RAF063/2122

Comfort Taking

Evidence Review: Technical Annex

Completed by London Economics for the Department for Energy Security and Net Zero prior to the 2024 general election in the UK. As such, any references to government policies, commitments, or initiatives may reflect the stance of the previous administration and were accurate at the time of writing.

London Economics (2024)

Views expressed in this report are from the relevant research agencies, based on data collected from research participants and other evidence, and not necessarily those of the UK government.

Contents

Appendices

A1: Rapid Evidence Assessment (REA) methodology

A **rapid evidence assessment (REA)** was conducted to collect evidence on the key research questions. This was conducted in March 2024.

Search protocol

An REA protocol was designed and developed in collaboration with Cambridge University and the Department for Energy Security and Net Zero (DESNZ) prior to conducting the search for literature. The first stage of developing the REA protocol was designing the eligibility criteria for the relevant literature. Broadly speaking, studies were included if they investigated or evaluated 'comfort taking' behaviour by households.

The following specific eligibility criteria were included:

- Population: Residential consumers, defined as homeowners, owner occupiers, and tenants who have installed energy efficiency measures and/or low carbon heating measures.
- Outcomes: In this context, one primary outcome is behavioural, specifically referring to households who 'comfort take', that is heating their home more frequently/to a higher temperature following the increase in energy efficiency of their property. Another primary outcome is the extent, or magnitude, to which households 'comfort take' and how that is measured.
- Intervention: The context of this study is those households who have increased the energy efficiency of a property (and which is associated with corresponding energy bill savings). We also included studies that report the impact of behaviour change interventions that aim to limit 'comfort taking'. This included individual, organisational or policy level interventions (e.g. educational and persuasive campaigns, framing/reframing of information, financial incentives or penalties/taxes).
- Setting: Household/residential settings only. We excluded other types of buildings (i.e. non-residential buildings).
- Design: We did not impose any restrictions related to study design. Eligible studies included primary research to explore household attitudes, perceptions, experiences, and behaviours related to 'comfort taking' (i.e. qualitative interviews, focus groups, surveys, observations). This also included primary research estimating energy bill savings following the increase in energy efficiency and the extent of comfort taking (i.e. surveys, interviews, observations). Studies also included experimental, modelling, observational designs and/or interventions and policy measures to estimate the extent of 'comfort taking'.

- Date: Studies conducted prior to 2014 were excluded.[1]
- Geographic location: We prioritised studies located within the UK, however, international studies were considered.

Search strategy

London Economics in collaboration with Cambridge University explored the potential for bibliometric analyses through the extraction of information on several main electronic databases: Web of Science, Scopus, ScienceDirect, the Cochrane Library for reviews and trials, and Google Scholar among others. Each of them offers specific advantages and disadvantages, but Scopus is characterised by great flexibility in terms of available filters and disciplines. Additionally, Scopus is the largest abstract and citation database of peer-reviewed literature. These are the main two reasons we used Scopus as the reference database for the REA. To select the relevant literature, London Economics and Cambridge University searched for peer-reviewed articles and high-level policy or institutional reports – i.e. grey literature- published in English. Three complementary processes were used to this end: (1) a Scopus search; (2) a review of references in pre-selected articles, based on key authors, conferences and reports identifications; and (3) a complementary separate search on grey literature.

An initial scoping and guidance from Cambridge University revealed that the term 'comfort taking' is not a widely used term in the literature. Therefore, it was necessary to include search terms related to 'rebound effect' and 'heating'. The search was based on a title, abstract and keywords search. The selected search terms related to three broad categories: Rebound Effect, AND energy efficiency AND household. The search terms related to each category and Boolean operators for combining search terms are summarised in Table 3.

Table 1**:** Search terms

Comfort Taking.	AND	Energy efficient heating measure	AND	Consumer
Rebound effect	AND	Energy efficiency OR retrofit OR comfort	AND	Household OR domestic OR residential OR behaviour

To identify grey literature, London Economics conducted an electronic search using Google search engine. The search terms used were the same as those presented in Table 3.

Several key criterion papers were identified from the list sent by DESNZ. The search strategy was piloted to ensure the criterion paper(s) were retrieved.

[1] The exception to this was Sorrell (2007) "An assessment of the evidence for economy-wide energy savings from improved energy efficiency" which was included in the REA as it is a key paper in this field of research.

Screening

The search results were then screened against the exclusion criteria by the study team at London Economics, and audited by academics at Cambridge University. The screening followed a three-stage process. Abstracts were screened and categorised into three groups (Definitely include (1), Maybe include (2), and Exclude (3)). Those falling under category 2 underwent a more detailed assessment of the paper against the specified exclusion criteria.

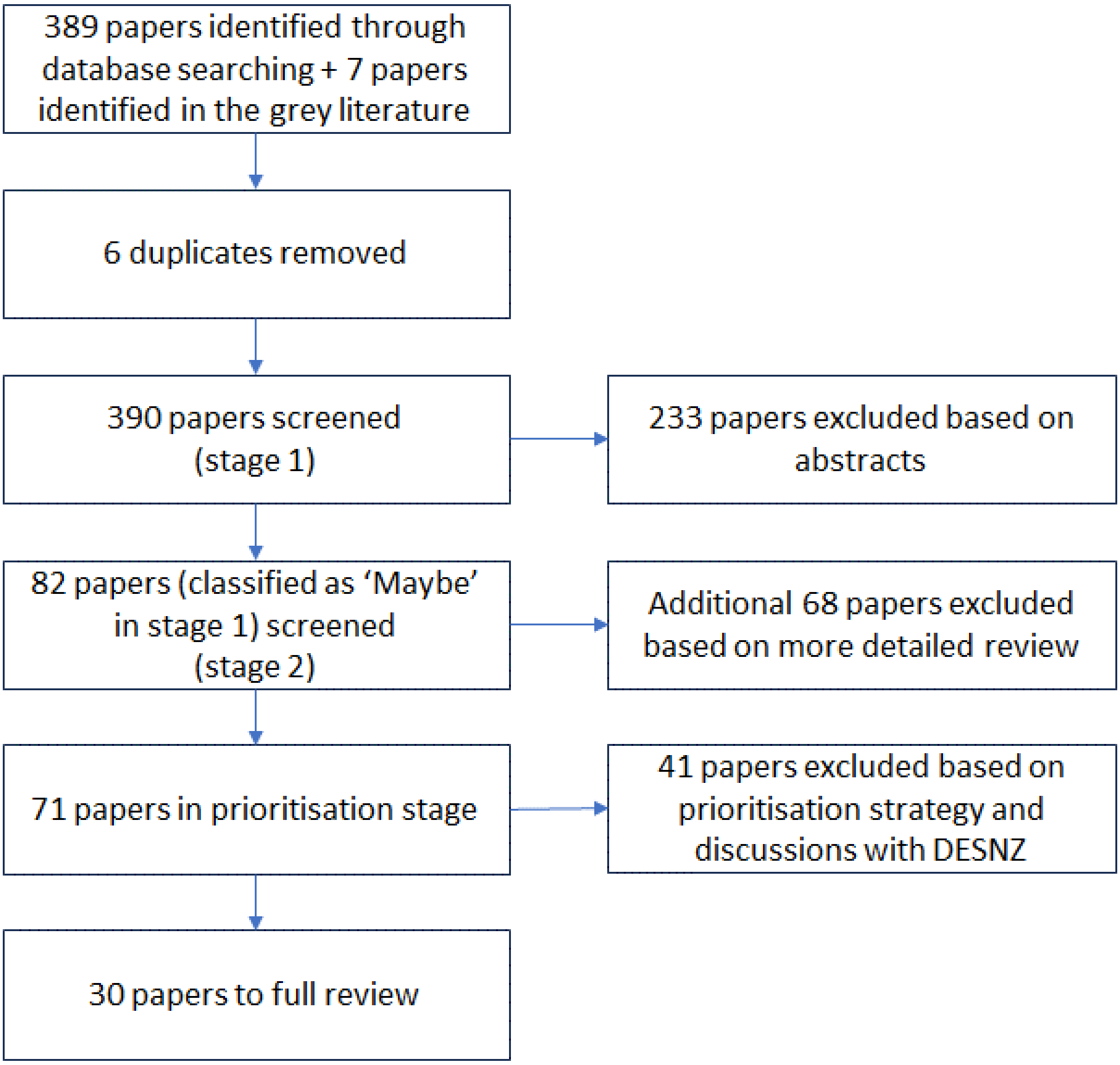
The third stage involved prioritisation of the shortlisted papers based on the following factors:

This process is summarised in the PRISMA flow diagram (Figure 1).

- **Relevance to the research questions**: Through our search, we prioritised papers which specifically referenced rebound effects in relation to heating and how the installation of energy efficiency measures influences household heating consumption.
- **Date of publication**: During initial analysis, a spike in publication rates of papers within our search parameters was highlighted since 2014. As a result, papers published post 2014 were prioritised. However, papers pre 2014 that appeared key were also considered.
- **Location:** Studies produced within the UK were prioritised, followed by studies in the rest of Europe. Studies from Australia, Canada, the US and the rest of the world were then additionally considered if they were deemed relevant.
- **Author:** Prominent authors within the field were established and their papers prioritised.
- **Number of citations**: Papers within significant citation numbers were initially considered over those with lesser citation numbers.

The REA search identified 389 academic papers. Through several rounds of abstract screening, more in-depth reviews and prioritisation, 28 academic papers were included in the analysis. An additional 7 papers from the grey literature were reviewed and 2 were included in the analysis.

Figure 1 PRISMA diagram of REA



Data extraction

An Excel-based analytical framework was developed by London Economics to extract the relevant data from the literature included in the full review. Data was extracted on:

- **Bibliographical information:** title, authors, publication year, country of publication and publication type.
- **Population**: type of consumer (owner occupier, tenant), key characteristics of households (e.g. able-to-pay).
- **Outcomes**: one primary outcome is behavioural, specifically referring to households who 'comfort take', that is heating their home more frequently/to a higher temperature following the increase in energy efficiency of their property. Another primary outcome is the extent, or magnitude, to which households 'comfort take' and how that is measured.
- **Type of energy efficiency measure.**

- **Confounders** i.e. behavioural factors driving comfort taking.
- **Intervention**: This could include individual, organisational or policy level interventions (e.g. educational and persuasive campaigns, framing/reframing of information, financial incentives or penalties/taxes).
- **Methodology**: study design, empirical/methodological approach.
- **Quality appraisal**: A red-amber-green (RAG) methodology was employed to assess quality based on several factors including a number of criteria such as empirical/methodological approach (e.g. the study's design, the recruitment process for sampling, the profile and applicability of the sample, the analysis conducted, the reliability of the findings) and the publishing source (e.g. a peer-reviewed journal is considered the highest quality).

The extracted data was triangulated using the analytical framework to collate evidence to answer the research (and sub-research) questions.

A2: Bibliometric information of the papers considered

Table 2: Bibliometric information of the papers considered

Author	Year	Paper title	Country
Aydin et al.	2017	Energy efficiency and household behaviour: the rebound effect in the residential sector	Netherlands
Bardsley et al.	2019	Domestic thermal upgrades, community action and energy saving: A three-year experimental study of prosperous households	UK
Calderón and Beltrán	2018	Effects of fabric retrofit insulation in a UK high-rise social housing building on temperature take back	UK
Calì et al.	2016	Energy performance gap in refurbished German dwellings: Lesson learned from a field test	Germany
Chitnis et al.	2014	Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups	UK
Chitnis and Sorrell	2015	Living up to expectations: Estimating direct and indirect rebound effects for UK households	UK
Chitnis et al.	2020	Rebound Effects for Household Energy Services in the UK	UK
Dütschke et al.	2018	Moral licensing-Another source of rebound?	International
Elsharkawy and Rutherford	2018	Energy efficient retrofit of social housing in the UK: Lessons learned from a community energy saving programme (CESP) in Nottingham	UK
European Environment Agency	2022	Behavioural factors influencing the uptake of energy efficiency in residential buildings	Europe
Freire-González and Puig-Ventosa	2015	Energy efficiency policies and the Jevons paradox	International
Galassi and Madlener	2017	The Role of Environmental Concern and Comfort Expectations in Energy Retrofit Decisions	Germany

Galassi and Madlener	2018	Shall I open the window? Policy implications of thermal-comfort adjustment practices in residential buildings	Germany
Galvin	2014	Constant' rebound effects in domestic heating: Developing a cross-sectional method	Germany
Galvin	2014	Making the 'rebound effect' more useful for performance evaluation of thermal retrofits of existing homes: Defining the 'energy savings deficit' and the 'energy performance gap'	Germany
Galvin and Sunukka-Blank	2015	Quantification of (p)rebound effects in retrofit policies - why does it matter?	UK, France, Germany
Galvin and Sunikka-Blank	2017	Ten questions concerning sustainable domestic thermal retrofit policy research	Europe
Halvorsen et al.	2016	Revisiting household energy rebound: Perspectives from a multidisciplinary study	Norway
Hediger et al.	2018	Turn It Up and Open the Window: On the Rebound Effects in Residential Heating	Switzerland
Hediger	2022	Rebound effects in residential heating: How much does an extra degree matter?	Switzerland
Mardones	2021	Ex-post evaluation of residential insulation program in the city of Temuco, Chile	Chile
Raynaud et al.	2016	Evidence of an indirect rebound effect with reversible heat pumps: having air conditioning but not using it?	Southern Europe
Reuter et al.	2021	Linking energy efficiency indicators with policy evaluation – A combined top-down and bottom-up analysis of space heating consumption in residential buildings	Germany, Switzerland
Santarius and Soland	2018	How Technological Efficiency Improvements Change Consumer Preferences: Towards a Psychological Theory of Rebound Effects	International
Seebauer	2018	The psychology of rebound effects: Explaining energy efficiency rebound behaviours with electric vehicles and building insulation in Austria	Austria

Sorrell	2007	An assessment of the evidence for economy-wide energy savings from improved energy efficiency	International
Suffolk and Poortinga	2016	Behavioural changes after energy efficiency improvements in residential properties	UK
Vivanco et al.	2016	How to deal with the rebound effect? A policy-oriented approach	International
Webber et al.	2015	The impacts of household retrofit and domestic energy efficiency schemes: A large scale, ex post evaluation	UK
York et al.	2022	The rebound effect and the challenge of moving beyond fossil fuels: A review of empirical and theoretical research	International

Peñasco and Anadón (2023) “Assessing the effectiveness of energy efficiency measures in the residential sector gas consumption through dynamic treatment effects: Evidence from England and Wales” was also considered for inclusion in this study due to its relevance to the research questions. However, this was excluded as this paper is currently undergoing revisions by the authors.

A3: Methodological information of papers which estimate a direct rebound effect

Hediger (2022). 'Rebound effects in residential heating: How much does an extra degree matter?' This study uses own-price elasticities of demand for heating to estimate the direct rebound effect in Switzerland. The authors estimate a regression model to determine if households living in more efficient dwellings set higher indoor temperatures using data from over 5000 households in Switzerland over 6 years. The study uses indoor temperature as a measure for heating usage. To approximate building efficiency, the authors use the building construction date and the accommodation type. The hypothesis being tested is that improved efficiency leads to increased temperature settings. The increase in indoor temperature identified is converted into energy consumption using the heating degree days (HDDs) method. The HDDs method assumes that a one-degree decrease in outdoor temperature requires the same amount of energy as a one-degree increase in indoor temperature. The study calculates the direct rebound effect by comparing the potential energy savings with the actual increase in energy consumption due to higher indoor temperatures.

Mardones (2021) 'Ex-post evaluation of residential insulation program in the city of Temuco, Chile' This study performs an ex-post evaluation of a residential insulation program, a subsidy for the remodelling of the roof, walls, windows, and other construction elements. An ex-post evaluation technique known as "matching with differences in differences" was used to identify the causal impact of the program. This method aims to correct the limitations that arise from either comparing households "before-after" an energy efficiency measure is installed or comparing those "with-without" installing an energy efficiency measure. The "before-after" design compares the energy consumption of a group of dwellings before and after installation, but this does not account for changes in external factors such as price of energy, change in family income or size etc. The "with-without" design compares the energy consumption of a group of dwellings with an energy efficiency measure installed and those without. This, however, does not account for the observable and unobservable differences between the groups before the intervention (e.g. environmental values, temperature preferences) which may bias the results. The limitations from these methods were corrected in this study to some extent by first matching groups of dwellings with and without energy efficiency measures based on their characteristics, such that the groups were as similar as possible, except for the fact that some have energy efficiency measures installed (treatment group) and some do not (control). The method then compares the before and after energy consumption for both groups to estimate the average treatment effect.

Chitnis et al. (2020). 'Rebound Effects for Household Energy Services in the UK' The authors use a unique database containing historical data on the price and quantity demanded of six household energy services spanning the past half-century. The study estimates direct rebound effects from estimates of own-price elasticity of demand for heating. Own-price elasticities are obtained from a household demand model, which specifies household expenditure on different goods and services as a function of total expenditure, price of 'category' and other variables. For example, to estimate the direct rebound effect of heating, the model includes heating as one of the categories of household expenditure, alongside other categories such as food and lighting. To convert elasticities into direct rebound effects, the study estimates the energy use and emissions associated with household expenditure on each category of good and service. The study draws upon historical data related to the consumption and price of energy services in the UK from 1964 to 2015 from the ONS.

Bardsley et al., (2019), 'Domestic thermal upgrades, community action and energy saving: A three-year experimental study of households The authors employed a matched treatment and control area approach to estimate the impact of behavioural interventions on direct rebound effects in affluent households in the UK. In the treatment group (TG), households interacted with a community environmental group (CEG) while also receiving home insulation upgrades. Conversely, the control group (CG) solely received home insulation upgrades without any CEG interaction. Initially,185 households participated, with 75 in the TG and 110 in the CG. However, due to attrition, the final sample sizes were 62 for TG and 91 for CG. The TG engaged with the CEG through events and activities aimed at promoting energy conservation. In contrast, the CG served as a baseline for comparison, receiving no such engagement. This allowed researchers to assess the effectiveness of the CEG's interventions. Energy consumption was assessed using utility bills and energy monitoring equipment. Additionally, surveys were conducted to collect data on energy use, including personal transport habits and intentions for energy savings. To estimate the direct rebound effect for both groups, the authors had to estimate the theoretical energy savings that could be achieved through the installation. To do so, they used a detailed physical and energy survey to gather information on the dimensions and construction of the dwelling's thermal envelope and details of the heating system.

Hediger et al. (2018), 'Turn It Up and Open the Window: On the Rebound Effects in Residential Heating' The research aims to capture stated behaviour by observing how individuals respond to hypothetical scenarios related to heating efficiency improvements using a stated preference methodology. The authors designed a choice experiment survey in which respondents were presented with various choices and trade-offs relating to heating usage, energy savings and spending preferences. Respondents were presented with scenarios in which the efficiency of their home had increased by a certain percentage and they were asked to what extent it would change their heating usage. This was measured on a sliding scale of how much of the potential savings they would allocate to increasing heating usage in their home. The average proportion of potential savings allocated to increasing heating usage was used as an estimate of the direct rebound effect.

Aydin et al. (2017), 'Energy efficiency and household behaviour: the rebound effect in the residential sector' The authors analyse a large panel dataset of 560,000 households in the Netherlands and estimate the elasticity of actual energy consumption relative to the engineering predictions of energy performance using a fixed-effects regression model. The authors also conduct a quasi-experimental analysis by estimating the rebound effect based on a subsample of dwellings that benefited from an energy efficiency subsidy program in the Netherlands and comparing the energy consumption of those who participated in the program and those that did not to estimate the rebound effect,

Raynaud et al. (2016), 'Evidence of an indirect rebound effect with reversible heat pumps: having air conditioning but not using it?' The authors conduct an ex-post evaluation of an energy efficiency program which provided financial incentives for a combination of energy efficiency measures (heat pump combined with insulation and/or solar heater). Over 200 households were surveyed regarding their energy consumption and the authors also analysed households energy bills over the last 3 years. The authors estimate energy consumption before and after installation of energy efficiency measures. The direct rebound effect is estimated using households' declared change of set heating temperature in the living rooms before and after retrofitting.

Calì et al. (2016), 'Energy performance gap in refurbished German dwellings: Lesson learned from a field test' The authors analyse the energy performance gap in three apartment buildings that have been retrofitted in a field test in Germany. The retrofits involved various insulation materials being installed as well as heat pumps in one of the buildings. Various elements of the buildings' energy services were monitored over a three year period, including indoor temperatures, air quality and energy flows. The authors estimate the energy performance gap which is defined as the difference between the actual and expected energy consumption of the buildings. Expected energy consumption was calculated based on expected heating energy consumption (assuming 19 degrees Celsius is the expected constant indoor temperature) and engineering factors of the building.

Galvin (2014), 'Making the 'rebound effect' more useful for performance evaluation of thermal retrofits of existing homes: Defining the 'energy savings deficit' and the 'energy performance gap' The paper conducts an empirical case study of three apartment buildings in southern Germany that underwent thermal retrofits. The study aims to demonstrate the variation in direct rebound effects that are estimated when using different definitions. The case study involves three buildings, each consisting of 30 identical and mirror-image apartments, making a total of 90 apartments. It compares pre-retrofit and post-retrofit energy consumption to assess the effectiveness of the retrofits. Data was collected through sensors in each apartment, measuring parameters such as space and water heating consumption over the year. The paper defines three distinct metrics to evaluate the rebound effect. Firstly, what the authors terms the 'classic rebound effect', which they define at the proportionate change in energy services consumption relative to the proportionate change in energy efficiency. Secondly, the Energy Savings Deficit (ESD), which quantifies the shortfall in energy savings as a proportion of the expected energy savings. Thirdly, the Energy Performance Gap (EPG), which assesses the over-consumption of energy as a proportion of the design energy demand rating.

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