egmond, C., Jonkers, R., & Kok, G. (2006b). One size fits all? Policy instruments should fit the segments of target groups. *Energy Policy*, *34*(18), 3464–3474. https://doi.org/10.1016/j.enpol.2005.07.017

Eirgrid, & Electric Ireland. (2018). *Power Off & Save Pilot. Project Progress Report 3*. Retrieved from http://www.eirgridgroup.com/site-files/library/EirGrid/Power-Off-Save-Progress-Report-3_290818.pdf

Energiesprong. (2019). Energiesprong website. Retrieved 27 March 2019, from Energiesprong website: https://energiesprong.org

EPA. (2019). Ireland's Greenhouse Gas Emissions Projections 2018-2040. Retrieved from https://www.epa.ie/pubs/reports/air/airemissions/ghgprojections2018-2040/Greenhouse_Gas_Projections.pdf

ESRI. (2019). *Carbon taxation in Ireland: Distributional effects of revenue recycling policies*. Retrieved from https://www.esri.ie/system/files/publications/QEC2019SUM_SA_Lynch.pdf

Fleiß, E., Hatzl, S., Seebauer, S., & Posch, A. (2017). Money, not morale: The impact of desires and beliefs on private investment in photovoltaic citizen participation initiatives. *Journal of Cleaner Production*, *141*, 920–927. https://doi.org/10.1016/j.jclepro.2016.09.123

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews*, *41*, 1385–1394. https://doi.org/10.1016/j.rser.2014.09.026

Government of Ireland. (2018). *Project Ireland 2040. National Planning Framework*. Retrieved from http://npf.ie/wp-content/uploads/Project-Ireland-2040-NPF.pdf

Government of Ireland. (2019a). *Climate Action Plan 2019 to Tackle Climate Breakdown*. Retrieved from https://www.dccae.gov.ie/documents/Climate%20Action%20Plan%202019.pdf

Government of Ireland. (2019b). *National Development Plan 2018–2027*. Retrieved from https://www.gov.ie/en/publication/83fec4-national-development-plan/

Gram-Hanssen, K. (2014). Existing buildings - Users, renovations and energy policy. *Renewable Energy*, *61*, 136–140. https://doi.org/10.1016/j.renene.2013.05.004

Handgraaf, M. J. J., Van Lidth de Jeude, M. A., & Appelt, K. C. (2013). Public praise vs. private pay: Effects of rewards on energy conservation in the workplace. *Ecological Economics*, *86*, 86–92. https://doi.org/10.1016/j.ecolecon.2012.11.008

Hardman, S., Chandan, A., Tal, G., & Turrentine, T. (2017). The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence. *Renewable and Sustainable Energy Reviews*, *80*, 1100–1111. https://doi.org/10.1016/j.rser.2017.05.255

Hecher, M., Hatzl, S., Knoeri, C., & Posch, A. (2017). The trigger matters: The decision-making process for heating systems in the residential building sector. *Energy Policy*, *102*, 288–306. https://doi.org/10.1016/j.enpol.2016.12.004

Hoffmann, C., & Geissler, A. (2017). The prebound-effect in detail: real indoor temperatures in basements and measured versus calculated U-values. *Energy Procedia*, *122*, 32–37. https://doi.org/10.1016/j.egypro.2017.07.301

Hoicka, C. E., & Parker, P. (2018). Assessing the adoption of the house as a system approach to residential energy efficiency programs. *Energy Efficiency*, *11*(2), 295–313. https://doi.org/10.1007/s12053-017-9564-x

House of Lords. (2011). *Science and Technology Select Committee. 2nd Report of Session 2010-12. Behaviour Change Report.* Authority of the House of Lords.

Houses of the Oireachtas. (2019). *Report of the Joint Committee on Climate Action Climate Change: A Cross-Party Consensus for Action*. Retrieved from https://data.oireachtas.ie/ie/oireachtas/libraryResearch/2019/2019-01-02_ireland-s-energy-transition-challenges-and-opportunities_en.pdf

Jenn, A., Springel, K., & Gopal, A. R. (2018). Effectiveness of electric vehicle incentives in the United States. *Energy Policy*, *119*, 349–356. https://doi.org/10.1016/j.enpol.2018.04.065

Johannsen, K. S. (2002). Combining voluntary agreements and taxes - An evaluation of the Danish agreement scheme on energy efficiency in industry. *Journal of Cleaner Production*, *10*(2), 129–141. https://doi.org/10.1016/S0959-6526(01)00031-2

Karlin, B., Davis, N., Sanguinetti, A., Gamble, K., Kirkby, D., & Stokols, D. (2014). Dimensions of Conservation: Exploring Differences Among Energy Behaviors. *Environment and Behavior*, *46*(4), 423–452. https://doi.org/10.1177/0013916512467532

Kastner, I., & Stern, P. C. (2015). Examining the decision-making processes behind household energy investments: A review. *Energy Research and Social Science*, *10*, 72–89. https://doi.org/10.1016/j.erss.2015.07.008

Lavelle, M. J., Rau, H., & Fahy, F. (2015). Different shades of green? Unpacking habitual and occasional pro-environmental behavior. *Global Environmental Change*, *35*, 368–378. https://doi.org/10.1016/j.gloenvcha.2015.09.021

Lee, E., Jung, C. S., & Hwang, M. S. (2016). Investigating supportive conditions for participation in voluntary environmental programs. *Journal of Environmental Planning and Management*, *59*(7), 1323–1340. https://doi.org/10.1080/09640568.2015.1074889

Li, X., Clark, C. D., Jensen, K. L., & Yen, S. T. (2016). The Effect of Mail-in Utility Rebates on Willingness-to-Pay for ENERGY STAR (Formula presented.) Certified Refrigerators. *Environmental and Resource Economics*, *63*(1), 1–23. https://doi.org/10.1007/s10640-014-9833-5

Liu, X., Yamamoto, R., & Suk, S. (2014). A survey of company's awareness and approval of market-based instruments for energy saving in Japan. *Journal of Cleaner Production*, *78*, 35–47. https://doi.org/10.1016/j.jclepro.2014.05.005

Mahapatra, K., & Gustavsson, L. (2009). Influencing Swedish homeowners to adopt district heating system. *Applied Energy*, *86*(2), 144–154. https://doi.org/10.1016/j.apenergy.2008.03.011

Mallaburn, P. (2018). *Principles of successful non-residential energy efficiency policy*. *2018-June*, 15–22. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85049877601&partnerID=40&md5=a4137558bd2905633fb33846c1f6eff6

Matosović, M., & Tomšić, Ž. (2018). Evaluating homeowners' retrofit choices – Croatian case study. *Energy and Buildings*, *171*, 40–49. https://doi.org/10.1016/j.enbuild.2018.04.020

Michelsen, C. C., & Madlener, R. (2013). Motivational factors influencing the homeowners' decisions between residential heating systems: An empirical analysis for Germany. *Energy Policy*, *57*, 221–233. https://doi.org/10.1016/j.enpol.2013.01.045

Michelsen, 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. https://doi.org/10.1016/j.enpol.2015.11.018

Miu, L. M., Wisniewska, N., Mazur, C., Hardy, J., & Hawkes, A. (2018). A simple assessment of housing retrofit policies for the UK: What should succeed the energy company obligation. *Energies*, *11*(8). https://doi.org/10.3390/en11082070

Mizobuchi, K., & Takeuchi, K. (2013). The influences of financial and non-financial factors on energy-saving behaviour: A field experiment in Japan. *Energy Policy*, *63*, 775–787. https://doi.org/10.1016/j.enpol.2013.08.064

Murphy, L. (2014). The policy instruments of European front-runners: Effective for saving energy in existing dwellings? *Energy Efficiency*, *7*(2), 285–301. https://doi.org/10.1007/s12053-013-9224-8

Murray, B., & Rivers, N. (2015). British Columbia's revenue-neutral carbon tax: A review of the latest "grand experiment" in environmental policy. *Energy Policy*, *86*, 674–683. https://doi.org/10.1016/j.enpol.2015.08.011

Nakano, S., & Washizu, A. (2017). Changes in consumer behavior as a result of the Home Appliance Eco-Point System: an analysis based on micro data from the Family Income and Expenditure Survey. *Environmental Economics and Policy Studies*, *19*(3), 459–482. https://doi.org/10.1007/s10018-016-0145-6

Narassimhan, E., & Johnson, C. (2018). The role of demand-side incentives and charging infrastructure on plug-in electric vehicle adoption: Analysis of US States. *Environmental Research Letters*, *13*(7). https://doi.org/10.1088/1748-9326/aad0f8

Nässén, J., & Holmberg, J. (2009). Quantifying the rebound effects of energy efficiency improvements and energy conserving behaviour in Sweden. *Energy Efficiency*, *2*(3), 221–231. https://doi.org/10.1007/s12053-009-9046-x

Nexant Inc. (2016). *Business Incentive Program Process Evaluation (Maine US)*. Retrieved from https://www.efficiencymaine.com/docs/EMT-BIP-Impact-Evaluation-Report-11_5_17.pdf

Nexant Inc. (2017). *Business Incentive Program Impact Evaluation (Maine US)*. Retrieved from https://www.efficiencymaine.com/docs/EMT-BIP-Impact-Evaluation-Report-11_5_17.pdf

Nishijima, D., Kagawa, S., Nansai, K., & Oguchi, M. (2019). Effects of product replacement programs on climate change. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.02.220

NMR Group Inc. (2017). *1606 Eversource Behavior Program Persistence Evaluation (Conneticut US)*. NMR Group Inc.

Nordic Council of Ministers. (2016). *Nudging and pro-environmental behaviour*. Retrieved from https://norden.diva-portal.org/smash/get/diva2:1065958/FULLTEXT01.pdf

Olsthoorn, M., Schleich, J., Gassmann, X., & Faure, C. (2017). Free riding and rebates for residential energy efficiency upgrades: A multi-country contingent valuation experiment. *Energy Economics*, *68*, 33–44. https://doi.org/10.1016/j.eneco.2018.01.007

Parag, Y., Capstick, S., & Poortinga, W. (2011). Policy attribute framing: A comparison between three policy instruments for personal emissions reduction. *Journal of Policy Analysis and Management*, *30*(4), 889–905. https://doi.org/10.1002/pam.20610

Rogan, F., Dennehy, E., Daly, H., Howley, M., & Ó Gallachóir, B. P. (2011). Impacts of an emission based private car taxation policy - first year ex-post analysis. *Transportation Research Part A: Policy and Practice*, *45*(7), 583–597. https://doi.org/10.1016/j.tra.2011.03.007

Rosenow, J., & Eyre, N. (2016). A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. *Energy Research and Social Science*, *21*, 141–144. https://doi.org/10.1016/j.erss.2016.07.005

Rudolph, C. (2016). How may incentives for electric cars affect purchase decisions? *Transport Policy*, *52*, 113–120. https://doi.org/10.1016/j.tranpol.2016.07.014

Schlomann, B., & Schleich, J. (2015). Adoption of low-cost energy efficiency measures in the tertiary sector—An empirical analysis based on energy survey data. *Renewable and Sustainable Energy Reviews*, *43*, 1127–1133. https://doi.org/10.1016/j.rser.2014.11.089

SEAI. (2018). *Changing energy behaviour – what works?* Retrieved from https://www.seai.ie/resources/publications/Changing-Energy-Behaviour.-What-Works..pdf

SEAI. (2019). *National Energy Projections 2019*. Retrieved from https://www.seai.ie/resources/publications/2019-04_SEAI2019ProjectionsReport_Final.pdf

SEAI, & ESRI. (2018). *Policy insights for encouraging energy efficiency in the home. A compilation of findings from a research fellowship co-funded by SEAI and ESRI*. Retrieved from https://www.seai.ie/resources/publications/Policy-Insights-Rport.pdf

Sekar, A., Williams, E., Hittinger, E., & Chen, R. (2019). How behavioral and geographic heterogeneity affects economic and environmental benefits of efficient appliances. *Energy Policy*, 537–547. https://doi.org/10.1016/j.enpol.2018.10.035

Simpson, S., Banfill, P., Haines, V., Mallaband, B., & Mitchell, V. (2016). Energy-led domestic retrofit: Impact of the intervention sequence. *Building Research and Information*, *44*(1), 97–115. https://doi.org/10.1080/09613218.2014.996360

Sorrell, S. (2009). Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy*, *37*(4), 1456–1469. https://doi.org/10.1016/j.enpol.2008.12.003

Sunikka-Blank, M., & Galvin, R. (2012). Introducing the prebound effect: The gap between performance and actual energy consumption. *Building Research and Information*, *40*(3), 260–273. https://doi.org/10.1080/09613218.2012.690952

Sussman, R., & Chikumbo, M. (2016). *Behavior Change Programs: Status and Impact*. American Council for an Energy-Efficient Economy.

Tanaka, K., Sekito, M., Managi, S., Kaneko, S., & Rai, V. (2017). Decision-making governance for purchases of solar photovoltaic systems in Japan. *Energy Policy*, *111*, 75–84. https://doi.org/10.1016/j.enpol.2017.09.012

Thomas, S., Suerkemper, F., Adisorn, T., & Hauptstock, D. (2016a). *Energy Efficiency Policies in Europe. Case Study: Energiesprong (Energy Leap) in The Netherlands*. Energy Efficiency Watch.

Thomas, S., Suerkemper, F., Adisorn, T., & Hauptstock, D. (2016b). *Energy Efficiency Policies in Europe. Case Study: KfW Programme - Germany*. Energy Efficiency Watch.

Umit, R., Poortinga, W., Jokinen, P., & Pohjolainen, P. (2019). The role of income in energy efficiency and curtailment behaviours: Findings from 22 European countries. *Energy Research & Social Science*, *53*, 206–214. https://doi.org/10.1016/j.erss.2019.02.025

UNFCC. (2016). *Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015*. Retrieved from https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf

Ürge-Vorsatz, D., Koeppel, S., & Mirasgedis, S. (2007). Appraisal of policy instruments for reducing buildings' CO2 emissions. *Building Research and Information*, *35*(4), 458–477. https://doi.org/10.1080/09613210701327384

Weiss, U., Chmella, T., Grein, A., & Milojkovic, F. (2017). Funding measured energy savings: first findings on performance-based "Energy Savings Meter" funding scheme. *Eceee Summer Study Proceedings 2017*. Retrieved from https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/2-policy-governance-design-implementation-and-evaluation-challenges/funding-measured-energy-savings-first-findings-on-the-performance-based-energy-savings-meter-funding-scheme/

Young, W., Davis, M., McNeill, I. M., Malhotra, B., Russell, S., Unsworth, K., & Clegg, C. W. (2015). Changing Behaviour: Successful Environmental Programmes in the Workplace. *Business Strategy and the Environment*, *24*(8), 689–703. https://doi.org/10.1002/bse.1836

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