Renewable & Sustainable Energy Reviews

Promoting Behavioural Change to Reduce Thermal Energy Demand in Households: A Review

Rebecca Hafner [a]*, David Elmes[b] & Daniel Read[b]

[a] University of Plymouth,
Drake Circus,
Plymouth,
PL4 8AA

[b] Warwick Business School,
University of Warwick,
Coventry,
CV4 7AL

* Corresponding author. Email: rebecca.hafner@plymouth.ac.uk ; Tel. +44(0) 1752 585278

Conflict of Interest Statement: All authors declare that they have no conflict of interest

Keywords: Behavioural science; sustainability; energy-efficient technology; demand reduction; behaviour change; choice optimisation

Abstract (200 words)

A reduction in thermal energy consumption in buildings is vital for achieving the reductions in carbon dioxide (CO_2) emissions that are part of EU-2050 targets. A key challenge faced by behavioural scientists is to understand what encourages people to adopt more efficient ways of achieving a satisfactory thermal experience. We review the psychological barriers to reducing thermal energy demand in the context of energy-efficient technology adoption, and discuss ways these barriers may be overcome. The barriers include: demand on cognitive resources due to decision complexity; tendency to procrastinate and discount future consequences; deferral to simplifying strategies including repeating past experience and copying the behaviour of others; the desire to act in ways that maintain a positive self-image; and inertia due to fear of regret that one's decision might be 'wrong'. We discuss behavioural approaches to overcome these barriers, such as emphasizing public choice of "green" technology, reframing of benefits, simplifying and optimising the choice environment, focusing on symbolic attributes of new technologies, and changing the temporal structure of costs and benefits. We provide a framework of suggestions for future research which together constitute an important first step in informing behaviour change efforts designed to reduce thermal energy consumption in households.

1 INTRODUCTION

The domestic built environment is responsible for a considerable and ever-increasing proportion (15 – 20%) of total energy-related greenhouse gas emissions (GHG) in Western Europe [1]. Indeed within the UK, emissions from buildings were found to account for 19% of UK GHG in 2016, having increased for the second year running [2], with progress made in reducing emissions from homes between 2008 – 2012 now at a standstill [2]. Consequently in the strive to avoid drastic climate change, defined as: 'allowing no more than 2°C global mean warming above pre-industrial conditions' [3], recent EU environmental policy advances aim to significantly improve energy efficiency in the domestic built environment. In its "Energy Roadmap 2050", the European Commission aims to reduce the emissions from houses and offices by around 90% in 2050 (in contrast to 1990 levels) [4]. According to the International Energy Agency, the largest use of energy in buildings is heating and cooling (37% of total energy use), and improvements are "not on track to achieve global climate commitments" [5]. Evidently, there remains a need for renewed strategies designed to reignite progress in the decarbonisation of the domestic built environment.

Research has shown that increased ownership of high consuming products and appliances is a key factor contributing to ever-increasing energy consumption in homes [6]. Consequently, one central aspect of a sustainable energy transition at the societal level involves developing effective means to support and encourage the adoption of innovative technologies designed to reduce energy demand [7, 8]. An example of efforts to address this is the UK Government's commitment to spend £4.5 billion between 2016 and 2021 to support the introduction of low carbon heat technologies into homes and businesses [9]. Yet this process of diffusion of new technologies is often a difficult and lengthy process, with continued preference for investment in old and (seemingly) inferior alternatives; thwarting the potential environmental benefits that could otherwise be achieved following successful widespread diffusion of home energy efficiency measures and technologies [7, 10, 11]. Indeed, using the examples of improved thermal insulation and energy-efficient appliances, Jaffe and Stavins discuss how this slow diffusion process is seemingly paradoxical, given that simple net present value calculations would show investment to be cost effective; an effect they term the "energy-efficiency gap" [12].

In this paper we provide an overview of psychological barriers to behaviour change known to contribute to the energy efficiency gap. Notably, a number of government policy documents have already made efforts to synthesise what is known about barriers to behaviour change [13, 14, 15, 16, 17, 18, 19, 20]. However, this existing knowledge is variable, and thus an overall concept of what is known about factors influencing behaviour remains somewhat hard to visualise. The main value of this paper, therefore, lies in its collation, summary and inference from notable academic and non-academic evidence into factors known to influence individual decision-making behaviour in the context of reducing thermal energy demand in homes. However, at this stage it is also important to note that only a portion of the emission reductions estimated by initial engineering calculations for new technologies are generally achieved in practice, due to the rebound effect. This refers to the observation that people may increase their energy consumption when its marginal cost is reduced. For instance, a fuel-efficient car is likely to be driven more because the cost-per-mile is reduced, or more efficient television technology is likely to lead to people choosing bigger screens. In this paper we focus on the decision to adopt more efficient technology, and leave aside the problem of how it is used. Nevertheless it is important to bear in mind that in practice, reductions in consumption associated with uptake of new technologies may not be as great as initial forecasts suggest [21, 22]

The current paper also provides an important advance from previous review documents as we focus on the relatively unexplored topic of energy reduction via large-scale investments in energy efficient appliances, such as installation of a heat pump or photovoltaic panels. Much previous research in social sciences and behavioural economics has focused on behavioural interventions which influence direct energy usage, particularly of electricity. For instance, Wilhite and Ling [23] discuss how more informative energy bills can lead to reductions of around 10% in direct energy usage (see also [24, 25]). The same principles also underpin research in smart technology development [26, 27]. Accordingly, reviewing the psychological barriers which prohibit pro-

environmental behaviours including sustainable energy consumption is the focus of many existing behaviour change policy documents ([13, 15, 16, 17]).

Comparatively little has been explored in the context of new technology adoption, and even less so in the field of heat consumption. This latter point is perhaps somewhat surprising given that the majority of energy consumed in the domestic sector is for heat uses. In a review of UK energy consumption practices the Department of Energy and Climate Change (DECC) showed that 85% (36,542 thousand tonnes of oil equivalent) was used for heating purposes (space heating, water heating and cooking/catering) and the remaining 15% (6,611 thousand tonnes of oil equivalent) for lighting and appliances [28]. This substantial proportion of energy consumption used directly for heating purposes highlights the need for behavioural change solutions which are specifically designed to target consumer behaviour in the field of heat supply, something which has been largely overlooked in previous review documents [13, 15, 16, 17, 18]. The current paper aims to address this lacuna. Previous non-behavioural research on the topic has largely used legislative measures (condensing boilers) or regulation to provide subsidies or set targets for suppliers, not consumers (loft insulation, cavity wall insulation) [29]. The current review advances this existing knowledge by providing a comprehensive review of the *psychological* barriers which prevent sustainable behaviour change in this context. Both one-off purchase decisions with long-term consequences (e.g. investing in 'green' technology), and frequently repeated behaviours (e.g. involving the daily use of equipment, such as regularly adjusting thermostat settings), require behaviour change at the societal level if thermal energy consumption in this domain is to be reduced. In this review we focus on the problem of increasing uptake of energy-efficient home heating technologies which involve a significant upfront financial outlay. This augments existing behaviour change review documents which have largely focused on changing frequently repeated behaviours with no immediate financial outlay for the consumer. We consider evidence provided by existing policy documents, as well as incorporating insight from wider social and psychological literatures, in order to provide a holistic approach to the topic of behaviour change. In addition, in a final expansion on previous review documents we provide a framework of suggestions for future research, which constitute a theoretically grounded basis for corresponding behaviour change interventions in this context, which will form a critical step in reducing thermal energy demand in households.

Throughout this paper we consider how each psychological barrier identified is relevant to this specific context, and how each affects either the process of weighing up costs and benefits, or the capacity to act upon the results of such analyses. These barriers limit the extent to which decision makers can be said to make economically 'rational' choices in this respect. One useful approach for understanding this discrepancy stems from dual process theory, widely popularized by Daniel Kahneman [30, 31]. This provides a distinction between two cognitive systems, an intuitive and automatic "System 1," and a deliberative and controlled "System 2." System 1 is associated with emotional, automatic and heuristic responding, and memory-based "intuitions". The hallmark of System 1 is that it enables tasks to be completed effortlessly – like driving a car for an experienced driver. System 2, on the other hand, is the seat of effortful and deliberative mental activity, which consciously compares costs and benefits, and likely versus unlikely outcomes. Using System 2 requires greater effort and draws on limited cognitive resources. When decisions are complex, when there is limited time, or when attentional resources are deployed elsewhere, people might defer to intuitive, as opposed to deliberative thinking. Moreover, System 1 may even be better when appropriate responses have been overlearned and automatized – once a juggler starts to deliberate about where the balls are they are likely to end up on the ground. In the case of thermal energy demand reduction, for both one-off purchase decisions and frequently repeated consumption practices cost/benefit analysis (CBA) is hard for consumers, and System 1 processes are likely to play a large role.

Evidence suggests people rarely make economically 'rational' decisions on the basis of net present value maximization, particularly when decision circumstances are complex, and this is due to the known impacts of limited cognitive capacities on decision making processes [32]. This is particularly relevant to the domain of pro-environmental behaviour change, where policy priority for the last two

decades has been to increase the number of options available to consumers [33] [34]. This has resulted in the production of choice environment(s) which are often structured in such a way that that they produce confusion rather than enlightenment. For instance, a survey by Which? [35] found that when it comes to changing energy tariffs, the typical consumer was faced by 109 different alternatives. In instances such as these, Simon [36] argued it is unrealistic to treat agents (organizations as well as individuals) as fully rational optimisers. He proposed there are restrictions on the capacity of agents to be rational, and that we should treat them as *intendedly* rational, but only *boundedly* so. For Simon, the bounds on rationality are cognitive limitations on knowledge, memory, and imagination. In a famous passage, he made the following contrasts between rationality and the actual capacity of agents (pp. 93 – 94):

(1) "Rationality requires a complete knowledge and anticipation of the consequences that will follow on each choice. In fact, knowledge of consequences is always fragmentary.
(2) Since these consequences lie in the future, imagination must supply the lack of experienced feeling in attaching value to them. But values can only be imperfectly anticipated.
(3) Rationality requires a choice among all possible alternative behaviors. In actual behavior, only a few of these possible alternatives ever come to mind."

The relevance of these limitations to the problem of reducing thermal energy consumption in homes is very clear. *Boundedly* rational individuals fail to actively engage in decisions which are perceived as complex (such as choosing a new home heating system), leading to deferral to intuitive thinking, and predictably biased behaviour patterns, meaning options that would be objectively seen as the 'best' may be overlooked. At the same time, people are intendedly rational, meaning we can expect them to want to choose options that are best for them in the long run.

The following review identifies factors likely to play the most important role during such decisions, with discussion of each structured along a framework of questions typically faced by decision makers in this domain. These include: Action inertia: Why do I have to change?; Social norms: What do my friends or neighbours do?; Emotion: How does it make me feel?; Perceived behavioural control: Can I do it?; Delay discounting: When will I get it?; and Habit: What do I usually do? We consider how each plays a role in preventing behaviour change with specific regard to encouraging uptake of 'green' technologies designed to reduce energy demand, such as ground source, air source, or hybrid-system heat pumps. Whilst this review is focused upon thermal technologies, the underlying principles generalise to uptake of all energy efficient technologies which require the decision maker to make an effortful choice outside of typical behaviour patterns. As such, the methods outlined in this paper may be of interest to researchers looking to develop behaviour change efforts in a variety of domains where uptake of technologies is slower than one might predict following rational choice models. The overall aim of the paper is to provide suggestions for future research which form a basis for initialising behaviour change efforts in this domain; ultimately allowing us to "nudge" consumers to make decisions that are good for themselves as well as society.

2 CONSIDERATIONS FACED BY DECISION-MAKERS IN THE CONTEXT OF HOME HEATING CHOICE

2.1 Action inertia: Why do I have to change?

People like things the way they are. This has been referred to as 'action inertia' or the 'omission' bias [37]. This is manifested in a number of behaviours. For instance, people will be reluctant to consider investing in new home heating systems, particularly if current systems still work, due to a general preference for inaction [see, 17]. People will prefer to fix existing systems rather than engage in the effortful process of choosing a new system. Verifying this, a recent survey by DECC found that in a non-emergency scenario (defined as one in which current systems are still functioning, but are perhaps coming towards the end of typical product lifespan), the majority of survey respondents would opt to do nothing, rather than consider a pre-emptive replacement [38]. In cases where one's hand is forced (i.e. an emergency break-down situation), consumers are likely to opt to replace with a replica, or with an intuitive 'upgrade' to the next model in the same line, or to defer responsibility by following 'expert' manufacturer or installer recommendations. In both cases

this general preference for inaction means people will avoid making decisions where possible, or if forced to act, will be biased towards maintaining previous decision circumstances.

A substantial body of empirical research has shown the ubiquity of this bias in determining behaviour. For instance, Ritov and Baron [37] showed how people displayed a general preference for inaction, even when this was associated with change, and reacted more negatively to a hypothetical financial loss when this was caused by action vs. inaction (see also [39, 40]). A simple to apply but powerful application of this principle involves the use of defaults: options which will be received unless an active choice is made for something else. For instance, Madrian and Shea [41] showed how automatic, default enrolment in pension schemes could increase employee savings, whilst opt-out, as opposed to opt-in defaults, have been shown to be effective in increasing likelihood of registration for organ donation [42]. Within the field of energy demand reduction, 'green' (i.e. environmentally friendly) electricity suppliers are more likely to be selected, over standard 'grey' suppliers, when these are provided as the default [43].

If people like to stick with what they know and with defaults, this is both a barrier to switching to new technology, but also a potential tool that can be used to leverage change. This idea is central to what Thaler and Sunstein [44] called "nudging." As with the examples above, if the energy efficient option can be framed as the default then preference for that option can be increased. For example, if the desired (i.e., energy efficient) system is provided as the standard in new build homes it is likely that people would accept these systems. Supporting this, researchers found that providing CFL (rather than incandescent), bulbs as the default in housing renovations increased use from 56% to 80% [45]. Indeed, this is recognised by the Government's Energy Performance of Buildings Directive that by 2020 all new buildings will be nearly zero-energy [46]. However, retrofitting existing properties with new technologies is also an imperative for achieving Government decarbonisation objectives. In this context, general preference for inaction may inhibit both the desire and motivation to engage in comparative analysis of costs and benefits; constituting a key problem for behavioural scientists who need to devise means of encouraging voluntary engagement in a complex choice process, in the absence of motivation from the individual. Indeed, demonstrating this, Mahapatra and Gustavsson [47] showed that preference for inaction was a key barrier to uptake of innovative heating technologies. In this study, the vast majority (80%) of homeowners surveyed stated they would not consider installing a new heating system, even when offered a significant government subsidy to switch to an energy efficient alternative, such as a heat pump. What is more, the extent to which users would consider installing a new innovative system was directly correlated with satisfaction with their existing system. Specifically, when subjects were satisfied with their existing system they preferred to maintain their existing circumstance, and showed increased reluctance to change their behaviour and consider novel alternatives in future. Similarly, Pelenur and Cruikshank [48] found that a general preference for inaction constituted one of the greatest barriers to the adoption of various home energy-efficiency measures, whilst Rundle-Thiele Paladino and Apostol [49] found that a barrier to the adoption of renewable energy systems was the perception that implementation of such systems is an unnecessary hassle, which simply takes 'too long' or is 'too complicated'.

Action inertia, or deferral to defaults and/or maintaining one's own previous decision circumstance works as a simplification strategy that provides the chooser with an outcome in the absence of mental investment in otherwise complex choice scenarios. Evidence from neuroscience shows people are more likely to defer to default options when making difficult, but not easy, decisions [50]. It is suggested this form of choice avoidance is prominent in many complex decision circumstances because it provides a shield against negative emotions associated with 'poor' choice outcomes [32, 51]. Refusal to engage in this comparative process will be particularly apparent when considering novel options which require a great deal of 'weighing up'. One way of overcoming this and encouraging engagement in the choice process is to simplify the choice set, so that people feel better able to cope with options available. For instance, simplifying choice sets by limiting the number of options available can increase the likelihood of investing in pension schemes [52]. The cognitive effort required when processing novel options constitutes a similarly complex scenario for decision

makers. This may explain reluctance to invest in new technologies designed to reduce thermal energy demand; as people are more likely to defer choice and/or stick with defaults when choosing is perceived to be complicated (see [47]). Jager [53] suggests that determining means of reducing perceived decision complexity could form a crucial step in encouraging uptake energy efficient technologies. Accordingly, it would be useful for future research to explore how to design and use simplified information in order to overcome the action inertia effect within this domain, and so encourage people to consider innovative 'green' alternatives. In addition, research has shown that pro-environmental behaviour (in this case, conservative energy use) may be motivated if detrimental health consequences of inaction are emphasised [24]. Research could explore the potential for health-feedback information pertaining to the negative consequences of non-green technology use to provide a means of simplification, and thus nudge behaviour in desired directions in this context, by re-focusing users on attainment of higher order goals, such as better health.

2.2 Social norms: What do my friends or neighbours do?

Normative information is critical in determining individual behaviour: people want to do what others do (*descriptive norms*), and what others wish them to do (*injunctive norms*) [54, 55]. People will be reluctant to act unless they perceive others acting in the same way: a key challenge for researchers looking to initiate uptake of new technologies not already used by the mass market.

A substantial body of research has explored the power of norms in guiding behaviour. For example, within the environmental domain, normative feedback information has been effectively used to induce voluntary reductions in water usage in households during times of drought [56]; to increase household recycling rates [57]; and to encourage conservative towel use amongst hotel guests [58]. Similar approaches have also been successful in reducing energy consumption. For example, in a randomized natural field experiment of over 600,000 households, the company OPower found that providing households with normative information lead to significant reductions in energy usage [25]; a finding also demonstrated in peer reviewed empirical research [59, 60].

Following a social norm can be seen as a decision simplification strategy that substitutes a rule ("I do what similar others do"), for any implicit or explicit calculation of costs and benefits. People may be unwilling to act unless they perceive others acting in the same manner, and unless they believe that others wish they act in the same manner. Such an understanding is often reflected in campaign-type activities that involve participation and communication between group members to encourage behaviour change (e.g. [19]). At present, social perceptions and norms surrounding energy use and purchase decisions are often relatively unclear, which is one key explanation for lack of attention to the issue of domestic energy use [61]. Addressing this and capitalising on the persuasive power of social influence in decision making may constitute a highly effective means of encouraging behavioural change in the context of thermal energy demand. For instance, Jager [53], found that social network effects play an important role in the diffusion of innovative technologies. Using the example of the decision to install domestic solar PV, Jager [53] found that the more other PV owners a person knows, the more important social motives become in the decision making process. Jager [53] suggests that this is because acting in accordance with social norms via purchase decisions such as this satisfies individual needs such as belongingness. Thus, social network effects can play an important role in reducing energy demand by encouraging widespread uptake of new technologies in some instances. However, whilst this may encourage diffusion of innovations once a substantial proportion of one's social network has already engaged in the process, the problem remains as to how we may utilise this element of social decision making theory to encourage consideration amongst early adopters in the first place, as well as how to increase the social salience of decisions which are not visible as PV, and which are less susceptible to social scrutiny and thus effecting action does not readily communicate our desire or intention to belong to a social group. In such instances, rollout of an intervention designed to encourage widespread pro-environmental behaviour change cannot necessarily rely on close contact between members of the participating group, indeed such a group may be widespread and thus may present less of a stronghold for social comparison at the individual level. The use of advertising campaigns which do not rely upon direct interaction between community members may therefore prove more effective for motivating behaviour change for these kinds of

‘socially invisible’ purchases. Similar campaigns have been used to change behaviour successfully in the past [see, 62, 63].

If choosers were informed of a shift towards new technologies using ‘community champions’ from an associated peer group, paired with an injunctive indicator of social approval if the individual were to act in accordance, this may prove an effective means of guiding behaviour in desired directions within this domain. Indeed, Westerhoff, Sheppard, Iype, Cote and Salter [64] found that “social mobilization initiatives” such as this could be highly effective in initiating action to mitigate climate change, by normalising sustainability into social practices and norms. In one such example, the ‘Good Life, Green Life’ intervention scheme, community representatives were filmed discussing the movement from concern to action on climate change. This film was then used as an engagement tool, which was widely circulated via a film launch, paired with social media outreach. Viewers of the film said it was successful in challenging stereotypes of environmentalists, and was also successful in countering feelings of isolation which previously constituted a key barrier to action at the individual level. Similarly Jager [53] suggests that using ‘examples’ of adopters may stimulate other people in the social network to change their behaviour. It would be interesting for future research to follow this line of reasoning and directly explore the potential for such schemes to incite behaviour change in the context of ‘green’ purchase decisions. Consequently, it would be useful for future research to explore the extent to which this may be addressed through development of intervention schemes that focus on promoting the actions of community champions who have recently made ‘green’ purchases, in order to help to establish and cement new social norms surrounding purchase decisions.

2.3 Emotion: How does it make me feel?

Many emotions, including worry, fear, disgust, happiness and elation, are known to impact upon decision making [65]. People may be reluctant to act unless a positive affective response is anticipated, or in an effort to avoid the experience of negative affect. People want to behave in ways that make them feel good about themselves. Referring to the role of emotion in decision-making, Elster [66] observed that: “economists have totally neglected the most important part of their subject matter” (pp. 1386). Decision makers are often theorised to make ‘cold’ decisions, on the basis of expected utility maximization. However, evidence suggests that emotion plays a crucial role in determining perception of, and response to, available options, often resulting in decisions based on intuitive processing, or ‘gut feelings’ rather than conscious deliberation. For example, decision makers will sell objects for less than their objective value, if induced to experience certain negative emotions such as sadness, guilt or disgust [67, 68]. A substantial body of research into *regret theory* has demonstrated the wide-reaching influence of this emotion on behaviour. Regret has been defined as ‘a negative cognitively determined emotion experienced when realizing or imagining that our present situation would have been better, had we acted differently’ [69]. A substantial body of research has demonstrated the often paralyzing impact of regret across a variety of choice contexts. For instance, parents who anticipated feeling regret if their child was to fall ill as a result of vaccination are less likely to have them vaccinated [70] (see also, [71]). In the context of energy, people may be reluctant to act if they anticipate the experience of regret from making a ‘wrong’ or ill-informed decision. Indeed, one explanation for action inertia following complex decisions is that choosers wish to shield themselves from the experience of regret following a possible ‘wrong’ choice [32, 51]; a finding which has been consistently demonstrated in empirical research [72, 73]. One way of overcoming this relates back to choice simplification. If options are presented such that the chooser does not feel overwhelmed (e.g. by using optimal levels of information, or through the provision of defaults), this may enable engagement in the choice process without fear of regret from making a ‘wrong choice’; potentially making selection of new technologies more feasible. Social norms can also be utilised to curb the emotional risk of making decisions involving new technologies. Specifically, normative information can be used to affirm potential courses of action, reassuring the decision maker that the target behaviour is associated with sound or satisfactory affective experience. Determining means of achieving this and assuring sound affective response in the context of new technology adoption remains an interesting avenue for future research.

In addition, Midden, Kaiser & McCalley [74] suggest that multimedia technologies provide new opportunities to both create and enrich sensory experiences as a route to raising awareness of future and/or distant issues. Such techniques have been shown to be effective in motivating pro-environmental behaviour change, by increasing the salience of negative affective response associated with unsound decision outcomes. For instance in one example, Leiserowitz [75] found that a survey of viewers of the movie "The Day After Tomorrow" (which dramatically conveyed the coming of a new ice age and giant flood as a direct consequence of global warming) led moviegoers to have higher levels of concern about climate change and to estimate real-world impacts as more likely. Similar effects were found amongst viewers of the recent BBC's 'Blue Planet' series, an effect colloquially dubbed the 'Attenborough Effect'. The series, which provided viewers with stark visual examples of the harm that humans are doing to marine ecosystems through lax use of plastic, led to a surge of interest and direct behavioural change in plastic pollution and recycling both at the individual and policy level within the UK (see, [76]). Research has shown how use of visual imagery such as this can play an important role in motivating behaviour change as a direct result of associated affective response, which in turn activates goals and facilitates message processing [77, 78, 79]. Accordingly, it would be useful for future research to explore how multimedia technologies may be utilised in order to motivate behaviour change in the context of innovative 'green' technology adoption, by increasing the salience of unsound affective impacts associated with continued progression along our current trajectory of increasing domestic energy demand, and perpetual reliance on high consuming systems and technologies. Alternate strands of research have shown how engagement in pro-environmental behaviours may be motivated by the anticipated experience of positive affect. For instance, within the environmental domain, research has shown that pro-environmental behaviour can be promoted by reminding people of past pro-environmental actions, due to a desire to project a consistent self-identity [80] (see also [81]). Research has also shown people are more likely to adopt eco-driving behaviours if provided with feedback emphasising environmental, as opposed to financial benefits [82]. It is suggested this is because environmental feedback elicits a 'social marketing decision frame'; encouraging altruistic motivations that benefit the welfare of others and the environment to be prominent considerations during choice [83]. Similarly, research into environmental 'spillover effects' has shown that promoting the benefits of a specific pro-environmental behaviour, such as car sharing, can 'spillover' and increase likelihood of engaging in other green behaviours such as recycling [84]. Interventions designed to increase green buying have been shown to have substantial spillover in many subsequent green decisions, including transport choice and water saving [85]. One explanation for these effects is that increasing the salience of self-transcending motivations strengthens environmental or energy-saving aspects of self-identity, encouraging engagement with other self-transcendent causes.

Decision makers often seek to act in ways that make them feel better about themselves, and acting upon altruistic motivations is one way of achieving this. Another approach concerns projection of status through choice outcomes. Indeed, according to the APA [16], a prominent barrier to behaviour change is social expectations about the kind of house or car one must have to be seen as successful. Demonstrating this, Maynard [86] asked owners of a Toyota Prius (a hybrid gas – electric vehicle) which factors had affected their decision to buy a hybrid car, and found the most important motivator concerned image: *"It makes a statement about me […] It shows the world that it's owner cares"* (see also, [87, 88]). Within the context of 'green' technology adoption, researchers have explored the significance of instrumental (functional), environmental and symbolic (self-identity and social status) attributes for the adoption of two sustainable innovations: electric vehicles and local renewable energy systems; finding that evaluation of the symbolic and environmental attributes of these innovations are the greatest predictors of intention to adopt [89]. Accordingly, behaviour change efforts could explore the potential for reflection upon symbolic attributes of new technologies to motivate behaviour in desired directions. As this research demonstrates, choice is often driven by a need to project the 'right' image to others, either reflecting social consideration, or other aspects of identity such as social status and prestige. This is also apparent when comparing choices of 'green' versus 'non-green' products made in public (group setting) versus in private (at home) [90].

Participants in 'public' choice conditions make significantly more pro-environmental choices, than participants who choose in private, where such reputational costs are not salient.

Thus, social perception of choice outcomes can lead decision makers to ignore the results of cost-benefit analyses, driven by a priority need to select outcomes which promote personal status to others. This is particularly poignant for the problem at hand. Specifically, whilst purchase of some innovative technologies such as solar PV have been shown to be influenced by projection of personal identity (i.e. seeing oneself as an environmentally sensitive person) [53], many homeowners' decisions about heating systems will be made in private, in the absence of wider social scrutiny. So, people may be more likely to select options which satisfy personal preferences, without taking wider social issues into account. It may be that if we can make such decisions more public, then we may guide choice in desired directions. For instance, if 'green' homes could be highlighted with a small token, such as a green leaf displayed on an outside wall, this added decision-visibility may encourage others to reflect on social perception of their own choices, potentially increasing likelihood of acting in accordance. Determining viable means of achieving this in practice and subsequent impact upon purchase behaviour remain interesting avenues for further research.

2.4 Perceived behavioural control: Can I do it?

In order to initiate behaviour change in desired directions, people must feel able to carry out an action successfully, and that that action will help bring about the expected outcome [14]. This concept has been termed *perceived behavioural control* (PBC) [91]; a powerful effect which appears in most socio-psychological models of behaviour change. According to the APA [16], decision makers may not act if changing personal behaviour is perceived as an ineffectual means of targeting large-scale global problems. Indeed, in their review of pro-environmental behaviour change studies, Hines, Hungerford and Tines [92] found that knowledge of issues and of action strategies (i.e. precisely *how* one should act in order to reduce impact on the problem) were closely associated with likelihood of engagement in pro-environmental behaviour. Similarly, DEFRA [18] revealed that feelings of disempowerment could deter individual decision makers from acting in pro-environmental ways, whilst Pelenur and Cruikshank [48] identified lack of information, and perceived lack of expertise as key barriers to behavioural change in the adoption of home energy efficiency measures. Further evidence comes from Ajzen's Theory of Planned Behaviour (TPB) [91] which ascertains that intentions are the closest antecedents of behaviour, and intentions are in turn predicted by attitude, norms, and crucially, PBC. The TPB has been used to successfully predict many pro-environmental behaviours, such as water saving [93] and household recycling [94]; as well as predicting likelihood of choosing to take public transport over a private car [95, 96].

Additional related evidence concerns the impact of information provision on intrinsic motivation. Research has found that autonomous motivation is a more effective predictor of behaviour, than extrinsic motivational factors such as financial incentives [97]. It is suggested that this is because energy saving behaviours need to be internalised if they are to be sustained, and that internalised behaviours are usually autonomously motivated and self-determined; a perspective largely congruent with the TPB. This is also consistent with research by Coleman and Eso-Ahola [98] who found that autonomously motivated behaviours are motivated most likely to be sustained in the long-term (see also, [99]). Similarly, Stern [17] identified lack of information as a key barrier to behaviour change in the context of energy efficient technology adoption. This relates directly to the Global Psychological Need Satisfaction Construct, which ascertains that the need for autonomy, competency and relatedness are crucial factors in determining decision motivation [100]. Similarly, Huebner, Cooper and Jones [101] found that lack of knowledge was a key barrier to behaviour change in the context of thermal energy demand. Specifically, lack of understanding about the option and importance of regularly adjusting thermostatic radiator values (TRV's) was identified as a key barrier to behaviour change in domestic heating practices. It is suggested that a lack of knowledge regarding the usage and impacts of innovative energy efficient heating systems may constitute a similar barrier to behaviour change in the context of new technology adoption. For instance, Jager [53] found that lack of knowledge regarding procedural and administrative procedures involved constituted a key barrier to installation of solar PV panels.

Crucially however, merely providing information may not be sufficient to create the feelings of competency and control that are essential in motivating choice: research has shown that information provision alone is ineffectual in promoting voluntary behaviour change to protect the environment [102], and that information must be autonomously sought, as opposed to merely presented, in order to enable this process [11]. The implications of this for motivating behaviour change centre on the most effective means of providing information. Research could explore the impact of interactive websites, for instance, which allow users to independently acquire information relevant to their enquiries. People are more likely to consider novel options if they feel fully informed within that domain. Therefore, for the kind of decisions we are considering in this review, development of an interactive website which allows choosers to explore novel technologies and attain information as and when required is one avenue that may have greater potential to encourage selection of these options in comparison to a standard, non-interactive choice environment. Alternatively, Westerhoff et al., [64] found that social mobilization efforts are effective in motivating behaviour change as they ensure citizens are meaningfully engaged in co-creating solutions (see, Section 2.2). Research has shown that such schemes are effective in motivating behaviour change as they directly encourage feelings of empowerment. This technique has been shown to lead to direct reductions in energy consumption when focusing on curtailment behaviours [see, 64]. It would be useful for future research to explore and contrast which means of information provision may be most effective in motivating widespread behaviour change within the context of large-scale 'green' purchase decisions.

2.5 Delay discounting: When will I get it?

Decisions often involve a trade-off among outcomes that occur at different times. Decision makers typically put less value on future outcomes than on near term ones, and the rate at which they discount the future is extremely high – well out of line with normative factors such as risk, prevailing interest rates, and inflation. Future consequences are therefore unlikely to receive proper weight in decision-making. For example, Shui and Ausubel, found participants preferred credit cards with short term 'teaser rates' that proved more costly in the long term [103], indicating that they heavily discounted delayed benefits relative to earlier ones. High rates of discounting have been used to explain a number of undesirable behaviours such as addiction, failing to save for retirement and procrastination [104, 105]. Within an environmental context, Allcott and Wozny demonstrated that car buyers' consistently underweight future fuel costs, leading to decreased likelihood of investing vehicles with greater fuel efficiency [106]. Similarly, in a large-scale survey on impacts of climate change the vast majority of those surveyed believed environmental conditions would be worse in 25 years than at present, and that environmental conditions were worse in other countries than their own [107]. Both temporal and spatial discounting of environmental problems in this manner is one explanation as to why people are reluctant to change their behaviour to meet larger-scale goals. In one illustration of this, Jacquet, Hagel, Hauert, Marotzke, Röhl and Milinski [108] found that rewards associated with pro-social action were heavily discounted with increased temporal distance. In this study, likelihood of co-operation in a group game framed around climate change was significantly reduced when associated rewards were framed as 'intergenerational' (i.e. delayed by several decades and over a larger number of beneficiaries). In this instance, all subjects failed to reach the collective target, demonstrating how discounting of temporally distant rewards plays a key role in determining likelihood of engagement in pro-environmental action. In addition, research has also shown that spatial discounting (i.e. the perception that conditions are worse elsewhere), can also act as a barrier to behaviour change: reducing motivation to act locally to meet larger-scale goals.

The implications of this for the problem of increasing uptake of new technologies in the energy retail market are substantial. Specifically, because payback periods involved in such investments are often lengthy (approximately 14 years for a ground source heat pump if offset by the Renewable Heat Incentive (RHI), in contrast to 1-4 years for a condensing boiler [109] [1]), it is likely that potential benefits will be disproportionally undervalued by decision makers. Indeed, Jager [53] demonstrated that discounting of future benefits constituted a key psychological barrier to behaviour

[1] Although precise payback periods will vary substantially depending on a variety of external, situational and technological variables

change in the decision to install solar PV. People give greater weight to short-term benefits, such extra cash left in the pocket post-choice, devaluing the relatively small, more uncertain, but potentially longer lasting gain of reduced energy bills each month. One way in which this might be overcome concerns emphasising shorter term benefits of investment, according to sequentially increased timescales. We could, for instance, explore whether focusing on shorter term gains every two, four, or six weeks, may have greater impact on likelihood of investment than focusing on payback periods. Indeed, research has shown one reason smart metering can be effective in reducing energy consumption is because it helps to mitigate the fact that people focus more on immediate rather than future consequences (i.e. the fact that most people pay for energy long after using it [110, 27]). Thus, the application of discounting theory would appear to lend itself well to the issue of motivating voluntary behaviour change in the context of technology adoption. In addition, Jager [53] suggests that expert support at the time of choice could also help to reduce the complexity consumers experience. As such, this may help to mitigate the extra time otherwise required in order to fully research innovative, unfamiliar alternatives. In order to overcome spatial discounting, research could also explore the potential for breaking down shorter-term gains into individually tailored personal goals, such as 'holiday funds'. Making short-term benefits more salient in this manner may provide the initial motivation needed to overcome usual discounting effects associated with seemingly unattainable or out-of-reach benefits. An alternate means of overcoming the effects of spatial discounting within this context concerns the nature and structure of information provision. Specifically it may be that providing decision makers with information relating to government decarbonisation objectives within the UK, broken down even further into objectives for the participants' local area to make the statistics even more salient, may help to increase motivation for people to act locally in order to meet these objectives. This remains an interesting avenue for further research.

2.6 Habit: What do I usually do?

The concept of habit is rooted in early behaviourist learning theory, which emphasized that thinking is not a necessary precursor to action [111]. Indeed, habitual behaviours can be characterized as situation-behaviour sequences that are or have become automatic, involving the association of a cue and a response, wherein the individual is not usually 'conscious' of these sequences [112]. A cue appears, such as a tempting dish or a cigarette, and without a moment's reflection, the food or the cigarette are in our mouth. Habitual behaviours differ conceptually from action inertia, as they result in the execution of particular, frequently repeated behaviours, where action inertia reflects a desire to do nothing, often resulting in avoidance of direct action. Habit formation is a highly adaptive process, since it enables people to perform necessary actions whilst keeping cognitive resources free for more demanding tasks [113]. However, because habits involve the removal of conscious deliberation from certain everyday choices, habitual behaviours are regarded by many as constituting one of the greatest psychological barriers to pro-environmental behaviour change [18, 114].

Regarding the problem of reducing energy consumption in homes, many curtailment behaviours relating to daily use of equipment (such as adjusting thermostat settings) may be reflexively carried out by habit, making them hard to change. For example, in a study by Huebner, Cooper and Jones [101] subjects were asked to discuss barriers to behaviour change in the context of heating practices, including use of domestic thermostatic radiator value (TRV) settings. Reliance on habitual behaviour patterns was found to constitute one of the greatest barriers to change, and also had direct impact on energy usage. Specifically, subjects who stated they were 'used to behaving in a certain way' were found to use more energy and were less likely to engage in energy saving actions known to impact upon thermal energy consumption. In addition, purchase decisions of 'green' products with a reduced environmental impact versus standard 'grey' alternatives may also affected by habit. For instance, in Janssen and Jager's [115] model based analysis of introduction of 'green' products to the market place, it was found that when subjects were allowed to create habitual behaviour patterns, this led to an increased likelihood that they would continue to do so, foregoing consideration of 'green' alternatives.

Research has suggested potential methods for changing habitual behaviours, including rehearsal of conscious behavioural cues, goal setting, commitment strategies and context changes [98], which may prove an effective strategy for reducing thermal energy demand if one is looking to target routine behaviours involving the daily use of equipment, such as those outlined by Huebner et al., [88] (for example including adjusting thermostat or TRV settings). However, with regards to the problem of increasing uptake of new technologies, it may be the case that large-scale one-off purchases such as these are less reliant upon habit. Frequent repetition of target behaviours is required in order for the behaviour to become habitual. As such, given that heating system choice is likely to be made on a fairly infrequent basis by most, it is unlikely that decisions will be made purely on the basis of habit. In this manner, it may be that habit does not constitute too great a hurdle in the context of increasing uptake of new technologies within the energy retail market. Nevertherless, Mahapatra and Gustavsson [47] suggest that one barrier to the adoption of innovative heating systems designed to reduce energy demand involves consideration of how difficult it will be to adapt one's customary behaviour for system use. Specifically, if users are highly accustomed to one particular type of system, it is likely that consideration of how difficult it will be to change one's behaviour when faced with an entirely new system, may constitute a significant barrier to uptake. As such, whilst choice of system itself may not be made reflexively by habit, consideration of habitual patterns of use may still play a role in preventing people from considering new systems and technologies. In addition, even when faced with a choice made on a relatively infrequent basis, such as heating system choice, research has shown that people typically prefer familiar alternatives [47]. However, this is likely attributable to desire for choice simplification and perceived behavioural control, as familiarity may elicit feelings of competency, allowing for choice with minimal effort to cognitive resources [see 53]. It would be interesting for future research to verify the extent to which varying large-scale purchase decisions are made by habit, using the Self-Report Index of Habit Strength devised by Verplanken and Orbell [112], as well as the extent to which the prospect of changing one's habitual patterns of use plays a role in determining consideration of innovative energy-efficient alternatives.

3 DISCUSSION AND CONCLUSIONS

This paper provides an overview of the most robust psychological barriers to behaviour change, as identified in the current academic and non-academic literatures, which are known to contribute to the energy efficiency gap [12]. These include: action inertia, social norms, emotion, perceived behavioural control, delay discounting, and habit. We have considered how each plays a role in preventing behaviour change with specific regard to encouraging uptake of 'green' technologies designed to reduce thermal energy demand, structured along a framework of questions typically faced by decision makers in this domain. We have demonstrated how each either affects capacity and / or desire to engage in the rational process of weighing up costs and benefits, or capacity to act upon results of such analyses; limiting the extent to which decision makers can be said to make economically 'rational' choices. In each section we have suggested some ways that information can be used to "nudge" consumers to make decisions that are good for themselves as well as society. To recap, these suggestions include: choice simplification (through information provision and choice set structure) to reduce both dependence on defaults and anticipated regret; communicating normative information (about the actions of 'champions' within a community via advertising campaigns); making private choices 'public' to capitalise on effects of social scrutiny; encouraging reflection upon symbolic attributes of new technologies; promotion of self-acquired knowledge; changing the temporal and spatial structure of costs and benefits; and rehearsal of conscious behavioural cues, goal setting, and context changes to target concerns about behavioural adjustments associated with everyday use of unfamiliar alternatives.

This report provides an advance from previous behaviour change review documents, by considering the implications of each effect tailored to the specific problem of reducing thermal energy demand in homes. We offer the suggestions above based on work to date and further work is needed to assess their relevance across of variety of 'green' decisions compared with rational economic factors, as well as to establish how such strategies may be most effectively tailored to meet the needs of differing population subsets, for example according to varying initial levels of interest or

engagement in the topic of energy saving [33], or whether or not individuals are likely to be earlier or later adopters of new technologies ([116] [117]). It is also important to note that additional psychological influences such as messenger effects, are not covered in this review as they do not necessarily constitute *barriers* to behaviour change. Yet these may nevertheless be considered as useful additional *enablers* of action. For instance, research has shown how decision makers may be affected by feelings towards the messenger: often disregarding information delivered by people they dislike or distrust [118]. In one example within the environmental domain, Craig and McCann [119] found that messages delivered by trustworthy sources were associated with more requests for energy conservation information, as well as greater energy savings in practice, in contrast to sources that were perceived to be low in measures of trustworthiness. As such, researchers may be wise to consider incorporating such effects into behaviour change campaigns in order to increase the likelihood that such strategies will be effective. For instance, specifically relevant to the context of thermal energy demand, Jager [53] found that independence from utility companies constituted an important component of the decision to install solar PV for subjects who were highly involved in the topic of conservation. It would be interesting for future research to build upon this and determine the parameters of this effect across varying investment decisions of 'green' innovations, as well as determining the most effective messenger types for encouraging engagement and uptake in this context.

By applying the principles reviewed here directly to future marketing campaign development, we may be able to support the transition to a low-carbon economy by increasing uptake of innovative systems and technologies designed to reduce domestic energy demand. For instance, on the basis of research reviewed here, we suggest such a scheme should aim to increase the salience of the anticipated negative affective response associated continued inaction in this context, as well as emphasising the actions of 'champion' figures, using real-life examples of early adopters of specific technologies. In addition, future campaigns should endeavour to simplify the presentation of new technologies, with a focus on debunking the perception that adoption would involve major disruption to routine usage behaviour patterns. It is likely that increasing the salience of this usage information within marketing campaigns may form a critical step in overcoming inertia, in order to encourage widespread consideration and uptake. Finally, such initiatives should also aim to change the temporal structure of costs and benefits in order to increase uptake of innovative 'green' alternatives. We previously reviewed how breaking down the benefits of pro-environmental action into daily or weekly gains can be highly effective in motivating behaviour change in desired directions (see, [108]). It would be useful for future research to determine how this may be most effectively incorporated into marketing strategies in practice, moving away from the attainment of longer-term goals from an intergenerational perspective (in terms of climate change mitigation), to a more localised perspective of shorter-term gains (such as shorter term gains to one's energy bills, including salient examples of how the saved money might be used).

In addition, as well as direct application to large-scale purchase decisions of appliances and technologies, the principles discussed have implications for application within the wider energy retail market, including consideration of high-consuming curtailment behaviours and smaller scale purchase decisions. For instance, the Department for Energy and Climate Change (DECC) explored the anticipated impact of engagement in varying curtailment behaviours on domestic energy use (the following savings are estimated based upon adoption across the whole of Great Britain's housing stock) [120]. The top energy-saving behaviours included (inter alia); turning the household thermostat down by 2 degrees from 20°C to 18°C (33TWh estimated saving); delaying the start of heating from October to November (11TWh estimated saving); and replacing a standard shower head with a water efficient shower head (5TWh estimated saving) [120]. Consequently, the application of the behaviour change principles discussed in this report may have substantial impact if applied in the wider context of these curtailment behaviours, and even to relatively small-scale purchase decisions such as a replacement shower head. What is more, The Behavioural Insights Team (BIT) report that using smart thermostats saves households 8% on their gas bill, which is twice the benefit of loft insulation [121], highlighting another potentially important area for future behaviour change

intervention focus. We recognise that many more examples exist of decarbonisation options within the field of residential energy demand, however given our focus on large-scale purchase decisions, providing further discussion of how each of the reviewed psychological barriers would relate to these specific alternate contexts is outside of the remit of the current paper. It would therefore be interesting for future research to continue to explore the varying impact of the psychological barriers reviewed here in differing contexts, focusing on behaviours that have been identified as making significant contribution to residential energy demand. Mattauch, Ridgway and Creutzig [122] previously reviewed how understanding of individual-level behaviour could contribute to the decarbonisation of the transport sector, and it would useful for future research to apply a similar methodological process to develop understanding of behaviour change potential within the wider residential energy sector.

The current research also has important implications for development of improved decision-making models designed to predict consumer behaviour in the context of new technology adoption. For instance, the Davis' [123] Technology Acceptance Model (TAM) is an information systems theory originally designed to predict acceptance and use of technologies in the context of informational technology (IT) systems. The model assumes that acceptance of IT systems is determined by two major variables: 1) perceived usefulness and 2) perceived ease of use. However the predictive value of the model has been called into question (see, 124]. We suggest that one explanation for this us that the model fails to take into account the myriad psychological influences discussed in the current paper. Later versions of the model have attempted to address this, to some extent. For instance, Venkatesh, Morris, Davis and Davis' Unified Theory of Acceptance and Use of Technology (UTAUT) [125] built upon the TAM but also included consideration of social influence as a driver for new technology adoption. The predictive value of the model was improved as a result, with the authors suggesting that the UTAUT explains up to 70% of the variance in intention to adopt new technologies [125]. At present, research in this area has predominately focused upon integration of IT systems and solutions. Consequently, the extent to which the results generalise to the context of diffusion of sustainable innovations is unclear, and accordingly this remains an interesting avenue for future research. What is more, the current research has demonstrated the importance of a wide range of psychological processes and influences in determining likelihood of adoption of new technologies in this context. Consequently, we suggest that future research should aim to carefully incorporate each of these factors into a revised version of the UTAUT, in order to further improve the predictive value of the model, and create a reliable means of assessing likelihood of adoption of sustainable innovations.

Overall, we hope that by providing suggestions for future empirical work we provide a theoretically grounded basis for initiating the widespread shift in social practices that will be vital in the transition to a low carbon economy in the domestic sector. Focusing on the example of large-scale purchase decisions, we reflect upon how each identified barrier affects decisions makers' desire, motivation, or capacity to engage in an alternative decision-making process to one that is economically 'rational' and solely based on the results of cost-benefit analyses. We have provided discussion of each of the psychological processes at play that override this deliberative approach to decision making. In doing so, we strengthen the case for moving away from classic economic subsidies as a solution to the problem at hand; moving instead towards psychological incentives and strategies, which will be critical in developing efforts to change the collective behaviour of society and reducing thermal energy demand [126, 127]. We suggest these barriers should be considered and understood by authorities, academics and retailers alike, as the behaviour change process is one which calls for collaborative effort between all parties working towards the same goal; of a greener more prosperous future.

Acknowledgements

This research was conducted by i-STUTE (the Interdisciplinary Centre for Storage, Transformation and Upgrade of Thermal Energy); one of six End Use Energy Demand (EUED) centres funded by the UK Research Councils' Energy Programme (RCUK).

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