[title page]

Title
Quantitative modelling of why and how homeowners decide to renovate energy efficiently

Authors
C. Wilson [a] *
H. Pettifor [a]
G. Chryssochoidis [b]

[a] Tyndall Centre for Climate Change Research, University of East Anglia, Norwich NR4 7TJ, UK
[b] Kent Business School, University of Kent, Canterbury CT2 7PE, UK

** corresponding author*: charlie.wilson@uea.ac.uk, 01603-591386

Highlights
- contextually-rich analytical framework for renovation decision-making
- path analysis and multivariate probit regression to model renovation decisions
- integrative model explaining both why and how homeowners decide to renovate
- results of national survey of renovation intentions of UK homeowners
- new insights on policies and service provision for energy efficient renovations

Abstract
Understanding homeowners' renovation decisions is essential for policy and business activity to improve the efficiency of owner-occupied housing stock. This paper develops, validates and applies a novel modelling framework for explaining renovation decisions, with an emphasis on energy efficiency measures. The framework is tested using quantitative data from a nationally-representative survey of owner-occupied households in the UK (n=1028).

The modelling advances formal representations of renovation decisions by including background conditions of domestic life to which renovating is an adaptive response. Path analysis confirms that three conditions of domestic life are particularly influential on renovation decisions: balancing competing commitments for how space at home is used; signaling identity through homemaking activities; and managing physical vulnerabilities of household members. These conditions of domestic life also capture the influence of property characteristics (age, type) and household characteristics (size, composition, length of tenure) on renovation decisions but with greater descriptive realism.

Multivariate probit models are used to provide rigorous, transparent and analytically tractable representations of the full renovation decision process. Model fits to the representative national sample of UK homeowners are good. The modelling shows that renovation intentions emerge initially from certain conditions of domestic life at which point energy efficiency is not a distinctive type of renovation. The modelling also shows clearly that influences on renovation decisions change through the decision process. This has important implications for policy and service providers. Efficiency measures should be bundled into broader types of home improvements, and incentives should target the underlying reasons why homeowners decide to renovate in the first place.

Keywords
renovation, decisions, policy, model, energy efficiency

Acknowledgements
This work was funded by the UK Energy Research Centre (UKERC) through grant NE/J006017/1. Full details of the project are available at www.tyndall.ac.uk/projects/value-propositions-energy-efficient-renovation-verd. Lucy Crane provided invaluable intellectual input.

[Manuscript]

1. Introduction: energy efficient renovation decisions

Improving the energy efficiency of the housing stock is integral to climate change mitigation and energy system objectives (IEA 2014). Long-term scenarios show energy use in buildings rising three to five-fold worldwide by 2100 (Levesque et al. 2017). Energy use for heating and cooling buildings is expected to grow globally by up to 40% to 2050 while "*efficiency retrofits present a tremendous opportunity to decrease energy use worldwide*" (Güneralp et al. 2017). In the EU, retrofit rates have to increase from their current 0.5 - 1.5% to around 2.5 - 3% of the housing stock per year to achieve policy goals (Sandberg et al. 2016). In the UK, up to 50% of energy used in homes could be saved through energy efficient renovations and other measures, contingent on policy to support household decision-making (Rosenow et al. 2017).

Around 67% of UK homes are owner-occupied, a proportion similar to the US and just below the EU average of 70% (Eurostat 2012). In owner-occupied homes, decisions to renovate with efficiency measures are the necessary precursor to energy-saving outcomes. Understanding why homeowners decide to renovate is therefore essential for effective policy design.

The objectives of this paper are to develop, validate and apply a descriptively-realistic model of energy efficient renovation decisions made within the context of everyday domestic life, and to demonstrate the relevance of this model for informing policy. This is consistent with Friege and Chappin (2014)'s recent review of decision models which concluded: "*a deeper understanding of the decisions of homeowners is needed and we suggest that a simulation model which maps the decision-making processes of homeowners may result in ... developing new mechanisms to tackle the situation*" (p196).

These objectives are consistent with the scope and concerns of *Applied Energy*. Research in this journal on energy-efficient home renovations has one of three broad aims: (1) improving analytical techniques and understanding of renovation measures, including in different housing types (e.g., Falke et al. 2016; Wu et al. 2017); (2) evaluating the technical and economic consequences of renovation activity in terms of future energy consumption, building performance, or performance gaps between estimated and actual energy savings (e.g., Kragh and Rose 2011; Mørck et al. 2012; Im et al. 2017); (3) understanding how renovation activity can be effectively stimulated through technical, policy or business-model innovations which support renovation decisions (e.g., Nair et al. 2012; Mahapatra et al. 2013; Liu et al. 2015).

By asking why and how homeowners decide to renovate energy efficiently, this paper is consistent with the third aim, although its findings are also relevant for more technical analysis. Occupant behaviour is frequently cited in *Applied Energy* articles as one of the main reason why analytical models over-estimate (Mørck et al. 2012) or under-estimate (Balaras et al. 2016) expected energy savings from energy efficient renovations. More broadly, user-responsive home energy management (under the rubric of 'intelligent energy systems') is one of seven headline issues tackled in applied energy research (Yan et al. 2017). Deviations from normative or optimised modelling assumptions emphasise the importance of research on how household *actually* make decisions to adopt and use energy-saving measures in order to understand the realistically-achievable potential for improving energy efficiency in homes (Dietz et al. 2009; Pisello and Asdrubali 2014; Falke et al. 2016). This is an issue of global importance. A study of different retrofit projects in China concluded that: "*in order to improve the effectiveness of energy-saving interventions, the motives, intentions and living habits of residents need to be given more consideration when designing and implementing retrofitting*" (Liu et al. 2015).

1.1. Quantitative Modelling of Energy Efficient Renovation Decisions

Choice experiments and other survey techniques for studying homeowners' decision making are important for identifying the drivers and barriers behind renovation investment decisions (Rommel and Sagebiel 2017), and the reasons why homeowners may or may not participate in programmes delivering energy-saving measures (Craig 2016). Understanding why certain homeowners have higher propensities to renovate can also help service providers segment their customer base (Taylor et al. 2014).

The dominant framing of energy efficient renovation decisions sees financial considerations as paramount (Wilson et al. 2015). Financial considerations include upfront costs, costs of capital, future cost savings, and payback periods (Rosenow and Eyre 2013). Commonly cited barriers to cost-effective efficiency investments include a lack of available capital or access to capital, unreliable contractors, a perceived deficit of credible information on renovation measures and outcomes, and the hassle and inconvenience of renovating (Mahapatra et al. 2013; Wang et al. 2015; Rommel and Sagebiel 2017). These barriers prevent otherwise positive beliefs and strong intentions towards energy efficiency from being realised (Skelton et al. 2009; GfK 2011).

Quantitative models of renovation decisions reinforce this basic financial framing. Discrete choice models based on stated preference data strongly emphasise financial attributes as explanatory variables. These allow the effectiveness of financial policy instruments like grants, subsidies and taxes to be evaluated (Jaccard and Dennis 2006; Banfi et al. 2008; Willis et al. 2011; Phillips 2012; Friege and Chappin 2014). Decision models based on observed market behaviour similarly focus on financial attributes (Skelton et al. 2009), but can also include a wider range of decision influences. These include property characteristics including size, age, type and location, and household characteristics including size, lifecycle, and the duration and type of home tenure (Jakob 2007; Grosche and Vance 2009; Braun 2010).

There is long-standing evidence that homeowners' decisions to carry out energy efficient renovations are not narrowly financial. Numerous cost-effective investment opportunities remain which homeowners do *not* pursue (Jaffe and Stavins 1994; Kragh and Rose 2011). Even in rented properties, ample opportunities exist to recoup efficiency investments through increased rental prices or lower energy costs (Im et al. 2017).

Some quantitative models broaden their explanatory variables to non-financial decision attributes. Models of heating system adoption decisions have included ease of use (Michelsen and Madlener 2012), and potential environmental benefits through CO_2 emission reductions (Achtnicht 2011). Models of energy efficient renovation decisions have included installation and contractor hassle (Stieß and Dunkelberg 2013), thermal comfort (Alberini et al. 2013), and air quality, noise reduction, and aesthetics (Galassi and Madlener 2017). Models of adoption decisions for specific renovation measures like energy-efficient windows have identified the influence of supply-chain actors (window sellers and installers) as well as homeowners' awareness of the cost and performance of windows with lower U values (Nair et al. 2012).

1.2. The Changing Contexts of Renovation Decisions

Energy efficient renovation decisions tend to be formally represented as being discrete financially-motivated events, subject to exogenous constraints or barriers (Wilson et al. 2015).

This representation of deliberative, instrumental, and isolable decisions has been criticised for failing to account for the context in which decisions to renovate are made. As Guy and Shove (2000) conclude with respect to narrowly-framed research on energy efficiency: "*greater attention should be paid to the changing contexts of energy-related decision-making*" (p135). For energy efficient renovations, these "*changing contexts*" mean life at home, or as Maller and Horne (2011) put it, "*the conventions and practices of households*" (p61). In other words, renovation decisions are situated within and emergent from everyday life at home and need to be analysed as such.

There are three important descriptively-realistic features of renovation decision making made in the context of everyday life at home.

First, decisions to renovate and subsequent renovation activities are part of a process by which households continually adapt their homes to the demands of domestic life. As Karvonen (2013) argues: "*Domestic retrofit is not an activity of changing a house … from poor energy performance to exceptional energy performance, but an intervention into the rhythms of domestic habitation*" (p569).

Second, from a decision-making perspective, efficiency measures are not a distinct type of renovation. Judson and Maller (2014) found that efficiency measures in one part of the home often went hand-in-hand with expansions or intensifications of other parts of the home (e.g., additional bathrooms). Noonan et al. (2013) found that US neighborhoods with homes undergoing larger remodelling projects had greater adoption rates for energy-efficient heating and cooling systems.

Third, models of renovation and other home-related decisions invariably represent the decision statically as a discrete point in time with a characteristic set of influences (McCormack and Schwanen 2011). Yet renovation decisions are long-drawn out processes or 'journeys', not singular events (Fawcett 2014).

These three features of renovation decision-making are omitted from quantitative analysis and modelling of energy efficient renovation decisions which narrowly emphasise:

i. renovation decision events, but not the processes preceding them nor the origins of the decision process;
ii. property and household characteristics, but not the conditions of domestic life from which renovation decisions emerge;
iii. energy-efficiency measures, but not other types of amenity renovation and improvements to the home.

By excluding variables characterising domestic life, and by failing to recognise the changing influences on renovation decisions as they progress, renovation decision models are limited in their ability to explain *why* households may be considering energy efficient renovations in the first place.

Box 1. Definitions and Terms.
Throughout this paper, we use the term 'renovations' to mean structural improvement work to a home or substantive physical changes to a property (Dixon and Eames 2013). 'Retrofits' and 'renovations' are generally used interchangeably. Renovations tend to have high time, cost, and/or skill requirements, and are typically carried out by professional contractors with appropriate technical expertise (Maller and Horne 2011).

We use the term 'energy efficient measures' to describe changes or upgrades to the building envelope, windows, doors, cavity or loft insulation, or heating and hot water systems (Dietz et al. 2009). In contrast, we use the term 'amenity measures' to describe changes to kitchens, living areas, bathrooms, lofts, and so on. These are not primarily energy-related although may include some efficiency measures.

We also note that renovations can include DIY (do-it-yourself) projects carried out by homeowners; but DIY projects do not have to form part of renovations. 'Home improvements', and in the US, 'remodelling', are general umbrella terms for all these activities (JCHS 2009).

2. Conceptual Framework

2.1. Renovation Decisions Made in the Context of Everyday Domestic Life

The decision model developed and applied in this paper is descriptively realistic, contextualised, and tractable for quantitative modelling. Its underlying conceptual framework was developed primarily to explain energy efficient renovation decisions, although many of its elements are generic to all renovation types. This allows the distinctiveness of energy efficient renovation decisions to be tested rather than assumed.

The decision process is approximated by a series of decision stages, adapted from the model used by Rogers (2003) to explain the adoption of innovations. This is shown in the upper part of Figure 1 with identifiable decision stages moving from initial awareness through positive attitude formation to an eventual decision and change in behaviour.

The innovation-decision model has been tested in many different contexts relevant to energy efficient renovations including the adoption of heating systems (Madlener 2007; Mahapatra and Gustavsson 2008; Michelsen and Madlener 2013) and solar photovoltaic systems (Faiers and Neame 2006; Islam 2014; Palm 2017). As shown in Figure 1, the decision process originates in conditions that create problems or needs to which current practices are maladapted (Nair et al. 2012). Social norms can also initiate decisions, particularly in the majority segments of potential adopters who are more receptive or susceptible to social influence (Rogers 2003; Jager 2006).

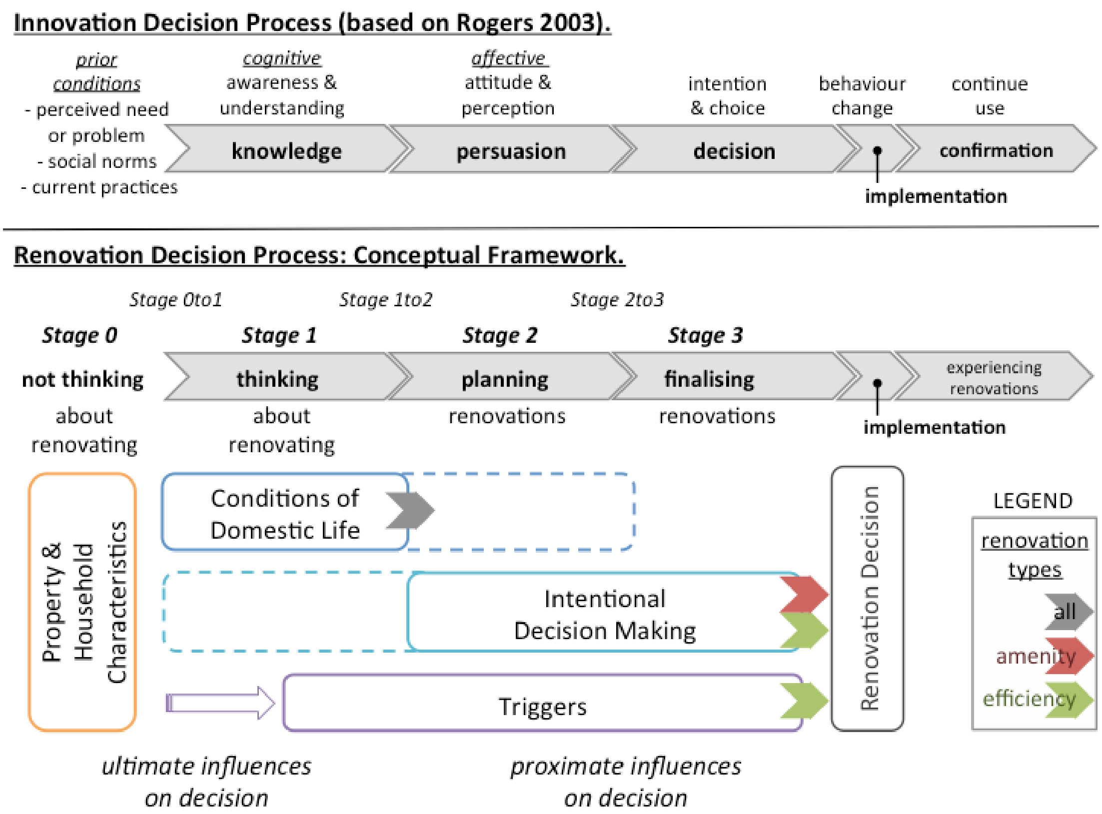
The lower part of Figure 1 represents the renovation decision process. It has three key features:

i. renovation decisions are a process represented by a series of four cross-sectional stages;
ii. renovation decisions emerge initially in response to certain conditions of domestic life, or in some situations can be triggered by extraordinary events;
iii. the distinctiveness of energy efficient renovation decisions becomes clear only during the later stages of the decision process as intentions to renovate strengthen.

The stages of the renovation decision process move from 'thinking about' (stage 1), 'planning' (stage 2), and 'finalising' renovations (stage 3). A final 'experiencing' stage describes how households experience and adapt domestic life to the structural changes made to their home (Tweed 2013). This paper is concerned with why and how homeowners decide to renovate, so the 'experiencing' stage is not considered further here.

A null non-decision stage (stage 0) is included as a control condition characterising homeowners 'not thinking about' renovations in any way. Inclusion of a control allows differences between renovators and non-renovators to be identified. Relatively few other studies have systematically explored the differences between renovating and non-renovating households through the use of control groups or samples of non-adopters (Craig 2016). One Swedish study found that if homeowners were satisfied with the physical condition, thermal performance, and aesthetic of their existing home, they were unlikely to renovate (Nair et al. 2010b). This article takes the converse approach in line with (Rogers 2003): unresolved tensions or problems in domestic life make it more likely homeowners will renovate.

FIGURE 1. CONCEPTUAL FRAMEWORK FOR RENOVATION DECISIONS MADE IN THE CONTEXT OF EVERYDAY DOMESTIC LIFE.



The conceptual framework shown in Figure 1 defines both outcome variables - renovation intentions culminating in a decision to renovate - and four blocks of explanatory variable:

- the 'Conditions of Domestic Life' (CDLs) describe issues, tensions or imbalances within homes and domestic life to which renovating is an adaptive response; an example is *Prioritising* which is the balancing of competing commitments for how space at home is used (see Section 2.2);

- 'Property & Household Characteristics' describe physical features of the property (e.g., age, type) and socio-demographic features of the household (e.g., size, composition) which may be associated with renovation decisions (see Section 2.3);
- 'Intentional Decision Making' describes attitudes and perceived social norms towards renovating; these are the explanatory variables in the innovation-decision process in Rogers (2003) (see Section 2.4);
- 'Triggers' describe one-off events that can either precipitate renovation decisions or short-circuit potentially lengthy decision processes; an example is a boiler breaking down (see Section 2.5).

As shown in Figure 1, the relevance of these explanatory variables changes over the decision process. The conceptual framework thus distinguishes proximate influences from ultimate influences on renovation decisions (Wilson et al. 2015).

2.2. Ultimate Influences: *Why* are renovation decisions made?

Ultimate influences explain *why* homeowners decide to renovate in the first place (*Stage 0to1* in Figure 1; note that the shorthand *Stage XtoY* is used throughout this paper to denote movement between stages in the decision model). Ultimate influences act through certain conditions of domestic life associated with renovating which are qualitatively characterised in sociological research on homes and domestic life. This paper represents a first attempt to include them in a quantitative decision model.

Table 1 identifies five Conditions of Domestic Life (CDLs) characteristic of renovating households identified in the literature. These CDLs were identified in a prior interview study with owner-occupied households in the UK (Wilson et al. 2013b), and are explained further in Appendix A1. (All Appendices are provided in online Supplementary Information).

The CDLs characterise why homeowners may decide to renovate their home as an adaptive response to tensions or imbalances in the use, function, design or arrangement of the home. The CDLs are broadly analogous to the prior conditions for the adoption of innovations identified by Rogers (2003) (see also Figure 1).

The CDLs have a high degree of generality and do not distinguish efficiency from amenity measures in the conceptual framework of renovation decisions (grey arrow in Figure 1). Moreover, the CDLs shown in Table 1 are neither exclusive, static, nor characteristic of all households. They should be interpreted as lenses through which to view certain salient characteristics of domestic life associated with a propensity to renovate.

The literature and interview data on which the CDLs are based provided certain expectations about how the CDLs interrelate. In particular, the conditions of *Prioritising*, *Embodying* and *Demonstrating* are considered antecedent to the *Adapting* condition. Tensions or imbalances can be created by competing commitments of household members, by the physicality of life at home, and by the absorption of social norms and other external influences. Each of these conditions of domestic life increases a household's propensity to make changes to the home. *Adapting* can therefore be regarded as an outcome condition within the set of five CDLs.

TABLE 1. CONDITIONS OF DOMESTIC LIFE (CDLS) ASSOCIATED WITH WHY HOMEOWNERS DECIDE TO RENOVATE.

Conditions of	Brief description	Renovating as a potential

Domestic Life (CDLs)		response to an imbalance or tension *between …*
Prioritising	The balancing of competing and at times conflicting commitments in domestic life (Munro and Leather 2000; Jarvis 2005).	... *between* the design or function of the home *and* the multiple, changing demands placed on it
Embodying	The impact of the body and its abilities on how space at home is used and arranged (Imrie 2004; Cole et al. 2008); includes old age and caring (Judson and Maller 2014).	... *between* the actual or anticipated physical abilities of household members *and* the configuration of the home
Demonstrating	The generation of thoughts and ideas for changing the home, including the absorption of social norms, media representations, and other external influences (Gram-Hanssen et al. 2007; Hand et al. 2007).	... *between* the current design and feel of the home *and* information signalled about how others have their homes
Home as Project	The meaning of home as a 'project' to be continually updated to express a household's identity (Aune 2007; Haines and Mitchell 2014).	... *between* the identity signalled by the home *and* household members' own sense of identity
Adapting	The tacit acknowledgement or explicit awareness of a need to change the physical characteristics of the home to solve perceived problems with objects or the use of space (Chappells and Shove 2005; Shove et al. 2007).	... *between* the home as it is *and* the home as it is could be adapted better to perceived needs

2.3. Property and Household Characteristics

Ultimate influences on renovation decisions that explain why homeowners start thinking about renovating are not typically included in decision models (Dodds 2014; Rommel and Sagebiel 2017). Instead, property and household characteristics are used as observable proxies for personal and contextual influences on renovation activity. As these characterise all households, regardless of their renovation intentions, they are shown on the left side of Figure 1 spanning the other blocks of explanatory variable.

The CDLs are designed to capture the same basic influences as property and household characteristics on renovation decisions but with greater descriptive realism. As an example, a household with elderly members in an old, un-insulated home might be more likely to renovate to improve energy efficiency. This expectation could be tested using property and household characteristics as explanatory variables for renovation propensity. But household composition and property age do not directly explain renovation decisions; the underlying causal mechanisms are omitted. In contrast, the conceptual framework shown in Figure 1 captures how elderly household members may experience physical discomfort in their home (*Embodying*) and how older properties may pose greater challenges for how space is designed and heated (*Prioritising*) (Table 1).

The CDLs therefore mediate the effect of property and household characteristics on renovation decisions. Expectations for these causal relationships include:

- *smaller properties, older properties* and *larger household sizes* are associated with *Prioritising* (balancing competing commitments);
- *household compositions with vulnerable members* (including young children and elderly people) are associated with *Embodying* (physical experience of thermal comfort);

short length of tenure (households who have recently moved in) is associated with *Adapting* (changing things around).

2.4. Proximate Influences: *What* renovation decisions are made?

Proximate influences reinforce renovation intentions once formed (*Stage 1to2* and *Stage 2to3* in Figure 1). Positive attitudes towards renovation outcomes and perceived social norms on renovating are the main forms of personal influence in the innovation-decision model (Rogers 2003). Attitudes towards energy efficient technology adoption are commonly found to be positive predictors of behavioural outcomes (Nair et al. 2010a; Michelsen and Madlener 2013). Perceived social norms have been shown to be influential on home energy use (Wilson 2014; Farrow et al. 2017) and home renovation activity (Noonan et al. 2013).

Proximate influences in the innovation-decision model explain how decisions become increasingly focused and object-specific as intentions strengthen. In the case of renovation decision making, specific attributes such as the energy efficiency of renovation measures become clear later on in the decision process (Mahapatra and Gustavsson 2008). Proximate influences on renovation decisions are therefore distinguished for efficiency and amenity renovations (red and green arrows in Figure 1).

2.5. Triggers of Renovation Decisions

Other important influences on renovation intentions include one-off, 'extraordinary' or high salience events which act as ‘triggers’ for renovation decisions. Triggers are included as a separate block of explanatory variable in the renovation decision model (Figure 1). Equipment breakdown is the principle type of trigger. Tweed (2013) notes how energy efficiency is "*barely differentiated from other aspects of experience within the home environment unless a problem occurs ... [domestic life] is a form of absorbed coping, which is only disrupted by ‘breakdowns’ that bring other concerns to the fore*." Other examples of triggers include a major change in household composition or circumstance (e.g., having a baby, moving job), or a step change in the adoption environment for energy-efficiency measures (e.g., short-term availability of very generous financial incentives, high levels of neighbourhood activity) (Skelton et al. 2009; EST 2010; Wilson et al. 2015; BPIE 2017). Depending on their immediacy and urgency, triggers can either bypass a cumulatively reinforcing decision process or precipitate it. Triggers are therefore shown in Figure 1 as beginning either in stage 1 (as an ultimate influence on why households start thinking about renovations) or in stage 2 (as a proximate influence on households' renovation plans).

2.6. Testing the Conceptual Framework

The conceptual framework shown in Figure 1 can be formalised as a series of hypotheses on energy efficient renovation decision-making:

H1: Influences on renovation decisions change over the decision process.

H2: The conditions of domestic life (CDLs) explain why homeowners start thinking about renovations.

H3: Energy efficient renovation decisions are not distinctive at the early stages of the decision process.

H4: The conditions of domestic life (CDLs) capture the influence of property and household characteristics on renovations.

These four hypotheses are all derived from descriptively-realistic studies of renovation decision-making noted above. H1 is based on observations that renovation decisions tend to be long-drawn out processes, lasting on average over a year (Fawcett 2014). H2 is based on sociological studies of domestic habitation and activities from which renovation decisions emerge (Judson and Maller 2014). H3 is based on market data including household expenditure surveys which show energy-efficiency measures tend to be installed alongside amenity measures (JCHS 2009; Wilson et al. 2013a). H4 is based on the conceptualization of CDLs as direct measures of the ultimate influences on renovation decisions (Wilson et al. 2013b).

To test these hypotheses, and so the validity of the conceptual framework for quantitative modelling of renovation decisions, each block of explanatory variable shown in Figure 1 was developed into sets of measurement items for inclusion in a nationally-representative survey of UK owner-occupied households. A comparative summary of each block of explanatory variable is provided in Appendix A1.

3. Materials and Methods

3.1. UK Homeowner Survey

An online survey was administered by Ipsos Mori in September 2012 to a representative sample of owner-occupied households in the UK. Individual respondents in each household were screened to ensure they were solely or jointly responsible for financial decisions regarding their home and were over the age of 18. The survey response rate was 15.9% with a median survey completion time of 26 minutes. Surveys completed in an unrealistically short time (3 times faster than the median) were excluded. The full survey instrument and dataset are publicly available via the UK Data Service (doi.org/10.5255/UKDA-SN-7773-1).

The survey used a quota sampling design to ensure even representation across the four decision stages. Screened respondents were asked to self-identify with one of four statements that best described their household's current renovation plans. Renovations were defined as major changes to the physical properties of the home which would usually require contractors or builders to do the work; do-it-yourself (DIY) projects, redecorating, and changing appliances were specifically excluded (see Box 1). Based on their responses, households were assigned to one of the three renovation decision stages (1-3) or the null non-decision stage (0):

- We are not currently thinking about renovations as a possibility (*assigned to stage 0*)
- We are currently thinking about renovations as a possibility (*stage 1*)
- We are currently planning renovations to be done at some point in the near future (*stage 2*)
- We are finalising plans for renovating or are currently in the middle of renovating (*stage 3*)

The quota sampling continued until at least 250 complete responses were received for each decision stage. A final sample of n=1,028 respondents completed the survey. The characteristics of each quota of n≈250 per decision stage were similar, and representative of the home-owning population in the UK. Full sample characteristics are provided in Appendix A2.

Respondents who self-identified as being in the renovation decision process (stages 1-3) were asked which measures they were considering, and whether any one-off events had 'triggered' their decision process. Measures were coded as efficiency (windows, doors, insulation, heating or hot water system) or amenity (kitchen, bathrooms, conversions, living spaces, other). Amenity measures dominated respondents' renovation plans, and around one third of respondents reported some trigger (Table 2).

TABLE 2. SAMPLE CHARACTERISTICS OF HOUSEHOLDS PER RENOVATION DECISION STAGE.

Sample Characteristics	stage 0 **not thinking about** renovating	stage 1 **thinking about** renovating	stage 2 **planning** renovations	stage 3 **finalising** renovations	all stages
Sample size	n=259	n=254	n=253	n=262	**n=1028**
Measures (efficiency only)	-	14%	9%	10%	**11%**
Measures (amenity only)	-	35%	38%	32%	**35%**
Measures (mixed efficiency + amenity)	-	51%	53%	58%	**54%**
Triggers (fix or replace) [a]	-	21%	25%	27%	**25%**
Triggers (other) [a]	-	9%	11%	15%	**11%**

[a] Triggers (fix or replace) = something has broken and needs fixing or replacing; Triggers (other) = unusually strong recommendations by someone who lives locally or by an expert or contractor, or extraordinarily attractive financial incentives.

It is important to note that the sample was cross-sectional which does not allow for longitudinal analysis of *within-subject* progression through the decision process. Consequently the hypotheses were tested through *between-subject* comparisons across the decision stages.

3.2. Measurement Items and Data

All variables used in the analysis based on measurement items from the survey are shown in Appendix A3. The names of variables are italicised throughout this paper (e.g., *Prioritising*).

All measurement items were short statements with a 7 point Likert scale response (1=strongly disagree | 7 = strongly agree). Multiple items were included for each of the CDLs and intentional decision variables, and were reduced into single factors if clear and interpretable factor structures were found (*Demonstrating*, *Attitudes*, *Social Norms*). For CDLs lacking a clear factor structure, single items were selected as most representative of the general meaning of the CDL (*Adapting*, *Prioritising*, *Embodying*, *Home as Project*).

Additional survey questions were included to identify property and household characteristics relevant to energy efficient renovations.

Various approaches were used to ensure individual responses characterized household-level renovation decision variables: (1) only sampling adult household members with financial decision responsibilities; (2) dynamically scripting question phrasing to be in the 'we/our' form for two or more person households, and in the 'I/my' form for single person households; (3) having question prompts such as "*How much do you agree with the following statements about your household?*"; (4) having further survey prompts reminding respondents to take the household perspective such as "*Now we are going to ask you about your household. We define household as one person or a group of people who live together in their only or main home, and share important financial decisions to do with this home*".

3.3. Analytical Methods

3.3.1. Mean Differences between Decision Stages

Responses per decision stage for all the CDL variables and intentional decision variables were tested for differences using a Scheffe multiple comparison test of means. The Scheffe test is a post hoc significance test which allows comparison between mean statistics for multiple groups. This served as an initial evaluation of whether influences changed over the decision process as well as the strength of particular variables in each decision stage (testing H1).

3.3.2. Path Analysis of Interrelationships between the Conditions of Domestic Life (CDLs)

Each CDL characterises a distinctive and specific condition of everyday life at home linked to renovation propensity. Hypothesised linkages between CDLs were formalised into a network of 'paths' or relationships. Empirical support for these relationships could then be tested using path analysis. Path analysis is an extension of multiple regression, providing estimates of the magnitude and significance of hypothesised causal connections between sets of variables. For the renovation decision model, path analysis was used to test the direction and strength of bivariate relationships between CDLs using pairwise partial correlations (controlling for other relationships). This resulted in a series of 'decision maps' of the relationships between CDLs (testing H2 and H4).

3.3.3. Multivariate Probit Models of Full Renovation Decision Model

The full decision model including all four blocks of explanatory variable was tested using multivariate probit regressions on dichotomous decision stage variables (Figure 1). The main outcome variable was *Stage 0to1* which compared households not thinking about renovating (stage 0) and households thinking about renovating in general terms (stage 1). The multivariate probit model is a further extension of path analysis, used to estimate several correlated outcome variables simultaneously. Multivariate probit was preferred as it enables clear comparison between renovation decision stages as well as providing goodness of fit statistics for the models (see Appendix A6 for further details).

4. Results

4.1. Mean Differences between Decision Stages

Table 3 reports mean responses for all CDL and intentional decision variables for households grouped by renovation decision stage. Scheffe tests confirm that four of the five CDLs are significantly stronger in renovating households (stages 1-3) compared to non-renovating households (stage 0). In other words CDLs help explain the initial formation of renovation intentions (consistent with H2). Table 3 shows the results for stage 0 compared to stage 1 and stage 2; full results are included in Appendix A4.

Attitudes and norms are also significantly stronger in households planning renovations compared to those not thinking about renovations (consistent with H1). However, a reverse causal interpretation cannot be ruled out. Positive attitudes towards renovating may strengthen intentions and move households forwards through the decision process; or households may decide to renovate for other reasons which makes attitudes more positive to ensure self-consistency and avoid dissonance.

TABLE 3. MEAN RESPONSE ON CDL AND INTENTIONAL DECISION VARIABLES FOR EACH DECISION STAGE.

Decision Variable	total n (all stages)	Mean Response (with s.d.) per Decision Stage				Scheffe Test [a]	
		stage 0	stage 1	stage 2	stage 3	stage 0to1	stage 0to2
Conditions of Domestic Life (CDLs)							
Prioritising	995	2.8 (1.7)	3.5 (1.9)	4.2 (1.8)	4.0 (1.9)	+ *	+ *
Embodying	867	2.7 (2.0)	2.7 (2.0)	2.9 (2.1)	3.2 (2.2)		+ [ns]
Demonstrating	1010	3.0 (1.3)	3.6 (1.3)	3.8 (1.4)	3.7 (1.4)	+ *	+ *
Home as Project	1018	3.3 (1.7)	4.0 (1.8)	4.6 (1.7)	4.7 (1.8)	+ *	+ *
Adapting	1008	2.6 (1.5)	3.0 (1.5)	3.4 (1.7)	3.6 (1.8)	+ *	+ [ns]
Intentional Decision Making							
Attitudes-Amenity	1006	3.9 (1.1)	4.3 (0.9)	4.7 (0.8)	4.8 (0.8)	+ *	+ *
Attitudes-Efficiency	1011	4.2 (1.2)	4.5 (1.1)	4.7 (1.1)	4.8 (1.1)	+ *	+ *
Social Norms-Amenity	997	4.2 (1.05)	4.4 (0.9)	4.5 (1.1)	4.5 (0.9)	+ *	+ *
Social Norms-Efficiency	998	4.2 (1.1)	4.5 (0.9)	4.4 (0.9)	4.5 (1.0)	+ *	+ *

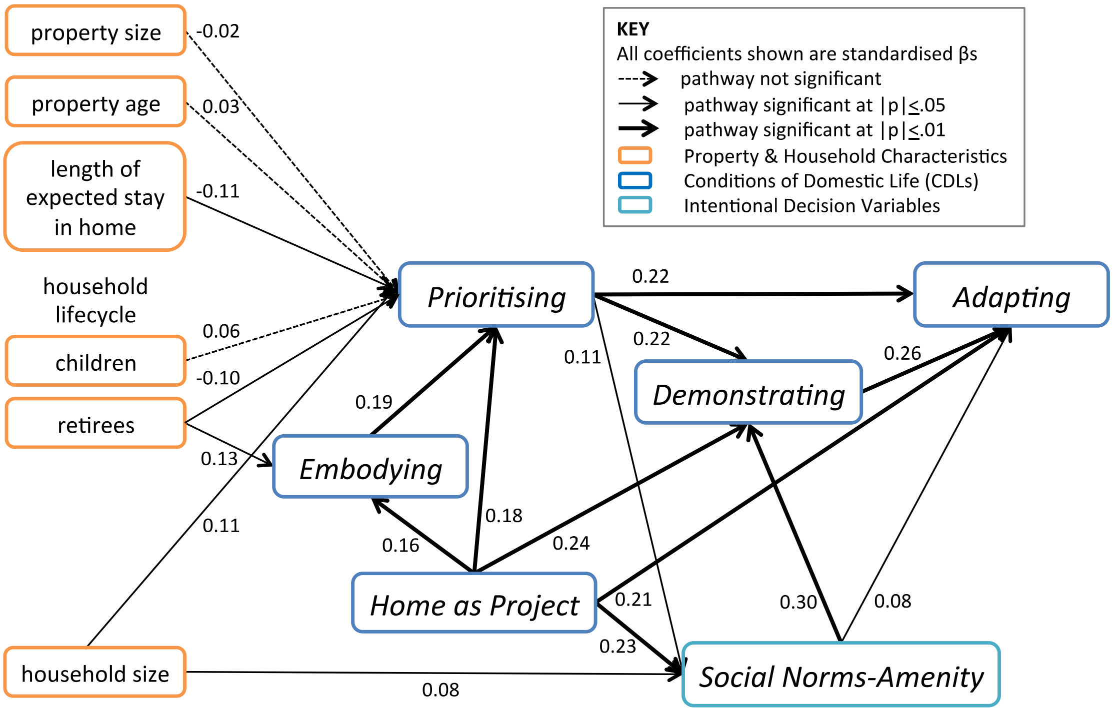
Notes: [a] + = mean response is higher; * = significant at p≤.05; [ns] = not significant.

4.2. Interrelationships between CDLs

Path analysis was used to test for strong and significant interrelationships between the CDLs, and between the CDLs and property and household characteristics. *Social Norms-Amenity* was also included as normative influence is one of the main sources of external influence internalised by households in the *Demonstrating* condition, and 89% of households in the sample were considering amenity measures (see Table 2).

The base path model for all households in stages 1-3 of the renovation decision process is summarised in Figure 2; full results are included in Appendix A5. In general, expected relationships between CDLs were all confirmed. The base model was further tested on subsamples of households in discrete decision stages, households considering only amenity measures, and households considering efficiency measures either alone, or mixed with amenity measures. Each model had a similar structure of interrelationships between CDLs as shown in Figure 2 for the base model (consistent with H3 and H4). Good overall model fits were found in all cases ($R^2 > 0.25$, CFI = 0.93 to 0.97, and RMSEA <= |0.05|; see Appendix A5 for full explanation of fit statistics).

FIGURE 2. ENDOGENOUS STRUCTURE OF CDLS FOR ALL RENOVATING HOUSEHOLDS (IN STAGES 1-3 OF THE RENOVATION DECISION PROCESS).



Adapting describes changing things around at home in response to perceived needs, and so serves as the outcome condition for the endogenous structure of the CDLs. The pathways to *Adapting* are clearly interpretable and explain why households need to make changes to their homes (consistent with H2).

Prioritising, *Demonstrating*, and *Home as Project* are all antecedent to *Adapting*. Each of these CDLs represent a potential source of tension or imbalance in domestic life which making changes to the home may help resolve. *Prioritising* captures imbalances between the physical arrangement of the home and the competing commitments or needs for it. *Home as Project* engenders homemaking as a means of expression and of signalling identity, potentially creating a dynamic tension between the home as it is and the home as it should ideally be. This is related to *Demonstrating* which measures the receptiveness of households to external sources of idea and influence for changing their home. As expected, *Demonstrating* and *Social Norms-Amenity* are also closely related. Normative influence is an important source of ideas and inspirations for changing the home which are internalised by households.

The influences of property and household characteristics on *Adapting* are mediated by particular CDLs which capture the underlying influence with greater descriptive realism (consistent with H4). Competing commitments on the use of space at home (*Prioritising*) are more common in larger households, and less common in households with elderly members and in households not intending to stay long in their current property. Each is clearly interpretable. Larger households have a greater range of demands on domestic space. A short expected length of tenure suggests moving home rather than renovating as a response to any imbalances or tensions (Coulter et al. 2011). The needs of elderly members are picked up by *Embodying* which characterises the anticipation or facing of tensions between physical capabilities and the use of the home.

4.3. Full Renovation Decision Model

4.3.1. Initial Formation of Renovation Intentions: CDLs and Triggers

Table 4 summarises the multivariate probit regression results for the direct effects of CDLs on the *Stage 0to1* and *Stage 0to1,2,3* outcome variables; full results, including antecedent relationships between CDLs, are reported in Appendix A6.

The *Stage 0to1* models test the initial formation of renovation intentions, distinguishing households not thinking about renovating (stage 0) from those thinking about renovating in general terms (stage 1). The *Stage 0to1,2,3* models have larger sample sizes and contrast non-renovators with renovating households at any stage of the decision process (stages 1-3 combined).

TABLE 4. MULTIVARIATE PROBIT MODEL COEFFICIENTS AND FIT STATISTICS: CDLS ONLY, DECISION STAGES 0TO1 AND 0TO1,2,3.

CDLs only as Explanatory Variables	Outcome Variable: *Stage 0to1* full sample	Outcome Variable: *Stage 0to1* excluding triggers	Outcome Variable: *Stage 0to1,2,3* full sample	Outcome Variable: *Stage 0to1,2,3* excluding triggers
Variable Coefficients (β)				
Prioritising	0.18**	0.18*	0.23**	0.24**
Embodying	-0.07	-0.02	-0.04	0.02
Demonstrating	0.14*	0.11	0.07	0.10
Home as Project	0.17**	0.18*	0.26**	0.24**
Adapting	-0.02	0.08	0.04	0.07
Model Statistics				
Pseudo R^2	0.12**	0.14**	0.20**	0.24**
AIC [a]	12,659	8,659	25,029	16,153
BIC [a]	12,817	8,803	25,213	16,321
N (*Stage 0*)	236	166	236	166
N (*Stage 1* or *Stage 1,2,3*)	239	159	716	451

Notes: ** $p \leq .01$; * $p \leq .05$.

[a] AIC = Akaike's Information Criterion, BIC = Bayesian Information Criterion.

Pseudo R^2 values for the full samples in the *Stage 0to1* and *Stage 0to1,2,3* models are 0.12 and 0.20 respectively. (Pseudo R^2s are closest in interpretation to a conventional R^2 in OLS regressions; see (Hagle and Mitchell 1992) and Appendix A6 for details). The information criteria (AIC, BIC) provide alternative measures for comparing the relative goodness of fit of different models, and include penalties for additional variables that do not significantly improve fit (Kuha 2004). Lower AIC and BIC values indicate better fits.

Removing households that report triggers improves the pseudo R^2 of the *Stage 0to1* model from 0.12 to 0.14, and of the *Stage 0to1,2,3* model from 0.20 to 0.24. Both the AIC and BIC values also drop by around one third. This is consistent with expectations that triggers bypass emergent decision processes, and so removing households reporting triggers improves model fit.

Overall the models confirm the role of the CDLs in explaining why households move out of the null non-decision stage (consistent with H2). CDLs that significantly predict the emergence of a renovation decision process are also consistent across models, with coefficients of similar strength, significance and direction (see Appendix A6 for details).

Using the results for the *Stage 0to1* model excluding triggers as an example, *Prioritising* (β=0.18*) and *Home as Project* (β=0.18*) are strong and significant predictors of change in decision stage, controlling for the effect of other variables. Shown in the path analysis to be precursors of the *Adapting* condition, both these CDLs also directly explain the initial formation of renovation intentions as a response to tensions or imbalances from competing commitments and mis-signalled identity respectively.

Contrary to prior expectations none of the other CDLs (*Embodying*, *Demonstrating, Adapting*) explained the initial formation of renovation intentions. *Embodying* is likely to be characteristic only of a subsample of households with physically vulnerable members including the elderly or young children (Figure 2). *Adapting* is a broad construct describing households with a propensity to change things around at home in response to perceived needs. This could be anything from rearranging furniture to redecorating or DIY, but also contracting out for major renovations. This breadth of interpretation means there is no simple relationship from *Adapting* to the renovation decision process. *Demonstrating* was an influential variable on *Adapting* in the path analysis, but does not directly predict renovation intentions in the probit model. One interpretation is that the *Demonstrating* condition is more commonly linked to design and DIY alterations to homes, but not to more substantial renovations (see Box 1).

4.3.2. Strengthening of Renovation Intentions through the Decision Process: Limited Explanatory Power of CDLs

Intentions once formed become more focused and object-specific (Ajzen 2001). Households deciding about renovations (stages 1-3) may be considering only amenity measures, only energy-efficiency measures, or a mix of both. Progression through the decision process (*Stage 1to2* and *Stage 2to3*) is modelled for households grouped by renovation type to test whether energy efficient renovation decisions are distinctive. Two renovation types are distinguished: amenity only, and efficiency only + mixed efficiency with amenity (combined to avoid small sample sizes).

The upper half of Table 5 reports the model fit statistics for *Stage 1to2* and *Stage 2to3* relative to the *Stage 0to1* model using only CDLs as explanatory variables, and excluding households who reported triggers; full model results including variable coefficients are included in Appendix A6.

The expectation is that these CDL-only model fits should progressively weaken because the CDLs lose explanatory power once renovation intentions are formed. This is broadly confirmed (consistent with H2). Three of the four models have similar or lower pseudo R^2s. The AIC and BIC in both the *Stage 1to2* and *Stage 2to3* models are lower relative to the *Stage 0to1* model but this is explained by the lower sample sizes. The *Stage 1to2* model for efficiency only + mixed renovators is anomalous as the pseudo R^2 increases relative to the *Stage 0to1* model. For this model, *Prioritising* increases in strength and significance as a predictor of *Stage 1to2* (see Appendix A6). It is not clear why. One interpretation is that households with strengthening intentions towards energy efficient renovations express these by making certain tensions in domestic life more salient to ensure self-consistency.

Additional models were tested with property and household characteristics included. Adding these as explanatory variables along with the CDLs did not improve model fits (consistent with H4); see Appendix A6 for details.

TABLE 5. MULTIVARIATE PROBIT MODEL FIT STATISTICS: DECISION STAGES 0TO1, 1TO2, AND 2TO3, EXCLUDING HOUSEHOLDS WHO REPORTED A TRIGGER. UPPER HALF OF TABLE SHOWS MODELS WITH CDLS ONLY AS EXPLANATORY VARIABLES; LOWER HALF OF TABLE SHOWS MODELS WITH CDLS AND INTENTIONAL DECISION VARIABLES AS EXPLANATORY VARIABLES.

	Outcome Variable: *Stage 0to1*	**Outcome Variable: *Stage 1to2***		**Outcome Variable: *Stage 2to3***	
Model Fit Statistics	**all renovation types**	**amenity only**	**efficiency only + mixed**	**amenity only**	**efficiency only + mixed**
CDLs only					
Pseudo R^2	0.14**	0.10	0.26*	0.15*	0.05
AIC [a]	8,659	4,126	3,251	3,893	2,803
BIC [a]	8,803	4,242	3,358	4,008	2,905
N (moving from *Stage X*)	166	74	63	82	62
N (moving to *Stage Y*)	159	82	62	71	45
CDLs and Intentional Decision Variables					
Pseudo R^2	0.25**	0.15*	0.33**	0.20*	0.17
AIC [a]	4,622	2,401	1,870	2,247	1,596
BIC [a]	4,748	2,498	1,965	2,343	1,685
N (moving to *Stage X*)	151	71	62	80	59
N (moving from *Stage Y*)	151	80	59	67	43

Notes: ** $p \leq .01$; * $p \leq .05$.
[a] AIC = Akaike's Information Criterion, BIC = Bayesian Information Criterion.

4.3.3. Strengthening of Renovation Intentions through the Decision Process: Intentional Decision Variables

Object-specific intentional decision variables become relevant as renovation intentions strengthen through the decision process. Including attitudes towards renovation outcomes and perceived social norms on renovating should improve the model fits for the later stages of the decision process, and also help distinguish amenity from efficiency renovation types.

This is broadly confirmed in the lower half of Table 5 which reports the model fit statistics using both CDLs and intentional decision variables as predictors of progression through the decision process, excluding households who reported triggers (see Appendix A6 for full results). Compared to the CDL-only models reported in the upper half of Table 5, pseudo R^2s are higher and/or more strongly significant in all cases, and the AIC and BIC are around one third to a half lower in all cases. In other words, the intentional decision variables help explain strengthening renovation intentions (consistent with H1).

Comparison of the model fits and variable coefficients also shows notable differences between amenity- and efficiency-focused renovation decisions (consistent with H3). As an example, positive attitudes towards specific renovation outcomes are significant influences on amenity renovators, but not efficiency renovators (see Appendix A6 for details).

5. Discussion

5.1. Validation of Conceptual Framework

This paper developed a novel conceptual framework to explain household renovation decisions, with an emphasis on energy efficiency measures. The conceptual framework introduced a block of variables describing certain conditions of domestic life (CDLs) associated with renovating. The CDLs explain the initial formation of renovation intentions as an adaptive response to tensions and imbalances with the design, arrangement, and use of space at home.

Four hypotheses were identified to test this central proposition of the conceptual framework. All four hypotheses were broadly confirmed. Table 6 summarises the evidence.

TABLE 6. EVIDENCE CONFIRMING HYPOTHESES ON RENOVATION DECISION MAKING (INCLUDING LINKS TO RELEVANT SECTIONS IN TEXT AND APPENDICES).

	Scheffe Tests	Path Analysis	Probit Models
H1: Influences on renovation decisions change over the decision process.	Significant mean differences between stages (4.1, A4).	Interrelationships between CDLs change in strength and significance between stages while maintaining similar structure (4.2, A5).	CDLs influential only in initial stages (4.3.2). Intentional decision variables help explain strengthening intentions (4.3.3, A6).
H2: The conditions of domestic life (CDLs) explain why homeowners start thinking about renovations.	CDLs stronger in renovating households compared to null non-decision households (4.1, A4).	Clearly interpretable interrelationships between CDLs (4.2, A5).	Good model fit for predicting households in renovation decision process (4.3.1, A6).
H3: Energy efficient renovation decisions are not distinctive at the early stages of the decision process.	-	Few differences in interrelationships between CDLs for amenity and efficiency renovators (A5).	Object-specific attitudes and perceived social norms become more influential through decision process (4.3.3, A6).
H4: The conditions of domestic life (CDLs) capture the influence of property and household characteristics on renovations.	-	CDLs mediate influence of property and household characteristics (4.2, A5).	Inclusion of household and property characteristics does not improve fit of CDL-only model (A6).

5.2. Implications for Policymakers & Service Providers

By situating renovation decisions within domestic life, the validated conceptual framework demonstrates how the tractable, empirical strengths of quantitative modelling can be retained in a contextual, descriptively-rich framing of renovation decisions as an adaptive response to certain conditions of domestic life. The resulting decision model explicitly recognises the complexities of homes as adoption environments for renovation measures, and explains not just *how* households plan energy efficient renovations, but also *why* they are considering renovations in the first place. This research provides new insights for policymakers and service providers seeking to stimulate energy efficient renovation decisions. This is a major challenge.

Across Europe, renovation rates remain stubbornly below what is needed to meet sustainable energy and climate change goals (Sandberg et al. 2016; Filippidou et al. 2017). The UK currently has no major policies to support improvements in the housing stock, yet reducing emissions from the residential sector is absolutely vital for near-to-medium term climate change goals (UK CCC 2017). The Green Deal was introduced with fanfare in 2013 and largely withdrawn less than two years later. Replacing obligations on utilities with a inform-and-finance approach targeting homeowners, the Green Deal did effectively raise the salience of energy efficient renovations but failed in other important ways (Pettifor et al. 2015). First, it treated energy efficient renovations as discrete rather than a 'mundane' feature of broader home improvements. Second, it was attractive to homeowners only once they had already decided to renovate rather than initiating renovation decisions. Third, it emphasised financial attributes of the decision (cost, interest rate, payback) rather than tapping into underlying tensions in domestic life which renovations could help resolve. These design flaws are characteristic of many, if not most policies aiming to stimulate energy efficient home renovations. Innovative one-stop shop type business models providing audit, finance and implementation work with quality control measures like the Green Deal have also been proposed and implemented in other countries including in Scandinavia (Mahapatra et al. 2013). However like the Green Deal in the UK, these rely on motivated homeowners initiating the decision process. Well-designed business models can increase conversion rates of initial contacts into renovators, but fail to address why homeowners may be deciding to renovate in the first place. Three main insights from this research can help address these flaws and so transform policymaking to boost renovation rates.

First, decisions to carry out renovations that include efficiency measures are influenced as much by factors relevant to amenity measures as by a desire to be more energy efficient. Energy-efficiency measures are much more commonly part of broader 'amenity' home improvements than a distinctive type of renovation; only one in ten UK renovators are considering only efficiency measures (Wilson et al. 2013a). Energy-efficiency policy should target the bundling of efficiency measures into other types of home renovation, rather than trying to stimulate efficiency-only renovations in households not considering renovations. Marketing, sales channels, and existing points of contact between homeowners and the amenity supply chain (such as installers visiting homes to quote or measure up) can be used to target efficiency measures at would-be amenity renovators.

Second, homeowners start thinking about efficiency renovations just as they do amenity renovations - as ways of resolving certain conditions of domestic life that create tensions, imbalances or issues within the home. Would-be renovators may face competing commitments in using available space at home; they may face or expect to face physical issues with home life; or they may think their home does not suitably express their own identity. Service providers can link their product and services more clearly to these underlying reasons why homeowners start thinking about renovating. The modeling analysis of energy efficient renovation decisions shows that efficiency measures can help make spaces in the home more useable or thermally comfortable, reduce environmental stresses on vulnerable household members, and combine functionality with design and aesthetics. These correspond to the *Prioritising*, *Embodying*, and *Home as Project* conditions respectively, each of which have significant and similarly strong effects on households thinking about or planning energy efficient renovations (see Appendix A6).

Third, market segmentation strategies can help identify households with conditions of domestic life most strongly associated with renovating. Using proxy indicators to identify homes with unresolved tensions over the use of space can help utilities, housing associations, and other actors in the renovation supply chain to target their service offerings more effectively (Taylor et al. 2014). The *Prioritising* condition describes households juggling competing commitments with how space at home gets used. This is more likely in larger households, those with more than one child, or more than one adult working from home, those whose members have a diverse range of activities and interests, or whose circumstances have just changed significantly (e.g., new job, new mode of transport, recently moved home). The *Embodying* condition, which describes households facing or expecting to face physical issues, is more likely in cases of poor health, old age, but also very young children. The *Demonstrating* condition describes households that see their homes as a means of expressing their own sense of identity, and that are more likely to receive ideas and inspiration from other people's homes, TV shows and stores, and to be DIY enthusiasts or serial home improvers. These proxy indicators all offer ways for service providers to target particular market segments with a higher propensity to renovate.

Market segmentation is more commonly is based on readily observable property and household characteristics. The modelling confirms that these are only indirectly linked to renovation decisions. The path analysis shows that smaller properties, older properties, larger households, households with young children, and households which have recently moved in, are all more likely to be balancing competing commitments for the design and use of space at home (*Prioritising*). Households with elderly members are also more likely to physically experience thermal discomfort (*Embodying*). Both these conditions in turn predict a propensity to change things around at home (*Adapting*) including through renovating. The multivariate probit models further test these relationships on renovation propensity and confirm significant effects of larger households and households with young children.

5.3. Implications for Applied Energy Research

There are several limitations to this research (see Appendix A7 for full discussion). In particular, the development and testing of measurement items for the conditions of domestic life (CDLs) is experimental. The applicability of the CDLs can usefully be tested further in open-ended interviews with samples of renovators and non-renovators to establish their validity in differentiated domestic contexts. In addition, using cross-sectional data to analyse movement between stages allows only correlational support for the basic representation of changing influences over the decision process. A longitudinal (panel) sample would allow causal effects to be identified, by analysing sub-samples of households who have moved forwards or backwards through the decision process.

In the introduction to this article, three broad streams of research on energy-efficient home renovations were identified as of interest to the *Applied Energy* readership: (1) technical and modelling analysis of renovation measures; (2) building performance, economic and energy consequences of renovating; (3) occupant behaviour and renovation decision-making. This article has contributed novel insights on this third stream, but these in turn inform more technical research in the first two streams. The adoption, use, and consequences of energy-saving measures in homes is clearly influenced by both technological and behavioural factors (Tran 2012). Technical research commonly points to the occupants of homes and buildings as the source of unexplained variance, model or estimation error, differences between expected and actual energy performance.

Understanding proximate influences on *how* homeowners decide to renovate is necessary for modelling the uptake and performance of specific energy renovation measures (Falke et al. 2016), for evaluating performance gaps (Mørck et al. 2012), and for designing user-centred home energy management solutions (Jin et al. 2017).

Understanding ultimate influences on *why* homeowners decide to renovate is necessary for designing, implementing and evaluating the consequences of policies and business models for stimulating renovation uptake (Mahapatra et al. 2013; Craig 2016; Johansson et al. 2017; Rommel and Sagebiel 2017).

By answering both why and how questions in combination, this article also provides a behaviourally-realistic basis for improving housing stock or energy system models used to evaluate efficiency potentials (Dodds 2014; Cayla and Maïzi 2015). System design and optimisation modelling tend to exclude the role of human agents when analysing the technical potential for renovation measures (Falke et al. 2016). Yet the homes, systems, or buildings being designed and modelled are *for* their occupants. Discrete decision models representing occupant behaviour can be integrated directly into systems models which describe exogenous influences from energy prices to policy measures (Bauermann et al. 2014).

6. Conclusions

This paper advances understanding and modelling of energy efficient renovation decisions by including the underlying reasons why homeowners decide to renovate, by representing the decision as a process comprising a sequence of stages rather than as a one-off event, and by showing that the distinctiveness of efficiency-type renovations emerges through the decision process rather than being distinctive from the outset.

The key contributions of this paper are:

i. a novel conceptual framework explaining renovation decisions, drawing on theory and empirical work on domestic life;
ii. an innovative mixed methods research design with quantitative measurement items developed from qualitative constructs characterising renovation decisions;
iii. results from a nationally-representative survey measuring decision variables (with the full dataset publicly available via the UK Data Service archive);
iv. path modelling to test the decision model and validate the conceptual framework;
v. multivariate probit regression to apply the model for developing robust, replicable policy insights.

As such, this paper is an original attempt to link contextualised qualitative research into homes and domestic life with more narrowly-framed quantitative modelling of renovation decisions. This is a critical area for researchers to develop further as it draws on descriptively-realistic characterisations of renovation decision-making to build a rigorous, replicable, and generalizable evidence base to inform public policy.

Online Supplementary Information (Appendices)

Further detail is provided in Appendices available as online supplementary information to this article:
A1. Blocks of explanatory variable in conceptual framework, and explanation of the CDLs.
A2. Sample characteristics.
A3. Survey measurement items.
A4. Scheffe multiple comparison of mean tests.
A5. Path analysis of interrelationships between CDLs.
A6. Multivariate probit models of the full renovation decision process.
A7. Limitations of this research.

The full survey instrument and dataset are publicly available via the UK Data Service (doi.org/10.5255/UKDA-SN-7773-1).

Online Supplementary Information (Appendices)

APPENDIX A1. Blocks of explanatory variable in conceptual framework.

Table A1 summarises each of the four blocks of explanatory variable in the conceptual framework set out in the main text. The conditions of domestic life (CDLs) are explained further below.

Property characteristics serve as proxies for contextual influences, although some studies measure a limited set of non-financial attributes of renovation measures like comfort (Jaccard and Dennis 2006). Household characteristics serve as proxies for personal influences on renovation decisions, although some studies measure these directly through environmental and energy-related attitudes and beliefs (Nair et al. 2010a; Organ et al. 2013). However, generic socio-demographic and attitudinal variables only weakly predict domestic energy consumption once physical building characteristics are taken into account (Huebner et al. 2015).

TABLE A1. BLOCKS OF EXPLANATORY VARIABLE IN THE CONCEPTUAL FRAMEWORK OF RENOVATION DECISION MAKING.

Blocks of explanatory variable	Brief description	Explanatory role in renovation decision process	Decision stages	Types of renovation
Conditions of Domestic Life (CDLs)	conditions at home which create tensions or imbalances that renovating can resolve	why homeowners start thinking about renovating in general terms	0to1 0to1,2,3	all types – no difference between amenity and efficiency
Property & Household Characteristics	physical and socio-demographic characteristics associated with renovation intentions	crude proxies for preconditions or underlying need to renovate (mediated by CDLs)	0to1 0to1,2,3	all types – no difference between amenity and efficiency
Intentional Decision Making	positive attitudes and normative influences cumulatively reinforce intentions towards renovating	how homeowners' intentions to renovate take shape in specific terms during the decision process	1to2 2to3	both amenity and efficiency, but different object-specific attitudes & norms in each case
Triggers	events outside everyday domestic life which sharply increase the need to renovate	precipitate decisions, short-circuiting staged decision process	0to1,2,3 1to2,3	efficiency (e.g., heating system breakdown)

The conditions of domestic life (CDLs) warrant further explanation as they are a novel and original contribution of this research. The CDLs were developed from prior research involving 35 interviews with owner-occupied households in the period January - May 2012 split between two study sites: Rackheath in Norfolk, and Sutton in South London. The interview sample was recruited to include households who had recently renovated, households who were thinking about renovating at some point in the future, and households with no plans to renovate. Renovator households included both energy efficient and amenity renovation types. Full details of the interview study are available in: (Wilson et al. 2013b).

Data from the interviews were analysed to identify conditions in the everyday lives of renovating households that were absent in non-renovating households. Renovating households were found to be considering renovations or to have renovated in response to perceived needs that arose from imbalances or tensions experienced as an ongoing condition of domestic life.

Prioritising

'*Prioritising*' is the balancing of competing and at times conflicting commitments. These commitments may relate to work, family, friends, community, interests, leisure, socialising, and so on. In its active form (and if dwelled upon), *Prioritising* can include the process of decision making to try and resolve different commitments, and allocate finite amounts of time, domestic space, resources, and so on (Munro and Leather 2000; Jarvis 2005); Jarvis 2005]. *Prioritising* may be identified through the existence of boundaries within the home or through the recognition of boundaries being crossed (Nippert-Eng 1996). Boundaries can be seen as constructs created to categorise and compartmentalise lives to help organise tasks or focus on one task or another. Common examples of boundaries include: work-life, adult-kids, quality time, relaxing-chores.

Embodying

'*Embodying*' centres on how views of the body and its abilities will impact the use of space at home (Imrie 2004). *Embodying* includes both the human body's physical connection to the place that is home, and how that place shapes living and life in the home (Imrie 2004). Manifestations of *Embodying* may change over time, or may pre-empt changes that are yet to occur with one or more household members, particularly children and elderly people. *Embodying* is ultimately concerned with the physicality of living. In energy terms, this links strongly to thermal comfort (Cole et al. 2008; Shove et al. 2008).

Demonstrating

'*Demonstrating*' describes the absorption and/or transmission of different approaches to the design and use of physical space at home. These approaches might include those seen in media representations, advertising, home stores, other people's homes, or changes in policy and social marketing. *Demonstrating* is concerned with specific, physical activities in or to the home, and can challenge or confirm activities as simple as hammering a nail into a wall or as complex as re-designing a whole home (Hand et al. 2007). *Demonstrating* can also generate thoughts and ideas for the home, or can place barriers in the way of achieving balance in domestic life (Gram-Hanssen 2007). *Demonstrating* is typically seen as bigger than the self or household, and is often impersonal or interpreted in reference to 'others' (Sparke 1995).

Social Norms

The awareness to and receptiveness of households to social norms is closely related to the *Demonstrating* condition. Social norms can be descriptive (I should do this because others are doing it) or injunctive (I should do this because others approve of it) (Cialdini and Goldstein 2004). Social norms may vary in the extent to which they are communicated through social networks. Individuals detect and seek to conform or comply with social norms for different reasons: to affiliate with others; to maintain a positive self-concept; and to affirm the accuracy of their perception of reality (Cialdini 2007). A growing body of evidence has shown the influence of social norms on energy-related behaviour in homes (Nolan et al.

2008), and on energy and environmental behaviour more generally (Alló and Loureiro 2014; Farrow et al. 2017).

Home as Project

Homes are not neutral contexts for decision making, nor neutral adoption environments for new technologies (Nansen et al. 2011). The home is not a static construct or representation but a dynamic expression of household members' feeling towards it (Baillie and Benyon 2008). Household members ascribe meanings to their homes when thinking through changes made to the physical house. Three clusters of meaning identified by Aune (2007) include: 'home as a project'; 'home as a haven'; and 'home as an arena for activities'. Homes may be seen as a project to be continually updated to express a household's identity, as a haven or secure space away from public life, or as a social arena for activities and exchange. These various meanings are neither exclusive nor fixed. Rather they emphasise how households' emotional connections with their homes impact on their expectations of comfort and associated homemaking activities including renovating.

Seeing a home as a project is of particular relevance here. *Home as Project* mediates whether the *Adapting* condition leads to major structural renovation works or to more minor adaptations. Certain households are strongly characterised by a view of their homes as a project through which they can demonstrate their skills and express their identity (Haines and Mitchell 2014). The display and status functions of homes make it likely that renovation activity will be noticed by peers or neighbors and so susceptible to social norms (Kempton and Layne 1994).

Adapting

'*Adapting*' involves either a tacit acknowledgement or an explicit awareness of changing the physical arrangement or material surroundings at home to meet competing needs or solve perceived problems with objects or the use of space. This might be a precursor to altering physical structures (e.g., knocking down walls), but initially attention might simply be on how furniture and furnishings are arranged. *Adapting* may also be consistent with a sentiment or admission to just make do with things as they are. Recognising that the current configuration of the home is not adapted to the household's current living patterns may be uncomfortable, and making do is a strategy for reducing dissonance just as thinking about making structural changes may be (Watson and Shove 2008). Although focused on physical spaces and structures, *Adapting* also has an emotional dimension in response to the challenges of prioritising commitments and household members' needs (Chappells and Shove 2005). *Adapting* could thus be a seemingly unconscious way of acknowledging some discontent with the current pattern of domestic life (Shove et al. 2007).

APPENDIX A2. Sample characteristics.

Table A2a summarises the sample characteristics for the quota sampling of each decision stage, and compares these against population means. Each decision stage has similar sample characteristics which are also broadly representative of the UK homeowner population. Table A2b provides further details on the representativeness of the sample across multiple categories of property age and property type.

TABLE A2A. SAMPLE CHARACTERISTICS VS. POPULATION MEANS.

Sample Characteristics	stage 0	stage 1	stage 2	stage 3	all stages	population (homeowners)
Background frequency in population (before quota sampling)	55%	17%	13%	14%		
Sample size (after quota sampling)	n=259	n=254	n=253	n=262	**n=1028**	
Household & Property Characteristics						
Median annual household income	£25-30k	£30-35k	£35-40k	£30-35k	**£30-35k**	£25.5k [b]
Mean household size	2.1	2.4	2.6	2.5	**2.4**	2.2 [d]
Most common property type	semi-detached house				**semi-detached house**	semi-detached house [a]
Most common property age (year built)	1950-1989				**1950-1989**	1945-1990 [c]
Most common length of tenure	>= 20 years				**>= 20 years**	10-19 years [a]
Most common expected future tenure	no plans to move				**no plans to move**	-
Respondent Characteristics						
Mean respondent age	54.3 yrs	49.8 yrs	48.0 yrs	47.2 yrs	**49.8 yrs**	45 to 64 [d]
Frequency of female respondents	52.5%	60.2%	46.6%	50.4%	**52.4%**	-

Notes: [a] (ONS 2011); [b] (ONS 2012); [c] (DCLG 2013a); [d] (DCLG 2013b).

TABLE A2B. SAMPLE CHARACTERISTICS VS. POPULATION-LEVEL PROPERTY AGE & TYPE.

	sample characteristics (all stages)	population (homeowners)[a]	
Property age			
Pre 1919	17%	20%	
1919-44	21%	19%	
1945-64	44%	19%	48%
1965-80		21%	
1981-90		8.6%	
Post 1990	18%	13%	
Property type			
Detached housing	29%	24%	
Semi-detached housing	34%	31%	
Terraced housing	22%	26%	
Other (bungalows and flats)	15%	19%	

Notes: [a] owner-occupied homes in England & Wales (ONS 2011) and [b] (ONS 2012)

APPENDIX A3. Survey measurement items.

As no pre-existing measurement items for the CDLs were available, multiple possible items for each CDL were developed and subjected to three rounds of testing for clarity, comprehensibility, and consistency during the period June – August 2012 (between 20-40 homeowners per round). A final set of three to four measurement items per CDL were selected for inclusion in the survey; see Table A3 and (Wilson et al. 2013b) for details. CDLs are not specific to energy efficient renovations so each item is expressed in a general form.

Measurement items for intentional decision variables were developed based on existing literature. Two items for *Attitudes* measured the evaluation of expected outcomes (Ajzen 2001). Three items for *Social Norms* measured descriptive norms (what others are doing), injunctive norms (what others approve of), and the extent to which norms are communicated through inter-personal networks (Cialdini 2007; Manning 2009). As intentional decision variables are object-specific, different sets of measurement items were included to distinguish energy efficient renovation decisions from amenity renovation decisions; see Table A3.

All measurement items were short statements with a 7 point Likert scale response (1=strongly disagree | 7 = strongly agree). Factor analysis of the full sample's responses to the multiple measurement items per CDL found a clear and interpretable factor structure for *Demonstrating* which is used in the analysis. The other CDLs lacked a clear factor structure, so single items were selected as most representative of the general meaning of the CDL. For the intentional decision variables, the multiple measurement items for both *Social Norms* and *Attitudes* (specified for both energy efficiency and amenity measures) reduced down into clearly interpretable factors. These factors are used in the analysis.

TABLE A3. MEASUREMENT ITEMS AND FACTORS FOR CONDITIONS OF DOMESTIC LIFE (CDLS) AND INTENTIONAL DECISION MAKING. NOTES: BASED ON FULL SAMPLE.

Variables used in analysis	Measurement item (1=Disagree | 7=Agree)	item mean (s.d.)	factor loading	Cron-bach's α	factor mean (s.d.)
Conditions of Domestic Life (CDLs)					
Prioritising (item)	New things we're doing in our lives mean we have to rethink the way we use our home	3.63 (1.88)	-	-	-
Embodying (item)	Physical issues faced by some household members influence how our home is arranged	2.89 (2.08)	-	-	-
Demon-strating (factor)	We take on board how other people have their homes when doing things to our home	3.96 (0.05)	0.94	0.85	3.52 (1.36)
	How homes are portrayed in the media can't help but influence what we do in our own home	3.68 (0.05)	0.87		
	We get inspired by things we see displayed or advertised in home stores	4.17 (0.05)	0.87		
Home as Project (item)	We see our home as a project, somewhere we can spend time and effort expressing ourselves and how we want to live	4.17 (1.84)	-	-	-
Adapting (item)	We're always changing things around at home	3.14 (1.65)	-	-	-
Intentional Decision Making					
Attitudes-Amenity (factor)	The pros of renovating clearly outweigh the cons	5.29 (0.04)	0.71	0.83	4.43 (0.95)
	The pros of renovating to improve the quality of life at home clearly outweigh the cons	5.67 (0.03)	0.90		
Attitudes-Efficiency (factor)	The pros of reducing the energy used in homes clearly outweigh the cons	5.44 (0.04)	0.92	0.85	4.53 (1.13)
	The pros of reducing the impact homes have on the environment clearly outweigh the cons	4.88 (0.04)	0.83		
Social Norms-Amenity (factor)	Many people are renovating their home's living spaces (like kitchens, living rooms and bedrooms)	5.17 (0.03)	0.94	0.85	4.40 (1.00)
	People think favourably of renovating living spaces in homes (like kitchens, living rooms and bedrooms)	5.34 (0.03)	0.85		
	People talk a lot with others about renovating living spaces in homes (like kitchens, living rooms and bedrooms)	4.55 (0.04)	0.75		
Social Norms-Efficiency (factor)	Many people are renovating their homes to make them more energy efficient	5.21 (0.03)	0.95	0.84	4.44 (0.95)
	People think favourably of renovating to make homes more energy efficient	5.50 (0.03)	0.94		
	People talk a lot with others about renovating to make homes more energy efficient	4.99 (0.04)	0.72		

APPENDIX A4. Scheffe multiple comparison of mean tests.

Table A4 summarises the Scheffe test results between decision stages.

TABLE A4. CHANGES IN MEAN RESPONSES THROUGH THE RENOVATION DECISION PROCESS.

	Forwards progression through decision stages					
	0to1	0to2	0to3	1to2	1to3	2to3
Conditions of Domestic Life (CDLs)						
Prioritising	+*	+*	+*	+*	+*	-
Embodying	+	+	+*	+	+*	
Demonstrating	+*	+*	+*	+	+	-
Home as Project	+*	+*	+*	+*	+*	+
Adapting	+*	+*	+*	+*	+*	+
Intentional Decision Variables						
Attitudes-Efficiency	+*	+*	+*	+*	+*	+
Attitudes-Amenity	+*	+*	+*	+*	+*	+
Social Norms-Efficiency	+*	+*	+*	-	+	+
Social Norms-Amenity	+*	+*	+*	+	+	-

Legend:

+*	Mean response is significantly higher at |p|<=.05
+	.... higher but not significant
-*	Mean response is significantly lower at |p|<=.05
-	.... lower but not significant
	No change

APPENDIX A5. Path analysis of interrelationships between CDLs.

Hypothesised interrelationships between the CDLs were formalised in a series of 'decision maps' for each decision stage. Path analysis was used to test the direction and strength of bivariate relationships using pairwise partial correlations (controlling for other relationships). All relationships with weak associations (r<=.3) or insignificant associations (|p|<0.05) were rejected. The resulting reduced-form 'decision maps' provided a parsimonious and generalizable series of causal pathways between variables describing the CDLs (testing H2 and H4). These interrelationships also included property & household characteristics, and general social norms on renovating (*Social Norms-Amenity)*, which are closely related to the *Demonstrating* condition.

Table A5 shows the full results of the path analysis by stage (and for the base model reported in the main text for stages 1-3 combined). Although the endogenous structure of the CDLs is very similar across decision stages, the strength of interrelationships between CDLs varies somewhat (consistent with H1). As an example, *Demonstrating* and *Social Norms-Amenity* mediate between *Prioritising* and *Adapting* but their influence weakens through the decision process. In stages 1 and 2, 68% of the total effect of *Prioritising* on *Adapting* is through these mediators but in stage 3 this is reduced to only 17%. In other words, households in the earlier stages of the renovation decision are more receptive to external sources of idea and inspiration for making changes to the home. They are also more likely to be influenced by social norms of renovation behaviour.

The overall model fit is higher for stage 0 (the null non-decision stage) compared to the renovation decision stages (1-3). In other words, the CDLs explain more variation in the *Adapting* condition in households who are not thinking about renovating. *Adapting* describes the condition of wanting or needing to make changes to the home, whether through major renovations, minor DIY, or just muddling through (i.e., perceiving a need to make changes but not acting on it). All these responses are possible for households in decision stage 0. In comparison, households in decision stages 1-3 are - by definition - considering renovations. This narrows down the interpretation of the *Adapting* condition, and so slightly weakens the explanatory power of the antecedent CDLs.

Adapting and *Home as Project* are closely related with households that see their home as an ongoing project being more likely to respond to a perceived need to change the home by undertaking major renovation work rather than more minor adaptations or just muddling through. *Home as Project* acts directly on *Adapting*, but is also mediated by the *Prioritising* and *Demonstrating* conditions.

TABLE A5. CAUSAL PATH MODEL COEFFICIENTS (STANDARDISED BETAS) AND MODEL FIT STATISTICS FOR EACH DECISION STAGE.

Antecedents for each CDL	stage 0	stage 1	stage 2	stage 3	stages 1-3 combined
Prioritising					
Embodying	0.18**	0.27**	0.11	0.18*	0.19**
Home as Project	0.15*	0.14*	0.18*	0.18**	0.18**
dependent children at home	0.07	0.18*	-0.02	0.05	0.06
retirees at home	-0.07	-0.06	-0.05	-0.18*	-0.10*
household size	0.08	0.08	0.20*	0.03	0.11*
years planning to stay in home	-0.32**	-0.07	-0.27**	-0.02	-0.11*
property size	0.01	-0.03	-0.02	-0.04	-0.02
property age	-0.02	0.03	-0.02	0.10	0.03
Embodying					
Home as Project	0.20**	0.03	0.16*	0.25**	0.16**
retirees at home	0.04	0.13	0.13*	0.12	0.13*
Demonstrating					
Prioritising	0.13*	0.22**	0.26**	0.16*	0.22**
Social Norms-Amenity	0.22**	0.39**	0.23**	0.28**	0.30**
Home as Project	0.34**	0.13*	0.27**	0.33**	0.24**
Social Norms-Amenity					
Prioritising	0.12	0.12	0.13*	0.07	0.11*
Home as Project	0.35**	0.16*	0.30**	0.24*	0.23**
household size	0.18**	0.19*	-0.02	0.06	0.08*
Adapting					
Prioritising	0.30**	0.17*	0.18*	0.29**	0.22**
Demonstrating	0.13	0.23*	0.28**	0.28**	0.26**
Social Norm-Amenity	0.21**	0.10	0.05	0.10	0.08*
Home as Project	0.09	0.18*	0.25**	0.14*	0.21**
Model Fits (R^2)					
Prioritising	0.22	0.18	0.18	0.15	0.15
Embodying	0.04	0.02	0.04	0.06	0.04
Demonstrating	0.27	0.29	0.29	0.30	0.29
Social Norms-Amenity	0.19	0.10	0.12	0.08	0.09
Adapting	0.27	0.23	0.32	0.33	0.31
Overall Model	0.42	0.25	0.37	0.32	0.28
Model Statistics					
RMSEA	0.054	0.038	0.038	0.036	0.043
CFI	0.93	0.96	0.96	0.97	0.96
N	177	199	203	195	597

Notes: All reported coefficients are standardized beta values (β); ** $|p| \leq .01$; * $|p| \leq .05$. RMSEA (root mean square error approximation), and CFI (comparative fit index) are both 'fit indices' used to compare the extent to which specified pathways been variables within a model are an improvement relative to a null model with no relationship between variables. A CFI >=0.95 and RMSEA between 0.01 to 0.05 is indicative of a good model fit in that there is a significant improvement relative to the null model.

Further path analysis was conducted for the different types of renovation (amenity only, efficiency only + mixed). Again, the general interrelationships between CDLs, and between CDLs and property and household characteristics, were found to be broadly similar. In other words, the CDLs have a similar explanatory role for both amenity and efficiency renovators.

APPENDIX A6. Multivariate probit models of the full renovation decision process.

The full decision model including all four blocks of explanatory variable was tested using multivariate probit regressions on dichotomous decision stage variables. Beginning with the CDLs, each block of explanatory variable was added hierarchically to isolate its incremental effect. Decision stage outcome variables are a more direct measure of renovation intentions than the *Adapting* condition used in the path analysis. To maintain consistency with the path analysis, the models simultaneously estimated the direct effects of CDLs and intentional decision variables on decision stage as well as antecedent relationships between CDLs. Formally, this is called a multivariate multiple probit regression (see Appendix A6).

The main outcome variable was *Stage 0to1* which compared households not thinking about renovating (stage 0) and households thinking about renovating in general terms (stage 1). The symbol 'to' is used to denote 'moving to' such that the *Stage 0to1* variable means moving from decision stage 0 to stage 1 (while noting that the stages are cross-sections of independent samples so do not show within-subjects progression).

Additional decision models were estimated with a *Stage 0to1,2,3* outcome variable comparing households in the null non-decision stage (0) with households in any of the three stages (1-3) of the decision process. These *Stage 0to1* and *Stage 0to1,2,3* models evaluate how well the CDL variables explain the origination or emergence of renovation intentions (testing H2).

A further set of models were estimated for *Stage 1to2* and *Stage 2to3* outcome variables to test for the influences on strengthening intentions through the decision process. These models were also used to examine the distinctive features of energy efficient as opposed to amenity renovation decisions (testing H3).

Initial Formation of Renovation Intentions: CDLs and Triggers

Table A6a shows the full multivariate probit model results for the *Stage 0to1* and *Stage 0to1,2,3* outcome variables with CDLs only as explanatory variables. These include the simultaneously estimated multivariate regressions for each explanatory variable in the probit model. The model fit statistics shown are McKelvey-Zavoina pseudo R^2s which are good estimators of fit for probit models, providing a relatively unbiased estimate of explained variance in terms of the probability of an event occurring (movement between renovation decision stages). Pseudo R^2s assume the existence of an underlying unobserved continuous dependent variable which has a standard normal distribution rather than a logistic curve. In this way it is closest to a OLS R^2 compared to other forms of pseudo R^2 (Hagle and Mitchell 1992).

TABLE A6A. FULL RESULTS OF MULTIVARIATE MULTIPLE PROBIT REGRESSIONS: CDLS ONLY; DECISION *STAGE 0TO1* AND *STAGE 0TO1,2,3*.

	ALL RENOVATION TYPES							
EXPLANATORY VARIABLES:	***STAGE 0->1***		***STAGE 0->1***		***STAGE 0->1,2,3***		***STAGE 0->1,2,3***	
CDLs only	**ALL SAMPLE**		**SAMPLE WITHOUT TRIGGERS**		**ALL SAMPLE**		**SAMPLE WITHOUT TRIGGERS**	
	ESTIMATES	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**
Model Coefficients (βs)								
ADAPTING								
PRIORITISING	0.28	0.00	0.23	0.00	0.26	0.00	0.25	0.00
DEMONSTRATING	0.20	0.00	0.24	0.00	0.24	0.00	0.28	0.00
HOME AS PROJECT	0.14	0.00	0.13	0.03	0.21	0.00	0.16	0.00
DEMONSTRATING								
PRIORITISING	0.24	0.00	0.26	0.00	0.25	0.00	0.27	0.00
HOME AS PROJECT	0.35	0.00	0.31	0.00	0.36	0.00	0.36	0.00
EMBODYING								
HOME AS PROJECT	0.07	0.23	0.08	0.28	0.16	0.00	0.19	0.00
retirees at home	-0.08	0.09	-0.12	0.05	-0.09	0.01	-0.09	0.05
PRIORITISING								
EMBODYING	0.21	0.00	0.17	0.01	0.17	0.00	0.15	0.00
HOME AS PROJECT	0.15	0.00	0.15	0.02	0.21	0.00	0.24	0.00
# years at current home	0.06	0.17	0.06	0.27	0.07	0.02	0.08	0.04
# years planning to stay in home	0.04	0.41	0.01	0.92	0.02	0.46	0.02	0.57
property size (# bedrooms)	-0.02	0.70	0.00	0.98	-0.02	0.55	-0.01	0.83
property age	-0.03	0.53	-0.07	0.23	-0.01	0.74	-0.03	0.40
# dependent children at home	0.16	0.01	0.13	0.10	0.11	0.01	0.09	0.09
# retirees at home	0.00	0.98	0.00	0.99	0.01	0.74	-0.01	0.75
household size	0.13	0.05	0.15	0.06	0.13	0.00	0.17	0.00
STAGE X->Y								
ADAPTING	-0.02	0.74	0.08	0.31	0.04	0.49	0.07	0.26
DEMONSTRATING	0.14	0.03	0.11	0.14	0.07	0.15	0.10	0.09
EMBODYING	-0.07	0.26	-0.02	0.84	-0.04	0.42	0.02	0.77
PRIORITISING	0.18	0.00	0.18	0.02	0.23	0.00	0.24	0.00
HOME AS PROJECT	0.17	0.01	0.18	0.01	0.26	0.00	0.24	0.00
Model Statistics								
MODEL FIT (R-SQUARE)								
STAGE X->Y	0.12	0.00	0.14	0.002	0.20	0.00	0.24	0.00
ADAPTING	0.21	0.00	0.20	0.00	0.29	0.00	0.28	0.00
DEMONSTRATING	0.21	0.00	0.20	0.00	0.24	0.00	0.26	0.00
EMBODYING	0.01	0.33	0.02	0.28	0.03	0.02	0.04	0.03
PRIORITISING	0.16	0.00	0.13	0.00	0.16	0.00	0.18	0.00
Loglikelihood								
H0 Value	-6292		-4292		-12476		-8038	
H0 Scaling Correction Factor for MLR	1.04		1.04		1.02		1.02	
Information Criteria								
Akaike (AIC)	12659		8659		25029		16153	
Bayesian (BIC)	12817		8803		25213		16321	
Sample-Size Adjusted BIC (n*=(n+2)/24)	12697		8682		25093		16200	
Sample Sizes								
N (moving from *Stage X*)	236		166		236		166	
N (moving to *Stage Y*)	239		159		716		451	
Number of Free Parameters	38		38		38		38	

Strengthening of Renovation Intentions through the Decision Process: Limited Explanatory Power of CDLs

Table A6b shows the full multivariate probit model results for the *Stage 0to1*, *Stage 1to2* and *Stage 2to3* outcome variables with CDLs only as explanatory variables. These include the simultaneously estimated multivariate regressions for each explanatory variable in the probit model. The *Stage 1to2* and *Stage 2to3* models distinguish amenity-only renovators (red shading) from efficiency-only and mixed efficiency + amenity renovators (green shading). Relative to the *Stage 0to1* models, the *Stage 2to3* models in particular are weaker fits, with coefficients either becoming insignificant or reversing in sign.

TABLE A6B. FULL RESULTS OF MULTIVARIATE MULTIPLE PROBIT REGRESSIONS: CDLS ONLY; DECISION *STAGE 0TO1, STAGE 1TO2* AND *STAGE 2TO3*.

	ALL RENOVATION TYPES		AMENITY ONLY		MIXED & EFFICIENCY ONLY		AMENITY ONLY		MIXED & EFFICIENCY ONLY	
EXPLANATORY VARIABLES:	***STAGE 0->1***		***STAGE 1->2***		***STAGE 1->2***		***STAGE 2->3***		***STAGE 2->3***	
CDLs only	**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**	
	ESTIMATES	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**
Model Coefficients (βs)										
ADAPTING										
PRIORITISING	0.23	0.00	0.22	0.00	0.18	0.07	0.29	0.00	0.30	0.01
DEMONSTRATING	0.24	0.00	0.19	0.02	0.31	0.00	0.31	0.00	0.21	0.04
HOME AS PROJECT	0.13	0.03	0.29	0.00	0.19	0.03	0.23	0.00	0.11	0.36
DEMONSTRATING										
PRIORITISING	0.26	0.00	0.20	0.02	0.41	0.00	0.17	0.06	0.40	0.00
HOME AS PROJECT	0.31	0.00	0.32	0.00	0.16	0.11	0.46	0.00	0.19	0.07
EMBODYING										
HOME AS PROJECT	0.08	0.28	0.04	0.71	0.10	0.31	0.11	0.23	0.27	0.00
retirees at home	-0.12	0.05	0.01	0.93	-0.24	0.03	0.00	1.00	-0.05	0.65
PRIORITISING										
EMBODYING	0.17	0.01	0.21	0.02	0.26	0.00	0.10	0.26	0.12	0.32
HOME AS PROJECT	0.15	0.02	0.20	0.03	0.18	0.04	0.26	0.01	0.29	0.00
# years at current home	0.06	0.27	-0.02	0.84	0.26	0.00	0.08	0.29	0.24	0.00
# years planning to stay in home	0.01	0.92	-0.02	0.80	0.08	0.34	-0.01	0.93	0.07	0.41
property size (# bedrooms)	0.00	0.98	-0.01	0.88	0.01	0.91	-0.02	0.80	-0.02	0.86
property age	-0.07	0.23	-0.04	0.58	0.04	0.65	0.02	0.77	0.07	0.43
# dependent children at home	0.13	0.10	0.16	0.18	0.22	0.06	0.08	0.51	0.05	0.74
# retirees at home	0.00	0.99	0.04	0.56	0.05	0.57	-0.03	0.74	0.00	0.99
household size	0.15	0.06	0.09	0.49	0.10	0.42	0.19	0.14	0.14	0.26
STAGE X->Y										
ADAPTING	0.08	0.31	-0.04	0.75	-0.11	0.38	0.30	0.01	0.10	0.49
DEMONSTRATING	0.11	0.14	0.10	0.33	0.12	0.33	-0.25	0.04	-0.06	0.66
EMBODYING	-0.02	0.84	-0.07	0.53	0.21	0.07	0.18	0.11	-0.07	0.62
PRIORITISING	0.18	0.02	0.09	0.43	0.27	0.02	-0.19	0.09	-0.18	0.22
HOME AS PROJECT	0.18	0.01	0.25	0.02	0.22	0.04	-0.17	0.15	0.18	0.18
Model Statistics										
MODEL FIT (R-SQUARE)										
STAGE X->Y	0.14	0.002	0.10	0.09	0.26	0.004	0.15	0.04	0.05	0.34
ADAPTING	0.20	0.00	0.26	0.00	0.26	0.00	0.40	0.00	0.24	0.00
DEMONSTRATING	0.20	0.00	0.17	0.01	0.23	0.00	0.28	0.00	0.25	0.00
EMBODYING	0.02	0.28	0.00	0.84	0.07	0.19	0.01	0.54	0.08	0.09
PRIORITISING	0.13	0.00	0.16	0.00	0.32	0.00	0.16	0.00	0.25	0.00
Loglikelihood										
H0 Value	-4292		-2025		-1588		-1909		-1364	
H0 Scaling Correction Factor for MLR	1.04		1.00		0.98		1.02		0.99	
Information Criteria										
Akaike (AIC)	8659		4127		3251		3893		2804	
Bayesian (BIC)	8803		4243		3359		4008		2905	
Sample-Size Adjusted BIC (n*=(n+2)/24)	8682		4122		3238		3888		2785	
Sample Sizes										
N (moving from *Stage X*)	166		74		63		82		62	
N (moving to *Stage Y*)	159		82		62		71		45	
Number of Free Parameters	38		38		38		38		38	

Strengthening of Renovation Intentions through the Decision Process: Household & Property Characteristics

The path analysis found that the influence of household & property characteristics on intentions to make changes to the home (the *Adapting* condition) is mediated by descriptively-realistic CDLs. Consequently, the expectation is that including household & property characteristics in the full decision models in addition to the CDLs should not substantially improve the model fits.

Table A6c reports the model fit statistics using both CDLs and household & property characteristics as explanatory variables, and excluding households who reported triggers. Compared to the CDL-only models reported in Table A6b, pseudo R^2s are higher in all cases as would be expected with additional explanatory variables, but the AIC and BIC statistics are almost identical. In other words, adding household & property characteristics to the CDLs does not improve relative goodness of fit for models explaining progression through the renovation decision process (consistent with H4).

TABLE A6C. MULTIVARIATE PROBIT MODEL FIT STATISTICS: CDLS AND HOUSEHOLD & PROPERTY CHARACTERISTICS, DECISION STAGES 0TO1, 1TO2, AND 2TO3, EXCLUDING HOUSEHOLDS WHO REPORTED A TRIGGER.

Model Statistics with CDLs and Household & Property Characteristics as Explanatory Variables	**Outcome Variable: *Stage 0to1***	**Outcome Variable: *Stage 1to2***		**Outcome Variable: *Stage 2to3***	
	all renovation types	**amenity only**	**efficiency only + mixed**	**amenity only**	**efficiency only + mixed**
Pseudo R^2	0.20**	0.19*	0.33**	0.23**	0.19*
AIC [a]	8,658	4,132	3,258	3,900	2,807
BIC [a]	8,829	4,269	3,386	4,036	2,927
N (moving from *Stage X*)	166	74	63	82	62
N (moving to *Stage Y*)	159	82	62	71	45

Notes: ** |p|<u><</u>.01; * |p|<u><</u>.05.

[a] AIC = Akaike's Information Criterion, BIC = Bayesian Information Criterion.

Table A6d shows the full multivariate probit model results for the *Stage 0to1*, *Stage 1to2* and *Stage 2to3* outcome variables with CDLs and household & property characteristics as explanatory variables. These include the simultaneously estimated multivariate regressions for each explanatory variable in the probit model. The *Stage 1to2* and *Stage 2to3* models distinguish amenity-only renovators (red shading) from efficiency-only and mixed efficiency + amenity renovators (green shading).

TABLE A6D. FULL RESULTS OF MULTIVARIATE MULTIPLE PROBIT REGRESSIONS: CDLS AND HOUSEHOLD & PROPERTY CHARACTERISTICS; DECISION *STAGE 0TO1, STAGE 1TO2* AND *STAGE 2TO3*.

	ALL RENOVATION TYPES		AMENITY ONLY		MIXED & EFFICIENCY ONLY		AMENITY ONLY		MIXED & EFFICIENCY ONLY	
EXPLANATORY VARIABLES:	***STAGE 0->1***		***STAGE 1->2***		***STAGE 1->2***		***STAGE 2->3***		***STAGE 2->3***	
CDLs and Household &	**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**		**SAMPLE WITHOUT TRIGGERS**	
Property Characteristics	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**	**ESTIMATES**	**p-value**
Model Coefficients (βs)										
ADAPTING										
PRIORITISING	0.23	0.00	0.22	0.00	0.18	0.07	0.29	0.00	0.30	0.01
DEMONSTRATING	0.24	0.00	0.19	0.02	0.31	0.00	0.31	0.00	0.21	0.04
HOME AS PROJECT	0.13	0.03	0.29	0.00	0.19	0.03	0.23	0.00	0.11	0.36
DEMONSTRATING										
PRIORITISING	0.26	0.00	0.20	0.02	0.41	0.00	0.17	0.06	0.40	0.00
HOME AS PROJECT	0.31	0.00	0.32	0.00	0.16	0.11	0.46	0.00	0.19	0.07
EMBODYING										
HOME AS PROJECT	0.08	0.28	0.04	0.72	0.10	0.31	0.11	0.23	0.27	0.00
retirees at home	-0.12	0.05	0.01	0.93	-0.24	0.02	0.00	0.99	-0.05	0.63
PRIORITISING										
EMBODYING	0.17	0.01	0.21	0.02	0.26	0.00	0.10	0.26	0.12	0.32
HOME AS PROJECT	0.15	0.02	0.20	0.03	0.18	0.04	0.26	0.01	0.29	0.00
# years at current home	0.06	0.27	-0.02	0.84	0.26	0.00	0.08	0.29	0.24	0.00
# years planning to stay in home	0.00	0.94	-0.02	0.80	0.07	0.34	-0.01	0.93	0.07	0.40
property size (# bedrooms)	0.00	0.98	-0.01	0.88	0.01	0.90	-0.02	0.81	-0.02	0.86
property age	-0.07	0.23	-0.04	0.58	0.04	0.65	0.02	0.77	0.07	0.42
# dependent children at home	0.13	0.09	0.16	0.18	0.22	0.06	0.08	0.51	0.05	0.74
# retirees at home	0.00	1.00	0.04	0.56	0.05	0.58	-0.03	0.73	0.00	0.99
household size	0.15	0.06	0.09	0.49	0.10	0.42	0.19	0.14	0.14	0.26
STAGE X->Y										
ADAPTING	0.08	0.312	-0.04	0.69	-0.16	0.23	0.34	0.00	0.12	0.41
DEMONSTRATING	0.08	0.281	0.12	0.24	0.12	0.36	-0.24	0.03	-0.01	0.95
EMBODYING	0.02	0.795	-0.07	0.52	0.28	0.01	0.19	0.08	-0.05	0.70
PRIORITISING	0.18	0.015	0.08	0.47	0.24	0.05	-0.16	0.13	-0.20	0.19
HOME AS PROJECT	0.18	0.011	0.27	0.01	0.26	0.01	-0.19	0.10	0.08	0.55
# years at current home	-0.07	0.299	-0.03	0.77	0.03	0.78	-0.07	0.48	0.00	1.00
# years planning to stay in home	0.04	0.528	0.08	0.40	0.04	0.71	-0.11	0.27	-0.19	0.12
property size (# bedrooms)	0.09	0.208	-0.19	0.07	0.03	0.75	0.13	0.18	0.14	0.26
property age	-0.06	0.401	-0.06	0.51	-0.13	0.21	-0.01	0.96	0.00	0.99
# dependent children at home	-0.05	0.542	0.17	0.24	-0.01	0.95	-0.21	0.14	-0.21	0.23
# retirees at home	0.22	0.001	-0.12	0.23	0.19	0.10	-0.01	0.90	-0.32	0.00
household size	0.01	0.920	-0.09	0.58	0.04	0.77	0.06	0.66	0.23	0.19
Model Statistics										
MODEL FIT (R-SQUARE)										
STAGE X->Y	0.20	0.000	0.19	0.01	0.33	0.00	0.23	0.01	0.19	0.04
ADAPTING	0.20	0.00	0.26	0.00	0.26	0.00	0.40	0.00	0.24	0.00
DEMONSTRATING	0.20	0.00	0.17	0.01	0.23	0.00	0.28	0.00	0.25	0.00
EMBODYING	0.02	0.28	0.00	0.85	0.07	0.18	0.01	0.53	0.08	0.09
PRIORITISING	0.13	0.00	0.16	0.00	0.32	0.00	0.16	0.00	0.25	0.00
Loglikelihood										
H0 Value	-4284		-2021		-1584		-1905		-1359	
H0 Scaling Correction Factor for MLR	1.03		1.00		0.97		1.01		0.99	
Information Criteria										
Akaike (AIC)	8659		4132		3259		3900		2807	
Bayesian (BIC)	8829		4270		3386		4037		2927	
Sample-Size Adjusted BIC (n*=(n+2)/24)	8686		4127		3244		3894		2785	
Sample Sizes										
N (moving from *Stage X*)	166		74		63		82		62	
N (moving to *Stage Y*)	159		82		62		71		45	
Number of Free Parameters	45		45		45		45		45	

<u>Strengthening of Renovation Intentions through the Decision Process: Intentional Decision Variables</u>

Table A6e shows the full multivariate probit model results for the *Stage 0to1*, *Stage 1to2* and *Stage 2to3* outcome variables with CDLs and intentional decision variables. These include the simultaneously estimated multivariate regressions for each explanatory variable in the probit model. The *Stage 1to2* and *Stage 2to3* models distinguish amenity-only renovators (red shading) from efficiency-only and mixed efficiency + amenity renovators (green shading). Intentional decision variables specific to efficiency measures were not included in the amenity-only models (grey shading).

There are some interesting differences between the amenity only and the efficiency only + mixed models. *Attitudes-Amenity* significantly predict strengthening intentions towards amenity renovations. This holds for *Stage 1to2* and *Stage 2to3*, but also *Stage 0to1* (in addition to the effect of the CDLs). However *Attitudes-Efficiency* do not help explain strengthening intentions towards efficiency + mixed renovations. Instead, the effect of adding intentional decision variables is to reinforce the direct effects of certain CDLs: *Prioritising* on *Stage 1to2*; and *Home as Project* on *Stage 2to3*.

One interpretation is that strengthening intentions through the decision process are linked to certain CDLs becoming more salient in renovating households. This was tested further by examining the correlations between *Attitudes-Efficiency* and *Social Norms-Efficiency* on the one hand, and *Prioritising* and *Home as Project* on the other. If these correlations increase through the decision process, then the two CDLs may be picking up the effect of the intentional decision variables in the probit models.

Correlations between attitudes and the two CDLs either increase very slightly or decrease through the decision process: -0.03 (stage 1) to 0.05 (stage 2) with *Prioritising*; and 0.26 (stage 2) to 0.15 (stage 3) with *Home as Project*. However, correlations between social norms and the two CDLs increase sharply: -0.04 (stage 1) to 0.26 (stage 2) with *Prioritising*; and 0.08 (stage 2) to 0.33 (stage 3) with *Home as Project*. This is consistent with the interpretation that as their intentions strengthen, energy-efficiency renovators are internalising normative influence through general underlying conditions for renovating: 'new things in our lives' or *Prioritising* for the *Stage 1to2* model; and 'expressing our identity' or *Home as Project* for the *Stage 2to3* model. This also helps explain why the *Social Norms* variables are not significant direct predictors of strengthening intentions in any of the models. As other studies have found, self-reported measures of receptiveness to normative influence tend to be weakened as respondents seek to rationalise their motivations (Nolan et al. 2008; Wilson and Dowlatabadi 2011). Curiously, however, this effect is specific to efficiency renovators. The same correlations in the amenity-only sample are broadly stable through the decision process.

As a final comment, the models of the efficiency only + mixed renovation decisions are on relatively small sample sizes with a 2:1 ratio of mixed to efficiency-only renovators. This inevitably dilutes a clear effect of intentional decision variables specific to energy efficiency. Larger sample sizes of efficiency-only renovators are needed to further test the conceptual framework.

TABLE A6E. FULL RESULTS OF MULTIVARIATE MULTIPLE PROBIT REGRESSIONS: CDLS AND INTENTIONAL DECISION VARIABLES; DECISION *STAGE 0TO1, STAGE 1TO2* AND *STAGE 2TO3*.

	ALL RENOVATION TYPES		AMENITIES		MIXED & ENERGY		AMENITIES		MIXED & ENERGY	
EXPLANATORY VARIABLES:	*STAGE 0->1*		*STAGE 1->2*		*STAGE 1->2*		*STAGE 2->3*		*STAGE 2->3*	
CDLs and Intentional	SAMPLE WITHOUT TRIGGERS		SAMPLE WITHOUT TRIGGERS		SAMPLE WITHOUT TRIGGERS		SAMPLE WITHOUT TRIGGERS		SAMPLE WITHOUT TRIGGERS	
Decision Variables	ESTIMATES	p-value	ESTIMATES	p-value	ESTIMATES	p-value	ESTIMATES	p-value	ESTIMATES	p-value
Model Coefficients (βs)										
ADAPTING										
PRIORITISING	0.21	0.00	0.22	0.00	0.14	0.17	0.30	0.00	0.25	0.03
DEMONSTRATING	0.23	0.00	0.18	0.04	0.32	0.00	0.31	0.00	0.25	0.02
HOME AS PROJECT	0.16	0.01	0.30	0.00	0.21	0.02	0.24	0.00	0.17	0.10
DEMONSTRATING										
PRIORITISING	0.25	0.00	0.20	0.02	0.44	0.00	0.15	0.09	0.44	0.00
HOME AS PROJECT	0.29	0.00	0.31	0.00	0.13	0.21	0.47	0.00	0.15	0.18
EMBODYING										
HOME AS PROJECT	0.08	0.24	0.03	0.74	0.11	0.25	0.13	0.16	0.32	0.00
retirees at home	-0.09	0.15	0.01	0.95	-0.25	0.03	0.00	0.99	-0.05	0.65
PRIORITISING										
EMBODYING	0.16	0.03	0.21	0.02	0.26	0.00	0.11	0.22	0.13	0.27
HOME AS PROJECT	0.15	0.02	0.19	0.04	0.21	0.03	0.23	0.01	0.28	0.01
# years at current home	0.06	0.32	0.00	0.96	0.24	0.00	0.10	0.22	0.23	0.01
# years planning to stay in home	0.01	0.87	-0.02	0.74	0.06	0.48	-0.02	0.83	0.05	0.58
property size (# bedrooms)	-0.01	0.94	-0.03	0.74	0.01	0.88	-0.04	0.70	-0.03	0.78
property age	-0.04	0.47	-0.04	0.56	0.03	0.71	0.01	0.93	0.10	0.33
# dependent children at home	0.12	0.13	0.18	0.14	0.22	0.07	0.07	0.57	0.07	0.63
# retirees at home	0.01	0.90	0.05	0.50	0.04	0.68	-0.01	0.93	-0.02	0.87
household size	0.14	0.11	0.08	0.52	0.08	0.55	0.20	0.13	0.08	0.55
STAGE X->Y										
ADAPTING	0.12	0.12	0.02	0.89	-0.06	0.63	0.30	0.01	0.05	0.75
DEMONSTRATING	0.20	0.01	0.05	0.65	0.37	0.00	-0.18	0.10	-0.29	0.05
EMBODYING	-0.04	0.58	-0.13	0.28	0.15	0.25	0.16	0.16	-0.13	0.34
PRIORITISING	0.01	0.94	0.06	0.59	0.07	0.60	-0.25	0.03	-0.03	0.84
HOME AS PROJECT	0.06	0.40	0.16	0.17	0.12	0.28	-0.19	0.10	0.33	0.03
SOCIAL NORMS-AMENITY	-0.07	0.35	-0.01	0.94	0.00	1.00	-0.17	0.12	-0.09	0.57
SOCIAL NORMS-EFFICIENCY	0.14	0.07			-0.12	0.28			0.21	0.21
ATTITUDES-AMENITY	0.35	0.00	0.25	0.02	-0.12	0.28	0.25	0.01	-0.13	0.40
ATTITUDES-EFFICIENCY	0.01	0.95			-0.07	0.60			-0.05	0.73
Model Statistics										
MODEL FIT (R-SQUARE)										
STAGE X->Y	0.25	0.00	0.15	0.04	0.33	0.00	0.20	0.02	0.17	0.08
ADAPTING	0.19	0.00	0.26	0.00	0.27	0.00	0.41	0.00	0.28	0.00
DEMONSTRATING	0.02	0.38	0.00	0.86	0.08	0.18	0.02	0.48	0.11	0.04
EMBODYING	0.12	0.00	0.16	0.00	0.31	0.00	0.16	0.00	0.25	0.00
PRIORITISING	0.18	0.00	0.16	0.01	0.24	0.00	0.28	0.00	0.26	0.00
Loglikelihood										
H0 Value	-2277		-1169		-901		-1092		-764	
H0 Scaling Correction Factor for MLR	1.04		1.02		1.01		1.01		1.00	
Information Criteria										
Akaike (AIC)										
Bayesian (BIC)	4623		2402		1870		2247		1597	
Sample-Size Adjusted BIC (n*=(n+2)/24)	4749		2499		1966		2343		1686	
	4641		2397		1858		2242		1579	
Sample Sizes										
N (moving from *Stage X*)	151		71		62		80		59	
N (moving to *Stage Y*)	151		80		59		67		43	
Number of Free Parameters	34		32		34		32		34	

APPENDIX A7. Limitations of this research.

There are several limitations to this body of research. These are summarised briefly in the main text, and expanded upon here.

In particular, the development and testing of measurement items for the conditions of domestic life (CDLs) is experimental. The CDLs are derived from a series of interviews with homeowners pre- and post-renovating, and in a control non-renovating group (Wilson et al. 2015 ECEEE). The reasoning enshrined in our conceptual framework of the renovation decision process (Figure 1) was that the CDLs provide descriptively-realistic accounts of why homeowners first start thinking about renovating. We tested this reasoning in our path analysis and decision modelling using quantitative measures generated by survey questions which are inherently restrictive. The applicability of the CDLs can usefully be tested further in open-ended interviews with samples of renovators and non-renovators to establish their validity in differentiated domestic contexts.

More generally, using simplistic and standardised survey questions to measure complex and contingent social phenomena is problematic from a number of perspectives, both methodological and epistemological (Browne et al. 2013). This is borne out by the decision modelling which revealed the effect of certain object-specific attitudes and norms to be confounded with general conditions of domestic life. Extensive testing of measurement items and checking against qualitative data can help improve quantitative analysis.

Another limitation of the conceptual framework and derived decision model is that a representation of renovations as a process comprising discrete stages may create arbitrary divisions along a continuum. Moreover, using cross-sectional data to analyse movement between stages allows only correlational support for the basic representation of changing influences over the decision process. A longitudinal (panel) sample would allow causal effects to be identified, by analysing sub-samples of households who have moved forwards or backwards through the decision process.

In sum, context-specific testing of the CDLs as narrative accounts of emergent renovation processes, and longitudinal within-subjects analysis of progression through the decision process, are both important areas for further research.

Bibliography

Achtnicht, M. (2011). "Do environmental benefits matter? Evidence from a choice experiment among house owners in Germany." Ecological Economics **70**(11): 2191-2200.

Ajzen, I. (2001). "Nature and Operation of Attitudes." Annual Review of Psychology **52**: 27–58

Alberini, A., S. Banfi and C. Ramseier (2013). "Energy Efficiency Investments in the Home: Swiss Homeowners and Expectations about Future Energy Prices." The Energy Journal **34**(1): 49-86.

Alló, M. and M. L. Loureiro (2014). "The role of social norms on preferences towards climate change policies: A meta-analysis." Energy Policy **73**(0): 563-574.

Aune, M. (2007). "Energy comes home." Energy Policy **35**(11): 5457-5465.

Baillie, L. and D. Benyon (2008). "Place and Technology in the Home." Computer Supported Cooperative Work **17**: 227–256.

Balaras, C. A., E. G. Dascalaki, K. G. Droutsa and S. Kontoyiannidis (2016). "Empirical assessment of calculated and actual heating energy use in Hellenic residential buildings." Applied Energy **164**(Supplement C): 115-132.

Banfi, S., M. Farsi, M. Filippini and M. Jakob (2008). "Willingness to pay for energy-saving measures in residential buildings." Energy Economics **30**(2): 503-516.

Bauermann, K., S. Spiecker and C. Weber (2014). "Individual decisions and system development – Integrating modelling approaches for the heating market." Applied Energy **116**(Supplement C): 149-158.

BPIE (2017). Trigger points as a 'must' in national renovation strategies. Brussels, Belgium, Buildings Performance Institute Europe (BPIE).

Braun, F. G. (2010). "Determinants of households' space heating type: A discrete choice analysis for German households." Energy Policy **38**(10): 5493-5503.

Browne, A. L., M. Pullinger, W. Medd and B. Anderson (2013). "Patterns of practice: a reflection on the development of quantitative/mixed methodologies capturing everyday life related to water consumption in the UK." International Journal of Social Research Methodology **17**(1): 27-43.

Cayla, J.-M. and N. Maïzi (2015). "Integrating household behavior and heterogeneity into the TIMES-Households model." Applied Energy **139**(Supplement C): 56-67.

Chappells, H. and E. Shove (2005). "Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment." Building Research and Information **33**(1): 32-40.

Cialdini, R. (2007). "Descriptive Social Norms as Underappreciated Sources of Social Control." Psychometrika **72**(2): 263-268.

Cialdini, R. and N. Goldstein (2004). "Social Influence: Compliance and Conformity." Annual Review of Psychology **55**(1): 591-621.

Cole, R. J., J. Robinson, Z. Brown and M. O'Shea (2008). "Re-contextualizing the notion of comfort." Building Research & Information **36**(4): 323-336.

Coulter, R., M. van Ham and P. Feijten (2011). "A longitudinal analysis of moving desires, expectations and actual moving behaviour." Environment and Planning A **43**: 2742-2760.

Craig, C. A. (2016). "Energy consumption, energy efficiency, and consumer perceptions: A case study for the Southeast United States." Applied Energy **165**(Supplement C): 660-669.

DCLG (2013a). Dwelling stock estimates: 2013, England. Housing Statistical Release. London, UK, Department of Communities and Local Government (DCLG).

DCLG (2013b). English Housing Survey. London, UK, Department of Communities and Local Government (DCLG).

Dietz, T., G. T. Gardner, J. Gilligan, P. C. Stern and M. P. Vandenbergh (2009). "Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions." Proceedings of the National Academy of Sciences **106**(44): 18452-18456.

Dixon, T. and M. Eames (2013). "Scaling up: the challenges of urban retrofit." Building Research & Information **41**(5): 499-503.

Dodds, P. E. (2014). "Integrating housing stock and energy system models as a strategy to improve heat decarbonisation assessments." Applied Energy **132**(Supplement C): 358-369.

EST (2010). Trigger points: a convenient truth - Promoting energy efficiency in the home. London, UK, Energy Saving Trust.

Eurostat (2012). Distribution of population by tenure status (Accessed 19 Sep 2014).

Faiers, A. and C. Neame (2006). "Consumer attitudes towards domestic solar power systems." Energy Policy **34**(14): 1797-1806.

Falke, T., S. Krengel, A.-K. Meinerzhagen and A. Schnettler (2016). "Multi-objective optimization and simulation model for the design of distributed energy systems." Applied Energy **184**(Supplement C): 1508-1516.

Farrow, K., G. Grolleau and L. Ibanez (2017). "Social Norms and Pro-environmental Behavior: A Review of the Evidence." Ecological Economics **140**: 1-13.

Fawcett, T. (2014). "Exploring the time dimension of low carbon retrofit: owner-occupied housing." Building Research & Information **42**(4): 477-488.

Filippidou, F., N. Nieboer and H. Visscher (2017). "Are we moving fast enough? The energy renovation rate of the Dutch non-profit housing using the national energy labelling database." Energy Policy **109**: 488-498.

Friege, J. and E. Chappin (2014). "Modelling decisions on energy-efficient renovations: A review." Renewable and Sustainable Energy Reviews **39**: 196-208.

Galassi, V. and R. Madlener (2017). "The Role of Environmental Concern and Comfort Expectations in Energy Retrofit Decisions." Ecological Economics **141**(Supplement C): 53-65.

GfK (2011). Survey of potential consumer demand for the Green Deal. London, UK, GfK NOP.

Gram-Hanssen, K. (2007). "Teenage consumption of cleanliness: how to make it sustainable?" Sustainability: Science, Practice, & Policy **3**(2): 15-23.

Gram-Hanssen, K., F. Bartiaux, O. Michael Jensen and M. Cantaert (2007). "Do homeowners use energy labels? A comparison between Denmark and Belgium." Energy Policy **35**(5): 2879-2888.

Grosche, P. and C. Vance (2009). "Willingness to Pay for Energy Conservation and Free-Ridership on Subsidization: Evidence from Germany." Energy Journal **30**(2): 135-153.

Güneralp, B., Y. Zhou, D. Ürge-Vorsatz, M. Gupta, S. Yu, P. L. Patel, M. Fragkias, X. Li and K. C. Seto (2017). "Global scenarios of urban density and its impacts on building energy use through 2050." Proceedings of the National Academy of Sciences **114**(34): 8945-8950.

Guy, S. and E. Shove (2000). The sociology of energy, buildings and the environment: Constructing knowledge, designing practice. Oxford, UK, Psychology Press.

Hagle, T. M. and G. E. Mitchell (1992). "Goodness-of-Fit Measures for Probit and Logit." American Journal of Political Science **36**(3): 762-784.

Haines, V. and V. Mitchell (2014). "A persona-based approach to domestic energy retrofit." Building Research & Information **42**(4): 462-476.

Hand, M., E. Shove and D. Southerton (2007). "Home extensions in the United Kingdom: space, time, and practice." Environment and Planning D-Society & Space **25**(4): 668-681.

Huebner, G. M., I. Hamilton, Z. Chalabi, D. Shipworth and T. Oreszczyn (2015). "Explaining domestic energy consumption – The comparative contribution of building factors, socio-demographics, behaviours and attitudes." Applied Energy **159**(Supplement C): 589-600.

IEA (2014). World Energy Outlook Special Report: Redrawing the Energy-Climate Map. Paris, France, International Energy Agency.

Im, J., Y. Seo, K. S. Cetin and J. Singh (2017). "Energy efficiency in U.S. residential rental housing: Adoption rates and impact on rent." Applied Energy **205**(Supplement C): 1021-1033.

Imrie, R. (2004). "Disability, embodiment and the meaning of the home." Housing Studies **19**(5): 745-763.

Islam, T. (2014). "Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data." Energy Policy **65**: 340-350.

Jaccard, M. and M. Dennis (2006). "Estimating home energy decision parameters for a hybrid energy-economy policy model." Environmental Modeling & Assessment **11**(2): 91-100.

Jaffe, A. B. and R. N. Stavins (1994). "The Energy Efficiency Gap: What Does it Mean?" Energy Policy **22**(10): 804-810.

Jager, W. (2006). "Stimulating the diffusion of photovoltaic systems: A behavioural perspective." Energy Policy **34**(14): 1935-1943.

Jakob, M. (2007). The drivers of and barriers to energy efficiency in renovation decisions of single-family home-owners. Zurich, Switzerland, Centre for Energy Policy & Economics (CEPE).

Jarvis, H. (2005). "Moving to London time - Household co-ordination and the infrastructure of everyday life." Time & Society **14**(1): 133-154.

JCHS (2009). The Remodeling Market in Transition. Cambridge, MA, Joint Centre for Housing Studies (JCHS), Harvard University.

Jin, X., K. Baker, D. Christensen and S. Isley (2017). "Foresee: A user-centric home energy management system for energy efficiency and demand response." Applied Energy **205**(Supplement C): 1583-1595.

Johansson, T., T. Olofsson and M. Mangold (2017). "Development of an energy atlas for renovation of the multifamily building stock in Sweden." Applied Energy **203**(Supplement C): 723-736.

Judson, E. P. and C. Maller (2014). "Housing renovations and energy efficiency: insights from homeowners' practices." Building Research & Information **42**(4): 501-511.

Karvonen, A. (2013). "Towards systemic domestic retrofit: a social practices approach." Building Research & Information **41**(5): 563-574.

Kempton, W. and L. L. Layne (1994). "The consumer's energy analysis environment." Energy Policy **22**(10): 857-866.

Kragh, J. and J. Rose (2011). "Energy renovation of single-family houses in Denmark utilising long-term financing based on equity." Applied Energy **88**(6): 2245-2253.

Kuha, J. (2004). "AIC and BIC." Sociological Methods & Research **33**: 188-229.

Levesque, A., R. Pietzcker, L. Baumstark and G. Luderer (2017). How will buildings' energy demand look in 2100? Quantifying future energy service demand from buildings. European Council for an Energy Efficient Economy (ECEEE) Summer Study. Hyeres, France.

Liu, W., J. Zhang, B. Bluemling, A. P. J. Mol and C. Wang (2015). "Public participation in energy saving retrofitting of residential buildings in China." Applied Energy **147**(Supplement C): 287-296.

Madlener, R. (2007). "Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria." Energy Policy **35**(3): 1992-2008.

Mahapatra, K. and L. Gustavsson (2008). "An adopter-centric approach to analyze the diffusion patterns of innovative residential heating systems in Sweden." Energy Policy **36**(2): 577-590.

Mahapatra, K., L. Gustavsson, T. Haavik, S. Aabrekk, S. Svendsen, L. Vanhoutteghem, S. Paiho and M. Ala-Juusela (2013). "Business models for full service energy renovation of single-family houses in Nordic countries." Applied Energy **112**(Supplement C): 1558-1565.

Maller, C. J. and R. E. Horne (2011). "Living Lightly: How does Climate Change Feature in Residential Home Improvements and What are the Implications for Policy?" Urban Policy and Research **29**(1): 59-72.

Manning, M. (2009). "The effects of subjective norms on behaviour in the theory of planned behaviour: A meta-analysis." British Journal of Social Psychology **48**(4): 649-705.

McCormack, D. P. and T. Schwanen (2011). "The space - times of decision making." Environment and Planning A **43**: 2801-2818.

Michelsen, C. C. and R. Madlener (2012). "Homeowners' preferences for adopting innovative residential heating systems: A discrete choice analysis for Germany." Energy Economics **34**(5): 1271-1283.

Michelsen, C. C. and R. Madlener (2013). "Motivational factors influencing the homeowners' decisions between residential heating systems: An empirical analysis for Germany." Energy Policy **57**(0): 221-233.

Mørck, O., K. E. Thomsen and J. Rose (2012). "The EU CONCERTO project Class 1 – Demonstrating cost-effective low-energy buildings – Recent results with special focus on comparison of calculated and measured energy performance of Danish buildings." Applied Energy **97**(Supplement C): 319-326.

Munro, M. and P. Leather (2000). "Nest-building or investing in the future? Owner-occupiers' home improvement behaviour." Policy and Politics **28**(4): 511-526.

Nair, G., L. Gustavsson and K. Mahapatra (2010a). "Factors influencing energy efficiency investments in existing Swedish residential buildings." Energy Policy **38**(6): 2956-2963.

Nair, G., L. Gustavsson and K. Mahapatra (2010b). "Owners perception on the adoption of building envelope energy efficiency measures in Swedish detached houses." Applied Energy **87**(7): 2411-2419.

Nair, G., K. Mahapatra and L. Gustavsson (2012). "Implementation of energy-efficient windows in Swedish single-family houses." Applied Energy **89**(1): 329-338.

Nansen, B., M. Arnold, M. Gibbs and H. Davis (2011). "Dwelling with media stuff: latencies and logics of materiality in four Australian homes." Environment and Planning D-Society & Space **29**(4): 693-715.

Nippert-Eng, C. E. (1996). Home and Work: Negotiating Boundaries throught Everyday Life. London, The University of Chicago Press.

Nolan, J. M., P. W. Schultz, R. B. Cialdini, V. Griskevicius and N. J. Goldstein (2008). "Normative Social Influence is Underdetected." Personality & Social Psychology Bulletin **34**(7): 913-923.

Noonan, D. S., L.-H. C. Hsieh and D. Matisoff (2013). "Spatial Effects in Energy-Efficient Residential HVAC Technology Adoption." Environment and Behavior **45**(4): 476-503.

ONS (2011). Housing: Social Trends 41. London, UK, Office of National Statistics (ONS).

ONS (2012). Annual Survey of Hours and Earnings. London, UK, Office of National Statistics (ONS).

Organ, S., D. Proverbs and G. Squires (2013). "Motivations for energy efficiency refurbishment in owner ‐ occupied housing." Structural Survey **31**(2): 101-120.

Palm, A. (2017). "Peer effects in residential solar photovoltaics adoption—A mixed methods study of Swedish users." Energy Research & Social Science **26**: 1-10.

Pettifor, H., C. Wilson and G. Chryssochoidis (2015). "The appeal of the Green Deal: Empirical evidence for the influence of energy efficiency policy on renovating homeowners." Energy Policy **79**: 161-176.

Phillips, Y. (2012). "Landlords versus tenants: Information asymmetry and mismatched preferences for home energy efficiency." Energy Policy **45**(0): 112-121.

Pisello, A. L. and F. Asdrubali (2014). "Human-based energy retrofits in residential buildings: A cost-effective alternative to traditional physical strategies." Applied Energy **133**(Supplement C): 224-235.

Rogers, E. M. (2003). Diffusion of Innovations. New York, Free Press.

Rommel, K. and J. Sagebiel (2017). "Preferences for micro-cogeneration in Germany: Policy implications for grid expansion from a discrete choice experiment." Applied Energy **206**(Supplement C): 612-622.

Rosenow, J. and N. Eyre (2013). "The Green Deal and the Energy Company Obligation." Proceedings of the Institution of Civil Engineers - Energy **166**(EN3): 127-136.

Rosenow, J., N. Eyre, S. Sorrell and P. Guertler (2017). Unlocking Britain's First Fuel: The potential for energy savings in UK housing. London, UK, UK Energy Research Centre.

Sandberg, N. H., I. Sartori, O. Heidrich, R. Dawson, E. Dascalaki, S. Dimitriou, T. Vimm-r, F. Filippidou, G. Stegnar, M. Šijanec Zavrl and H. Brattebø (2016). "Dynamic building stock modelling: Application to 11 European countries to support the energy efficiency and retrofit ambitions of the EU." Energy and Buildings **132**(Supplement C): 26-38.

Shove, E., H. Chappells, L. Lutzenhiser and B. Hackett (2008). "Comfort in a lower carbon society." Building Research and Information **36**(4): 307-311.

Shove, E., M. Watson, M. Hand and J. Ingram (2007). The Design of Everyday Life. Oxford, Berg.

Skelton, B., D. Fernandez and A. Fitzgibbons (2009). Energy Saving Trust Green Finance Uptake. Final Debrief. London, UK, Quadrangle & Energy Savings Trust (EST).

Sparke, P. (1995). As Long as It's Pink: The Sexual Politics of Taste. Halifax, The Press of the Nova Scotia College of Art and Design.

Stieß, I. and E. Dunkelberg (2013). "Objectives, barriers and occasions for energy efficient refurbishment by private homeowners." Journal of Cleaner Production **48**: 250-259.

Taylor, N. W., P. H. Jones and M. J. Kipp (2014). "Targeting utility customers to improve energy savings from conservation and efficiency programs." Applied Energy **115**(Supplement C): 25-36.

Tran, M. (2012). "Technology-behavioural modelling of energy innovation diffusion in the UK." Applied Energy **95**(Supplement C): 1-11.

Tweed, C. (2013). "Socio-technical issues in dwelling retrofit." Building Research & Information **41**(5): 551-562.

UK CCC (2017). Meeting Carbon Budgets: Closing the policy gap. London, UK, UK Committee on Climate Change.

Wang, X., M. Lu, W. Mao, J. Ouyang, B. Zhou and Y. Yang (2015). "Improving benefit-cost analysis to overcome financing difficulties in promoting energy-efficient renovation of existing residential buildings in China." Applied Energy **141**(Supplement C): 119-130.

Watson, M. and E. Shove (2008). "Product, Competence, Project and Practice: DIY and the dynamics of craft consumption." Journal of Consumer Culture **8**(1): 69-89.

Willis, K., R. Scarpa, R. Gilroy and N. Hamza (2011). "Renewable energy adoption in an ageing population: Heterogeneity in preferences for micro-generation technology adoption." Energy Policy **39**(10): 6021-6029.

Wilson, C. (2014). "Evaluating communication to optimise consumer-directed energy efficiency interventions." Energy Policy **74**(0): 300-310.

Wilson, C., G. Chryssochoidis and H. Pettifor (2013a). Understanding Homeowners' Renovation Decisions: Findings of the VERD Project. London, UK, UK Energy Research Centre (UKERC).

Wilson, C., L. Crane and G. Chryssochoidis (2013b). The conditions of normal domestic life help explain homeowners' decisions to renovate. ECEEE Summer Study (European Council for an Energy Efficient Economy), Toulon, France.

Wilson, C., L. Crane and G. Chryssochoidis (2015). "Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy." Energy Research & Social Science **7**(0): 12-22.

Wilson, C. and H. Dowlatabadi (2011). Aligning Consumer Decisions and Sustainabilty Objectives: Energy Efficiency in the Residential Retrofit Market. The Business of Sustainability: Trends, Policies, Practices and Stories of Success. S. G. McNall, J. C. Hershauer and G. Basile. New York, Praeger Press. **2:** 221-240.

Wu, R., G. Mavromatidis, K. Orehounig and J. Carmeliet (2017). "Multiobjective optimisation of energy systems and building envelope retrofit in a residential community." Applied Energy **190**(Supplement C): 634-649.

Yan, J., T. Shamim, S. K. Chou, U. Desideri and H. Li (2017). "Clean, efficient and affordable energy for a sustainable future." Applied Energy **185**(Part 2): 953-962.