BEHAVIOURAL FACTORS INFLUENCING THE UPTAKE OF ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS

EUROPEAN ENVIRONMENT AGENCY
FINAL REPORT

December 2022

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This report has been prepared by a Team from Ramboll led by Matteo CASPANI and Evelina Gunnarsson in the context of a project funded by the EEA.

Ramboll thanks all involved expert from the EEA, the EEA Scientific Committee, the EIONET network and other institutions who participated and/ or provided inputs, reviews, and comments during the work process, in particular (alphabetical order):

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EUROPEAN ENVIRONMENT AGENCY

Contract reference:
3502/B2022/EEA/58936

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Table of abbreviations

ABCD	Attention, Belief formation, Choice, and Determination
BPIE	Building Performance Institute Europe
CEB	Council of Europe Development Bank
EEA	European Environment Agency
EED	Energy Efficiency Directive
EED	Energy Efficiency Directive
EERM	Energy Efficiency Renovation Measure
EPBD	Efficiency Performance of Buildings Directive
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificates
EU	European Union
GHG	Greenhouse Gas
LEAAN	Local Energy Efficiency Active and Networks
LTRS	Long-Term Renovation Strategies
NECP	National Energy and Climate Plan
OSS	One-stop-shops
ZEB	Zero Energy Buildings

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1. Introduction

1.1 Overview of this study

This document is the Final Report of the project "Behavioural factors influencing the uptake of energy efficiency in buildings". This project, running from March 2022 until December 2022, was commissioned by the European Environment Agency (EEA) and performed by Ramboll.

In a context where the European Union (EU) has committed to decarbonise its economic system, with the goal of achieving climate neutrality by 2050, the reduction of greenhouse gas (GHG) emissions from buildings becomes paramount. Despite this, climate neutrality in the buildings sector is still a far-off goal, with fossil fuels satisfying most of the energy needs for heating and cooling, and most of the built environment still requiring energy-efficient renovation interventions to reduce its operational carbon[1]. Today the EU building stock accounts for about 36% of total GHG emissions in the EU[2], representing one third of energy related EU emissions and using 40% of the energy in the EU[3]. Residential buildings in particular are responsible for about two-thirds of total energy consumption in the EU buildings sector[4].

To achieve at least a 55% reduction in GHG emissions compared to 1990 by 2030, and climate neutrality by 2050, the EU must at least double its annual energy renovation rate for buildings by 2030, from 1% to 2% per year, as well as significantly increase the rate of deep renovations, from the current rate of 0.2% to 3%[5]. While the EU has launched several initiatives and updated legislations since 2019 to meet its 2030 climate target, including the European Green Deal, the Renovation Wave, and the Recovery Plan for Europe, so far, the existing policy framework proved to be insufficient to accelerate the pace of change and deliver the expected emission reductions. This is particularly true for the energy efficient renovation of the existing building stock, while for new buildings the EU directives on energy efficiency are proving to be an effective instrument throughout the Union[6].

One of the reasons behind the insufficient delivery of energy efficiency in buildings policies may be the knowledge gap and limited consideration of the behavioural factors affecting the investment decisions in energy efficiency renovation. The role played by human behaviour and decision-making, in determining the adoption of more efficient technologies in buildings, have often been overlooked by the traditional approaches and policies solely focusing on monetary and financial incentives. Nonetheless, in the last decade a new strand of literature emerged focusing not only on the technical potential for energy savings, but also analysing the impact of human behaviour.

[1] "Operational carbon" refers to the carbon emissions associated with the energy used to run the building once complete to satisfying demands such as heating, cooling, hot water generation, lighting, etc. In most existing buildings, these energy demands are met by burning fossil fuels such as natural gas and oil, or by using electricity. For a definition of "operational carbon", see for example: https://www.netzerocarbonguide.co.uk/guide/where-to-start/what-is-a-net-zero-carbon-building/summary

[2] Buildings Performance Institute Europe (2022). Report on the evolution of the European regulatory framework for buildings efficiency. Available at: https://www.bpie.eu/wp-content/uploads/2022/02/rev6_SPIPA_EU.pdf

[3] European Environment Agency (2021). Greenhouse gas emissions from energy use in buildings in Europe. Available at: https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emissions-from-energy/assessment

[4] ODYSSEE-MURE (2021). Energy efficiency in buildings in the EU. Policy brief. Available at: https://www.odyssee-mure.eu/publications/policy-brief/buildings-energy-efficiency-trends.pdf

[5] Buildings Performance Institute Europe (2021). Deep renovation: Shifting from exception to standard practice in EU Policy. Available at: https://www.bpie.eu/publication/deep-renovation-shifting-from-exception-to-standard-practice-in-eu-policy/

[6] Trotta, G., Spangenberg, J., and Lorek, S. (2018). Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries. Energy Efficiency 11, 2111-2135. https://link.springer.com/article/10.1007/s12053-018-9739-0

Against this background, the project aims to synthesise and present the findings from behavioural sciences to increase the knowledge of the broad variety of factors which affect decisions regarding renovation in buildings. The final goal is to inform policymakers and develop behaviourally informed policies in the area of energy efficiency in buildings. In addition, the present report identifies and characterises the relevant stakeholders involved, their behaviours, motivations, and the decision-making process of investing in energy efficiency in buildings. The scope of this report is limited to residential buildings, but covers both energy efficiency interventions in the pre-renovation phase, as well as those which limit energy consumption (i.e. the rebound effect) in the post-renovation phase.

Specifically, the report presents the results of a study, which had the following objectives:

1. Analysing the broad variety of factors affecting decisions in renovation, and the role of behavioural factors in influencing the uptake of energy efficiency measures and energy consumption levels after the renovation (i.e. the rebound effect)
2. Identifying and characterising relevant key stakeholders and their decision process of investing in energy efficiency in buildings
3. Mapping options for measures that address the identified behavioural mechanisms in the pre- and post-renovation phases
4. Analysing gaps and collecting completed and ongoing good practices
5. Deriving recommendations to European, national and local policy makers on how to include behavioural factors to improve energy efficiency investments in buildings policies.

Based on the findings in these areas, policy recommendations for the consideration of policymakers were developed to highlight the measures that could help address existing obstacles hindering the implementation of energy efficiency renovation in the residential sector and, in general, to support the green transition and the European Green Deal objectives.

1.2 Overview of this report

The table below summarises the main structure of the report, taking into account the different objectives of the project and the methodology followed.

While considering the content of the previous Inception and Intermediate Reports, as well as the comments received during the two Workshops held with experts from the EIONET network, this report presents the results of the different activities performed.

Table 1.1 Overview of the structure of the report

Chapter	Description
1 Introduction	This chapter introduces the study, the structure of the report, and some key definitions.
2 Background and context: Energy efficiency progress in the EU residential sector	This chapter serves in framing the big picture on energy efficiency uptake in the EU residential sector and in describing the existing economic and behavioural approaches applied to analyse the topic.
3 Understanding stakeholders' behaviour in relation to energy	This chapter describes in detail the knowledge and understanding of behavioural factors affecting the decision

efficiency in residential buildings' renovation	making of key stakeholders about investing in energy efficient renovation.
4 Behaviour in buildings renovated energy efficiently: the rebound effect	This chapter explains what the rebound effect is in the context of the residential buildings sector, presents estimates on its size and heterogeneity, and how behavioural insights can help in limiting it.
5 Consideration of behavioural factors in energy efficiency policies in residential buildings	This chapter describes how behavioural factors are considered in existing directives and policies that aim to incentivise investment in energy renovation. It also presents some best practice examples.
6 Conclusions and policy recommendations	This chapter draws the main conclusions of the study based on the evidence gathered and presented in the previous chapters.
7 Bibliography	This section presents the full list of references used for the study.
8 ANNEX – Methodological approach	This annex outlines the methodological approach adopted to carry out this study.
9 ANNEX – Literature on drivers and barriers	This annex lists the identified literature categorised by drivers and barriers.

1.3 Key definitions

The following table showcases a series of key definitions used through the study. These definitions are introduced early in the report to guide the reader in understanding the following chapters.

Table 1.2 Key definitions used in the study

Term	Definition
Energy efficiency	The definition of energy efficiency changes depending on the context in which it is being used. The EU Energy Efficiency Directive broadly describes energy efficiency as 'the ration of output of a performance, service, goods or energy, to input of energy[7].' Economists often distinguish between technical energy efficiency and economic energy efficiency[8]: Technical energy efficiency compares the quantity of inputs used to produce given outputs (or vice versa) to a standard of best practice. Economic energy efficiency is characterised by considering cost-effectiveness and profit/utility maximization. Economists emphasize that improved energy efficiency is not necessarily the same as improved economic efficiency, since the latter considers, for example, all inputs, the costs of the inputs, and the mix of outputs[9].

[7] European Parliament, 2015. *Briefing: Understanding Energy Efficiency*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568361/EPRS_BRI(2015)568361_EN.pdf

[8] Saunders, H. D. et al., 2021. *Energy Efficiency: What Has Research Delivered in the Last 40 Years?* Annual Review of Environmental Resources 46: 135-165.

[9] Ibid.

Energy efficiency in buildings	The extent to which the energy consumption per square metre of floor area of the building compares to established energy consumption benchmarks for that particular type of building under specific climatic conditions[10]. The typical benchmark[11] is the median level of performance of all the buildings in a given category and good practice. Comparisons with benchmarks of annual energy use per square metre of floor area or treated floor area (kWh/m^2 /annum) allow the standard of energy efficiency to be assessed and priority areas for action to be identified[12].
Energy efficiency investment	Energy investment is defined in terms of household economics. Household economics assess the decisions made by a household, both from a micro and macroeconomic level. Regarding energy efficiency, investment is considered as purchase of consumer goods, such as energy efficient appliances[13], but it can also refer to the full cost of refurbishments that reduce energy use[14]. Depending on the specific intervention performed, energy investments can lead to different levels of renovation[15] of the building. EU legislation still has to define the concept of 'deep renovation', but according to the recast of the Energy Efficiency Performance of Buildings Directive (EPBD)[16], 'deep renovation should be defined as a renovation that transforms buildings into nearly zero-energy buildings. This definition serves the purpose of increasing the energy performance of buildings and should be changed from 2030 so that deep renovation refers to transformations of buildings into zero-emission buildings.
Energy consumption	Energy consumption throughout the report refers to final energy consumption, which is the total energy consumed by end users (in this case, households)[17].
Energy sufficiency	In line with the IPCC report 2022 on climate mitigation[18], energy sufficiency refers to the series of measures aimed at 'tackling the cause of GHG emissions by avoiding the demand for energy over the lifecycle of buildings and appliances.' Energy sufficiency measures include, for example, optimising the use of buildings, adjusting the size of buildings to the needs of households, or repurposing unused existing buildings.

[10] Global Building Performance Network, 2013. *What is a deep renovation definition? Technical report. https://www.gbpn.org/wp-content/uploads/2021/06/08.DR_TechRep.low_.pdf.*

[11] The benchmarks are determined by analysing data on different building types within a given country.

[12] United Nations Industrial Development Organization, 2009. *Energy Efficiency in Buildings*. https://www.unido.org/sites/default/files/2009-02/Module18_0.pdf.

[13] Sanstad, A.H. *Notes on the Economics of Household Energy Consumption and Technology Choice.* Lawrence Berkeley National Laboratory. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/consumer_ee_theory.pdf

[14] International Energy Agency (2021). Energy Efficiency 2021. Available at: https://www.iea.org/reports/energy-efficiency-2021.

[15] According to the Joint Research Center, energy renovation is an umbrella term describing a series of interventions in a building (i.e. modernization, retrofit, restoration, etc.) which deliver different levels of energy savings. More information is available at: https://e3p.jrc.ec.europa.eu/articles/energy-renovation#toc-2.

[16] Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/DOC/?uri=CELEX:52021PC0802&from=EN.

[17] Eurostat Statistics Explained. *Glossary: Final energy consumption*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Final_energy_consumption.

[18] Intergovernmental Panel on Climate Change (2022). Climate Change 2022 – Mitigation of Climate Change. Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/report/ar6/wg3/.

2. Background and context: Energy efficiency progress in the EU residential sector

The aim of this chapter is twofold. Firstly, this chapter provides an overview of the current energy efficiency uptake in the residential sector in the EU, presents the concept of energy efficiency gap, and explains how renovation and deep renovation, in particular, can help to close this gap. Secondly, it introduces the theoretical frameworks that traditionally have been applied to analyse the energy efficiency gap in residential buildings and to identify the factors that determine it.

So far, EU Member States have been lagging behind in their pathway towards achieving the 2030 energy efficiency target, with less progress then expected across all sectors.

2.1 Energy efficiency progress in the EU residential sector

Energy efficiency of end-use sectors, including transport, services, households, and industry, in the EU has improved by over 30% since 1990[19]. Several energy efficiency policies and measures have been adopted in the EU since the 1990s to reduce household energy consumption, both at the EU level (such as eco-design and energy labelling) as well as at the national level (such as subsidies and information campaigns)[20]. However, the decrease in overall end-use energy consumption within the residential sector is not entirely attributed to energy efficiency improvements. Other factors, such as the development of new built surfaces and materials, energy prices, and consumer behaviours have all contributed to the declining rate[21].

It is important to note that within the residential sector, many of the energy efficiency improvements were offset by the increase in residential energy demand, due to larger homes, new services, as well as new (and larger) appliances and equipment. For instance, a study looking at the drivers of energy consumption of households from 2000 to 2019 at the EU level showed that having 'larger homes' is the third largest reason explaining the increase in energy consumption[22]. However, the overall negative effect of some of these drivers on energy consumption has improved since 2014. Indeed, factors such as having 'larger homes', 'more dwellings' and 'more appliances' increased energy consumption by an average of 2.5 Mtoe per year before 2014 in households, while after 2014 this reduced to an increase of 1.8Mtoe per year[23]. While this study confirmed the importance of including factors like the increasing size of houses when considering energy efficiency, the impact of this parameter is not expected to increase in the coming years.

[19] European Environmental Agency (2021). *Progress on Energy Efficiency in Europe*. https://www.eea.europa.eu/data-and-maps/indicators/progress-on-energy-efficiency-in-europe-3/assessment#:~:text=Over%20the%20period%201990%2D2016,sector%20(1.6%20%25%2Fyear).

[20] S. Tsemekidi Tzeiranaki et al. (2019). *Analysis of the EU Residential Energy Consumption: Trends and Determinants*. Energies 12.

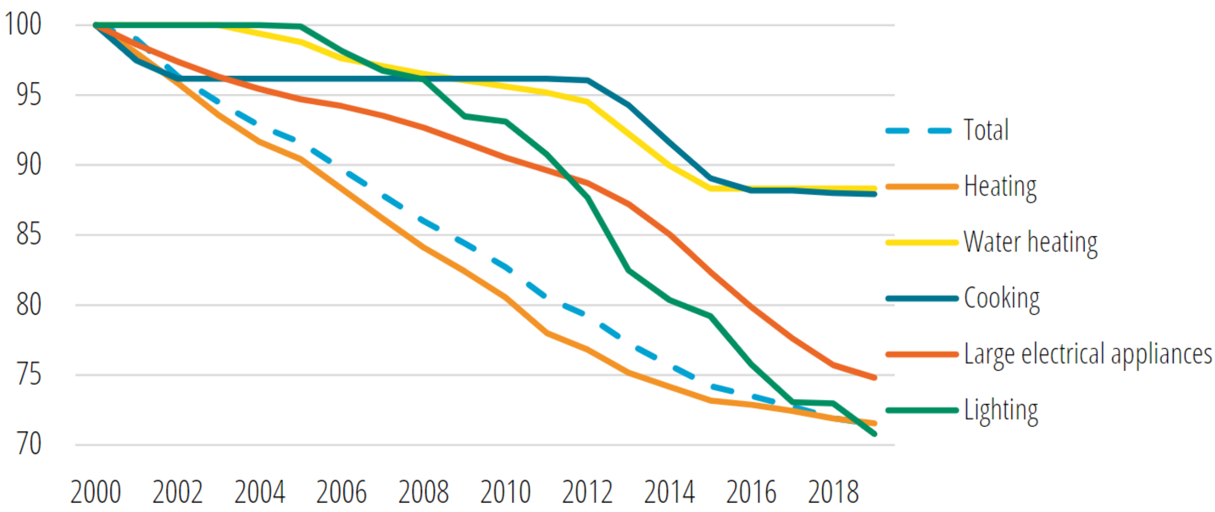
[21] Enerdata (2021). *Evolution of household energy consumption patterns across the EU*. https://www.enerdata.net/publications/executive-briefing/households-energy-efficiency.html.

[22] Ibid.

[23] Ibid.

Despite the increased home space, according to ODEX[24], an overall energy efficiency index, EU household efficiency has improved by 29% between 2000-2019. ODEX aggregates specific consumption trends by end-use to measure overall energy efficiency progress at the sectoral level. More specifically, ODEX is a weighted average of the specific consumption of 10 manufacturing branches[25]. Although residential energy efficiency continues to improve, according to the data a significant slowdown has been observed since 2014.

Figure 2.1 Trends in household energy efficiency at the EU level, according to ODEX



Source: Enerdata (2021).

The amended Energy Efficiency Directive (EU) 2018/2022), which entered into force in December 2018, set an energy efficiency target to reduce energy consumption in 2030 by at least 32.5% compared to 2007 consumption projections for 2030[26]. The Commission's 2020 assessment of the 27 Member States' National Energy and Climate Plans (NECPs) however revealed that several Member States are falling short of the 32.5% target. In fact, 2020 has been the first year in which the EU27 met its yearly energy efficiency target, with final and primary energy consumption levels being about 5% below the 2020 target. This was mostly due to the impact of the COVID-19 pandemic, which caused a significant slowdown for industry and transport in 2020. Preliminary data for 2021 already indicate an increase of approximately 5% compared to the levels of energy consumption in 2020 due to the post-pandemic recovery.

Achieving the 2030 32.5% reduction target will therefore require continuous intensive reductions in energy consumption, well beyond what currently set by Member States in their NECPs[27]. Overall, this indicates the **existence of a gap** in ambition between the 2030 energy efficiency target and

[24] ODEX is the index used in the ODYSSEE-MURE project to measure the energy efficiency progress by main sector (industry, transport, households, services) and for the whole economy (all final consumers).

[25] European Environmental Agency, 2019. *Energy efficiency index (ODEX) for final consumers in the EU*. https://www.eea.europa.eu/data-and-maps/daviz/energy-efficiency-index-in-households-3#tab-chart_1

[26] These projections are derived from the European Commission's 2007 baseline scenario.

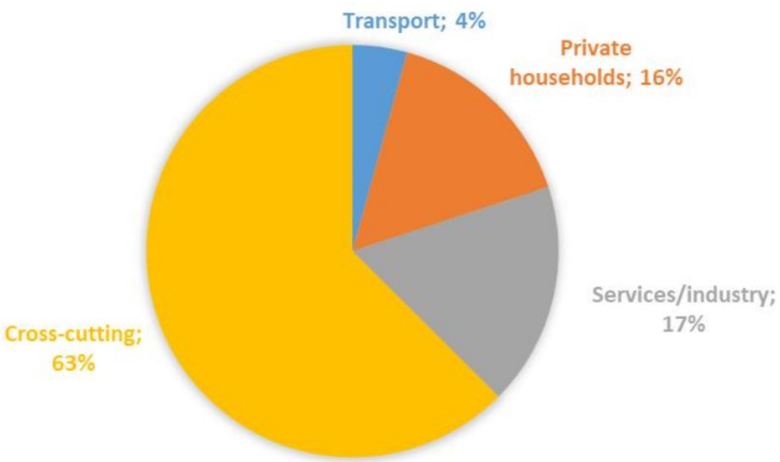
[27] European Environment Agency (2022). Trends and projections in Europe 2022. EEA Report No 10/2022. Available at: https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2022

planned Member States' measures, which will likely deliver a 4.6% higher final energy consumption level in 2030[28].

In this context, energy efficiency binding targets will also become tighter in the next future. In 2021 the European Commission adopted its proposal for a recast of the Energy Efficiency Directive as part of the European Green Deal, proposing an EU energy efficiency target of a 9% reduction in 2030 compared to the projections of the 2020 Reference Scenario. This corresponds to a 36% reduction in final energy consumption and a 39% reduction in primary energy consumption by 2030 compared to the 2007 consumption projections for 2030. More recently, in the REPowerEU plan the Commission proposed a further increase to the EU energy efficiency target from 9% to 13% reduction compared to the 2020 Reference Scenario.

To achieve these more ambitious targets, Member States will inevitably have to make substantial efforts and investments compared to what has been done so far. Among the energy savings that were reported in the last decade, almost two thirds (63%) were due to cross-cutting measures that target various sectors, including buildings[29], but only 16% of savings were reported within residential households as showed in the figure below.

Figure 2.2: Distribution of cumulative energy savings in 2014-2017 eligible under Article 7 per sector type



Source: European Commission (2020).

Even though many countries are at risk of not meeting their energy efficiency targets, there are only few studies that quantitatively explore the **energy efficiency gap** at the Member State level, and even less that are solely focused on the residential sector. However, a study conducted by O Broin et al. (2015) examined the Swedish residential sector and concluded that the energy efficiency gap will range between 14-19% by 2030[30]. In comparison, another study found that the energy efficiency gap in electricity-intensive industries is far greater, with estimates between 35-38% by

[28] Ibid.

[29] European Commission, 2020. *REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL 2019 assessment of the progress made by Member States towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive as required by Article 24(3) of the Energy Efficiency Directive 2012/27/EU*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:0326:FIN.

[30] Ó Broin, E.; Mata, É.; Nässén, J.; Johnsson, F., 2015. *Quantification of the energy efficiency gap in the Swedish residential sector*. Energy Efficiency, 8 (5): 975–993. doi: 10.1007/s12053-015-9323-9.

2030[31]. Altogether, although energy efficiency has consistently improved over the past few decades, the energy efficiency gap persists.

The following section will explore the concept of the energy efficiency gap in more detail and its persistence throughout the EU.

2.2 The concept of energy efficiency gap

Residential buildings across the EU account for approximately 29% of final energy consumption[32], and about one third of energy related GHG emissions[33] EU climate policy has been particularly focused on improving energy efficiency to reduce the emissions in the residential sector. Several studies over the course of the past two decades have highlighted the potential to reduce energy consumption and GHG emissions through investment in energy-efficient appliances and equipment at home[34]. In fact, at a societal level, improving energy efficiency can produce net savings, and studies reveal that the present discounted values of future energy savings greatly exceed the upfront cost of energy efficient products.[35]

Despite the future benefits of investing in energy efficiency, improvements in energy efficiency do not always necessarily lead to reductions in energy consumption[36], and consumers often behave as if they 'undervalue' future savings. This aspect, among many others, suggests that the way individuals make decisions about energy efficiency leads to a slower uptake of energy efficiency products than is expected[37]. This phenomenon has become referred to as the *energy efficiency gap*. **Generally, the energy efficiency gap describes the slower than socially optimal rate of diffusion of energy efficient products**.

A recent study (2022) examining the total energy efficiency gap on a national level (across multiple sectors such as the transport, residential and industrial sectors) was done by developing an indicator-based approach, which allowed for consideration of different channels to provide a holistic impression of potential energy efficiency deficiencies[38]. The channels included political effort (energy efficiency policy implementation), quantitative modelling (potential vs. realization of energy efficiency efforts), and benchmarking (comparison between Member States (MS) in terms of energy efficiency trends, level and policies.) A rating system with a scale of A to G was further developed to compare the energy efficiency gap across the member states ~~MS~~. The assessment was based on external data sources and interviews with a range of political stakeholders. All 14 MS examined in the study received a ranking between D and B. (see the figure below). Although the scale does not

[31] Paramonova, S.; Thollander, P.; Ottosson, M., 2015. *Quantifying the extended energy efficiency gap-evidence from Swedish electricity-intensive industries*. Renewable and Sustainable Energy Reviews, 51: 472–483. doi: 10.1016/j.rser.2015.06.012

[32] ODYSSEE-MURE (2021). Energy efficiency trends in buildings in the EU. Available at: https://www.odyssee-mure.eu/publications/policy-brief/buildings-energy-efficiency-trends.pdf

[33] EEA (2021). Greenhouse gas emissions from energy use in buildings in Europe. Available at: https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emissions-from-energy/assessment

[34] These include: Creyts, Jon, Anton Derkach, Scott Nyquist, Ken Ostrowski, and Jack Stephenson. 2007. Reducing U.S. greenhouse gas emissions: How much at what cost? McKinsey & Company; Granade, Hannah Choi, Jon Creyts, Anton Derkach, Philip Farese, Scott Nyquist, and Ken Ostrowski. 2009. Unlocking energy efficiency in the U.S. economy. McKinsey & Company; and McKinsey & Company. 2009. Pathways to a low-carbon economy: Version 2 of the Global Greenhouse Gas Abatement Curve.

[35] Gillingham, K. et al., 2014. *Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence*. Review of Environmental Economics and Policy 8 (1), 18-34.

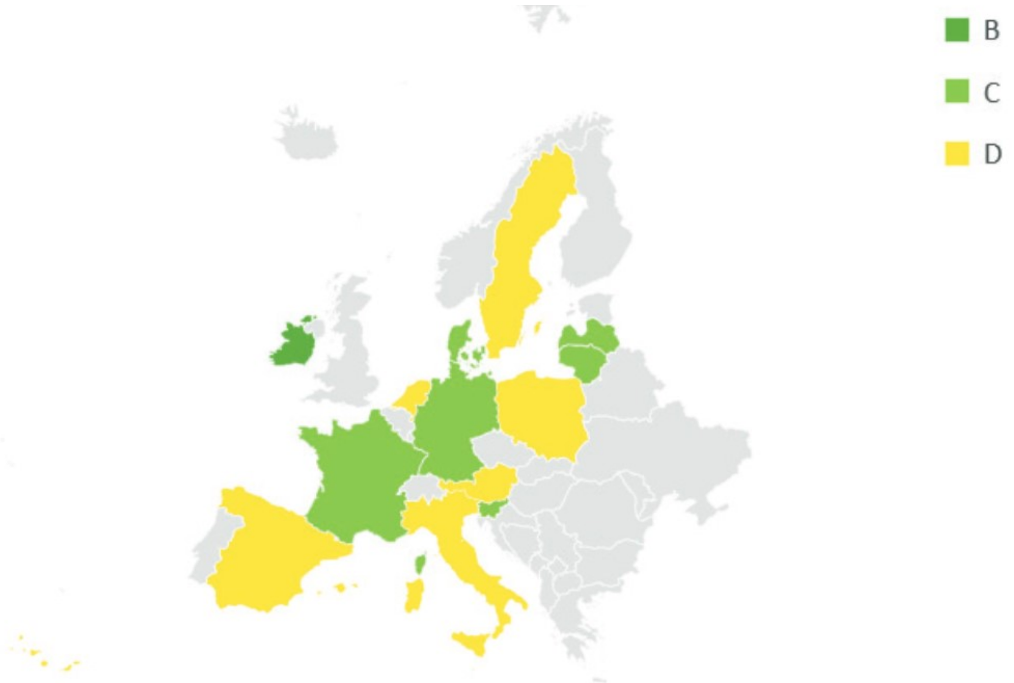
[36] Trotta, G. et al., 2018. *Energy efficiency in the residential sector: Identification of promising policy instruments and private initiatives among selected European countries*. Energy Efficiency 11, 2111-2135.

[37] Gillingham, K. et al., 2014. *Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence*. Review of Environmental Economics and Policy 8 (1), 18-34.

[38] Chlechowitz, M. et al., 2022. *An Indicator based Approach to the Energy Efficiency First Principle*. Working Papers "Sustainability and Innovation" S10/2021, Fraunhofer Institute for Systems and Innovation Research (ISI).

provide the exact size of the energy efficiency gap, it provides insight into which countries still have energy efficiency deficiencies. As per the rating system, Ireland is the best performing country (score of 77) followed by France (score of 69). While no country received an A label, there is also no country located at the bottom half of the scale either.

Figure 2.3 Energy efficiency gap across the EU



Source: Chlechowitz et al. (2021).

2.3 Closing the energy efficiency gap through energy renovations

The way to close the energy efficiency gap is through the acceleration of the energy renovation rate. Energy renovation is a broad term that can be divided into several categories. One way to categorise energy renovations is by renovation activities such as renovations of the ***building envelope*** (e.g. insulation of external walls or replacement of windows and doors), renovation of the ***building technical systems*** (e.g. mechanical ventilation, air-conditioning or heat recovery systems) or the addition of systems for ***renewable heat*** or ***renewable electricity generation*** (for example the installation of solar panels or a geothermal heat pump)[39].

The advantages of energy renovation in buildings have been clearly described and documented. For example, the Building Performance institute Europe (BPIE) conducted a quantitative analysis on the energy savings potential through better insulation in eight selected Member States (France, Germany, Italy, Poland, Czechia, Slovakia, Slovenia, and Romania), and estimated that investing in building renovation can deliver multiple benefits[40]. Notably, it can substantially reduce the use of fossil fuels for heating in buildings, achieving a 44% reduction in gas consumption while saving 45% of final energy demand. In another study, the French Ministry of Ecological Transition showed

[39] Economidou, M.,2015. *Energy renovation.* European Energy Efficiency Platform (E3P) Joint Research Centre. https://e3p.jrc.ec.europa.eu/articles/energy-renovation#toc-2

[40] BPIE (2022). Putting a stop to energy waste: How building insultation can reduce fossil fuel imports and boost EU energy security https://www.bpie.eu/publication/putting-a-stop-to-energy-waste-how-building-insulation-and-reduce-fossil-fuel-imports-and-boost-eu-energy-security-2/

that conventional energy savings associated with financially assisted renovations were estimated at 8.2 TWh/year in 2019. Moreover, between 2016 and 2019, the average energy gain per subsidized home increased by 23%, from 2.8 MWh/year per dwelling in 2016 to 3.4 MWh/year in 2019[41]. These results indicate a clear potential for energy renovation to not only reduce the GHG emissions associated with the buildings section, but also to enhance energy security in the EU thanks to sizable energy savings.

However, it is important to recognise that different activities may achieve different levels of energy efficiency depending on country-specific factors such as the local climate and the pre-renovation energy performance of the building[42]. For this reason, it is more suitable to categorise energy renovations by the level of energy efficiency achieved, relative to pre-renovation levels. Seen from this perspective, it is possible to identify three main types of energy renovations[43]:

- Single measures (or shallow renovations)
- Standard renovations
- Deep renovation leading to nearly-zero or zero energy buildings (ZEB).

While shallow renovations entail minor energy improvements, such as changing to more energy efficient household appliances, standard renovations which are classed as the combination of a few single measures, typically result in between 20% and 30% energy savings compared to the pre-renovation level, though sometimes less. Instead, when a building is transformed through renovation to a zero-energy building, all the possible types of renovation are implemented, and renewable energy technologies are used to satisfy the electric and heating demands of the building.

The concept of deep renovation is harder to define and is still missing from the current EU legal framework, despite being an acknowledged major factor in decarbonising the building sector[44]. Indeed, a 2013 study by the Global Buildings Performance Network (GBPN) attempted to find a harmonised definition of deep renovation. It identified and disentangled several definitions of the concept in existence across Europe and the US and showed there was no common definition[45]. According to the recast of the Energy Efficiency Performance of Buildings Directive (EPBD), deep renovation should be defined as a renovation that transforms buildings into nearly zero-emission buildings. This definition serves the purpose of increasing the energy performance of buildings and should be changed from 2030 so that deep renovation refers to transformations of buildings into zero-emission buildings. In general, the BPIE recently defined deep renovation as the process of capturing in one or few steps the full potential of a building to reduce its energy demand, based on its typology and climatic zone[46].

Deep renovation can be achieved in several renovation steps spread over the years (staged deep renovation) or in a single step, where all the energy efficient components are installed in one

[41] Ministère de la transition écologique (2022). LA RÉNOVATION ÉNERGÉTIQUE DES LOGEMENTS BILAN DES TRAVAUX ET DES AIDES ENTRE 2016 ET 2019 https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2022-03/rapport_onre_mars2022.pdf

[42] European Commission, 2014. Financing the energy renovation of buildings with Cohesion Policy funding. *Technical Guidance.* https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/financing_energy_renovation.pdf

[43] Ibid.

[44] BPIE (Buildings Performance Institute Europe) (2021). *Deep Renovation: Shifting from exception to standard practice in EU Policy*. https://www.bpie.eu/publication/deep-renovation-shifting-from-exception-to-standard-practice-in-eu-policy/

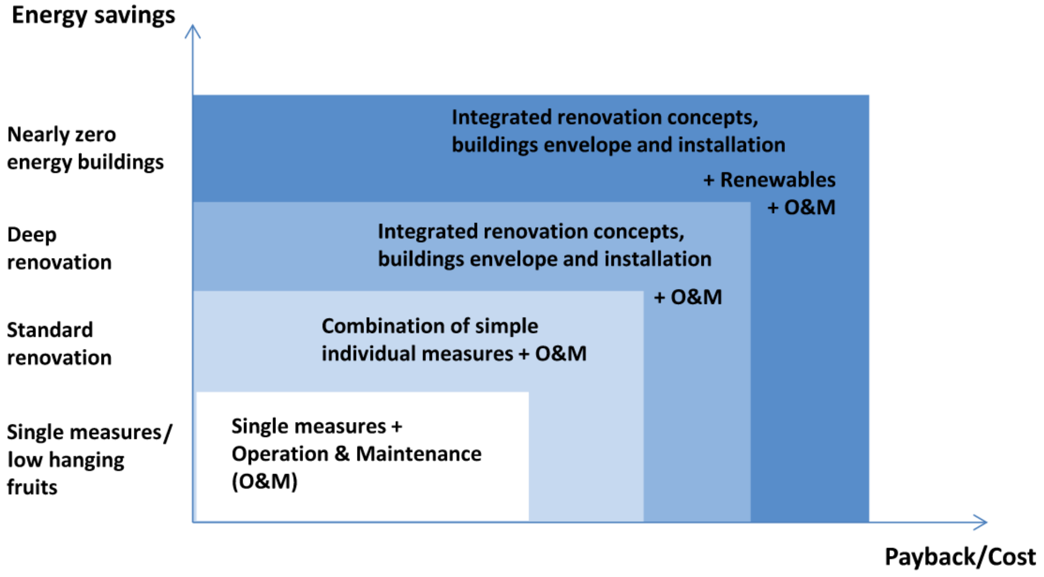
[45] Global Buildings Performance Network (GBPN), 2013. *Deep Renovation Definition – Technical report*. https://www.gbpn.org/report/what-deep-renovation-definition-3/

[46] Buildings Performance Institute Europe (BPIE) (2021). *Deep renovation: Shifting from exception to standard practice in EU policy*. https://www.bpie.eu/wp-content/uploads/2021/11/BPIE_Deep-Renovation-Briefing_Final.pdf

occasion[47]. Due to the past lack of EU-wide guidance setting out the criteria for a deep renovation, the minimum qualifying standard can differ between Member States[48]. However, Member states typically require a building to have a certain minimum EPC level after renovation to qualify as a deep renovation, which is normally set out in their Long-Term Renovation Strategies (LTRS) required as part of the EPBD[49]. While the number of steps matters in regard to the cost effectiveness of the renovation[50], it is important that the renovation is effectively deep in the sense that it captures the full economic energy efficiency potential of improvement works, leading to a very high energy performance[51].

The following Figure summarises the energy savings and payback/costs of the different renovation types.

Figure 2.4: Categorization of energy efficiency investments



Source: European Court of Auditors (2020)[52].

Deep renovations are necessary for sufficient emission reductions, as it is not possible to achieve climate neutrality by 2050 without a deep renovation of the existing buildings stock. The BPIE estimated that, by 2030, 70% of the renovations taking place should be deep if GHG must be reduced by at least 55% compared to 1990 levels. Deep renovations are also crucial to avoid lock-in effects in buildings which would prevent the full benefits of renovation from being realised. As

[47] Fritz, S., Pehnt, M., Mellwig, P., & Volt, J. (2019). Planned staged deep renovations as the main driver for a decarbonised European building stock. ECEE Summer Study Proceedings. Available at: https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2019/7-make-buildings-policies-great-again/planned-staged-deep-renovations-as-the-main-driver-for-a-decarbonised-european-building-stock/

[48] BPIE (Buildings Performance Institute Europe) (2021). *Deep Renovation: Shifting from exception to standard practice in EU Policy*. https://www.bpie.eu/publication/deep-renovation-shifting-from-exception-to-standard-practice-in-eu-policy/

[49] BPIE (Buildings Performance Institute Europe) (2021). *Deep Renovation: Shifting from exception to standard practice in EU Policy*. https://www.bpie.eu/publication/deep-renovation-shifting-from-exception-to-standard-practice-in-eu-policy/

[50] ADEME (2021). La rénovation performante par étapes. Available at: https://librairie.ademe.fr/urbanisme-et-batiment/4168-renovation-performante-par-etapes.html

[51] Shnapp, S., Sità, R. & Laustsen, J. (2013). What is a deep renovation definition? Global Buildings Performance Network (GBPN).

[52] European Court of Auditors (2020). Energy efficiency in buildings: greater focus on cost-effectiveness still needed. Special Report 2022/11.

buildings have on average a long lifespan (80 to 100 years), implementing only standard renovations would increase the risk of locking higher emissions in for decades[53]. Additionally, highly energy efficient buildings are necessary for other decarbonisation measures in the overall energy systems, such as the positive enabling role it provides in terms of easing the integration of renewable energy sources[54].

Deep renovations in the EU can reduce the total energy consumption by 36% by 2030. Furthermore, deep renovations can reduce energy import dependency, create growth, create innovation and employment, reduce fuel poverty and lead to more comfortable and healthy residential buildings[55]. However, deep renovations in the EU are currently only undertaken on 0.2% of buildings each year. The number of annual deep renovations is relatively constant within the member states, with only Cyprus (0.4%), Spain and Italy (0.3% respectively) renovating above the EU annual average. It is the Commissions' intention to encourage more and deeper renovations of the building stock through the Renovation Wave. For instance, to reach the EU 2030 climate target and neutrality by 2050, the number of deep renovations should increase to 3% no later than 2030[56].

How climate change affects energy efficiency uptake

While deep renovations should be implemented more frequently to achieve the energy efficiency targets, studies have shown that climate change will increase the uncertainty of retrofitted buildings meeting the desired outputs[57]. Changes in weather, such as rising temperatures and the increased occurrence of weather extremes, may furthermore affect the renovation needs for energy efficiency. For instance, the demand of heating is expected to decrease[58]. Overheating in newly constructed or renovated buildings also is possible, even if they are well insulated. This can occur if building design does not adequately consider the combination of solar gains, internal gains and ventilation strategies. However, according to a study by Berger *et al.* (2016), the energy savings made in wintertime due to insulation may outweigh the summer constraints even in future scenarios[59].

Recent research on the topic includes a study that investigated the case of a deep renovation performed for a Swedish multi-residential building from the 1970's[60]. Various energy-saving measures and future climate change scenarios were examined, especially the risk of overheating. In most future scenarios, cooling demand increased while heating demand decreased and renovations to the building envelope resulted in reduced heating demand and increased cooling demand. However, cooling strategies such as efficient ventilation systems could potentially minimize the impacts of overheating in future scenarios. Another paper focusing on the Alpine region also confirmed that improved insulation may increase households' vulnerability to

[53] Cabeza, L. F. and Ürge-Vorsatz, D., 2020. *The role of buildings in the energy transition in the context of the climate change challenge*. Global Transition, 2: 257-260. https://doi.org/10.1016/j.glt.2020.11.004

[54] Buildings Performance Institute Europe, 2021. Deep renovation: Shifting from exception to standard practice in EU policy. https://www.bpie.eu/wp-content/uploads/2021/11/BPIE_Deep-Renovation-Briefing_Final.pdf

[55] Boza-Kiss, B., Bertoldi, P., Della Valle, N., & Economidou, M. (2021). One-stop shops for residential building energy renovation in the EU. Analysis & Policy Recommendations. JRC Science for Policy Report [JRC125380]

[56] Buildings Performance Institute Europe (BPIE) (2021). *Deep renovation: Shifting from exception to standard practice in EU policy*. https://www.bpie.eu/wp-content/uploads/2021/11/BPIE_Deep-Renovation-Briefing_Final.pdf

[57] Nik, V. M., Mata, E., Kalagasidis, A. S., & Scartezzini, J. L. (2016). Effective and robust energy retrofitting measures for future climatic conditions—Reduced heating demand of Swedish households. Energy and Buildings, 121, 176-187

[58] Andrić, I., Pina, A., Ferrão, P., Fournier, J., Lacarrière, B., & Le Corre, O. (2017). The impact of climate change on building heat demand in different climate types. Energy and Buildings, 149, 225-234

[59] Berger, T., Amann, C., Formayer, H., Korjenic, A., Pospichal, B., Neururer, C., & Smutny, R. (2016). Impacts of external insulation and reduced internal heat loads upon energy demand of offices in the context of climate change in Vienna, Austria. Journal of Building Engineering, 5, 86-95

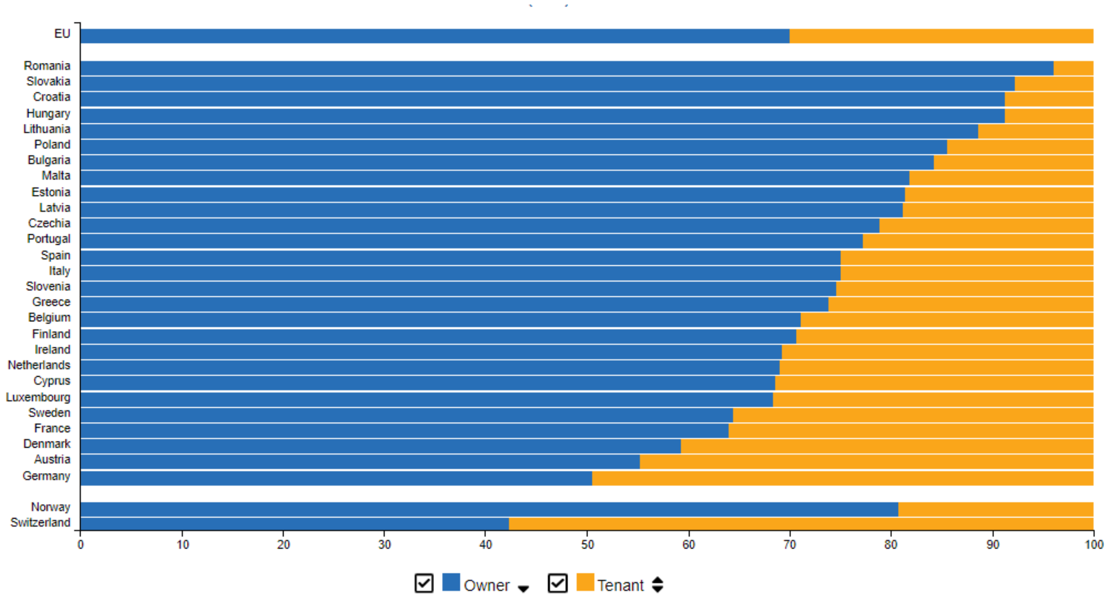
[60] Tettey, U. Y. A., & Gustavsson, L. (2020). Energy savings and overheating risk of deep energy renovation of a multi-storey residential building in a cold climate under climate change. Energy, 202, 117578

overheating[61][62]. For this reason, renovation of isolation must be accompanied by an assessment of the climate of the region as well as potential cooling technologies to anticipate overheating. Going further, some scholars argued that the most critical renovation measures leading to overheating are the insulation of the floor and the increase of the airtightness in the residential building for EU27[63] For them, external shading systems might contribute to decreasing the discomfort linked to overheating, especially in northern countries.

How the ownership structure affects energy efficiency uptake

As it will be further detailed in the next sections, the ownership structure of residential homes largely affects energy efficiency uptake. When considering the ownership structure of the residential building stock across the EU, 70% of the population are homeowners, and the remaining 30% are tenants (2020)[64]. However, whether individuals own a home or are tenants varies significantly across the EU as depicted in the Figure below. For instance, in Romania, 96% of the population owns their home (similarly, 92% in Slovakia and 91% in Hungary) in comparison to Germany where only 50% own homes (similarly, 45% in Austria and 41% in Denmark)[65].

Figure 2.5 Share of people living in households owning or renting their home



Source: European Commission (2020).

In addition to the ownership structure, the building typology is also important to consider, as the type of dwelling has an impact on energy consumption levels. For instance, in theory, a semi-

[61] Hao, L., Herrera-Avellanosa, D., Del Pero, C., & Troi, A. (2022). Overheating Risks and Adaptation Strategies of Energy Retrofitted Historic Buildings under the Impact of Climate Change: Case Studies in Alpine Region. Applied Sciences, 12(14), 7162.

[62] EEA (2022). Cooling buildings sustainably in Europe: exploring the links between climate change mitigation and adaptation, and their social impacts. Available at: https://www.eea.europa.eu/publications/cooling-buildings-sustainably-in-europe

[63] PSOMAS, T., HEISELBERG, P., & Duer, K. (2016). Overheating assessment of energy renovations. REHVA Journal, 53(1), 32-35.

[64] European Commission, *EU Building Factsheets*, https://ec.europa.eu/energy/eu-buildings-factsheets_en.

[65] Ibid.

detached home consumes less energy per m^2 than a detached home[66]. Similar to the ownership breakdown across the EU, the building stock also differs significantly across Member States. For instance, in the UK and Ireland, single-family dwellings represent over 80% of the building stock, whereas in countries like Spain and Estonia, more than 70% of residential buildings are multi-family dwellings[67].

Furthermore, social housing makes up just over 10% of dwellings across the EU, meaning that tenants occupy dwellings at a reduced rate or for free[68]. Programs for deep energy retrofit and renovation are not typically tailored to social housing, and in many instances no action on energy efficiency is taken. When it is, substandard solutions are frequently chosen since the sector struggles with budget constraints and limited financial support[69]. In fact, each year, almost 1 million social homes are in need of renovation, which would require and additional EUR 57 billion in funding in order to complete[70].

It is also important to note the socio-economic realities of home ownership when considering residential ownership structures and stakeholders. Over 34 million EU residents live in energy poverty and are unable to keep their home adequately warm[71] Indoor comfort temperature in summer becomes more and more an issue as well. People with low incomes tend to have little control over their energy use, causing a vicious circle of high energy bills and the inability to pay for these bills, which puts them at increased risk for health and wellbeing problems[72]. People with inefficient buildings are more likely to be exposed to the increasing nature of heatwaves and cold spells due to climate change, which also increases health risks[73]. As a result, a strategic approach of reducing energy poverty includes renovating inefficient social housing as they offer huge potential for both reducing energy consumption and improving the health and wellbeing of EU citizens.

2.4 Two parallel schools dominate modern economics: the neoclassic and the behavioural approach

Historically, the energy efficiency gap in residential buildings have been analysed in the scientific literature with the lenses of two distinct approaches, each one focusing on a specific series of factors as determinants of the lower than expected uptake of energy efficiency renovation measures.

These approaches are represented by the two parallel schools of thought that dominate modern economics: the neoclassical approach and the behavioural approach. While the more traditional neoclassical approach has certainly been a useful policy tool throughout the 20th century, in recent decades it has been challenged by the behavioural approach, which incorporates experimental and empirical evidence on human behaviour. For that reason, both approaches are necessary for effective policy guidance. This is particularly true in an area as complex and multi-faceted as energy policy. The theoretical foundations of the two approaches are described in more detail below.

[66] Ibid.

[67] Ibid.

[68] European Commission, 2018. *Energy efficiency upgrades in multi-owner residential buildings.* file:///C:/Users/micto/Downloads/energy_efficiency_upgrades_in_multiowner_apartment_buildings_final%20(1).pdf

[69] Heart Project, 2020. *Could social housing be the first to decarbonize?* https://heartproject.eu/news/could-social-housing-be-the-first-to-decarbonize/

[70] European Commission, 2020. *A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives.* https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

[71] Ibid.

[72] Ibid.

[73] Ibid.

2.4.1 The neoclassical approach in brief

Neoclassical economics is the cornerstone of conventional economic analysis. Its roots can be traced back to 18th- and 19th century thinkers such as Adam Smith and John Stuart Mill, whose work influenced the notion that humans use limited resources to maximize their utility (well-being) [74]. Thus, in neoclassical economics, individuals are assumed to be independent agents who make rational decisions according to the principle of utility maximization. This means that:

- In decision situations, individuals select the option that gives them the highest utility (profit) when evaluating costs and benefits.
- Individuals have strict preferences between different options, and these preferences are stable over time.
- Individuals seek out and make use of all available information before making decisions[75].

From this perspective, the slow adoption of energy efficient technology should not be viewed as a mistake that needs to be corrected by policy. Rather, it is the result of agents making rational choices, thereby accurately reflecting their preferences and maximization of utility within a given system of incentives or lack thereof. Nonetheless, the neoclassical school of thought proposes that market failures – situations in which the basic neoclassical assumptions are violated – can explain why we still may observe outcomes that are not, for example, socially or environmentally desirable[76]. Examples of how market failures affect energy efficiency in residential buildings are provided in the sections below.

2.4.2 The behavioural approach in brief

The behavioural approach stands in stark contrast to the neoclassical one, mainly because it considers that individuals are not fully rational. Instead, it is assumed that individuals have limited ability to process information and that their rationality is therefore bounded[77]. For that reason, individuals use heuristics, mental shortcuts, to simplify decision processes. This often results in systematic and predictable errors in their judgment, known as biases[78]. For example, a person renovating his or her home may not take the time to fully research the energy efficiency of various types of insulation material, but instead, selects the material that others use. In this case, the person is using a social norm as guidance to simplify their decision process. Moreover, individuals tend to discount long-term benefits against short-terms rewards. This could for instance result in homeowners being unwilling to make an investment today (e.g. an energy efficient renovation), which would benefit them in the long-run (saved money due to do decreased energy consumption).

The behavioural approach includes insights from other fields of behavioural science as well, such as social and cognitive psychology. The result is an evidence-based approach that attempts to realistically explain what shapes human behaviour and decision-making[79]. Seeing that heuristics and biases play a major role in behavioural problems[80], policymakers across Europe are beginning

[74] Harsanyi, J. C., 1992. *Utilities, preferences and substantive goods*. Social Choice and Welfare, 14(1), 129-145.

[75] Della Valle, N. and Bertoldi, P., *Mobilizing Citizens to Invest in Energy Efficiency*, EUR 30675 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-36152-7, doi:10.2760/137315, JRC124667.

[76] Bator, F. M., 1958. *The Anatomy of Market Failure*. The Quarterly Journal of Economics, 72(3), 351-379.

[77] Simon, H. A., 1955. *A behavioural model of rational choice*. The Quarterly Journal of Economics, 69(1), 99– 118.

[78] Kahneman, D. and Tversky, A., 1974. *Judgment under uncertainty: Heuristics and biases*. Science, 185(4157), 1124–1131.

[79] BASIC Toolkit, OECD 2019

[80] A behavioural problem is a pattern in behaviour that occurs despite people having good reason to act otherwise. Hence a behavioural problem is not a result of lack of: access to information; proper attitudes; right incentives or sanction; or a need for further regulation such as a ban or prohibition. In practice, such behaviour is often referred to as "irrational" (BASIC Toolkit, OECD 2019)

to integrate behavioural insights into several policy areas, thereby improving prospects for policy better adapted to actual human behaviour[81]. The BASIC framework, which was developed by OECD to provide guidelines for applying the behavioural approach to public policy, suggests that behavioural problems have four main aspects: Attention; Belief formation; Choice; and Determination (ABCD) [82]. These are exemplified and contrasted by rational choice theory in Table 2.1.

Furthermore, Section 2.5.2 details how some biases and heuristics specifically influence energy efficiency in residential buildings.

Table 2.1: The ABCD framework

	What rational choice theory says	What the behavioural approach says	Example
Attention	Individuals focus on what is most important in light of their knowledge and preferences.	Individuals have limited attention and are easily distracted.	Individuals are often overwhelmed by a lot of decisions that must be made and hence overlook energy efficiency decisions.
Belief formation	Individuals form their beliefs according to the rules of logic and probability.	Individuals rely on mental shortcuts or intuitive judgments and often over/underestimate outcomes and probabilities.	Individuals underestimate the long-term savings of making energy efficiency decisions.
Choice	Individuals make choices that maximise their expected utility.	Individuals are influenced by the framing and the social as well as situational context of choices.	Individuals make decisions based on what they believe others in their surrounding (e.g. in the industry) expect them to do (social norm).
Determination	Provided that one decides to pursue certain long-term goals, one should stick to the plan.	Individuals' willpower is limited and subject to psychological biases.	Individuals maintain the status quo (not making an energy efficiency decision) since they perceive other choices (including more energy efficient choices) as too complicated.

2.5 Factors influencing energy consumption in residential buildings

A wide range of circumstances, mechanisms and concepts - here jointly defined as factors – influence energy consumption in residential buildings. In this section we present some examples of identified factors influencing energy efficient decision making divided into neoclassical and the behavioural approach.

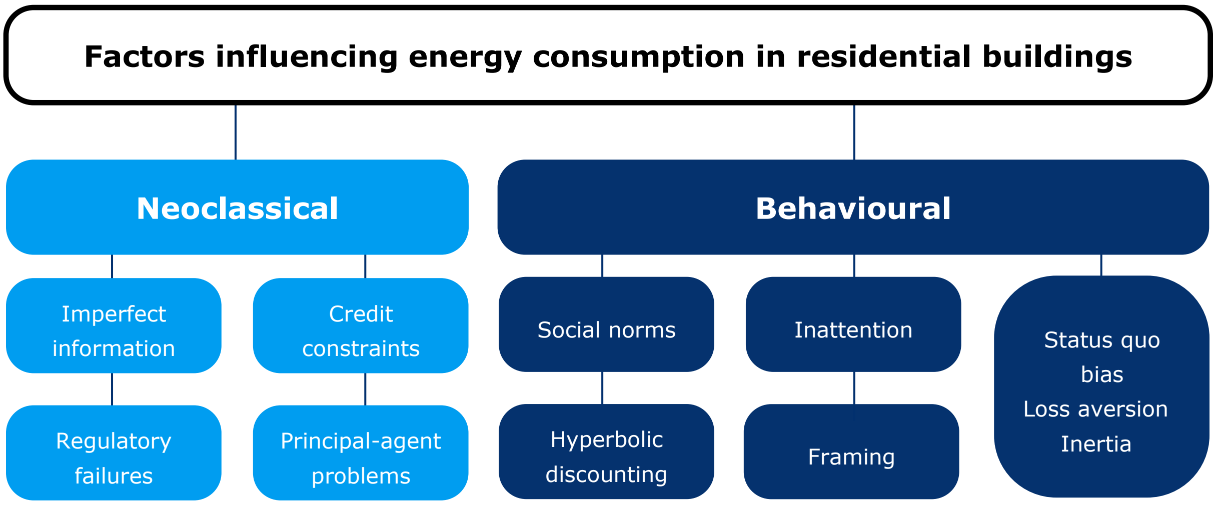
Moreover, in practice, there will be factors that are difficult to categorise into the two different theoretical concepts. An example of this is imperfect information (which is a neoclassical factor)

[81] Baggio, M., et al, 2021. The evolution of behaviourally informed policy-making in the EU. Journal of European Public Policy, 28(5), 658-676.

[82] BASIC Toolkit, OECD 2019

and information processing which becomes biased due to behavioural factors such as inattention or framing.

Figure 2.6 Illustration of factors that influence energy consumption in buildings



2.5.1 Factors according to the neoclassical approach

According to neoclassical economic thought, any deviation from the social and economic optimum (e.g., maximum energy efficiency) is caused by market failures. Market failures occur when markets are not functioning in a way that meets the basic assumptions of the neoclassical model[83]. For that reason, the neoclassical perspective proposes the following explanatory factors for energy efficient behaviour in residential buildings:

Imperfect information, meaning that actors in the market are not fully informed about the effects of their energy consumption decisions. Imperfect information affects both consumers and producers of energy efficient solutions. For instance, consumers may not be aware of the full benefits of purchasing a more energy efficient air conditioning system, resulting in underdevelopment of demand for energy efficient goods. Suppliers of energy efficient solutions may then fail to realize the full benefits of producing energy efficient and innovative products because the incentives are not big enough. This results in a less-than-optimal supply of energy efficient solutions. To correct this market failure, the neoclassical approach proposes informational policy instruments such as energy efficiency labelling and educational activities[84].

Credit constraints, meaning that agents who would like to invest in energy efficient solutions cannot obtain financing[85]. The neoclassical class of economic models assumes that capital markets are perfect, i.e., that for a risk-adjusted price, an agent seeking to invest can always find capital to sustain the investment. However, many agents do not have access to capital. This is particularly

[83] Dennis, K., 2006. *The Compatibility of Economic Theory and Proactive Energy Efficiency Policy*. The Electricity Journal, 19(7), 58-73.

[84] Bukarica, V. and Tomšić, Ž., 2017. *Energy efficiency policy evaluation by moving from techno-economic towards whole society perspective on energy efficiency market*. Renewable and Sustainable Energy Reviews, 70(2017), 968-975.

[85] Palmer, K. and Walls, M., 2016. *Using information to close the energy efficiency gap: a review of benchmarking and disclosure ordinances*. Energy Efficiency, 10(2017), 673-691.

true for low-income individuals and smaller businesses, who may face discrimination by lenders[86]. Credit constraints thus hinder the uptake of energy efficient solutions. This phenomenon is particularly prominent when there are large upfront costs associated with an energy efficient solution[87].

Regulatory failures, often lead to situations in which the price of a good does not accurately reflect its marginal cost, thereby distorting agents' incentives[88]. An example of this is when taxes on energy fail to include the full cost of fossil fuel combustion. To address this market failure, the neoclassical perspective proposes changed regulatory standards such as carbon taxation[89].

Principal-agent problems[90], are situations in which the incentives of two or more agents are not aligned. A common example is a situation in which a tenant consumes energy, and a landlord pays the energy bill. As the tenant has no incentive to economize their energy usage, this leads to an overconsumption of energy[91]. Moreover, there are also situations with the reverse dynamic: the landlord decides whether to make an energy efficient investment, and the tenant pays rent for the residential unit. Since the tenant cannot fully observe the quality of the energy efficient solution, he or she will not be prepared to pay a higher rent for a more energy efficient home. This situation leads to underinvestment in energy efficient residential solutions, as the landlord cannot recoup energy efficient investments[92]. The neoclassical model proposes situations such as these can be resolved by more efficient contracting and disclosure ordinances between the involved parties.

2.5.2 Factors according to the behavioural approach

In contrast to the neoclassical approach in which deviations from the social and economic optimum are explained solely through market failures, the behavioural approach suggests that such deviation can be caused by several other factors relating to individual behaviour. Below we list some examples of behavioural factors influencing energy as potential explanations to why we do not observe the optimal outcome of maximum energy efficiency:

Social norms. People are generally influenced by the attitudes and behaviours of others and tend to follow different social norms[93]. This means that people tend to motivate their decisions by what is socially approved or common[94]. As it relates to decision-making, simply knowing what most

[86] Golove, W. and Eto, J., 1996. *Market barriers to energy efficiency: a critical reappraisal of the rationale for public policies to promote energy efficiency*. Berkeley, CA: Lawrence Berkeley National Laboratory LBL-38059, UC-1322.

[87] Gillingham, K. and Palmer, K., 2014. *Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence*. Review of Environmental Economics and Policy, 8(1), 18-34.

[88] Ibid.

[89] Thonipara, A., et al, 2019. *Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns*. Energy Policy, 129(2019), 1156-1167.

[90] Also known as split incentives.

[91] Gillingham, K., Harding, M. and Rapson, D., 2012. *Split incentives in residential energy consumption.* The Energy Journal 33(2).

[92] Myers, E., 2018. Asymmetric Information in Residential Rental Markets: Implications for the Energy Efficiency Gap. Energy Institute at Haas, Berkeley, California. Working paper.

[93] Social norms can be divided into two types: injunctive (norms that are perceived as socially approved by the group) and descriptive (norms that are common within the group, without judgment on whether it is good or bad). See R.B. Cialdini, R.R. Raymond och C.A. Kallgren. *A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places*. Journal of personality and social psychology. Vol 58, nr. 6, 1990, s. 1015

[94] Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). *Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour*. Renewable and Sustainable Energy Reviews, 41, 1385-1394.

people choose, can motivate conformity. For instance, seeing that most of your neighbours are installing solar panels might induce you do install them yourself[95].

Status quo bias. Behavioural research has shown that people tend to prefer to maintain the current situation, such as sticking with the default option, even when an alternative may yield a more advantageous outcome[96]. This is highly relevant in terms of selecting energy plans or suppliers: if there is a default option, more people will select that option as opposed to any alternative. Our preference for the status quo has several possible explanations such as:

Loss aversion. People weigh losses more heavily than gains of equal size. This translates into people often focusing on risks, costs or losses associated with adopting a new behaviour[97] or energy efficiency measures such as retrofitting[98]. When faced with a decision, people weight potential loss more heavily than potential gain. Loss aversion also enables status quo bias since it leads to greater regret for action than for inaction; more regret is experienced when a decision changes the status quo than when it maintains it. Therefore, an individual might avoid changing to a potentially more energy efficient plan, simply due to the risk that it will not work out.

Inertia. Status quo bias may also be explained by the fact that people as well as organisations tend to follow established routines. These routines may be entrenched, making changing those behaviours difficult. If an individual faces a difficult decision, they may simply revert to choosing the option which includes the least resistance without alternating behaviours[99]. The prevalence of inertia and the lack of change it entails is relevant for instance when it comes to complex decisions such as changing energy plans or supplier, which is relevant both for households as well as organisations.

Inattention. Even in cases where costs and benefits are clearly communicated, people may still make suboptimal decisions if they are not aware of them due to inattention.[100] Even in cases when searching for information is costless, inattention can still be a crucial factor in explaining suboptimal behaviour. A study conducted for the European Commission in 2010 on the retail electricity market found that 41% of consumers do not know whether they have the cheapest tariff and 53% of consumers do not know their energy usage[101].

Hyperbolic discounting. People tend to discount long-term benefits against short-term rewards.[102] Preferring short-term gains is not per definition irrational. However, hyperbolic discounting suggests that not only do people discount future gains, but their preferences are also not constant over time. This means that people might be willing to wait longer for rewards they already expect to receive in the distant future while assigning a significant discount to small delays in rewards they expected to receive soon. In terms of energy efficiency, this means that people

[95] Horne, C., & Familia, T. (2021). *Norms, Norm Sets, and Reference Groups: Implications for Household Interest in Energy Technologies*. Socius, 7, 23780231211039035.

[96] Ibid.

[97] Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). *Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour*. Renewable and Sustainable Energy Reviews, 41, 1385-1394.

[98] Schleich, J., Gassmann, X., Meissner, T., & Faure, C. (2019). *A large-scale test of the effects of time discounting, risk aversion, loss aversion, and present bias on household adoption of energy-efficient technologies*. Energy Economics, 80, 377-393.

[99] Abrardi, L. (2019). *Behavioral barriers and the energy efficiency gap: A survey of the literature*. Journal of Industrial and Business Economics, 46(1), 25-43.

[100] Ibid.

[101] ECME Consortium European Commission. (2010). *The functioning of retail electricity markets for consumers in the European Union*. Final report. EAHC/FWC/2009 86 01.

[102] Pothitou, M., Kolios, A. J., Varga, L., & Gu, S. (2016). *A framework for targeting household energy savings through habitual behavioural change*. International Journal of Sustainable Energy, 35(7), 686-700.

may be unwilling to accept a short-term cost increase (by paying to switch to a more energy efficient plan for instance) even though they would benefit financially in the long run[103].

Framing. People's decisions are influenced by which choices are available and how they are presented. Presenting choices in different orders or framing the same choice in terms of losses instead of gains may alter a decision made[104]. Thus, people may select a less efficient plan or supplier, simply because the option was presented in a certain favourable way. For instance, framing a decision to switch to a more energy efficient option in positive terms ("if you switch plans, you will decrease your carbon footprint") rather than in negative terms ("if we do not reduce our energy consumption, pollution and energy dependence will ensue") may increase uptake[105].

[103] Kallbekken, S., Sælen, H., & Hermansen, E. A. (2013). *Bridging the energy efficiency gap: A field experiment on lifetime energy costs and household appliances*. Journal of Consumer Policy, 36(1), 1-16.

[104] Pothitou, M., Kolios, A. J., Varga, L., & Gu, S. (2016). *A framework for targeting household energy savings through habitual behavioural change*. International Journal of Sustainable Energy, 35(7), 686-700.

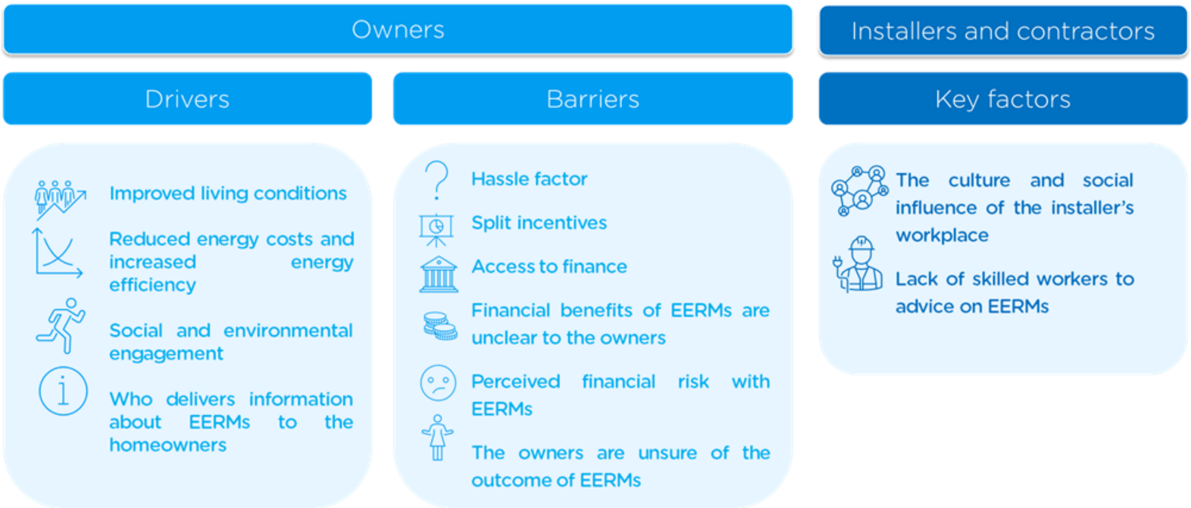
[105] Abrardi, L. (2019). *Behavioral barriers and the energy efficiency gap: A survey of the literature*. Journal of Industrial and Business Economics, 46(1), 25-43.

3. Understanding stakeholders’ decision-making in relation to energy efficiency in residential buildings’ renovation

This chapter is aimed at presenting the key stakeholders involved in the renovation process. The primary stakeholders in this study are the owners, since they are ultimately the ones deciding on whether to carry out a certain type of renovation aimed at increasing the energy efficiency of their building. Other important stakeholders are installers and contractors since they can often be seen as “gatekeepers” of energy efficiency measures in renovations.

The study also presents several factors that influences installers and contractors as well as owners. The figure below shows an overview of the factors identified in this study, which will be further explained in this chapter.

Figure 3.1. Overview of factors



3.1 The property owners are the key stakeholders in the energy efficiency renovation process, followed by installers and contractors

One of the objectives of this study is to understand the behavioural factors that affect the decision about investing in energy efficient renovation, with the aim of understanding their role and identifying ways to accelerate energy efficiency uptake in the EU residential sector. To comprehend the energy efficiency decisions made in renovations, a mapping of relevant stakeholders has been undertaken. The mapping of stakeholders is based on expert interviews and a literature review[106]. The mapping concludes that the owners are the most important stakeholder in the energy efficiency renovation process, followed by contractors and installers. The next sections describe the obtained results in detail.

[106] See for instance: Arning, K., Zaunbrecher, B. S., & Ziefle, M. (2019). The influence of intermediaries’ advice on energy-efficient retrofit decisions in private households. In Proceedings of the eceee.and Camarasa, C., Heiberger, R., Hennes, L., Jakob, M., Ostermeyer, Y., & Rosado, L. (2020). Key decision-makers and persuaders in the selection of energy-efficient technologies in EU residential buildings. Buildings, 10(4), 70.

The decision-making process is often complex and involves several stages and multiple decisions. From understanding that there is a need to carry out a renovation, to search for appropriate energy efficiency renovation measures (EERMs) and finally implement the renovation.

3.1.1 The owners are the key stakeholders

The initial mapping shows that the owners are the most important stakeholders, since they are the ones who pay the cost of renovation and therefore ultimately make the decision of whether to renovate or not. Both the literature and expert interviews confirm that owners are crucial stakeholders to increase the energy efficiency of residential buildings in Europe.

The owners can be categorised further into homeowners (owners who live in their property, e.g. a detached house or apartment) and landlords (owners who rent out their property). Landlords can be divided into subcategories based on the ownership structure of the building. Homeowners consume the energy as well as pay the rent and operating costs, such as gas or electricity, while in the case of landlords it is the resident that consumes and covers the related energy costs.

3.1.2 Installers and contractors have a crucial influence on the owners' decision on EERMs

The mapping also reveals that the owners are highly influenced by installers and contractors. The role of ***installers and contractors*** has been highlighted as crucial in empirical studies. Installers supply the technical knowledge, shape the scope of energy renovations, and ultimately affect the energy consumption patterns.[107] Installers and contractors are often craftspeople who are implementing the renovation and advice the owners on the materials to be used, the technical solutions to implement, etc. for the renovation. Throughout the renovation process, installers and contractors can provide both practical and technical expertise.

Especially owners of single-family houses, whose renovation process is less complex than the renovation process in large multi-family buildings and who usually do not command renovation-related professional knowledge, tend to rely heavily on the professional advice of installers.[108] This places installers in a position where their own preferences and skills are instrumental in shaping the technical solutions installed in homes[109]. For example, a study of heating installers in the UK indicates that installers operate as a "community of practice" whose shared experiences and social networks ultimately influence the selection and installation of heating systems[110].

Additionally, installers have been found to influence the diffusion of energy efficient technologies depending on their personal beliefs regarding the usefulness of these technologies, to the extent that they can be viewed as "gatekeepers" of energy efficiency measures in renovations[111]. In conclusion, the installers are key stakeholders in the energy efficiency renovation process.

3.1.3 Overview of other identified stakeholders involved in the renovation process

Beside owners and installers/contractors, the mapping shows that there are other important stakeholders involved in the renovation process. In broad terms all stakeholders can be categorized

[107] Arning, K., Zaunbrecher, B.S. and Ziefle, M., 2019. *The influence of intermediaries' advice on energy-efficient retrofit decisiosn in private households. ECEEE Summer Study Proceedings, June, pp. 1177-1188.*

[108] Ibid.

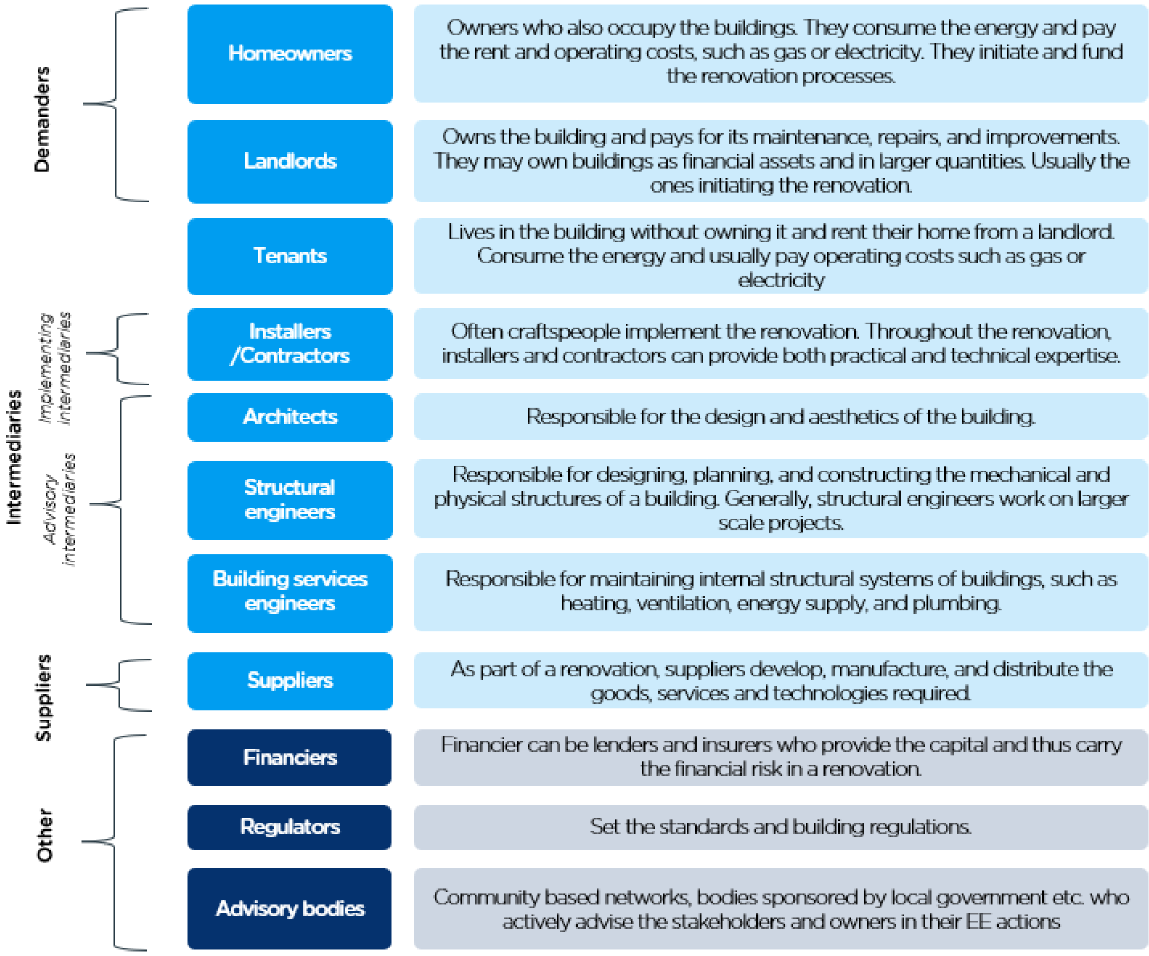
[109] Owen, A., Mitchell, G. and Gouldson, A., 2014. *Unseen influence: The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology.* Energy Policy 73, pp. 169-179.

[110] Wade, F., Hitchings, R. and Shipworth, M., 2016. *Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom.* Energy Research & Social Science 19, pp. 39-47.

[111] Zaunbrecher, B.S., et al, 2021. *Intermediaries as gatekeepers and their role in retrofit decisions of house owners.* Energy Research and Social Science, 74, 101939

into four groups: **demanders**; **intermediaries**; **suppliers**; and **others** (see the figure below). The demanders consist of the owners of the property as well as the residents (tenants). Intermediaries are installers/contractors who are advising the owner and are often the ones who carry out the renovation. Intermediaries can also be architects, structural engineers and building services engineers who are *advisory* intermediaries. Other important stakeholders are financiers, regulators, and advisory bodies. The stakeholders are presented further in the figure below.[112].

Figure 3.2. Overview of stakeholders



3.2 Overview of key factors influencing owners' decision to uptake EERMs

The overall assessment of the literature review and involvement of experts allowed us to identify several important drivers and barriers influencing the owners' decision to invest (or not) in energy efficient renovation measures.

It is important to highlight that there is limited knowledge and literature on the role of behavioural factors influencing the owners' decision on whether to renovate or not. Nevertheless, the identified literature reports several behavioural mechanisms, which are presented in 'fact boxes' in the next sections. Moreover, several studies are based on self-reported behaviour and not on actual renovation decisions.

[112] This overview of stakeholders should be seen as a simplification of the system of renovation actors, and there could also be overlapping between the different stakeholders.

3.3 Key drivers for owners to uptake EERMs

This study identifies four key drivers for owners to implement EERMs. The overall assessment shows that the most important drivers have a direct and clear impact on the owners, such as improved living conditions. Several studies confirm that energy efficiency is often seen as a side benefit of a renovation and is rarely the main driver for owners. However, the interviews with practitioners in in the field confirmed the opposite, especially in the light of the current energy crisis in Europe. The concept of energy efficiency will most likely also become an important factor as the awareness of the European population will most likely continue to increase. Other important drivers identified are social and environmental engagement and the messenger of information on EERMs.

3.3.1 Improved living conditions is a key driver for owners to implement EERMs

Improved living and building conditions are highlighted as one of the most important drivers of energy efficiency renovation. Several studies emphasize that the prospect of becoming energy efficient is often seen as a mere "side benefit", and that owners primarily implement EERMs based on their wish to improve their living conditions[113][114][115].

Wanting to improve living conditions can thereby be seen as one of the more important drivers in owners' adoption of EERMs and many studies provide similar evidence. A study of Swedish homeowners suggests that current living conditions such as thermal discomfort, age of the building, and past investment in the building envelope determine homeowners' preferences for certain types of EERMs such as making the building envelope more energy efficient[116]. Similarly, increased comfort and improved living quality are also pointed out as important factors affecting energy refurbishment decisions of homeowners of detached houses in France, Switzerland and Spain.[117] Also, the intention to embellish house appearance has also been shown to motivate renovation measures among homeowners[118]. A study on French, German, Italian, Spanish and Swiss homeowners shows that adapting their home to their needs, such as better thermal comfort, is a key driver for implementing EERMs[119]. A study of older Dutch homeowners (55< years) shows that their main motives for implementing an EER is deeply connected with their idea of a good quality of life[120].

Improved living conditions is also important for landlords, since it increases the satisfaction of their tenants. Technical problems and complaints by tenants have been documented as drivers that can initiate EERMs among both private and public landlords[121]. Private landlords who own blocks of flats

[113] Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. (2011). *Barriers and drivers to energy-efficient renovation in the residential sector*. Empirical findings from five European countries. ECEEE Report.

[114] Klöckner, C. A., & Nayum, A. (2016). Specific barriers and drivers in different stages of decision-making about energy efficiency upgrades in private homes. Frontiers in psychology, 7, 1362.

[115] Sustainable Energy Authority of Ireland, Behavioural insights on energy efficiency n the residential sector. Available at: https://www.seai.ie/publications/Behavioural-insights-on-energy-efficiency-in-the-residential-sector.pdf

[116] Nair, G., Gustavsson, L., & Mahapatra, K. (2010). Factors influencing energy efficiency investments in existing Swedish residential buildings. Energy Policy, 38(6), 2956-2963.

[117] Beillan, V. et al. (2011) Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE 2011 Summer Study, 1083-1093.

[118] Baumhof, R., Decker, T., Röder, H., & Menrad, K. (2018). *Which factors determine the extent of house owners' energy-related refurbishment projects? A Motivation-Opportunity-Ability Approach*. Sustainable cities and society, 36, 33-41.

[119] Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. (2011). *Barriers and drivers to energy-efficient renovation in the residential sector*. Empirical findings from five European countries. ECEEE Report.

[120] Druta, O., Schilder, F., & Lennartz, C. (2021). Home improvements in later life: competing policy goals and the practices of older Dutch homeowners. International Journal of Housing Policy, 1-21.

[121] Femenías, P., Mjörnell, K., & Thuvander, L. (2018). *Rethinking deep renovation: The perspective of rental housing in Sweden*. Journal of cleaner production, 195, 1457-1467.

in poor condition can, by renovating, both improve living conditions and increase the value of the property. A flat building with better standards is more sought after by tenants and renting out its units will thereby be easier for the private landlord[122]. One study on landlords in Sweden, Denmark and Cyprus also indicates that indoor quality and elimination of moisture are key drivers for implementing an energy efficiency renovation[123].

3.3.2 Energy prices will most likely become an important driver

Several experts highlight that increased energy prices, and energy efficiency, will most likely become an important driver for owners to implement EERMs. The main reason behind this is the current energy crisis in Europe, triggered by the war in Ukraine. When the prices were lower, people did not have the same incentives to renovate. Even if/when the prices go down again, a potential result of the energy crisis could be that owners become more aware of the importance of being more resilient to future possible price shocks, and direct more attention to this aspect. Thus, the behavioural mechanism salience might serve as an important aspect[124]. Another behavioural relevant behavioural factor is the loss aversion[125], individuals have strong aversions towards losses, such as having less money due to increased energy prices.

Salience relates to how people take note of messages or information based on how it is presented. Information is *salient* to us when it stands out by being different or easily noticeable. For instance, how consumers decide to respond to increased energy prices will depend partly on how salient the new price level is to them.

Loss aversion refers to the phenomenon where the psychological pain of loosing is higher than the pleasure of gaining. This translates into people often focusing on risks, costs or losses associated with adopting a new behaviour or energy efficiency measures such as retrofitting. When faced with a decision, people perceive the disutility of losing something as far greater than the utility of gaining something.

There is not much literature confirming that reduced energy cost is an important driver for owners. For instance, one study on Irish homeowners found that investments in EERMs were mainly driven by a wish to save money[126]. There are older studies (from 2008 and 2006) which conclude that cutting energy use itself is never the main issue in renovation projects[127][128].

Moreover, taking ownership structure into account, reduced energy costs is most likely a more important driver for those owners who also live in their property (this will be further discussed in section 4.4.5). However, a study investigating the attitudes of owners of rental housing in Sweden

[122] Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. (2011). *Barriers and drivers to energy-efficient renovation in the residential sector*. Empirical findings from five European countries. ECEEE Report.

[123] Gohardani, N., Björk, F., Jensen, P. A., Maslesa, E., Kanarachos, S., & Fokaides, P. A. (2013*). On stakeholders and the decision making process concerning sustainable renovation and refurbishment in Sweden, Denmark and Cyprus.* Archit. Environ, 1, 21-28.

[124] Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. American economic review, 93(5), 1449-1475.

[125] Novemsky, N., & Kahneman, D. (2005). The boundaries of loss aversion. Journal of Marketing research, 42(2), 119-128.

[126] Aravena, C., Riquelme, A., & Denny, E. (2016). *Money, comfort or environment? Priorities and determinants of energy efficiency investments in Irish households*. Journal of consumer policy, 39(2), 159-186.

[127] Ademe. (2008)., *Observatoire permanent de l'Amélioration Energétique du Logement* (OPEN): 2007 campaign results

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

showed that, in some instances, landlords are motivated to uptake EERMs by their willingness to reduce maintenance costs and high energy use[129].

Furthermore, the building typology also plays a role since the type of dwelling has an impact on energy consumption and performance. For instance, in theory, a semi-detached home consumes less energy per m^2 than a detached house[130]. Residents of detached houses may therefore see a greater need to save money by improving the energy efficiency of their building.

3.3.3 Social and environmental engagement motivate the uptake of EERMs

Several studies indicate that both social and environmental aspects motivate owners to uptake EERMs. A study conducted in Sweden[131] found that wanting to take social responsibility, by taking the needs of tenants into account when implementing energy efficient renovation measures, is becoming increasingly common. This study found that a sense of social responsibility was a driver both for private and public housing companies. Similarly, a study on Dutch public property owners[132] found that a felt sense of responsibility to drive change can motivate them to take the lead in sustainable innovation, such as improving energy efficiency. Interviewed experts describe how owners of social housing buildings are driven by providing good services to their residents and that they feel a big responsibility to do so. The feeling of responsibility covers both social inclusion and concerns of climate change, such as contributing to a low carbon culture.

For Norwegian homeowners, a sense of social responsibility or "moral obligation" has also been shown to drive willingness to implement EERMs[133]. Moreover, homeowners who express pro-environmental beliefs through, for example, membership in pro-environmental organisations are also more prone to implement energy efficiency measures. A similar conclusion can be drawn for those who engage in energy saving practices such as reducing indoor temperature/air conditioning, washing clothes more efficiently and switching off the stand-by mode on appliances. Such behaviours have also been shown to be a driver for energy efficient renovation for homeowners[134].

Other factors such as gender, age, and level of education have been shown to impact environmental engagement and the tendency to implement EERMs. Women tend to show a higher degree of environmental engagement and feel more responsible when it comes to caring for the environment[135]. Moreover, younger homeowners have been shown to be more environmentally conscious. A higher level of education has also been shown to increase the likelihood of homeowners to implement EERMs[136].

[129] Femenías, P., Mjörnell, K., & Thuvander, L. (2018). *Rethinking deep renovation: The perspective of rental housing in Sweden*. Journal of cleaner production, 195, 1457-1467.

[130] Ibid.

[131] Mjörnell, K., Femenías, P., & Annadotter, K. (2019). *Renovation strategies for multi-residential buildings from the record years in Sweden—Profit-driven or socioeconomically responsible?*. Sustainability, 11(24), 6988.

[132] Hartmann, A., Reymen, I. M., & Van Oosterom, G. (2008). *Factors constituting the innovation adoption environment of public clients*. Building research & information, 36(5), 436-449.

[133] Klöckner, C. A., & Nayum, A. (2016). *Specific barriers and drivers in different stages of decision-making about energy efficiency upgrades in private homes*. Frontiers in psychology, 7, 1362.

[134] Ameli, N. & Brandt, N., 2015. *Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes*. Environmental Research Letters 10 (2015) 044015.

[135] Ipsos. 2018. Uncover the underlying motivations and barriers for energy efficient renovations: Report for European Climate Foundation. https://europeanclimate.org/wp-content/uploads/2019/11/12-03-19-uncover-the-underlying-motivations-and-barriers-for-energy-efficient-renovations.pdf (Viewed 2022-10-11)

[136] Nair, G., Gustavsson, L., & Mahapatra, K. (2010). *Factors influencing energy efficiency investments in existing Swedish residential buildings*. Energy Policy, 38(6), 2956-2963.

3.3.4 Who delivers information about EERMs to the homeowners is important

Homeowners are more prone to listen to advice about EERMs when it comes from a source they can trust. Information from familiar people, such as friends and family, is more likely to have an impact on their decision about whether to implement EERMs compared to information from other sources, such as public information campaigns. One study indicates that information sought from personal contacts (i.e., people in the owners' social network) can increase the likelihood of owners adopting EERMs by a factor of four[137]. Information sought from personal contacts accessible to the owners may also reduce their uncertainties about an EERM[138]. Moreover, another study on French, Bulgarian, German, Spanish and Polish households found that those who live in rural areas seem to be more influenced by their peers compared with homeowners in cities[139].

The literature shows that personal contacts are of great importance to make the homeowner aware of the fact that they should implement an EERM. However, when they have made the decision to renovate, professionals, such as installers and contractors, seem to be of higher importance. When an owner has shown an interest in making a renovation, installers and contractors become highly important[140][141][142][143]. Moreover, a study from Slovenia indicates that professional advice is more important when the homeowner is planning to implement multiple EERMs at once, compared to owners who implement smaller renovation measures[144].

A phenomenon closely related to the messenger effect is the concept of social norms. There is evidence that social norms are an important factor for household's decision to decrease their energy consumption (hence in the usage phase)[145]. But there is less evidence for decisions related to EERMs. There are some studies that indicate that homeowners are more prone to install solar panels

The messenger effect implies that it matters who provides information to owners. In contrast, according to neoclassic theory, the information source should not influence choices, which seems to not be the case in the decision-making process for EERMs for owners.

Social norms refer to the fact that people tend to be motivated by what is seen as socially approved or common behaviour. Social norms can be divided into two different categories: injunctive and descriptive norms. Descriptive norms are related to the observation of others' behaviours (e.g., seeing neighbours installing solar panels), while injunctive norms refer to the perceptions of what is approved or disapproved by other (e.g., my neighbours talk about solar panels as being a good investment).

[137] McMichael, M., & Shipworth, D. (2013). *The value of social networks in the diffusion of energy-efficiency innovations in UK households*. Energy Policy, 53, 159-168.

[138] Ibid.

[139] Ipsos. 2018. Uncover the underlying motivations and barriers for energy efficient renovations: Report for European Climate Foundation. https://europeanclimate.org/wp-content/uploads/2019/11/12-03-19-uncover-the-underlying-motivations-and-barriers-for-energy-efficient-renovations.pdf (Viewed 2022-10-11)

[140] SEAI. *Behavioural insights on energy efficiency in the residential sector*. https://www.seai.ie/publications/Behavioural-insights-on-energy-efficiency-in-the-residential-sector.pdf (Viewed 2022-10-11)

[141] Arning, K., Zaunbrecher, B.S. and Ziefle, M., 2019. The influence of intermediaries' advice on energy-efficient retrofit decisiosn in private households. ECEEE Summer Study Proceedings, June, pp. 1177-1188.

[142] Owen, A., Mitchell, G. and Gouldson, A., 2014. Unseen influence: The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology. Energy Policy 73, pp. 169-179.

[143] Wade, F., Hitchings, R. and Shipworth, M., 2016. Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom. Energy Research & Social Science 19, pp. 39-47.

[144] Hrovatin, N., & Zorić, J. (2018). *Determinants of energy-efficient home retrofits in Slovenia: The role of information sources*. Energy and Buildings, 180, 42-50.

[145] Allcott, H. (2011). Social norms and energy conservation. Journal of public Economics, 95(9-10), 1082-1095.

when they are aware that their neighbours are doing so[146][147][148]. However, it is important to mention that social norms could also act as a barrier. If energy efficiency measures are not perceived as socially accepted or "normal" by a homeowners' community, this can discourage the uptake of energy efficient renovation measures[149].

3.4 Key barriers for owners to the uptake of EERMs

We identify six key barriers for owners to uptake EERMs. A key barrier is the hassle factor, and that owners face a complex decision-making process when considering implementing an EERM. If the owners perceive a renovation to be too complicated, it might result in sub-optimal decisions or no decision at all. The data collection also identifies other important barriers such as unclear financial benefits, perceived financial risk, uncertainty of the outcome of an EERM, split incentives and access to finance. In this study it is not possible to determine whether these barriers are mainly due to market failures, such as asymmetric information or regulatory failures, or merely due to behavioural factors. Most likely, for all barriers, it is a combination of them.

3.4.1 The hassle factor serves as a major barrier

Several studies indicate that the so-called hassle factor forms a substantial barrier for owners, especially individual households, to uptake EERMs. The hassle factor is related to the amount of perceived or actual effort involved in a certain decision[150]. EERMs are often perceived as something complicated to carry out by the owners, both the amount of time they have to invest but also where to find the right finance and reliable companies to conduct the renovation. When a task is perceived as too complicated, it might result in sub-optimal decisions or no decisions at all.

One study from the UK showed that homeowners did not insulate their lofts because they perceived too much of hassle clearing belongings from the loft area before insulation[151]. This points to the fact that homeowner may sometimes *want* to implement renovation measures and view them as beneficial. However, they might still avoid doing so due to a sense of aversion toward the extra hassle that is brought along with such tasks. In the expert survey results, the hassle factor is confirmed as central and that removing non-financial barriers has been proven efficient in encouraging EERMs.

Furthermore, several studies indicate that homeowners find it a hassle to apply for subsidies or loans, leaving them to postpone the application. For instance, they might not know where and how

[146] Horne, C., & Familia, T. (2021). *Norms, Norm Sets, and Reference Groups: Implications for Household Interest in Energy Technologies*. Socius, 7, 23780231211039035.

[147] Haque, A. N., Lemanski, C., & de Groot, J. (2021). *Why do low-income urban dwellers reject energy technologies? Exploring the socio-cultural acceptance of solar adoption in Mumbai and Cape Town*. Energy Research & Social Science, 74, 101954.

[148] Palm, A. (2016). *Local factors driving the diffusion of solar photovoltaics in Sweden: A case study of five municipalities in an early market*. Energy Research & Social Science, 14, 1-12.

[149] Haque, A. N., Lemanski, C., & de Groot, J. (2021). *Why do low-income urban dwellers reject energy technologies? Exploring the socio-cultural acceptance of solar adoption in Mumbai and Cape Town*. Energy Research & Social Science, 74, 101954.

[150] de Vries, G., Rietkerk, M., & Kooger, R. (2020). The hassle factor as a psychological barrier to a green home. Journal of Consumer Policy, 43(2), 345-352.

[151] DECC. (2013). *Removing the hassle factor associated with loft insulation*: Results of a behavioural trial. London: Department of Energy and Climate Change

to apply[152][153][154]. This argument is reinforced by expert interviews and expert survey results, where administrative barriers when applying for finance are viewed to be a major problem across Europe. In Germany, for example, the subsidies are not adapted to the needs of the target group. It is challenging to navigate the timing and bureaucracy around subsidies. Thus, although subsidies exist, they are not always useful for people. Experts also highlighted that in some instances there is a lack of coordination of different supporting institutions, both on national and local levels, which make the decision process for the owner harder to overlook. Another challenge for owners is to find a reliable contractor, that they can trust, for the renovation[155].

Other studies emphasize that homeowners cannot find a place for large renovation measures within the context of everyday life and daily practices[156][157]. Renovation measures, especially those that imply breaking daily routines, are seen as burdensome for residents simply because they are perceived as out of the ordinary. This is especially true for larger renovation measures, since those are more likely to be regarded as over and above daily habits or anticipated upkeep of one's household. A study on Portuguese homeowners indicates that younger homeowners usually perform more "little-by-little" energy renovations compared with the older, who appreciate more single events for renovate[158]. Most likely, younger homeowners are occupied with other things, such as work and taking care of their children, and thus struggle to find time for doing an EERM.

The literature also shows that not only individual households, but also small landlords state limited amount of time as a barrier[159]. One Swedish study indicate that step by step renovations is also a good strategy for both private and public landlords, which better suit the needs of the tenants[160]. So, even for owners, like real-estate companies, the hassle factor could potentially be an important factor, and most likely even more significant when conducting large-scale renovations such as deep renovations.

[152] Ibid.

[153] Allcott, H., & Mullainathan, S. (2010). Behavior and energy policy. Science, 327(5970), 1204-1205.

[154] DECC. (2011). Understanding Potential Consumer Response to the Green Deal. London: Department of Energy and Climate Change

[155] DECC. (2011). Understanding Potential Consumer Response to the Green Deal. London: Department of Energy and Climate Change

[156] Hrovatin, N., & Zorić, J. (2018). *Determinants of energy-efficient home retrofits in Slovenia: The role of information sources*. Energy and Buildings, 180, 42-50.

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

[158] Abreu, M. I., de Oliveira, R. A., & Lopes, J. (2020). Younger vs. older homeowners in building energy-related renovations: Learning from the Portuguese case. Energy Reports, 6, 159-164.

[159] März, S. (2018). *Beyond economics—Understanding the decision-making of German small private landlords in terms of energy efficiency investment*. Energy Efficiency, 11(7), 1721-1743.

[160] Mjörnell et al Rethinking deep renovation: The perspective of rental housing in Sweden https://www.sciencedirect.com/science/article/abs/pii/S0959652617332766

3.4.2 The financial benefits of EERMs are not clear to the owners

Hyperbolic discounting. People tend to discount long-term benefits against short-term rewards. Preferring short-term gains is not per definition irrational. However, hyperbolic discounting suggests that not only do people discount future gains, but their preferences are also not constant over time. This means that people might be willing to wait longer for rewards they already expect to receive in the distant future while assigning a significant discount to small delays in rewards they expected to receive soon. In terms of energy efficiency, this means that people may be unwilling to accept a short-term cost increase (by paying to switch to a more energy efficient plan for instance) even though they would benefit financially in the long run.

Another key barrier highlighted in the literature is that owners are not sure whether the investment into an EERM is financially beneficial or not, and they have an aversion to delayed gains. Homeowners may pay more attention to the immediate investment costs of an EERM than to future savings from increased efficiency[161]. Even though studies have confirmed that implementing EERMs is generally an economically viable strategy for landlords[162], it seems to be hard for the owners to understand the benefits.

This could potentially be explained by the well-known phenomenon of *hyperbolic discounting,* the tendency to prefer immediate rewards to long-term benefits[163]. Additionally, since the return on energy efficiency investments often is delayed, calculating the costs and benefits is an intricate task, and homeowners might have limited cognitive ability to plan and limited energy specific knowledge[164]. As a result, owners may choose not to invest in energy efficiency renovation measures[165].

3.4.3 The perceived financial risk with EERMs is high among owners

Risk aversion refers to the human tendency to avoid risks or uncertain future events, even if the uncertainty comes with a higher expected return.

Another key barrier related to the uncertainty of the long-term benefits is the perceived financial risk associated with energy efficient renovations. Individual households are typically more risk averse than real-estate companies. Since the actual realised energy savings might be uncertain, households may be unwilling to invest a large amount of money that could constitute a large share of their total budget. In addition, households may not be sure that they will live in the same building for a sufficiently long period to obtain enough of the benefits from the investment to make it financially attractive. One study indicates that older homeowners have an uncertainty of not being able to profit from the renovation[166]. A behavioural mechanism worth mentioning is risk aversion bias to describe an individual's worry about potential uncertainty in the future[167].

Risk aversion is not only a barrier among individual households, but also a challenge for real estate companies. One Swedish study shows that investing in energy efficiency is perceived as a risky up-front investment for both private and public landlords, and the owner might not be sure whether

[161] Della Valle, N., & Bertoldi, P. (2021). Mobilizing citizens to invest in energy efficiency. EUR–Scientific and Technical Research Reports. Ispra: Joint Research Centre.

[162] Kok, N., Miller, N., & Morris, P. (2012). *The economics of green retrofits*. Journal of Sustainable Real Estate, 4(1), 4-22.

[163] Laibson, D. (1997). *Golden eggs and hyperbolic discounting.* The Quarterly Journal of Economics, 112(2), 443-478.

[164] Della Valle, N., & Bertoldi, P. (2021). Mobilizing citizens to invest in energy efficiency. EUR–Scientific and Technical Research Reports. Ispra: Joint Research Centre.

[165] International Energy Agency, 2020. Behavioural insights for demand-side energy policy and programmes. . https://userstcp.org/news/behavioural-insights-for-demand-side-energy-policy-and-programmes-report-published/

[166] Jan Paul Baginski, Christoph Weber, *A consumer decision-making process? Unfolding energy efficiency decisions of German owner-occupiers*. HEMF Working Paper 08/2017. 2017.

[167] Werner, Jan (2008). "Risk Aversion". The New Palgrave Dictionary of Economics. pp. 1–6

the upfront cost justifies the potential savings, which is particularly the case for large-scale renovations such as deep renovations[168]. One study conducted in the UK shows that the main barrier for investing in EERMs for private landlords is the large up-front cost[169].

One German study concluded that many small private landlords aged sixty and above depend on the rental income as part of their pension, which means that they may lack the incentives of benefitting from energy efficiency in the long term. The study also found that the willingness to invest decreases with age. Risk aversion, dislike of debt and a wish to avoid the organisational burden of large investments are reasons that could explain such unwillingness[170].

Another uncertainty that homeowners face is how climate change will affect their buildings. Several studies have shown that climate change will increase the uncertainty of retrofitted buildings' potential to meet the desired outputs[171]. This aspect of uncertainty may therefore be difficult for owners to overcome completely.

3.4.4 Owners are often unsure of the outcome of EERMs

Besides the uncertainties related to the future financial benefits, the literature reveals that homeowners are often unsure about other outcomes before the renovation takes place, for example building quality, benefits of an EERM and health risks associated with a renovation. Compared with accepting the unknowns, many homeowners could be inclined to drop the renovation decision to avoid the risk of loss.

One study from Germany on small private landlords shows that they fear that a renovation will worsen the building quality and one reason behind this might be the lack of knowledge about the actual outcome of an EERM[172]. Several studies indicates that homeowners are not sufficiently informed about the need to insulate their homes, despite its benefits. One study shows that households with children are less willing to improve attic insulation and that the reason for this may be the fear of exposing the children to health risks[173]. Thus, owners might fail to invest in EERMs when they are not well-informed and when they potentially have incorrect beliefs about outcomes and benefit of an EERM.

3.4.5 Split incentives is an important barrier

Split incentives is a well-known barrier highlighted in the literature on energy efficiency in the residential sector. Split incentives refers to any situation where the benefits of a transaction do not accrue to the actor who pays for the transaction which ultimately can discourage energy efficiency improvements to come into effect.

One of the most common forms of split incentive is the *efficiency-related split incentive* which refers to when the resident is in charge of the energy bill but cannot make the decision on what EERMs to

[168] Femenías, P., Mjörnell, K., & Thuvander, L. (2018). *Rethinking deep renovation: The perspective of rental housing in Sweden*. Journal of cleaner production, 195, 1457-1467.

[169] Hope, A. J., & Booth, A. (2014). *Attitudes and behaviours of private sector landlords towards the energy efficiency of tenanted homes*. Energy Policy, 75, 369-378.

[170] März, S. (2018). *Beyond economics—Understanding the decision-making of German small private landlords in terms of energy efficiency investment*. Energy Efficiency, 11(7), 1721-1743.

[171] Nik, V. M., Mata, E., Kalagasidis, A. S., & Scartezzini, J. L. (2016). Effective and robust energy retrofitting measures for future climatic conditions—Reduced heating demand of Swedish households. Energy and Buildings, 121, 176-187

[172] März, S. (2018). *Beyond economics—Understanding the decision-making of German small private landlords in terms of energy efficiency investment*. Energy Efficiency, 11(7), 1721-1743.

[173] Azizi, S., Nair, G., & Olofsson, T. (2020). *Adoption of Energy efficiency measures in renovation of single-family houses: A Comparative approach*. Energies, 13(22), 6042.

carry out (the *landlord-tenant dilemma*[174]). The fact that owners of buildings are the ones to undertake the renovation investment, and tenants the ones to benefit from reduced energy savings, gives rise to a split-incentive. Building owners are thus refraining from making an energy efficiency investment since they would not benefit from a lower utility bill or that they would not be able to recoup the investment in the rent. On the other way around, when the person who pays the utility bill is the same person who owns the residence, they are more likely to carry out an EERM. For instance, owner-occupied buildings (as opposed to renter-occupied) have been shown to be more likely to have energy efficient appliances, heat pumps and thermal insulation[175].

Multi-tenant and *multi-owner split incentives* occur when there is a structure of collective decision making between different actors. The decision structure functions as a barrier for EERM[176]. For instance, in Germany and France a study highlights the difficulties of carrying out EERMs when there are co-ownerships. Blocks of flats that are in co-ownership appear to be the most challenging cases for energy-efficient retrofit[177]. A plausible explanation could be that since the decision to renovate is shared among multiple parties, the feeling of individual responsibility may be reduced, resulting in the fact that no household attempts to push for the implementation of renovation measures. *Homeowners* living in multi-owner buildings might also find themselves in a deadlock if they wish to renovate, since major renovation decisions may require the board's approval[178].

Usage-split incentives occur when residents are not the ones paying their energy bill and thus have little motivation to be frugal with their energy consumption. This happens when tenants pay a "warm rent" in which utility bills for heating etc. is covered by the landlord. The concept of warm rent is relatively common in Sweden and Germany[179].

When energy efficient measures do not pay off until *after* the property gets transferred to its next owner or tenant, *temporal split incentives* occur. When the occupant does not know how long they will live in the building, a high capital investment may not be perceived as appealing[180].

3.4.6 Access to finance forms a barrier for owners to uptake EERMs

The overall assessment of the data collection shows that access to finance is a barrier for owners to conduct energy efficient renovations, both in terms of households' income but also to be able to achieve external financing.

[174] CEPI 2010, *Landlord/Tenant Dilemma*, http://www.cepi.eu/index.php?mact=Profile,cntnt01,downloadfile,0&cntnt01returnid=400&cntnt01uid=4e1ab8924c033&cntnt01showtemplate=false&hl=en#:~:text=The%20landlord%2Ftenant%20dilemma.

[175] Ameli, N. and Brandt, N., 2015. *Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes.* Environmental research letters 10 044015.

[176] Castellazzi, L., Bertoldi, P., & Economidou, M. (2017). Overcoming the split incentive barrier in the building sector. Publications Office of the European Union, Luxembourg.

[177] Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. (2011). Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report.

[178] Economidou, M., Sagaert, V., Laes, E., Wüstenberg, M., Kauppinen, J., & Puhakka, P. (2018). Energy Efficiency Upgrades in Multi-Owner Residential Buildings—Review of Governance and Legal Issues in 7 EU Member States. Publications Office of the European Union: Luxembourg.

[179] Castellazzi, L., Bertoldi, P., & Economidou, M. (2017). Overcoming the split incentive barrier in the building sector. Publications Office of the European Union, Luxembourg

[180] Castellazzi, L., Bertoldi, P., & Economidou, M. (2017). Overcoming the split incentive barrier in the building sector. Publications Office of the European Union, Luxembourg.

For homeowners, a higher income corresponds to a higher chance of implementing EERMs, and the other way round as well. Households with low income are less likely to implement energy efficient renovation measures, simply due to insufficient financial means[181][182].

Interviewed experts confirm that low-income household have more difficulties in accessing financing. For instance, even though there are some loans available designed for EERMs with no interest rates, these loans are still not accessed by low-income households as they are not eligible for any loans. However, an important aspect is that in general, financial incentives have been proven to be the most effective once homeowners are already committed to renovating[183]. Moreover, residents with low income tend to have little control over their energy use, which causes a vicious circle between high energy bills and the struggle to pay them. Such a financially strained situation hinders the implementation of EERMs and puts these residents at increased risk for health and wellbeing problems[184].

3.4.7 Additional potential barriers influencing the owners' decision on EERMs

The study identifies some additional barriers influencing the owners to uptake EERMs: these are the lack of awareness of the need for implementing EERMs, and existing regulatory barriers. A lack of awareness among homeowners of the necessity of renovating was highlighted as an important barrier both in interviews with experts, and also in the expert survey results. Particularly, they point out that many owners do not perceive their home as needing renovation or do not know the characteristics of their dwelling in terms of energy performance.

Next, there seems to be specific regulatory challenges for certain types of buildings, such as heritage historical buildings and social housing dwellings. Experts highlight that altering characteristic of heritage buildings is complicated by conservation restrictions as well as maintaining culturally important building characteristics when implementing EERMs.

Moreover, policies for deep energy retrofitting and renovation are not typically tailored to *social housing*, which makes it difficult for public landlords to implement EERMs[185]. In many instances, no action on energy efficiency is taken, and when it is, substandard solutions are frequently chosen since the sector struggles with budget constraints and limited financial support (as also mentioned in page 16).[186]

3.5 Overview of factors influencing installers and contractors

As it has been mentioned throughout the report, installers and contractors have a unique role in affecting owners' decision to implement EERMs. These stakeholders provide advice that often ends

[181] Ameli, N. and Brandt, N., 2015. *Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes.* Environmental research letters 10 044015.

[182] Nair, G., Gustavsson, L., & Mahapatra, K. (2010). Factors influencing energy efficiency investments in existing Swedish residential buildings. Energy Policy, 38(6), 2956-2963.

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

[184] Ameli and Brandt (2015). What Impedes Household Investment in Energy Efficiency and Renewable Energy? https://www.oecd-ilibrary.org/economics/what-impedes-household-investment-in-energy-efficiency-and-renewable-energy_5js1j15g2f8n-en

[185] European Commission, 2018. *Energy efficiency upgrades in multi-owner residential buildings.* file:///C:/Users/micto/Downloads/energy_efficiency_upgrades_in_multiowner_apartment_buildings_final%20(1).pdf

[186] Heart Project, 2020. *Could social housing be the first to decarbonize?* https://heartproject.eu/news/could-social-housing-be-the-first-to-decarbonize/

up affecting owners[187][188]. This section broadens the perspective by looking at which factors may influence the type of advice on EERMs that installers and contractors choose to provide to owners.

Installers and contractors are influenced by the culture and social impact of their workplace. Personal commitment to energy efficiency has been shown to be a motivator for installers to include EERMs. The lack of skilled workers is, however, a key barrier for installers to advice on EERMs. While the main focus on this study is on owners, we also present in the next sections some relevant drivers and barriers for installers and contractors, although it is important to mention that there is not much literature on what factors lie behind installers and contractors' tendency to give advice on EERMs to owners.

3.5.1 The culture and social influence of the installer's workplace is a factor determining whether practitioners' advice on EERMs

Personal commitment to energy efficiency seems to be a motivator for installers to include EERMs. Some are driven by a personal commitment, whereas others see their role to implement the changes they can. Another factor that has been proven to motivate installers is their pride in the work they do. If an EERM is framed as essential to deliver a high quality of work, then this could act as a driver[189].

Social relationships are also a key factor. The influence of other practitioners is important to enhance a culture where energy efficiency is a natural part of the business[190]. This factor is also highlighted by expert interviews. There may be a custom of certain practice in the industry that influences the installers decisions. The relationships between the installers and suppliers furthermore impact the type of EERMs that are implemented. An interviewed expert described that in Sweden, installers tend to have relationships with one supplier and use their products. It can therefore be more effective to continue using those products that they are used to and know how to handle than switching to other products even though it is not the most energy efficient alternative. Hence, installers and contractors might have a strong preference for maintaining the status-quo[191].

> ***Status quo bias***: individuals tend to prefer to maintain the current situation, such as sticking with the default option, even when an alternative may yield a more advantageous outcome. This is highly relevant in terms of selecting energy plans or suppliers: if there is a default option, more people will select that option as opposed to any alternative. Our preference for the status quo has several possible explanations, such as the previous mention behavioural mechanism loss aversion.

[187] Arning, K., Zaunbrecher, B.S. and Ziefle, M., 2019. *The influence of intermediaries' advice on energy-efficient retrofit decisiosn in private households. ECEEE Summer Study Proceedings, June, pp. 1177-1188.*

[188] Owen, A., Mitchell, G., & Gouldson, A. (2014). Unseen influence—The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology. Energy policy, 73, 169-179.

[189] Murtagh, N., Owen, A. M., & Simpson, K. (2021). What motivates building repair-maintenance practitioners to include or avoid energy efficiency measures? Evidence from three studies in the United Kingdom. Energy Research & Social Science, 73, 101943.

[190] Ibid.

[191] Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. Journal of risk and uncertainty, 1(1), 7-59.

3.5.2 Limited knowledge of EERMs and lack of skilled workers

Lack of skilled workers is a key issue for the industry to be able to give advice on energy efficiency to owners as well as to perform the renovation works. Interviews with experts show that the lack of skilled workers to do EERMs is widespread across Europe and a barrier to more energy efficient renovations. This situation further exacerbated following the housing crisis and labour shortages. There is a large demand to train more workers and to get more people to choose the installer profession. One interviewed expert highlights the responsibility of the governments to create policies that encourage people to choose the profession. Moreover, there is a need to raise the status of the occupation, which for instance is highlighted by experts as a substantial issue in Spain. The lack of a skilled work force as a barrier to energy efficient renovations in the residential sector is also confirmed by literature[192]. Contractors tend to lack knowledge on new products as well as the meta-skills to have an overview on the entire renovation process. Furthermore, in some countries, the demanders of renovations can only receive a subsidy if the installer/contractor is certified by a specific organism. This is for example the case of the "Qualibat" certification provided in France to professional craftsmen capable of complying with the construction standards in force and possessing the necessary qualifications to carry out these energy renovation works.

Cognitive load refers to the limited capacity of the human brain to process information. Our limited cognitive capacity can explain why people often are forgetful or miss important information.

Installers tend to be fully booked and do not have the time or incentives to develop the skills needed for energy efficient renovations. Due to the high amount of work and limited knowledge they also might not have the cognitive ability to give effective advice on energy renovations. In the behavioural science literature, a commonly mentioned phenomena that might explain this is the concept of cognitive load[193]. As previously mentioned, a large part of the companies in the industry are small businesses and may only have a few employees. One of the interviewed experts explains how if, for instance, there are only five employees in a company, one cannot afford to go away for training. These micro-enterprises form a large part of the construction sector, there appears to be very few public policies that specifically targets micro-enterprises[194].

[192] Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. 2011. Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report.

[193] Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive science, 12(2), 257-285.

[194] Owen, A., Mitchell, G. and Gouldson, A., 2014. *Unseen influence: The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology.* Energy Policy 73, pp. 169-179.

4. Behaviour in buildings renovated energy efficiently: the rebound effect

After having analysed, in the previous chapter, the stakeholders and the key behavioural factors influencing their decisions in the energy efficiency renovation process, this chapter focuses on the post-renovation phase and looks at the way individuals, in particular residents, behave once the energy efficient components have been installed. Specifically, this section analyses the so-called rebound effect and explains how this strongly determines the energy savings that can be obtained by implementing renovation in residential buildings.

From the review of the literature, it clearly emerges how the rebound effect is an essential element that needs to be taken into account when designing energy efficiency policies and improvements, since significant rebound effects have been estimated in the residential sector across Europe. This however changes substantially across Member States and income groups, with evidence suggesting that the rebound effect is larger for poorer households in low-income countries.

Behavioural factors can play an important role in tackling the rebound effect and in reducing energy consumption levels, but they should not be regarded as a standalone solution. Instead, behavioural initiatives should be put in place in combination with more traditional market-based solutions.

4.1 What is the rebound effect?

The idea of a rebound effect has been a long-standing issue within the energy efficiency debate. The main discussion topic is whether reductions in energy consumption due to energy efficiency measures can be calculated by a simple engineering calculation or not, i.e. whether a 20% increase in thermal efficiency will result in a 20% reduction in aggregate energy consumption[195]. In practice, this does not happen since potential savings are partially or totally offset by various mechanisms.

Specifically, the rebound effect is associated with consumers' tendency to consume more energy due to the economic gains achieved through efficiency improvements[196]. The rebound effect is generally understood as that due to secondary effects, improvements in energy efficiency actually provide smaller reductions in energy consumption and/or material resources than anticipated, and, in some cases, may even result in a net increase[197]. For instance, after improving the insulation in a house, the residents may adjust the heating so that the average temperature in the house is higher than before. This is an example of a direct rebound effect.

It is also important to note that rebound effects in residential setting are not just a result of energy efficiency improvements such as replacing lightbulbs, but also due to behavioural changes such as reducing internal temperatures. This is because the cost saving from *sufficiency measures* will either be spent on good and services or invested, both of which will lead to energy use and GHG emissions[198].

[195] Bulus, Abdulkadir and Nurgun Topalli, 2011. Energy Efficiency and Rebound Effect: Does Energy Efficiency Save Energy? Energy and Power Engineering 3, doi: 10.4236/epe.2011.33045.

[196] Ibid.

[197] Freeman, Rachel, 2018. *A Theory on the Future of the Rebound Effect in a Resource Constrained World*. Frontiers on Energy Research, Sustainable Energy Systems and Policies. doi: 10.3389/fenrg.2018.00081.

[198] Chitnis, 2014, *Who rebounds most?*

Residents (or tenants) of the building influence energy use through their day-to-day behaviour. Such behaviour can be both adaptive, i.e., adapting to the building environment through actions such as adjusting thermostats or opening windows, or non-adaptive, i.e., utilising installed equipment and appliances[199]. For that reason, the behavioural patterns of residents greatly influence final energy consumption. Tenants are often reluctant to incur short-term costs of energy efficiency technology, even though they may benefit directly from renovation and lower energy costs.[200] This is also supported by observational studies[201].

According to the existing scientific literature, it is possible to identify the following types of rebound effects:

- ***Direct:*** for households, direct rebound effects result from increased energy consumptions – such as heating, lighting and appliances – due to the fallen associated costs as a result of improved energy efficiency[202]. The development of energy efficiency services will reduce the price of that service, however it may lead to an increase in consumption.[203] For instance, replacing traditional lightbulbs with fluorescents resulting in lower lighting costs, however residents may choose to use more lighting throughout the house or not be as vigilant switching the lights off when they are not in use. Therefore, although the efficient lightbulbs reduce the energy consumption, the increase in usage may reduce or even negate the efficiency savings.
- ***Indirect***: In contrast to direct rebound effects, indirect describes the increased consumption of other goods and services due to the net savings from the energy efficiency measures[204]. Therefore, it implies that consumers react to an energy efficiency improvement or a sufficiency-related behavioural change by increasing consumption in another area[205]. For instance, the same residents who replaced all their lightbulbs may instead use the money saved on an overseas holiday.
- ***Economy-Wide:*** the measure of the total rebound throughout a country's entire economy as a consequence of energy efficiency increases[206]. The economy-wide rebound effect is an aggregate measure of a country's direct and indirect rebound effects. They include changes in the use of energy to produce complementary and substitute goods or inputs and other flow-on effects that affect energy use across the economy as well as the direct rebound[207]. Scholars particularly argue that evidence of 33 studies suggest that economy-wide rebound effects may erode more than half of the expected energy savings from improved energy efficiency. [208]

[199] D'Oca, S., Hong, T. and Langevin, J., 2018. *The human dimensions of energy use in buildings: A review.* Lawrence Berkeley National Laboratory, Berkerley,

[200] CEPI 2010, *Landlord/Tenant Dilemma*.

[201] Andersen, R.V., et al, 2009. *Survey of occupant behaviour and control of indoor environment in Danish dwellings.* Energy and buildings, 41(1), pp. 11-16.

[202] Chitnis, Mona et al. 2014. *Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups.* Ecological Economics 106.

[203] Bulus, Abdulkadir and Nurgun Topalli, 2011. *Energy Efficiency and Rebound Effect: Does Energy Efficiency Save Energy?*

[204] Ibid.

[205] Reimers, H. et al., 2021. *Indirect rebound effects on the consumer level: A state-of-the-art literature review*. Cleaner and Responsible Consumption 3.

[206] Galvin, R. and Sunikka-Blank, M., 2016. *Quantification of (p)rebound effects in retrofit policies – Why does it matter?* Energy 95, 415-424.

[207] Stern, D. I. (2020). How large is the economy-wide rebound effect?. Energy Policy, 147, 111870.

[208] Brockway, P. E., Sorrell, S., Semieniuk, G., Heun, M. K., & Court, V. (2021). Energy efficiency and economy-wide rebound effects: A review of the evidence and its implications. Renewable and Sustainable Energy Reviews, 141, 110781.

- ***Transformational***: at a higher level, the transformational rebound effect describes how changes in technologies lead to changes in consumer preferences. This occurs when an increase in energy efficiency results in organizational and social change, which increases the demand of that product.[209] For instance, changes to business models (such as the development of e-commerce) and improvements to automation have led to increased consumption[210].

At the consumer level, one can distinguish efficiency-based and sufficiency-based rebound effects. Efficiency-based effects are most referred to as indirect rebound effects, where it can be described as a result of consumers using more energy efficient technologies, which implies that the price of this technology decreases, and consumers save money. This enables consumers to spend their savings elsewhere, which ultimately results in an increase in emissions. However, sufficiency can also contribute to rebound effects. In this case, sufficiency refers to consumers reducing consumption, generally motivated by financial savings. However, the financial savings can then lead to economically motivated indirect rebound effects. For instance, consumers who keep their home at a lower temperature to save money and reduce GHG emissions may, in turn, use the financial savings to travel by plane more often, thereby increasing emissions. Therefore, cost savings from sufficiency measures will often be spent on good and services or invested, both of which will lead to energy use and GHG emissions[211].

A significant contribution on energy sufficiency from Sorrell et, al. (2020) found that energy sufficiency actions are associated with rebounds and spillovers. The authors argued in particular that the rebound effects can minimise the expected energy and emission savings from sufficiency actions. However, they explained that sufficiency actions may have only limited impact on aggregate energy use and related emissions[212].

The figure below illustrates the concept of the rebound effect. Mechanisms including economic, psychological, and other (such as behavioural, i.e. a lack of knowledge) all contribute to direct, indirect and macroeconomic (transformational) rebound effects. Although the potential energy savings could be large, due to these mechanisms, the actual energy savings could be lower than expected. Altogether, for efficiency measures, potential savings can be calculated, however, due to behavioural changes that result from these measures, rebound effects occur, and thus resource consumption often does not decrease as much as anticipated[213].

[209] Galvin, R. and Sunikka-Blank, M., 2016. *Quantification of (p)rebound effects in retrofit policies – Why does it matter?* Energy 95, 415-424.

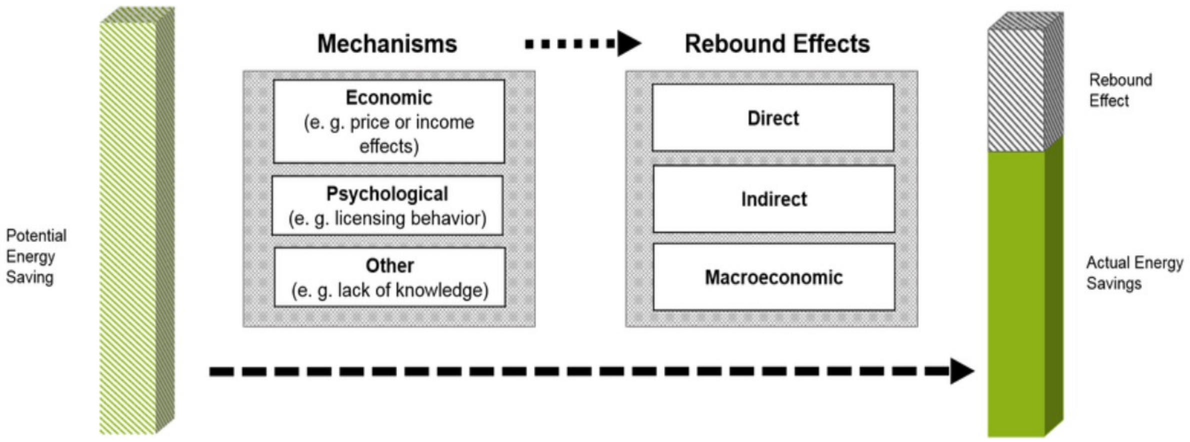
[210] Freeman, 2018, *A Theory on the Future of the Rebound Effect.*

[211] Chitnis, 2014, *Who rebounds most?*

[212] Sorell et, al. (2020). The limits of energy sufficiency: A review of the evidence for rebound effects and negative spillovers from behavioural change https://www.sciencedirect.com/science/article/pii/S2214629620300165

[213] Energy Efficiency Rebound, *What's the Rebound Effect?* *https://www.ee-rebound.de/englisch/rebound-effect/what-s-the-rebound-effect/*.

Figure 4.1 Mechanisms and rebound effects



Source: Energy Efficiency Rebound (2022).

4.2 Evidence and heterogeneity of the rebound effect in the EU

4.2.1 Quantifying the rebound effect

Despite the acknowledgement that the rebound effect exists, this is difficult to quantify. In fact, although the existence of the rebound effect is widely acknowledged, the real debate lies within the identification of the size and effect that it has on energy efficiency measures[214]. This is because measuring the rebound effect is not a straightforward process, as it involves estimating the elasticity of demand of an energy service in relation to energy efficiency[215]. Under neoclassical assumptions, the rational consumer is expected to respond to a decrease in energy prices the same way that they would respond to an improvement to energy efficiency. However, this is not always the case, as consumers tend to respond differently due to bounded rationality[216]. This is the idea that in the decision-making process, people will attempt to seek the decision that will be good enough, rather than try to optimize. Therefore, while making decisions about household efficiency, individuals might be inclined to focus on information that is prominent (even if it is not the best option) due to cognitive limitations and attentions scarcity[217].

However, several models have been developed under varying theoretical frameworks, as the estimation of the rebound effect is important due to the fact that even a low direct rebound effect can trigger high indirect rebound effects[218]. The most common way to estimate the direct rebound effect is through elasticities, and for indirect, through energy content (the amount required to implement the energy efficiency measures) and secondary effects of energy efficiency measures[219].

[214] Aydin, Erdal et al., 2017. *Energy efficiency and household behaviour: the rebound effect in the residential sector.* RAND Journal of Economics 48, no. 3.

[215] Ibid.

[216] Ibid.

[217] Ibid.

[218] Freire-Gonzalez, Jaume, 2017. *Evidence of direct and indirect rebound effect in households in EU-27 countries*. Energy Policy 102.

[219] Ibid.

While it is important to note that additional empirical research is required to obtain more homogenous estimates of the rebound effect for the individual Member States[220], the uncertainty around the numbers estimated has long been used to justify inaction[221]. However, this seems to be a mistake for the design of energy efficiency policies since a broad literature review indicates that the rebound effect is well present across EU Member States and could jeopardise the success of energy efficiency policies.

4.2.2 Heterogeneity across income levels

At the national level, a study conducted by the United Kingdom's Government in 2016 found that energy savings were reduced by 15% in the country due to the "comfort-taking" effect. This corresponds to the increase in indoor temperature as a response to energy efficiency improvements, the direct rebound effect. Another example is Ireland, which assumes a high overall rebound effect of 70% associated with the "comfort-taking" effect in low-income households when calculating the outcomes of energy saving measures[222].

Additionally, an article investigating the direct rebound effect in residential heating using a sample of 563,000 households in the Netherlands sheds light on the heterogeneity of the rebound effect. Using an instrumental variable approach, including dwelling age and the stringency of building codes at the time of construction as instruments, the authors found a direct rebound effect of 27% among homeowners, and 41% among tenants[223]. More specifically, the authors explain that if the efficiency of an average building is doubled, this leads to a 59% reduction in the energy consumption of rental dwellings and a 73% reduction in the energy consumption of owner-occupied dwellings.

Striving to explain these results, the study estimated separately the direct rebound effect for different wealth quantiles and income groups. The results show that as households become richer, the rebound effect decreases. Indeed, the direct rebound effect for the lowest wealth quantile is around 40%, while it is only 19% for the highest wealth quantile. Among tenants, the lowest income quantile presents nearly 49% of the rebound effect, while it is in the range of 38%–40% percent for the upper quantiles. These results are supported by the broader literature. Indeed, low-income households, which more often live in poorly insulated dwellings, are more sensitive to efficiency improvements as they are expected to be more cost-sensitive (having higher price elasticity). [224] In this context, scholars argue efficiency policies that specifically target energy-inefficient buildings may result in a higher rebound effect than average[225].

Interestingly, there exist some slight variations in the interpretation of the correlation between households' income and the direct rebound effect. For instance, another paper studying the correlation between the direct rebound effect and households' income in Nordic countries in the residential sector, observed that the direct rebound effect is higher for middle-class households compared to lower-class and upper-class households[226]. To the authors, this is rational since an

[220] Ibid.

[221] DCENR, 2014. National energy efficiency action plan 2014, Department of communications, Energy and Natural Resources, Government of Ireland.

[222] Vivanco, David Font, René Kemp, and Ester van der Voet. "How to deal with the rebound effect? A policy-oriented approach." Energy Policy 94 (2016): 114-125.

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

[224] ibid.

[225] Borenstein, S. (2015). "A Microeconomic Framework for Evaluating Energy Efficiency Rebound and Some Implications." Energy Journal, Vol. 36(1), pp. 1–21.

[226] Fazeli, R., & Davidsdottir, B. (2016). Correlation between Rebound Effect and Household Income. In 34th International Conference of the System Dynamics Society.

increase in the income of upper-class households is unlikely to lead to additional income used for heating, while lower-class households were found to be the most sensitive household categories to high energy expenses. [227] While these findings may vary with regard to the methodology used to compute and the geographical scope chosen, all in all, both studies allow us to conclude that wealth and income matter when looking at the energy efficiency policy of the residential sector[228].

It is important to consider that when low-income households redirect new-found savings from energy efficiency towards increased energy consumption, it allows them to heat more, or heat at all, their homes. While this results in a direct rebound effect, it also improves the overall quality of their living environment. A report from the Council of Europe Development Bank (CEB) thus argued that when poor households use the savings at their convenience, the rebound effect can be perceived as generating positive well-being outcomes[229].

4.2.3 Heterogeneity across EU Member States

Interestingly, at the EU level, spatial variations in the rebound effect were observed by several scholars. Although studies differ in their categorisation of which country experiences backfires (the most extreme case of rebound occurs when the rebound effect exceeds the value of unity i.e. energy efficiency gains render an increase in energy consumption) due to their different methodological approaches, several scholars have observed that there exists significant heterogeneity in the rebound effect. Again, this is determined by factors such as household wealth and income, and the actual energy use intensity[230] [231].

A study that evaluated the direct and indirect rebound effects in all the EU Member States (2017) found that seven countries, namely Poland, Belgium, Bulgaria, Lithuania, Sweden, Denmark, and Finland, experienced backfire, meaning that the achieved energy efficiency gains equal the increased energy consumption level, while the remaining 20 countries experienced direct and indirect rebound effects of over 50%[232]. The authors estimated that the weighted average of the overall rebound effect across the EU is between 73-82%[233]. Importantly, this research concludes that additional measures are needed to address energy efficiency even when the direct rebound effect is low to limit indirect effects such as re-spending.

A more recent European study (2021) explored the limits of energy efficiency policies in the residential sector looking at direct and indirect rebound effect[234]. Using an econometric approach toward the estimation of the rebound effect based on the ODEX index, the authors provided estimates of the overall rebound effect at the aggregate, sub-period, and country levels over the period 2000–2015. The study makes two important contributions, first, on the change of the

[227] Ibid.

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

[229] CEB (2019) Energy Poverty in Europe https://coebank.org/media/documents/CEB_Study_Energy_Poverty_in_Europe.pdf

[230] Freire-González, J. (2017). Evidence of direct and indirect rebound effect in households in EU-27 countries. Energy Policy, 102, 270-276.

[231] Baležentis, Butkus, M., Štreimikienė, D., & Shen, Z. (2021) Exploring the limits for increasing energy efficiency in the residential sector of the European Union: Insights from the rebound effect. Energy Policy, 149, 112063–. https://doi.org/10.1016/j.enpol.2020.112063

[232] Freire-González, J. (2017). Evidence of direct and indirect rebound effect in households in EU-27 countries. Energy Policy, 102, 270-276.

[233] Ibid.

[234] Baležentis, Butkus, M., Štreimikienė, D., & Shen, Z. (2021) Exploring the limits for increasing energy efficiency in the residential sector of the European Union: Insights from the rebound effect. Energy Policy, 149, 112063–. https://doi.org/10.1016/j.enpol.2020.112063

rebound effect over time, and second on the spatial variations in the direct and indirect rebound effect in the EU.

On the variation of the overall rebound effect over time, the authors found that there was a decline in the overall rebound effect from 2000 to 2015 in the EU. For the authors, this is explained by the fact that there were some improvements in energy efficiency and technological improvements over time in the household sector resulting in energy efficiency gains. This consequently reduced the rebound effect.

On the special variation of the overall rebound effect in the EU, the paper suggests that middle- or low-income countries in the EU face the most serious rebound effect[235]. For example, Bulgaria, the Czech Republic, Estonia, Hungary, Italy, Romania, Slovenia, and Spain face the most pronounced rebound effects, even leading to backfire. For the authors, the direct rebound effect plays an important role in these countries since households can increase their comfort level by using additional appliances due to increasing energy efficiency. For this reason, measures like educational campaigns, labelling, smart metering, and initiatives related to the digital economy, can create incentives to engage in sustainable behaviours and suppress the rebound effect. Yet, according to them, the most effective mitigation strategies in low- and middle-income EU countries are the labelling and standardization of the appliances connected with support measures. However, the authors specify that these countries are not likely to suppress the totality of the rebound effect in the short run.

Additionally, the same study found that partial rebound effect was observed in high- and middle-income countries such as Austria, Denmark, Croatia, Germany, Greece, Latvia, Lithuania, and Poland[236]. In these countries, initiatives like the spread of sharing economies and smart metering may appear as effective policies to improve energy conservation and environmentally friendly behaviours. This is explained by the fact that high-income countries are not likely to face substantial increases in energy consumption due to the direct rebound effect, while middle-income countries may still undergo this change.

Finally, the same study concluded that several high-income countries such as Belgium, Finland, Ireland, and Luxembourg, showed zero direct rebound effects. Although this statement may be debated in the academic community, these results show that there exists an important linkage between the level of economic development of a country and the rebound effect[237]. Hence, this is a parameter that should be considered when thinking of rebound mitigation strategies.

Table 4.1 Summary of presented estimates on the rebound effect

Reference	Geography	Time period	Indicator	Estimate
Vivanco et al (2016)	UK	2016	Direct rebound effect	15%
Irish Government	Ireland	2015	Direct rebound effect	70%

[235] Baležentis, Butkus, M., Štreimikienė, D., & Shen, Z. (2021) Exploring the limits for increasing energy efficiency in the residential sector of the European Union: Insights from the rebound effect. Energy Policy, 149, 112063–. https://doi.org/10.1016/j.enpol.2020.112063

[236] Ibid.

[237] Ibid.

Aydin et al (2017)	Netherlands	2016	Direct rebound effect among homeowners	27%
			Direct rebound effect among tenants	41%
			Reduction in the energy consumption of rental dwellings when the energy efficiency of a building is doubled	59%
			Reduction in the energy consumption of owner-occupied dwellings when the energy efficiency of a building is doubled	73%
			Direct rebound effect for the lowest wealth quantile	40%
			Direct rebound effect for the highest wealth quantile	19%
			Direct rebound effect among tenants in the lowest income quantile	49%
			Direct rebound effect among tenants in the upper income quantile	38-40%
Freire-González, J. (2017)	EU (all excluding Poland, Belgium, Bulgaria, Lithuania, Sweden, Denmark, and Finland)	2017	Direct and indirect rebound effects	Over 50%
	All EU countries		Weighted average of rebounds across the EU	73-82%
	EU (Poland, Belgium, Bulgaria, Lithuania, Sweden, Denmark, and Finland)		Direct and indirect rebound effect	100% (backfire)
Baležentis et al. (2021)	EU (Bulgaria, the Czech Republic, Estonia, Hungary, Italy, Romania, Slovenia, and Spain)	2000-2015	Direct and indirect rebound effect	100% (backfire)
	EU (Belgium, Finland, Ireland, and Luxembourg)		Direct and indirect rebound effect	0%

4.3 Mitigating the rebound effect: behaviour matters

Although the literature on rebound mitigation has been scarce to date, and efforts have generally focused on market-based solutions, some scholars have identified policy pathways that also include non-market instruments. A substantial amount of these contributions considers behavioural factors as a promising way to mitigate the rebound effect. Contrary to the traditional economic theories of consumer behaviour, contemporary contributions from the social sciences consider the social and cultural aspects of consumption[238]. This modern strand of literature argues that consumption,

[238] Jackson, T., 2005. Motivating sustainable consumption: a review of evidence on consumer behaviour and behavioural change: a report to the Sustainable Development Research Network. Centre for Environmental Strategy, University of Surrey, United Kingdom.

environmental values, and attitudes, are also culturally and socially defined[239] [240]. It generally argues that energy efficiency policies must be considered in the broader context of human behaviour and consumption trends to ensure the best possible energy savings[241]. From this standpoint, a long-term low-carbon economy may only be achievable through measures that re-evaluate behavioural and lifestyle practices[242].

Importantly, behavioural initiatives, or so-called ‘people’s centred approaches’, are not necessarily dissociated from the use of classical economic tools and technology. Rather, most scholars suggest that a better understanding and application of social and behavioural insights may offer the opportunity to catalyse and amplify technology-based energy savings. They could consequently close the gap between the expected and the actual energy savings from traditional efficiency programs[243] [244] [245].

An increasing number of evidence suggests that behaviour, lifestyle, and culture have a major impact on the energy demand from buildings. In 2009, several studies already stated that people-oriented strategies could reduce energy consumption[246] [247] [248] These notably agreed that behavioural initiatives could reduce energy consumption in both personal transportation and residential buildings by a total of 25%. Moreover, a study from the International Energy Agency (IEA) reported that behavioural actions have a sizable impact on European countries. For instance, it was estimated that in Ireland, small behavioural changes such as adjusting to indoor temperature setting, could lead to reducing energy use by 2.4 TWh per year in the case of residential buildings[249].

Khanna et al. (2021)[250] provided a more recent and valuable contribution on the subject. By performing a machine learning-assisted systematic review and meta-analysis, they comparatively assessed the effectiveness of interventions striving to reduce energy demand in residential buildings. The study concluded that behavioural interventions could lead to substantial emissions reductions in the context of the replacement or upgrade of heating and non-heating equipment, or structural changes in buildings[251]. More specifically, it estimated that behavioural actions can lead

[239] Ibid.

[240] P. de Haan, M.G. Mueller, A. (2005). Peters Does the hybrid Toyota Prius lead to rebound effects? Analysis of size and number of cars previously owned by Swiss Prius buyers Ecol. Econ., 58 pp. 592-605

[241] Sorrell, S. (2007) "The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency."

[242] Fink. (2011). Promoting behavioral change towards lower energy consumption in the building sector. Innovation (Abingdon, England), 24(1-2), 7–26. https://doi.org/10.1080/13511610.2011.586494

[243] Ehrhardt-Martinez, Karen; Donnelly, Kat A. and John A. “Skip” Laitner. (2010). “Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities.” Washington, D.C.: American Council for an EnergyEfficient Economy.

[244] Lutzenhiser, Loren. (2009). “Behavioral Assumptions Underlying California Residential Sector Energy Efficiency Programs.” Prepared for CIEE Behavior and Energy Program Oakland, CA: CIEE.

[245] Ehrhardt-Martinez, K., & Laitner, J. A. (2010). Rebound, technology and people: mitigating the rebound effect with energy-resource management and people-centered initiatives. In ACEEE summer study on energy efficiency in buildings (pp. 7-76).

[246] Laitner, John A. “Skip”, Ehrhardt-Martinez, K; V McKinney. (2009). “Examining the Scale of the Behaviour Energy Efficiency Continuum.” in ECEEE 2009 Summer Study: Act! Innovate! Deliver! Reducing Energy Demand Sustainably. La Colle sur Loup, France: European Council for an Energy-Efficient Economy.

[247] Dietz, T; Gardner, G T.; Gilligan, J; Stern, P C.; Michael P. Vandenbergh. (2009). “Household actions can provide a behavioral wedge to rapidly reduce United States. carbon emissions.” Proceedings of the National Academy of Sciences of the United States of America. Washington, DC: National Academy of Sciences.

[248] Leighty, Wayne and Alan Meier. (2010). “Short-term Electricity Conservation in Juneau, Alaska: A Study of Household Activities.” Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings.

[249] IEA (2021). The Potential of Behavioural Interventions for Optimising Energy Use at Home https://www.iea.org/articles/the-potential-of-behavioural-interventions-for-optimising-energy-use-at-home

[250] Khanna, Tarun M., et al. (2021) “A Multi-Country Meta-Analysis on the Role of Behavioural Change in Reducing Energy Consumption and CO2 Emissions in Residential Buildings.” Nature Energy, vol. 6, no. 9, pp. 925–32

[251] Ibid.

to a three- to fivefold difference in energy use for the provision of similar building-related energy service levels. This implies that addressing current growth trends in energy demand from residential buildings through behavioural change is crucial[252].

A broad literature review also indicates that nudging is a particularly promising behavioural change approach to promote pro-environmental behaviours amongst people[253]. Indeed, this type of behavioural intervention focuses on the design of choice environments that facilitate personal and socially desirable decisions [254]. It was famously defined as '*any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives*'[255].

Lades (2019) remarked that although the literature did not reveal an explicit link between nudging and the rebound effect, nudging is a promising strategy to counter the rebound effect. The author explained that initiatives like using smart meters and influencing social norms, which fall within nudging strategies, have already proven to be efficient strategies to mitigate the rebound effect[256]. Following this reasoning, several nudge-based mechanisms have been used over the years to promote residential energy efficiency[257]. For instance, 'informational nudge', in the form of feedback information, was used by Cappa et al. (2020)[258] in an energy-demand management project. It proved the effectiveness of providing feedback to citizens to lower their energy consumption. Similarly, in Singapore, the 'Project Zero Carbon', which aimed at educating primary and secondary school students on electricity use, was effective in bringing the electricity conservation message at home and influencing families' electricity behaviour[259]. Since these examples target energy use in the residential sector, one could expect to also lead to a reduction in the rebound effect.

4.3.1 Policy frameworks to mitigate the rebound effect

There exist different policy pathways and strategies to mitigate the rebound effect (direct and indirect). Interestingly, several policy frameworks rely on considerations from behavioural insights. To different degrees, they are motivated by the belief that by raising awareness about energy efficiency, one can significantly reduce the rebound effect[260] [261]. A non-exhaustive list of relevant policy frameworks is displayed in the table below.

[252] Ibid.

[253] Wee, S. C., Choong, W. W., & Low, S. T. (2021). Can "Nudging" Play a Role to Promote Pro-Environmental Behaviour?. Environmental Challenges, 5, 100364.

[254] Mertens, S., Herberz, M., Hahnel, U. J., & Brosch, T. (2022). The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioral domains. Proceedings of the National Academy of Sciences, 119(1), e2107346118.

[255] Thaler, R. H., & Sunstein, C. R. (2009). Nudge: Improving decisions about health, wealth, and happiness. Penguin.

[256] Lades , L. (2019) "Mitigating the Rebound Effect in the Residential Sector to tackle Climate Change," University College Dublin. Available at: https://doi.org/https://verimlilikkutuphanesi.sanayi.gov.tr/Library/ShowPDF/1372.

[257] Stern, P.C. (1992), ‗What Psychology Knows About Energy Conservation' American Psychologist, Vol. 47 No. 10, pp. 1224–1232

[258] F. Cappa, F. Rosso, L. Giustiniano, M. Porfiri (2020). Nudging and citizen science: the effectiveness of feedback in energy-demand management J. Environ. Manage., 269, Article 110759

[259] S. Agarwal, S. Rengarajan, T.F. Sing, Y. Yang (2017). Nudges from school children and electricity conservation: evidence from the "Project Carbon Zero" campaign in Singapore Energy Eco., 61, pp. 29-41

[260] Vivanco, David Font, René Kemp, and Ester van der Voet. (2016) "How to deal with the rebound effect? A policy-oriented approach." Energy Policy 94 114-125.

[261] J.S. Nørgaard (2008) Avoiding rebound through a steady-state economy H. Herring, S. Sorrell (Eds.), Energy Efficiency and Sustainable Consumption: The Rebound Effect, Palgrave Macmillan, Basingstoke, United Kingdom

Table 4.2 Policy pathways to mitigate the rebound effect

Scholar	Policy framework
van den Bergh (2011)[262]	(1) information provision and "moral suasion" (2) command-and-control (3) price regulation (4) subsidies (5) tradable permits
Santarius (2011)[263]	(1) efficiency standards (2) ecotaxes and absolute caps (3) sustainability communication
Maxwell et, al. (2011)[264]	(1) design, evaluation, and performance of policy instruments, (2) sustainable lifestyles and consumer behaviour (3) awareness raising and education in business (4) technology and innovation (5) economic instruments (6) new business models
Vivanco et, al. (2016)[265]	(1) recognizing the rebound effect in the policy design (2) using a broader definition of the rebound effect (3) benchmarking tools (4) sustainable consumption and behaviour (5) technological innovation (6) environmental economic policy instruments (7) new business models

Analysing policy frameworks to mitigate the direct and indirect rebound effect allow us to see that most rebound mitigation strategies are based on the idea that by informing consumer behaviour one can leverage behavioural change. These are based on the consideration that people tend to consume more than they need if they are not aware of their total consumption levels. Consequently, people should be confronted with their individual consumption patterns and be motivated to reduce the absolute consumption of energy and wider resources.

Additionally, it is important to note that most policy frameworks suggest using a combination of behavioural and economic initiatives to counter the rebound effect. Indeed, behavioural actions are not a silver bullet to the rebound effect. Rather, behavioural initiatives should be considered as part of a synergistic package to increase the effectiveness of energy efficiency policies266.

4.3.2 Behavioural actions suggested by existing policy frameworks

After mapping policy frameworks to mitigate the rebound effect, it seems relevant to give a closer look at the relevant policy pathways. Looking at Maxwell et al.'s framework is relevant since it is a comprehensive and detailed rebound mitigation framework at the EU level. It provides us with a clear vision of actions that may counter the rebound effect. These are listed below.

[262] Van den Bergh, Jeroen CJM. (2011) "Energy conservation more effective with rebound policy." Environmental and resource economics 48.1 43-58

[263] Schneidewind, Uwe. (2012) "Green Growth Unravelled-How rebound effects baffle sustainability targets when the economy keeps growing."

[264] Maxwell, Dorothy, et al. (2011) "Addressing the rebound effect." A report for the European Commission DG Environment

[265] Vivanco, D. F., Kemp, R., & van der Voet, E. (2016). How to deal with the rebound effect? A policy-oriented approach. Energy Policy, 94, 114-125.

[266] Khanna, Tarun M., et al. (2021) "A Multi-Country Meta-Analysis on the Role of Behavioural Change in Reducing Energy Consumption and CO2 Emissions in Residential Buildings." Nature Energy, vol. 6, no. 9, pp. 925–32

- *Action 1 - Smart billing and metering of electricity*: Aligned with other scholars, Maxwell et, al. advocate for the use of smart billing and smart metering of electricity. Indeed, evidence suggests that the use of smart meters and enhanced billing with additional information on consumption could significantly reduce the direct rebound effect from efficiency improvements.
- *Action 2 - Product standards, ethical standards, technical standards*: The authors argue that standards can help shape behaviour and habits when they form a framework for everyday activities and phenomena. Indeed, technical standards can help shape habits or overcome environmentally harmful habits. For example, automatic heating systems can be programmed to automatically turn down at night-time and adapt themselves automatically to the exterior temperature without the intervention of the consumer[267].
- *Action 3 – Setting positive example of role models*: The promotion of environmentally friendly behaviours through role models in business, government, schools, and other social linkages are believed to be a way to transfer pro environmental behaviours such as energy saving to consumers. For instance, opinion leaders and popular figures in society could promote a lifestyle which features a low environmental impact to re-define consumers behaviour. [268]
- Action 4 - *Behaviour-influencing initiatives with mass media campaign*: Additionally, behaviour-influencing initiatives are believed to be an effective complementary strategy to change people's behaviour. This type of action is most widely pursued through mass media campaigns. The idea is that mass media campaigns have the power to persuade and influence people in different directions to adopt an idea, attitude, or action by rational and symbolic means[269].
- *Action 5 - Fighting misleading green advertising and message causing rebound:* Finally, the authors consider that businesses and organisations might be spreading, intentionally or not, misleading messages about energy consumption and this should be considered while striving to mitigate the rebound effect. For example, in 2009, the supermarkets brand Tesco in the United Kingdom was promoting the use of new energy efficient light bulbs by offering Airmiles in exchange. This shows that mitigation strategies must also counter messages promoting harmful environmental behaviours[270].

In this policy framework, the different actions proposed impact different types of rebound effect. On the one hand, it can be argued that actions 1 and 2 will mitigate the direct rebound effect since they focus on the direct energy consumption of households. On the other hand, actions 3, 4 and 5 should impact more significantly the indirect rebound as they strive to improve people's consumption habits in general.

More recently, Vivanco et al. (2016)[271] suggested a policy framework combining seven different strategies (displayed in the previous table) as well as a combination of behavioural actions (as displayed below). Mixing traditional economic intervention with behavioural action is also backed up in the broader literature[272]. For instance, one possibility consists in combining economic instruments such as taxes with targeted technology eco-innovation to mitigate the magnitude of

[267] Maxwell, Dorothy, et al. (2011) "Addressing the rebound effect." A report for the European Commission DG Environment

[268] ibid

[269] ibid

[270] ibid

[271] Vivanco, D. F., Kemp, R., & van der Voet, E. (2016). How to deal with the rebound effect? A policy-oriented approach. Energy Policy, 94, 114-125.

[272] European Commission (2022). Environmental policy mixes have high potential, but must be handled with care. Science for policy Brief

economic rebound effects from cost differences[273]. In this context, the use of consumer behaviour actions such as consumption information and standardisation to shift consumption patterns, may strengthen the effects of carbon taxes.

According to the authors, by combining different instruments, it is possible to increase the effectiveness of energy efficiency policies. Vivanco et al. (2016) classified the different suggested actions by type of measure, as listed below:

Type of measure - Consumption information: Similarly to other scholars, Vivanco et al. (2016) suggested that an action with high potential to increase environmental awareness is to confront consumers with their individual consumption levels to reduce the direct rebound effect from efficiency improvements, especially for those products with high environmental intensity, such as heating.

- *Action 1 - smart meters*
- *Action 2 - enhanced billing*
- *Action 3 - counteracting adverts that unknowingly aggravate rebound effects.*

Type of measure - Identity signalling: Additionally, the authors recommended that signalling pro-environment values can be an effective way to promote the consumption of products associated with lower rebound effects.

- *Action 4 - valuing the adoption of environmentally sustainable behaviours and products through models*
- *Action 5 - promoting visible symbols.*

Type of measure – Standardisation: As explained in Maxwell's section, standardisation can be used to shape behaviour towards more sustainable consumption patterns in several cases and can therefore be used to mitigate the size of direct rebound effects from efficiency-oriented innovations.

Action 6 - technical standards

Action 7 - labelling standards.

Type of measure - Autonomous frugal behaviour: Finally, although this might be a difficult measure to accept socially, the authors believe that restraining and moderating individual's consumption by reducing their buying power is an effective action to mitigate the rebound effect.

Similarly to the previous policy framework, different actions may impact different types of rebound effect. Here, actions 1, 2, 6 and 7 should reduce the direct rebound effect since they target the very root of energy consumption and behaviours. The other actions may reduce both the direct and indirect rebounds because they focus on promoting environmentally friendly behaviours more generally. Hence, it is important to consider that, in the end, any policy actions striving to urge the adoption of more sustainable behaviours has the potential to minimise the indirect rebound effect.

[273] Vivanco, D. F., Kemp, R., & van der Voet, E. (2016). How to deal with the rebound effect? A policy-oriented approach. Energy Policy, 94, 114-125.

5. Consideration of behavioural factors in energy efficiency policies in residential buildings

This chapter provides an overview of how currently existing energy efficiency policy tools and initiatives take into account the behavioural factors described in the previous chapters at the EU level, national level, and local level. The aim is to identify which factors have so far been considered and addressed in existing legislation and policies, as well as to identify which ones, on the contrary, are still missing, therefore limiting the effectiveness of policies and leading to partial delivery of the expected results.

It is clear that while there is some consideration of behavioural insights in energy efficiency policies at the EU level, the majority of policy tools and initiatives are concentrated at the national and local levels. Moreover, these tend to focus on reducing daily residential energy consumption, more than encouraging investments in renovation. The main stakeholder groups addressed through existing policies are homeowners, whereas there is less of a targeted approach towards landlords, installers and contractors. While the rebound effect has been identified as a significant issue affecting residential energy efficiency, there are notable gaps in energy efficiency policies to address this important factor.

Besides presenting a review of these initiatives and analysing gaps and inconsistencies, the next sections are also dedicated to listing some best practice examples which represent successful stories and that could be potentially replicated in other contexts, for example in other Member States or at the EU level.

5.1 The inclusion of behavioural insights in energy efficiency directives and policies

Traditionally, policies related to improving energy efficiency in the residential sector have taken an exclusively economic approach in order to dictate consumer energy use. For example, there are a range of long-standing policies across the EU and at the Member State level which provide for subsidies or time-of-use energy pricing, information provision, and regulatory requirements[274].

While these regulations increase energy efficiency to a certain extent, there is a need for more holistic and well-rounded policies which also consider behavioural insights behind energy efficient choices, if the EU wants to achieve zero net emissions by 2050[275]. Behavioural insights should be equally considered alongside more traditional policy mechanisms at early stages of the policy-making process in order to boost the potential for energy efficiency[276]. To this end, the European Commission's Joint Research Centre founded the Competence Centre on Behavioural Insights specifically for this purpose, as a mechanism to support policymaking by providing evidence on human behaviour through research, expert assistance, and capacity-building[277]. The centre

[274]International Energy Agency (2021). *The Potential of Behavioural Interventions for Optimising Energy Use at Home* https://www.iea.org/articles/the-potential-of-behavioural-interventions-for-optimising-energy-use-at-home

[275] Ibid.

[276] Della Valle, N. and Bertoldi, P. (2021). *Mobilizing citizens to invest in energy efficiency*, EUR 30675 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-36152-7, doi:10.2760/137315, JRC124667.

[277] See online: https://knowledge4policy.ec.europa.eu/behavioural-insights_en

publishes materials and conducts studies covering a broad range of policy sectors, including energy[278].

Common behavioural factors which have an effect on energy efficiency in the residential sector are status quo bias, loss aversion, and framing, as presented in the previous chapters. These are typically addressed using legislative measures including the provision of information to promote behavioural change, energy performance standards, and specifically addressing the challenges faced by vulnerable consumers and those facing energy poverty[279][280]. For instance, as part of the Greek National energy efficiency Action Plan (NEEAP), the 'Energy Savings in Existing Housing Programme' launched a large-scale information campaign alongside a special holding fund for renovation with the support of several national banks, in order to tackle those who are most loss averse[281]. Nevertheless, other behavioural factors such as the hassle factor and cognitive load, have not commonly been addressed in directives and policies.

Recent revisions to EU policy and national legislation are addressing split incentives as a common barrier to energy efficiency renovation measures. Article 21 of the recast of the Energy Efficiency Directive (EED) addresses the need for solutions to split incentives between tenants and owners, or among owners[282]. France amended its tenancy law in 2009 to persuade owners to invest in renovation by allowing them to ask tenants to contribute towards energy efficiency investment costs[283]. This contribution is separate to rent obligations and cannot exceed 50% of the cost of energy savings[284]. Importantly, this can only apply when the renovations have been substantial, and the dwelling reaches a minimum Energy Performance Certificate (EPC) rating[285].

5.2 Effectiveness of including behavioural insights in policies

Currently, the majority of reports evaluating the effectiveness of policies which incorporate behavioural insights into energy efficiency policies are focused on consumption-based interventions. There is significantly less information on the impact of including behavioural insights in policies related to renovation investment decisions. Of those studies which investigate the latter, few are quantitative, resulting in little numerical evidence of the effectiveness of such policies. However, some examples are detailed below.

[278] See online: https://knowledge4policy.ec.europa.eu/behavioural-insights/topic/behavioural-insights-energy_en

[279] Trotta, G., Spangenberg, J. & Lorek, S. (2018) *Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries*. Energy Efficiency 11, 2111–2135 (2018). https://doi.org/10.1007/s12053-018-9739-0

[280] Frederiks,E, Stenner, K, Hobman, H (2015). *Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour* VOL 41 1385-1394. https://www.sciencedirect.com/science/article/pii/S1364032114007990

[281] European Commission (2017) *Energy Savings in Existing Housing Programme, Greece Case Study*. https://www.fi-compass.eu/sites/default/files/publications/Energy%20Savings%20in%20Existing%20Housing%20Programme%2C%20Greece_0.pdf

[282] European Commission, *Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on energy efficiency (recast),* 14 July 2021, COM(2021), available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0558

[283] Economidou, M., & Bertoldi, P. (2015*). Practices to overcome split incentives in the EU building stock*. In ECEEE summer study proceedings.

[284] Ibid.

[285] Ibid.

In the United States, reports have estimated that potential energy savings from behavioural interventions in the residential sectors could be as much as 16% to 20% of home energy demand[286]. Not only have behavioural interventions proved successful as a policy mechanism, but they are often more cost-effective than structural efficiency interventions by reaching a wider audience for only 20% of the implementation costs[287].

In Ireland, they estimate that behavioural interventions such as adjusting indoor temperature settings, could potentially allow the country to lower its total energy consumption by around 5% compared to its 2015 energy usage[288].

In Greece, the Energy Savings in Existing Housing Programme, while it did not exclusively target behavioural factors, renovated 51,152 residential properties from July 2010 to February 2017, with an annual domestic sector energy savings of 853 GWh[289]. The programme provided partially subsidised loans and non-repayable grants to address reluctant private investment in residential renovation, which worked alongside national information campaigns on the importance of energy efficiency. The successful implementation of this programme can be seen as an example of how residential energy efficiency investments in combination with activities to target behavioural factors can lead to greater energy savings than design efficiency interventions alone[290].

5.2.1 EU directives and policies dedicated to promoting energy efficiency

Energy Performance of Buildings Directive

As a key element of the Renovation Wave, the implementation of the Energy Performance of Buildings Directive (EPBD) has been at the forefront of the EU movement towards carbon neutrality by 2050. Within the EPBD, Member States are required to adopt a long-term renovation strategy (LTRS) which acts as a planning tool for ultimate decarbonisation of their building stock. The national long-term renovation strategies allow Member States to set out a clear agenda towards supporting the renovation of the national building stock in line with current EU goals for energy efficiency in buildings, both residential and commercial, via concrete policy measures. Generally, they contain support for improving the access to finance, technical support, advisory tools (e.g. OSSs), better information, and addressing energy poverty.

While behavioural factors are not explicitly addressed in the EPBD in relation to the long-term renovation strategies, many Member States have addressed them in their national strategies.

286 Frankel, D., Heck, S., Tai, H. (2013). *Sizing the potential of behavioural energy-efficiency initiatives in the US residential market. McKinsey & Company.* See online: https://www.mckinsey.de/~/media/mckinsey/industries/electric%20power%20and%20natural%20gas/our%20insights/giving%20us%20energy%20efficiency%20a%20jolt/sizing%20the%20potential%20of%20behavioral%20energy%20efficiency%20initiatives%20in%20the%20us%20residential%20market.pdf

287 Hibbard, P., Baker, J., Birjandi-Feriz, M., Krovetz, H. (2020). *Utility energy efficiency program performance from a climate change perspective: A comparison of structural and behavioral programs*. See online: https://www.analysisgroup.com/Insights/publishing/utility-energy-efficiency-program-performance-from-a-climate-change-perspective-a-comparison-of-structural-and-behavioral-programs/

288 Sustainable Energy and Authority of Ireland (2018). *Changing energy behaviour – what works?* See online: https://www.seai.ie/publications/Changing-Energy-Behaviour.-What-Works.pdf

289 European Commission (2017) *Energy Savings in Existing Housing Programme, Greece Case Study.* https://www.fi-compass.eu/sites/default/files/publications/Energy%20Savings%20in%20Existing%20Housing%20Programme%2C%20Greece_0.pdf

290 Ibid.

Specifically, the effect of behaviour on energy efficiency was mainly addressed through advisory tools[291].

Another key policy measure of the EPBD, particularly for consumers in residential settings, are Energy Performance Certificates. EPCs inform consumers of the energy efficiency performance of buildings to inform their renting or purchasing of property, and act as a key factor in their decision making[292]. EPCs are a beneficial tool for property-owners as well as consumers, as higher energy savings in residential buildings in Europe have resulted in significantly higher property value, according to a 2014 review of the impacts of EPCs[293]. While EPCs are designed to inform cost-effective improvements from an economic standpoint, their ability to inform consumers of the current energy saving ability of their homes can contribute towards certain drivers for renovation, such as improving living conditions. However, EPCs have been found to exhibit high levels of heterogeneity across EU Member States largely due to the national competences given in deciding the specificity of national regulations, resulting in varying levels of efficacy[294]. The competence of the certifier is one of the most influential factors in determining success in the quality and cost of EPCs across the EU, as each Member States can dictate their own training schemes and accreditations for experts[295].

Electricity Directive and Regulation (2019)

The Electricity Directive and Electricity Regulation set common rules for the internal market for electricity and notably, it provides consumers with more tools to allow them to actively participate in the energy market. There are linkages from the Electricity Directive to behavioural factors where the increased access to information on consumption can lead to positive behavioural change. However, there are doubts whether there are sufficient concrete measures set out in these legislations to lead to a significant change in energy efficiency investments, particularly without a broader consideration and incorporation of energy efficiency into markets and regulations[296].

Energy Efficiency Directive

The primary EU Directive dedicated to promoting energy efficiency is the Energy Efficiency Directive. As of 2021, there has been a proposal in place to recast the EED[297] to raise the ambitions of the targets for energy efficiency that have already been set out. The recast proposal requires Member States to reduce their energy consumption by an additional 9% by 2030 in comparison to the 2020 projection scenarios. A more recent proposal from the European Commission in May 2022 proposed to increase the additional savings to 13%, in order to reduce the reliance on non-EU fossil fuel

[291] European Commission (2022). *Commission Staff Working Document: Analysis of the national long-term renovation strategies.* See online: https://ec.europa.eu/energy/sites/default/files/swd-on-national-long-term-renovation-strategies.pdf

[292] See online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/certificates-and-inspections_en

[293] Triple E Consulting (2014). *Final Report – European Commission: Market study for a voluntary common European Union certification scheme for the energy performance of nonresidential buildings*. See online: https://energy.ec.europa.eu/final-report-building-certification-schemes_en

[294] Taranu, V., Verbeeck, G. (2018). *A closer look into the European Energy Performance Certificates under the lenses of behavioural insights—a comparative analysis.* Energy Efficiency 11, 1745–1761. https://doi.org/10.1007/s12053-017-9576-6

[295] Arcipowska, A, Anagnostopoulos, F, Mariottini, F, Kunke, S. (2014). *Energy Performance Certificates Across The EU.* BPIE. https://www.bpie.eu/wp-content/uploads/2015/10/Energy-Performance-Certificates-EPC-across-the-EU.-A-mapping-of-national-approaches-2014.pdf

[296] Rosenowabc, J, Cowarta, R,Bayera, E, Fabbrid , M. (2017). *Assessing the European Union's energy efficiency policy: Will the winter package deliver on 'Efficiency First'?* https://www.sciencedirect.com/science/article/pii/S2214629617300403

[297] Importantly, in the new EED recast it is expected to become mandatory to reach a minimum EPC level to rent/buy a property.

imports[298]. In the European Commission's recommendation to Member States for transposing the obligations of the EED, consumer behaviour is referenced as an important factor to consider when implementing energy efficient measures across all sectors[299]. The EED introduced a mandatory requirement for Member States to introduce consumption-based cost allocation and billing for water heating to incentivise consumers to engage in energy efficient practices through an increased knowledge of their usage[300]. The EED is the legal pillar for smart metres and the accurate metering and billing of energy in apartments and multi-purpose buildings in the EU, which is a crucial piece of legislation considering accurate consumption feedback has been shown to reduce final energy consumption in households by 5-10%[301].

Within Articles 12 and 17 of the EED, Member States are required to mobilise different stakeholders, including local and regional authorities, in promoting suitable information, raising awareness, and organising training initiatives to fully inform consumers of the benefits and logic behind making energy efficiency improvement measures in residential properties[302].

While behavioural factors are considered in the EED up to a certain extent, the recommendations tend to be focused on consumption-based behaviours, with a lack of consideration for behavioural influences on the renovation stage.

5.2.2 Examples of policy initiatives at the national and regional level: EU Member States and neighbouring countries

Smart meters

Policies related to the installation of smart meters in residential properties are widespread throughout the EU as a result of provisions set out in the EED and Electricity Directive. Many Member States have introduced policies at the national level to modernise and increase the uptake of smart meters[303], which can substantially increase the awareness of residents regarding their energy consumption levels. They have been shown to lead to average energy savings of 2% and savings as high as 10%[304]. Smart meters have played a central role in Finland's smart-electricity movement since legislation on their large-scale, 100% deployment came into force in 2009[305], in tandem with their state-run sustainable development company Motiva, which was founded in order to implement

[298] Council Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. (2012). OJ L 315.

[299] Commission Recommendation (EU) 2019/1658 of 25 September 2019 on transposing the energy savings obligations under the Energy Efficiency Directive. C/2019/6621.

[300] Economidou, M., Todeschi, V., Bertoldi, P., D'Agostino, D., Zangheri, P., & Castellazzi, L. (2020). *Review of 50 years of EU energy efficiency policies for buildings.* Energy and Buildings, 225, 110322.

[301] Zangheri, P., Serrenho, T., & Bertoldi, P. (2019). *Energy savings from feedback systems: A meta-studies' review*. Energies, 12(19), 3788.https://www.mdpi.com/1996-1073/12/19/3788

[302] Trotta, G., Spangenberg, J. & Lorek, S. *Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries*. Energy Efficiency 11, 2111–2135 (2018). https://doi.org/10.1007/s12053-018-9739-0

[303] Ibid.

[304] European Commission (2020). *Benchmarking smart metering deployment in the EU-28*. See online: https://energy.ec.europa.eu/benchmarking-smart-metering-deployment-eu-28_en

[305] Energiateollisuus (2017*). Finnish Energy's position on the features of next-generation electricity meters*. Position Paper. See online: https://energia.fi/files/1697/Finnish_Energy_position_paper_features_of_next_generation_electricity_meters_final_20170810.pdf

their first Energy Efficiency Action Plan in 1993[306]. Similar country-wide smart meter roll outs have been successfully carried out in Italy, Spain, and the UK[307].

The majority of national policies and programmes involving smart meter installation do not explicitly address the role of behavioural factors in the installation phase for consumers, but rather the post-installation energy consumption behaviours. The primary behavioural factors which affect smart meter installation is often loss aversion and framing where homeowners are mostly concerned with any potential losses (primarily financial in this case) rather than focusing on the benefits or gains. A Danish study showed that presenting homeowners with salient, loss-framed information reduced the demand for smart meter installation by 7-11%, in comparison with unframed information[308]. Indeed, the UK Smart Metering Energy Efficiency Advice Project's review of best practice acknowledges that loss-framed messaging tends to be more successful in engaging stakeholders[309]. However, the successful use of framing to incentivise investment in renovation is varied and context dependent, as seen in a nationally representative US study of homeowners which framed the purchase of an energy efficient furnace as a gain, loss, or saving. It showed that there was no significant difference in the likeliness to invest between the three groups[310]. While this is a non-EU example of furnaces rather than smart meters, it is clear that within the policy design context, framing can be an important factor to consider to ensure the success of home renovation programmes.

Heat pumps and upskilling

The EU has set out an ambitious target to install 20 million heat pumps in the EU by 2026, and a total of nearly 60 million by 2030. This is in recognition of the large potential for high efficiency electric heat pumps to drive the reduction in emissions from heating in the buildings sector[311]. Heat pumps have the potential to become a staple in retrofitted residential homes to improve energy efficiency. However, the high initial installation cost of heat pumps renders them a less attractive option than alternative less efficient and fossil-fuel based options. Another serious barrier to improving the energy efficiency of residential buildings is the lack of skilled workers to carry out the renovations, including heat pump installations. A UK trial study showed that poorly installed heat pumps, coupled with over-complicated usage instructions and a lack of user knowledge greatly reduced the energy efficiency potential of the devices[312]. In order to counteract this, policies or regulations on heat pump installation in Member States should include a mix of cohesive policies including pricing mechanisms to incentivise the cost saving aspect compared to traditional fossil

[306] Ministry of Economic Affairs and Employment of Finland (2019). Finland's Integrated Energy and Climate Plan. 2019:66 See online: https://energy.ec.europa.eu/system/files/2020-01/fi_final_necp_main_en_0.pdf

[307] Trotta, G., Spangenberg, J. & Lorek, S. (2018). *Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries*. Energy Efficiency 11, 2111–2135. https://doi.org/10.1007/s12053-018-9739-0

[308] Bager, S., Mundaca, L.. (2017). *Making 'Smart Meters' smarter? Insights from a behavioural economics pilot field experiment in Copenhagen, Denmark*, Energy Research & Social Science, Volume 28, Pages 68-76, ISSN 2214-6296, ttps://doi.org/10.1016/j.erss.2017.04.008.

[309] UK Government Department for Business, Energy & Industrial Strategy (2016). *Smart Metering Energy Efficiency Advice Project.* See online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/587341/Review_of_Energy_Efficiency_Advice_Best_Practice.pdf

[310] Sussman, R., Chikumbo, M., & Gifford, R. (2018). *Message framing for home energy efficiency upgrades*. Energy and Buildings, 174, 428-438.

[311] IEA (2022), *Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030*, IEA, Paris https://www.iea.org/reports/installation-of-about-600-million-heat-pumps-covering-20-of-buildings-heating-needs-required-by-2030

[312] Energy Saving Trust (2010). *Getting warmer: a field trial of heat pumps* https://energysavingtrust.org.uk/sites/default/files/EST_Heat_Pump_Trials%20part%202a.pdf

fuel systems, financial support for installation to both new and existing properties, training programmes for installers and users, and regulatory measures including appliance standards[313]. Several countries have instituted similar specific policies dedicated to upskilling installers on heat pump installations, these include but are not limited to: Austria, Croatia, Finland, Ireland, and Italy[314].

Advisory tools

Perhaps the most prevalent energy efficiency legislation across Member States is the use of advisory tools to directly address several behavioural factors such as loss aversion, inattention, and framing. Advisory tools include one-stop-shops, as well as training and information campaigns for consumers. The latter, according to a European Commission analysis of the national long-term renovation strategies, is the key mechanism in which behavioural factors are actively addressed by many Member States when promoting EERMs[315]. While almost all advisory tools offer free advice to consumers on EERMs, certain countries have programmes to train specific energy consultants to advise homeowners, including in Italy and Malta.

For example, the REACH project, which had a south-eastern European scope (Bulgaria, Northern Macedonia, Croatia, and Slovenia), was a project co-funded by the Intelligent Energy Europe Programme of the European Union centred around mobilising energy-poor households to be able to save energy via behavioural changes as well as concrete physical measures[316.] To do this, around 200 energy consultants were trained to interact with households and provide them with free advice on energy savings and examples of good practices from other EU countries, as well as providing them with free energy-saving devices. Through the energy consultants, initial and follow-up surveys of households were conducted and a large amount of data on attitudes to home renovations was collected. The project ended in 2017 and the results and main findings of the program can give important insights into the behavioural factors and their relation to energy efficiency in residential homes. One key finding was the importance and prevalence of the messenger effect[317]. Some households were reluctant to receive visits from the unknown energy consultants. However, households tended to trust other, more well-established organisations than REACH (specifically the Red Cross and Caritas) which, once cooperation with those organisations was established, the households tended to be more receptive.

5.2.3 Shortcomings and inconsistencies of behavioural insights in energy efficiency policies

Current energy efficiency policies across the EU which include behavioural insights often tend to address the reduction of daily residential energy consumption, and poorly consider policies which incentivise investment in residential renovations. This is seen through the emphasis on the installation of energy usage-tracking devices, such as smart-metres, and awareness campaigns for energy saving techniques. These are important tools necessary for the EU's roadmap towards carbon neutrality for 2050. However, in order to render them fully effective, a holistic, all-

[313] Lowes, R. Rosenow, J., Scott, D., Sunderland, L., Thomas, S., Graf, A., Baton, M., Pantano, S., Graham, P. (2022). *The perfect fit: Shaping the Fit for 55 package to drive a climate-compatible heat pump market*. Regulatory Assistance Project, Agora Energiewende, CLASP, Global Buildings Performance Network.

[314] International Energy Research Centre (IERC) (2021). *Heat Pumps Skills for NZEB Construction (HP4ALL)*: Report of best practice initiatives designed to increase the skills in the energy sector. See online: https://hp4all.eu/wp-content/uploads/2021/07/HP4ALL-D2.1-HP-Skills-Review-of-Best-Practice-V3.0.pdf

[315] European Commission (2022). *Commission Staff Working Document: Analysis of the national long-term renovation strategies.* See online: https://ec.europa.eu/energy/sites/default/files/swd-on-national-long-term-renovation-strategies.pdf

[316] See online: http://reach-energy.eu

[317] REACH (2017). *Fighting energy poverty: achievements and lessons of project REACH*. https://reachenergy.door.hr/hr/wp-content/uploads/sites/2/2017/06/D-1.1-REACH-Publishable-Report.pdf

encompassing approach is needed which implements policies at the renovation stage to ensure highly efficient homes, alongside policies which encourage efficient post-renovation behaviours and usage-tracking devices.

There are evident gaps in policies addressing certain stakeholder groups at all levels of governance. There are few policies focused on landlords and the split incentive dilemma (aside from the French Zero-rated eco-loan), where landlords are reluctant to invest in energy efficient renovation measures as they tend to be loss averse, and the property in need of renovation is often not their own primary residence.

Similarly, the overwhelming majority of the literature and policy initiatives collected concerning residential renovation was focused on the homeowner perspective, with little emphasis on targeting installers and contractors. While property owners have been identified as the key stakeholders when it comes to energy efficient renovation decision making, it is important to acknowledge the influence of installers and contractors. This is especially pertinent considering a key issue raised has been the lack of skilled workers and limited knowledge of installers and contractors. Indeed, there are national and regional level programs aimed at upskilling and training for this purpose, but this is less concretely evident at the EU level.

Most energy efficiency policies which actively incorporate behavioural insights are at the national and local levels. While some mechanisms to promote energy efficient renovation measures at the EU level also consider the barriers and drivers related to behavioural insights, such as the energy efficiency awareness measures required under the EED, they largely tend to be more generic, overarching recommendations than those that specifically include behavioural insights. In this sense, facilitating the exchange of information across countries could be a good solution to increase the transferability of the so-called best practices from national and local policy experimentations, and potentially promoting their upscale and harmonisation at the EU level.

Despite being a central issue identified in hindering the effectiveness of energy efficiency measures, there is a significant lack of evidence of the rebound effect being addressed in policies across the EU and its Member States. In order to effectively renovate the EU's existing building stock to the energy efficiency standards needed to achieve the goals of the Fit for 55 package, the rebound effect must be managed and anticipated at the policy level, to then incentivise people to invest in renovation in a successful manner.

5.3 Collection of best practice examples

This section presents a collection of best practice examples across Europe that have been collected and identified through desk research and through the interaction with the involved experts from the EIONET network. These represent good examples that help to overcome behavioural barriers and can help policy makers in designing better policies for accelerating the uptake of energy efficiency renovation measures.

Each best practice example is described in order to:

- Identify the mechanism behind the measure's implementation and behavioural change
- Link the example with the specific behavioural factors described in the previous chapters
- Assess the proved or foreseen effectiveness of the measure (and its monitoring)
- Comment on the transferability of the measure to other countries or ultimately at the EU level.

SEAI (Sustainable Energy Authority of Ireland)

The SEAI has established a dedicated Behavioural Economics Unit which specialises in encouraging behavioural change in homeowners and businesses. They have developed a clear framework for the consumer decision making process which feeds into policy making for EERMs.

Type of measure: Framework, research unit, advisory tools
Geographic level: national, local

2020 Pilot Study: Home Energy Events programme

Overview: A pilot study was conducted to assess whether hosting home energy events could increase the number and depth of energy efficiency upgrades in homes. Specifically, the study investigated the number of homeowners who moved from the awareness and engagement stage to the renovation decision-making stage.

Key actions:

- Assess the feasibility of running home energy events in Ireland, the willingness of homeowners to participate and host home energy events in their homes, and whether home energy events would have strong attendance.
- Identify potential barriers to uptake, event attendance, and investment in energy efficiency measures; and identify learnings to inform a potential expansion of the home energy event concept.
- Provide an initial assessment of the effectiveness of home energy events to stimulate investment in home energy efficiency measures.

Barriers & drivers addressed:

Drivers:

- Messenger effect/who delivers the information
- Reduced energy costs and increased energy efficiency
- Improved living conditions
- Social and environmental engagement

Barriers:

- Unclear financial benefits
- Perceived financial risk
- Unsure of outcomes

Behavioural insights addressed: The programme was specifically designed to address several behavioural barriers including information overload, availability bias, low salience of benefits/heat loss, loss aversion, social norms, trust, decision fatigue, present bias, planning fallacy, and lack of prompt/cue. Specific solutions were developed for each of these within the programme.

Results:

- High effectiveness in generating awareness and engagement among homeowners, with 96% of guests to home energy events stating that they were very or extremely satisfied with the event, and 56% saying that they were likely to install energy efficiency measures within 3 months of the event, with attic insulation installation as the most popular measure (N=64).
- There was less effective translation into renovation actions after a 3-month follow up period with only around 4% of those who received free BERs (an incentive of the home energy events) installing energy efficient measures (N=72).

SEAI (Sustainable Energy Authority of Ireland)

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Type of measure: Grant (financial support)
Geographic level: national, local

<u>2017 Deep Retrofit Pilot Programme</u>
Overview: A pilot programme was launched in 2017 to help understand how to make homes more energy efficient and reduce the overall energy demand.
The deep retrofits carried out involved:
- Reduction of heat loss through wall insulation, roof insulation, floor insulation, and window upgrades
- Installation of efficient renewable heating system, mainly an air-source heat pump
- Mechanical ventilation
- Other renewable energy technologies, such as solar panels for water heating.

Barriers & drivers addressed:
Drivers:
- Reduced energy costs and increased energy efficiency
- Improved living conditions

Barriers:
- Unclear financial benefits
- Access to finance

Behavioural insights addressed:
- Loss aversion
- Inattention
- Hyperbolic discounting

Results:
- 261 homes were renovated up to July 2019 and 100% of homes reached a BER A rating after deep renovation.
- Avg. energy savings of 36,600kWh per year per home
- Avg. reduction of CO_2 emissions of 10,160 kg CO_2 equivalent per year per home
- Avg. cost per home was €49,600. Homes meeting BER A criteria (100% of the pilot) were eligible for a grant that covered 50% of the costs of the renovation.

REACH (Reduce Energy use And Change Habits)

Bulgaria, Croatia, Macedonia & Slovenia

REACH was a project designed to address energy poverty at a practical and structural level. The purpose was to empower energy poor households to take actions to save energy and change their habits, and to establish energy poverty as an issue that demands structural solutions at local, national and EU level. The project ran from 2014 to 2017.

Type of measure: Research unit, advisory tools
Geographic level: EU, national, local

<u>2020 Pilot Study: Home Energy Event programme</u>

Overview:
REACH used a combined approach to achieve its objectives. There was a research component where the four country partners collected data and analysed specific aspects of energy poverty, including mapping the key stakeholder including local actors (such as social support services, local authorities, or schools). Around 200 energy consultants were trained to conduct home-visits to energy poor households and provide them with tailor-made advice on energy savings, provide free energy-saving devices and report good practices from other EU countries.

Key actions:
Aims:
- Compile data and analyse the energy poverty situation in the four countries in order to gain a solid definition of the state of energy poverty and to inform policy recommendations
- Engage and empower local actors to tackle energy poverty
- Empower energy poor households to reduce their energy and water use and provide some with further support when needed
- Engage decision-makers in tackling energy poverty as an issue that demands structural tailor-made solutions, provide them with recommendations for addressing the problem and create a platform for concerted formulation of structural solutions at national and EU level.

Barriers & drivers addressed:
Drivers:
- Improved living conditions
- Reduced energy costs and increased energy efficiency

Barriers:
- Unclear financial benefits
- Access to finance

Behavioural insights addressed:
- Messenger effect
- Social norms

Results: Over 200 energy consultants were trained resulting in 1,564 home-visits and over 6,650 free energy and water saving devices installed. An investment of 48,200 EUR worth of energy saving devices were installed with a device-lifetime potential savings of 840,000 EUR. At the project-wide level, device-lifetime energy savings equate to 14.17GWh or 1.218 toe, over 163.000 m3 of water and 3.747 t of CO_2.

SustaiNAVility

Navarra, Spain

SustaiNAVility was a 3-year long project with the general objective to promote, under the umbrella of the energy plan of Navarra, energy efficiency in the region of Navarra, Spain in 3 target groups: public entities (municipalities and public buildings), private buildings (citizens) and enterprises, promoting an investment of 16.3 million euros in renewable and energy efficiency. The concept of SustaiNAVility was the utilisation of regional grants as boosters or drivers of energy efficiency related investments. The project included other non-financial measures to incentivise investment in energy efficiency renovations, including through technical guides written for different target audiences.

Type of measure: Research unit, advisory tools
Geographic level: Local

Residential component
Key actions:

- Renovation of private homes was promoted in social housing neighbourhoods in 5 municipalities. Global Intervention Projects (GIPs) were established to improve the aggregation of investments in energy efficiency in buildings, which involves a group of different building types within a neighbourhood coming together to define a single design for a rehabilitation project, to be applied throughout the neighbourhood.
- Awareness days for users and consumers with the aim of educating them in the use and management of energy efficiency technologies. A total of 24 actions were carried out, in which a total of 544 people participated. Examples of specific awareness activities carried out:
    - "RESPONSIBLE CONSUMPTION AND ENERGY COMMUNITIES"
    - "CAN I REDUCE AN ELECTRICITY BILL AT HOME?"
- A series of 5 technical guides for users, consumers, and experts were prepared and disseminated
- Communication actions, such as: project website, regional TV and radio broadcast, press conferences, presentations and workshops with the industrial sector, municipalities, technicians, neighbours, media publications, participation in conferences, etc.

Barriers & drivers addressed:

Drivers:

- Crucial messenger
- Improved living conditions
- Reduced energy costs and increased energy efficiency
- Social and environmental engagement

Barriers:

- Unclear financial benefits
- Perceived financial risk
- Access to finance

Behavioural insights addressed:

- Social norms
- Inattention

Results: (for whole project, not just residential/social housing): SustaiNAVility achieved total primary energy savings of 38.18 GWh/year, and a renewable production of 2,940 MWh/year, as well as a reduction of GHG emissions of 7,303 t/CO2/year. Additionally, it identified new financing methods that could help to overcome the main barriers of the energy efficiency investments and boost their implementation.

REFURB

(REgional process innovations FOR Building renovation packages opening markets to zero energy renovations)

Belgium, The Netherlands, Denmark, Slovenia, Estonia and Germany

REFURB focused on creating One-stop-shops to bridge the gap between the building sector and homeowners. It was based around an online tool which could help homeowners overcome their lack of understanding of the benefits of refurbishing their home to be more energy efficient, as well as how to navigate the complex range of suppliers available to carry out renovations and the alternative financing options available. Dedicated renovation packages were created for different market segments and regions in Europe. The online tool helps users understand how to achieve a nearly-zero energy standard renovation, with 50 - 80% energy reduction, using a step-by-step approach.

Type of measure: Research unit, advisory tools, OSS
Geographic level: EU, national

Key actions:

- To provide private homeowners with overview, advice, and local one-stop-shop solutions in order to compensate the fragmentation of renovation offers

Barriers & drivers addressed:

Drivers:

- Crucial messenger
- Reduced energy costs and increased energy efficiency

Barriers:

- Hassle factor
- Perceived financial risk
- Unclear financial benefits
- Access to finance

Behavioural insights addressed:

- Status quo bias
- Loss aversion
- Inattention
- Framing

Results:

The main outcomes were

- Defining compelling offers for integrated nearly zero-emission building house renovation.
- Developed methodology, the toolbox and a template for creating compelling offers
- Created a database of 10 country specific and market/ownership segment including compelling offers for BE, DK, DE, NL, SI and EE.

Table 5.1 Overview of other best practice examples

Example	Details
INNOVATE *To develop and roll-out integrated energy efficiency service packages in 11 target territories*	Targeted specific barriers from the homeowner perspective when retrofitting their homes for improved energy efficiency. The project set up OSSs (incl. independent advisors) to motivate homeowners to carry out deep renovations. Key activities: • Provide pre-set, attractive renovation packages that homeowners can select from, and which can be tailored • The set-up of business solutions, among them OSSs. Drivers addressed: • Messenger effect • Reduced energy costs and increased energy efficiency Barriers addressed: • Hassle factor • Perceived financial risk • Unclear financial benefits • Access to finance Results: The project is ongoing.
Energy Hunt programme *Energy consultants*	Guidance delivered to households through energy consultants in Sweden. Key activities: • Providing energy-saving advice and tips to households via energy consultants employed by municipalities but financed via state subsidies. Drivers addressed: • Messenger effect Barriers addressed: • Hyperbolic discounting Results: • An overall energy saving of 10% • This was mostly due to behavioural changes, as all of the major home improvement measures suggested in the project were seen as expensive by the households and they either rejected or postponed the investment to later. • However, the small sample size should be taken into account (N = 10 households).
Niagara Mohawk programme *Energy education and testing the effects of behavioural interventions applied in combination with one-off installations*	In the US, the Niagara Mohawk Power Corporation ran a Power Partnerships Pilot which tested the success of energy education on energy usage, and the combined effect of behavioural interventions and one-off purchase (in this case installation of insulation or draught-proofing). Key activities: • Multi-session, comprehensive, in-home energy educations programmes • Insulation/drought-proofing installations Drivers addressed: • Messenger effect

	Barriers addressed: • Hassle factor • Access to finance Results: • Insulation/draught-proofing alone reduced average gas use by 16%. • Insulation/draught-proofing combined with energy education increased the average gas saving to 26%
SEAI heat pump guides *Provision of guides on the implementation, technology, and operation and maintenance of heat pumps for non-domestic premises; quick start guides for consumers*	The SEAI created 3 guides on heat pumps for non-domestic premises, each with a unique purpose and targeting certain actors. Additionally, they conducted research on the effectiveness of providing simplified instructions as a 'quick start guide' to consumers how owned heat pumps. Key activities: This initiative created the following guides • The Implementation Guide focuses on the decisions associated with each stage of a heat pump project • The Operation & Maintenance Guide gives information on operating a heat pump system • This Technology Guide describes in more detail the different parts of a heat pump system • A survey of 2,043 participants testing the use of a standard heat pump manual and a 'quick start guide'. Drivers addressed: • Reduced energy costs and increased energy efficiency • Messenger effect Barriers addressed: • (For installers/contractors) Limited knowledge of EERMs and lack of skilled workers • Hassle factor Results: • Participants of the survey improved performance on heat pump controls tasks by 11% on average when provided with a 'quick start guide', compared with providing them with the standard manual only. • These guides can increase the potential for heat pumps to contribute to energy efficiency in the 'after renovation' stage for residential and other properties.
Eco-bot pilot *Chat-bot tool using low-resolution smart-meter data to encourage energy efficient behaviours*	Eco-bot is a tool to monitor energy consumption for consumers and businesses using advanced signal processing (i.e. energy disaggregation) and using low-resolution smart meter data. The tool was tested in 3 European pilots involving businesses and consumers. Key activities: • Creation of a chat-bot tool to inform consumers and businesses of their energy consumption data (global and appliance level), provide recommendations to improve energy efficiency, and configure usage notifications. Drivers addressed: • Reduced energy costs and increased energy efficiency Barriers addressed: • Unclear financial benefits of EERMs

	Results: • In the 2 residential-focused pilots, 77.8% of total regular users (N = 41) actively changed their energy consumption patterns either by behavioural changes or investments in renovations/new appliances. • The residential pilots did not achieve their goals of 15% electricity and 5% heating energy savings, most likely due to the onset of the COVID-19 pandemic, however they did reduce by a small amount (<2%) indicating the pilot may have helped reduce the expected increase from COVID-19.

Low Carbon Behaviours Framework (Scottish Government)
Key behavioural framework and policymaking tool
	In 2013, the Scottish Government created a behaviours framework as part of their 'Low Carbon Scotland' initiative which identified the key behaviours to influence, outlined the Scottish Government's evidence-based approach and actions they would take, and how these actions would be monitored.
	Key activities:
	• Created the ISM (Individual, Social, Material) tool which collates insights from all fields of behavioural science and turns them into a practical tool for policymaking. It was specifically created to encompass all aspects involved in determining people's behaviours:
	  ○ Individual level: making the sustainable choice the default choice
	  ○ Social level: fostering common values and developing positive social norms
	  ○ Material level: supporting the development of technologies and infrastructure, applying relevant legislation, and influencing lifestyles towards sustainability
	Drivers addressed:
	• Reduced energy costs and increased energy efficiency
	Results:
	• After assessing the use of the ISM tool in practice, the Scottish Government acknowledged its usefulness in engaging policymakers and identifying barriers, but also that it has been less successful in developing concrete actions and policy options and needs to be further integrated into the policymaking process in the future.

Zero-rated eco-loan (Eco-prêt à taux zéro) *Loan scheme for landlords (France)*	Under the Finance Law 2009 (Loi de Finance 2009), French landlords can apply for a zero-interest loan for energy efficient renovations from €7,000 to €30,000, over 15 years. Key activities • Provision of loans for landlords Drivers addressed: • Improved living conditions • Reduced energy costs and increased energy efficiency Barriers addressed: • Split incentives Results: • 35,574 loans were granted in 2019, for an average amount of €13,342.

Informa Echo: Efficient Energy Management Ecosystem (EURE) *Various activities which inform energy policymaking in Slovenia*	The EURE is a pilot project from Informa Echo (based in Slovenia) which is based on integrating EU, national, business and citizen efforts towards reducing energy consumption. It can allow a Member State to continuously monitor energy management and support energy and environmental targets and can be adapted to the circumstances of each individual Member State. Key activities: • Survey on energy efficiency in Slovenia (REUS) to provide insights into household energy use, changes over time, and intentions to invest in home energy efficiency • Websites and social media to engage energy consumers, raise awareness, and provide advice • Web application to allow users to calculate their energy savings • Guidance for municipalities and public institutions to promote energy efficiency to consumers • Database of indicators for monitoring trends in energy management based on collected data from the above activities, to be used in all phases of policymaking. Drivers addressed: • Reduced energy costs and increased energy efficiency Barriers addressed: • Unclear financial benefits of EERMs • Unsure of outcomes of EERMs Results: REUS has been used in government policy in Slovenia for the past 15 years.
SOFIAC ***One-stop-shop service to eliminate barriers to implementing energy efficiency projects***	SOFIAC is a Canadian initiative which provides a one-stop-shop for businesses in the commercial, industrial, and multi-residential sectors to take advantage of energy efficiency and GHG emission reduction opportunities. It will soon be developed for France. Key activities: • Preselecting suppliers based on experience and innovation. The 3 types of partners involved are enterprises specialised in energy efficiency potential identification, expert firms in savings and measurement verification, and energy service companies. • Allows clients to immediately benefit from savings generated from reduced energy consumption by removing the initial investment requirement. Drivers addressed: • Reduced energy costs and increased energy efficiency, split incentive Barriers addressed: • Access to finance Results: • Current and planned SOFIAC projects are estimated to reduce GHG emissions by 20,000 tons in the next 5 years (in Canada)

6. Conclusions and policy recommendations

Based on the evidence collected and analyses presented, this chapter draws the key conclusions of the study and presents the policy recommendations to foster the uptake of energy efficiency renovation measures in EU residential buildings. Specifically, the recommendations aim to suggest policy improvements that could help addressing existing obstacles hindering the deep energy renovation rate of the EU residential building stock to be in line with the 2030 and 2050 EU energy efficiency targets, as well as highlight what complementary measures could be implemented to mitigate the rebound effect.

In addition, this chapter reflects on issues that emerged during the development of this study which warrant further investigation. The last section, therefore, presents some ideas on potential avenues for future research on the topic.

6.1 Conclusions on relevant factors influencing key stakeholders in the renovation decision process

The research conducted in this study highlighted that there is a broad range of factors influencing stakeholders' choices in their decision-making process to invest in energy efficiency renovation. Besides well-known non-behavioural factors such as imperfect information and credit constraints, behavioural factors can help us in understanding those instances in which there are deviations from the social and economic optimum that can't be explained solely through market failures (as e.g., in the case of landlords who do not benefit from energy saving investments themselves), as suggested by the more traditional neoclassical approach. When considering energy efficiency renovation in residential buildings, behavioural factors motivate those instances in which we do not observe the optimal outcome of achieving maximum energy efficiency. In other words, when the owners do not make the rational decision of investing in energy efficiency renovation, despite the economic benefits that such choice would entail.

Overall, our analysis identified a list of important factors influencing owners, installers and contractors, which act as drivers or, on the contrary, barriers to the renovation of residential buildings. The following four **drivers influencing owners** to uptake energy efficient measures were identified:

- **Improved living and building conditions**: these are among the most important drivers for owners to invest in energy efficiency renovation. It clearly emerged from the analysis that owners do value having adequate thermal comfort and indoor living conditions and are prone to make the building envelope of their house more energy efficiency to achieve these. Also, the intention to embellish their house appearance seem to motivate renovation measures among homeowners. This is particularly relevant for landlords, since renovating a building has the effect of increasing the satisfaction of tenants, minimise potential technical problems and complaints, increase the value of the property, and make it easier to rent on the market at higher prices.
- **Reduced energy costs and increased energy efficiency**: while reducing energy consumption and its related cost has only been perceived as a side benefit of a renovation, it will most likely become an important driver for owners to invest. The Russian invasion of Ukraine in 2022 generated a profound shock on energy markets and a sharp increase in the price of the most commonly used fuel for indoor heating i.e. natural gas, historically largely

imported in Europe from the Russian Federation. The salience of the resulting sudden increase in energy costs increased owners' awareness towards their energy consumption levels and the importance of being more resilient to future price shocks. This represented a learning experience for owners and one that might keep conditioning their behaviour in the future, especially for those owners who also live in their property and bear the energy bill costs.

- **Social and environmental engagement**: the more socially and environmentally engaged owners are those most likely to implement energy efficiency renovations. There is significant evidence highlighting that a sense of social responsibility, for example towards fulfilling the needs of tenants, can be a primary driver for both private and public housing companies. In particular, owners of social housing buildings show a big sense of responsibility or "moral obligation" to provide a good accommodation and housing services to their residents. Homeowners who express pro-environmental beliefs through, for example, membership in pro-environmental organisations, are also more prone to implement energy efficiency interventions. A similar conclusion can be drawn for those who engage in energy saving practices such as reducing indoor temperature/air conditioning, washing clothes more efficiently and switching off the stand-by mode on appliances.
- **The messenger effect**: owners are more prone to listen to the advice on energy efficiency renovation measures when it comes from a source they trust. Information from personal contacts such as friends and family is likely to impact more the homeowner's decision than information from other sources such as public information campaigns. Peers such as neighbours and the homeowner's community also exert a significant influence since they determine what is socially approved or considered as common behaviour. Conversely, advice from professionals such as installers and contractors seem to be of higher importance only when the owner has already decided to implement a renovation.

Other factors such as gender, age, and the level of education have been shown to impact the level of environmental engagement and the tendency to implement energy efficiency renovations. Young women show more responsibility towards environmental matters, while a high level of education has also been shown to increase the likelihood for homeowners to implement energy efficiency interventions.

The study also identified two important **behavioural factors influencing installers and contractors** on the advice they give to owners on energy efficient renovation measures, although the literature analysing these elements is rather scarce:

- **The culture and social influence of the installer's workplace**: personal commitment to energy efficiency seems, in particular, to be a key motivator for promoting energy efficiency interventions. The behaviour of other practitioners in the sector also significantly influences installers' advice and preferences.
- **The existence of a positive relationship with the suppliers**: installers tend to have relationships with one or relatively few suppliers and keep using their products. This is indeed more convenient for them instead of switching to other products, since the latter option would also entail a higher cognitive and potentially time effort to learn using the new product, even if it is the most energy efficient alternative. Hence, installers and contractors might have a strong preference for maintaining the status-quo.

Besides the two behavioural factors listed above, it is important to highlight that the **lack of skilled workers** to advice on energy efficient renovation measures is a key problematic in the construction industry limiting renovations across all EU Member States. Installers tend to be fully booked and do not have the time or incentives to develop the skills needed for energy efficient renovations. Due to the high amount of work and limited knowledge, they also might not have the cognitive ability to give effective advice on energy renovations.

The study also identified six important **barriers for owners** to uptake energy efficient renovations:

- **The hassle factor**: One of the primary barriers limiting the adoption of energy efficiency measures, especially deep renovation, is the perceived level of effort and disruption which renovation can cause in the everyday life of homeowners and residents. This relates to not only the implementation phase of the energy efficiency measures, but also to the pre-implementation phase when the owners need to invest time in collecting information (e.g. on financing sources, contracting companies, etc.) to take a decision. When the process is perceived as too lengthy or complicated, it might result in sub-optimal decisions or no decisions at all. Examples include the hassle for homeowners to apply for subsidies and loans, the burden on daily routines of residents caused by large renovation measures, and the lack of time especially for young owners. Since the financial return on energy efficiency investments is often delayed, calculating the costs and benefits is also an intricate task that might lead homeowners to not invest.
- **Lack of clarity on the financial benefits of energy efficient renovation**: owners are not sure whether the investment into energy efficient renovation is financially beneficial or not, and they have an aversion to delayed gains. Homeowners may pay more attention to the immediate investment costs than to future savings from increased efficiency. In general, owners prefer immediate rewards to long-term benefits due to hyperbolic discounting.
- **The perceived financial risk with renovation is high among owners**: the long-term nature of the benefits stemming from implementing energy efficiency measures increases the associated perceived financial risk and the uncertainties on the possibility to profit from the renovation. The large up-front cost of deep renovation represents a significant barrier for both private and public landlords, who are generally risk averse, dislike debt, and prefer to avoid the organisational burden of large investments.
- **Wrong beliefs on the outcomes of renovation**: many owners are unsure about the outcomes of renovation, and fear that implementing it might negatively impact the building quality or generate health risks, particularly for children.
- **Split incentives**: the most common form of split incentive is the efficiency-related split incentive which refers to when the resident is in charge of the energy bill but cannot make the decision on what energy efficient measure to carry out (i.e. the landlord-tenant dilemma). The fact that owners of buildings are the ones to undertake the renovation investment, and tenants the ones to benefit from reduced energy savings, gives rise to a split-incentive.
- **Access to finance and the level of income**: Low-income households, in particular, have more difficulties in accessing financing to perform renovation, as often they are not eligible for the types of loans offered. In addition, residents with low income tend to have little control over their energy use, which causes a vicious circle between high energy bills and the struggle to pay them.

6.2 Conclusions on the role of behavioural factors in mitigating the rebound effect

After having reviewed the literature analysing the direct and indirect rebound effect in the EU and the potential policy frameworks to mitigate it, it is possible to draw the following conclusions:

- Generally, although numbers on the rebound effect lack precision and consistency, there seems to be enough evidence showing that the rebound effect, especially the direct one, is an essential element to consider when designing energy efficiency policies and energy efficiency improvements. Indeed, the literature extensively encourages policymakers to incorporate considerations for the direct rebound effect into the assessment of the outcomes of energy efficiency improvement measures and programs[318]. This is specifically true for the residential sector, where significant rebound effects have been observed across Europe.

- There exists heterogeneity in the direct rebound effect, across countries and across income levels, and identifying such variation may contribute to better assessing the potential outcomes of energy efficiency policies in the residential sector[319]. Hence, it is important to consider the two following factors:
    - On the one hand, the literature suggests that poorer households experience a higher direct rebound effect[320]. While this may vary across countries, these contributions suggest that income matters when looking at energy efficiency policy of the residential sector[321].
    - On the other hand, some scholars suggest that the overall rebound effect occurs more in middle- or low-income countries in the EU[322]. While this may be subject to academic debate, these findings suggest that there exists an important linkage between the level of economic development of a country and the rebound effect.
- Behavioural considerations must be at the centre of any strategy striving to reduce the direct as well as the indirect rebound effect. These can be pursued through several different initiatives and actions including smart meters, communication campaigns, and standardisation.
- Finally, behavioural initiatives should not be regarded as standalone solutions to the rebound effect. Rather they should be considered as part of a synergistic package to increase the effectiveness of energy efficiency policies[323]. Each policy framework striving to mitigate the rebound effect should rely on a combination of economic and behavioural factors.

6.3 Recommendations for implementing behaviourally informed policies to boost the renovation rate and decrease energy consumption

This section presents recommendations for the development and design of behaviourally informed policies to boost the renovation rate and decrease energy consumption in residential buildings.

6.3.1 Improving the effectiveness of energy efficiency policies

Traditionally, policies related to improving energy efficiency in the residential sector have taken an exclusively economic approach in order to dictate consumer energy use. While these regulations are often successful and increase energy efficiency to a certain extent, there is a need for more holistic and well-rounded policies which also consider behavioural insights behind energy efficient

[318] Aydin, Kok, N., & Brounen, D.. (2017) Energy efficiency and household behaviour: the rebound effect in the residential sector. The Rand Journal of Economics, 48(3), 749–782. https://doi.org/10.1111/1756-2171.12190

[319] Ibid.

[320] Ibid.

[321] Ibid.

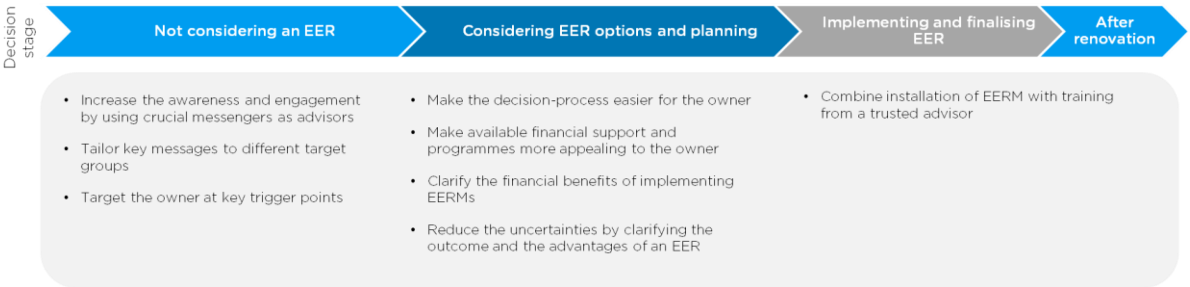
[322] Baležentis, Butkus, M., Štreimikienė, D., & Shen, Z. (2021) Exploring the limits for increasing energy efficiency in the residential sector of the European Union: Insights from the rebound effect. Energy Policy, 149, 112063–. https://doi.org/10.1016/j.enpol.2020.112063

[323] Khanna, Tarun M., et al. (2021) "A Multi-Country Meta-Analysis on the Role of Behavioural Change in Reducing Energy Consumption and CO2 Emissions in Residential Buildings." Nature Energy, vol. 6, no. 9, pp. 925–32

choices, if the EU wants to achieve net zero emissions by 2050. Behavioural insights should indeed be equally considered alongside more traditional policy mechanisms at early stages of the policy-making process to boost the potential for energy efficiency in residential buildings and decrease energy consumption in the post-renovation phase.

There is a potential for policymakers to improve existing policies, regulations and standards to increase energy efficient renovations by using behaviourally informed measures, despite the lack of evidence. Below, we list a few examples on how behavioural insights can be used in future policy measures, which are based on the best-practice examples identified, but also commonly used behavioural insights tools.

Figure 6.1 Possible measures to address identified barriers and drivers



Increase the awareness and engagement by using crucial messengers as advisors

Policymakers should focus on promoting among homeowners the adoption of energy efficiency measures and increasing awareness on the benefits of renovation, while debunking incorrect beliefs about the outcomes and benefits of renovation. However, **besides using information campaigns through mass media, policymakers could leverage existing or new policies by using influential stakeholders as crucial messengers**. This could be done for example by providing free advice on energy savings and examples of good practices to homeowners not only via trained energy consultants and companies, but also via local communities and well-established organisations, for example charities and local associations. As demonstrated by the REACH project, owners tend to trust and be more receptive towards local and well-established organisations such as the Red Cross and Caritas, while they are less prone to listen to the advice provided by sources they don't know. This practice could also help in reducing the uncertainties towards the benefits of energy efficiency renovation measures.

Tailor key messages to different target groups

While awareness campaigns should aim at describing what the homeowner would gain from making an energy efficiency renovation intervention and hence reduce its associated uncertainties, these should also be tailored to specific target groups. First of all, among homeowners, there is substantial evidence highlighting that gender, age, and the level of education are important determinants of the tendency to implement renovation. On one hand, **communication campaigns should be directed towards the profiles that are more prone towards environmentally friendly behaviour and energy efficiency interventions**, for example well-educated women. On the other hand**, policies for the more difficult to reach groups should be tailored to overcome the barriers they face**. For example, step by step renovations should be promoted among young homeowners and tenants since they are less costly and easier to implement, while large renovations suit better the daily routine of older homeowners. However, step by step solutions should be implemented only with the aim of achieving deep renovation and, therefore, avoiding lock-in into less efficient renovations. Secondly, property owners can be of different types (e.g. residents, small landlords, real estate companies, etc.), have different needs, and face different obstacles. For instance, for large property owners, increasing the value and profitability of their stock may be a key message in the communication. For this reason, **different instruments need to be used in combination to effectively alleviate energy efficiency barriers**, for example by combining regulation and financial incentives with effective communication.

Target the owner at key trigger points

Most homeowners take a decision to invest in renovation of their house, especially deep renovation, at key trigger points, for example at the end-of-life replacement of a heating system or other major piece of equipment, when taking out a mortgage or during a major building renovation (initially for reasons other than energy efficiency). For a shallow retrofit such as a draught-proofing, this could be related to a minor renovation such as redecoration of a room. In this sense, **policymakers should target energy efficiency interventions concurrently with these trigger points or crucial life events**, for example introducing incentives for performing renovation when buying a new property, while combining this with target group tailored financial instruments.

Make the decision-making process easier for owners

The hassle factor serves as a major barrier for owners, both for homeowners and landlords, and there is a major need of a simplification of the decision-making process and reduction of the perceived or actual effort involved. This requires removing all potential barriers that might induce the owners to not proceed with the investment in renovation, for example by **simplifying the administrative procedure to apply for subsidies or loans and by adapting it to the needs of the specific target group**, whether it is for private or public owners. As showed by the ReFURB project, providing a full end-to-end service via **one-stop-shops** offering a choice of tailored financial advice and renovation packages to different target groups (e.g. young families, empty nesters, etc.) can help the owners in accessing all the required information in a single place (e.g. on an website) and significantly simplify the owners' decision-making process. Clearly, the one-stop-shop needs to be **tailored to the target group**, for example relying on websites and internet tools for younger homeowners and setting up physical contact points for older people, as well as business-to-business communication to real estate companies. Another practice that proved to be effective to reduce the hassle for private and public landlords is to perform step by step renovations, as this procedure suits better the needs of tenants. Moreover, facilitate the execution of the renovation works by supporting the owners to find reliable contractors and craftsmen.

Make available financial support and programmes more appealing to the owners

The financially related barriers identified in the study, such as perceived financial risk and uncertainty of the benefits, could be addressed by making available financial support and programmes more appealing to the owners, by clarifying the benefits and mitigating the perceived risk for the owners. Besides the previously listed solutions related to the simplification of the administrative process to access financial support, **innovative solutions aimed at ensuring clear guidance for homeowners on what institutions can provide financial support for energy efficient renovations** could also be useful to increase adoption rates. An example of this is the SustaiNAVility project in Spain, where attractive regional grants were used as boosters or drivers of energy efficiency related investments, in projects incorporating the state of the art in technology and new funding schemes. To make the investment more appealing to homeowners, one possible intervention would also involve the creation of **incentives to reduce the up-front cost** (e.g. installation cost), which is often perceived as the greatest barrier for investing in renovation.

Clarify the financial benefits of implementing energy efficiency renovation measures

The up-front cost of performing a renovation is a major barrier to energy efficiency uptake in residential buildings since owners do not fully understand future energy cost savings from increased efficiency, and only pay attention to the immediate investment cost. While this phenomenon is well-known in the literature, **policymakers should prioritise the communication aimed at highlighting the energy cost savings that can be realised with renovation**. The current energy crisis in Europe represents a window of opportunity since, on one hand, energy efficiency represents an important leverage to increase the energy independence of the EU, and on the other hand, people are becoming more aware of the importance of being more resilient to future price shocks, as they are directly facing the impact of skyrocketing energy prices on their energy bills. This is particularly true for homeowners, but landlords might also experience more pressure from their tenants to implement energy efficiency measures.

Reduce the uncertainties by clarifying the outcome and the advantages of renovation

The energy use and costs before and after implementing a renovation should be made more transparent. While energy performance certificates offer a valuable tool for understanding the energy performance of a building during sale and lease transactions, the information provided in the certificate does not directly determine the energy related operating expenses for the user with or without renovation. **More transparent information can lead to more informed decisions and incentivise owners to invest at key trigger points**. In this sense, policymakers could ask utility companies to include on each energy bill the amount of energy and the corresponding cost saving that could be achieved if the energy class of the dwelling is improved.

Combine installation of energy efficiency renovation measures with training from a trusted advisor

Training is an essential aspect that can significantly help in achieving energy and emission reductions from energy efficiency renovation measures. On one hand, **training provided to the user at the same time as the adoption of new technology** (or other energy efficiency interventions) **has been proven to be effective to address the rebound effect after the renovation**. Evidence shows that combining education on energy savings behaviour and on how to use the new installed product is more effective on reducing energy consumption compared with when only installation is made. One the other hand, **training provided to the workers carrying out the renovation ensures that the energy efficiency measure is implemented correctly, and its benefits are realised**. The lack of skilled workers among installers and contractors in some cases can lead to poorly installed renovation and renewable technologies such as heat pumps, therefore reducing the energy efficiency potential of the devices. To counteract this, policies should include training programmes for installers as well as appliance standards.

6.3.2 Mitigating the rebound effect in the post-renovation phase

Besides influencing the decision-making process of investment in energy efficiency of residential houses, **behavioural factors represent a promising way to mitigate the direct and indirect rebound effect after the renovation is made**. Indeed, an increasing number of evidence suggests that behaviour, lifestyle, and culture have a major impact on the energy demand from buildings, and that promoting pro-environmental behaviours, in particular **raising awareness about energy efficiency, can counter the direct and indirect rebound effect**. Again, peers such as neighbours and the homeowner's community also exert a significant influence since they determine what is an approved social practice and considered as appropriate behaviour.

On one hand, this can be achieved through regulation promoting adoption of **smart meters and enhanced billing** with additional information on energy consumption levels, which have been shown to reduce the direct rebound effect from efficiency improvements. **Setting product and technical standards**, for example for different types of energy efficiency renovation interventions, can also help in minimising the risk of implementing counterproductive and low-quality renovations.

On the other hand, behaviour-influencing initiatives are believed to be an effective complementary strategy to promote environmentally friendly behaviours. This type of action can be pursued through **mass media campaigns**, by setting **pro-environmental role models**, and by **confronting consumers with their individual consumption levels** to reduce the direct and indirect rebound effect from efficiency improvements and foster the exchange about measures taken and their success. However, there is mix evidence on traditional informational campaign effect on actual behaviours. Informational campaigns could therefore be accompanied with policy-measures that guide the target group in the decision-making moment.

Importantly, policy pathways to mitigate the rebound effect recommend that **behavioural initiatives should not be regarded as a standalone solution to the rebound effect**. Rather, they should be considered as part of a synergistic package to increase effectiveness of energy efficiency policies. Hence, policy frameworks to mitigate the rebound effect usually **rely on a combination of economic and behavioural actions**.

6.4 Identified data gaps and avenues for future research

A key finding of the study is the lack of research available analysing how behavioural insights can be used to increase the uptake of energy efficiency renovation measures, in particular deep energy renovation. Partially, this is due to the relative novelty of the topic, especially when applied to energy efficiency in residential buildings. Besides the research gap in the scientific literature, this aspect is also indicating that there is a limited number of elaborated policy instruments to address the behavioural barriers that lead to a lower than expected delivery of energy efficiency in buildings policies.

To help filling this gap and raise awareness among policymakers at all levels, we identified a few areas of research that could benefit from further investigation from academic, research institutes, NGOs, and international organisations:

- Further research should be undertaken to study owners' decision-making and the role played by behavioural factors in a renovation process (including deep renovation), for example conducting more behavioural insights studies on actual behaviours and use randomised control trials to evaluate the effect.
- The majority of studies evaluating the effectiveness of policies which incorporate behavioural insights are focused on consumption-based interventions. There is significantly less information on the impact of including behavioural insights in policies related to renovation investment decisions. Of those studies which investigate the latter, few are quantitative, resulting in little numerical evidence of the effectiveness of such policies. Given the raising number of policy experiments incorporating behavioural insights at the national, regional and local levels, further research should be promoted on analysing the factors that determine the success of these experiences.
- Due to the limited number of studies, it is not possible to make any clear distinctions on whether the identified factors vary between different renovation types such as standard renovations and deep renovation. While all identified drivers and barriers are relevant regardless of the scale of renovation, the bigger the renovation, most likely the greater the barriers to overcome. Given the urgent need to promote deep renovations in residential

buildings to accelerate climate mitigation and avoid locking higher emissions for decades, additional targeted research should be promoted on deep renovation and the knowledge shared with policymakers at EU, national and local levels.

- Increase knowledge, awareness, and application of frameworks (such as the BASIC framework developed by the OECD) to provide guidelines to policymakers for applying the behavioural approach in energy efficiency policy. This would help policymakers in adapting policy initiatives to actual human behaviour and incorporate evidence-based insights from the different fields of behavioural science, such as social and cognitive psychology.

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ANNEX – METHODOLOGICAL APPROACH

The methodology adopted in this study is a mix of literature reviews, interviews with experts, workshops, and desk research.

To create a comprehensive understanding of the situation regarding **energy efficiency progress/gap/potential** in the residential sector in the EU, the project team reviewed relevant literature from academic publications, reports from research institutes and international organisations, and grey literature using a Rapid Evidence Assessment (REA). This initial review was framed around four main research questions:

- What is the meaning of 'energy efficiency gap'?
- What are the differences between the neoclassical and the behavioural economic approaches?
- What are the main behavioural and non-behavioural factors influencing the uptake of energy efficiency measures in residential buildings?
- What is the current situation of energy efficiency uptake in the EU residential sector?

The answers to these questions are based on a systematic review starting with identification of search terms, literature search, screening of the initial results, compilation of a list of sources and development of a review structure.

After having framed the big picture around energy efficiency in residential buildings in Europe, the following step involved a **mapping exercise of the stakeholders involved in the renovation process** of residential houses with the aim of shortlisting the most crucial ones, as their decisions determine the uptake of efficient renovation actions. This activity was performed via a series of explorative interviews with experts that have a good understanding and are directly involved in the renovation process, for example owners' associations, installers, contractors, and citizens' associations.

The insights gained through the interviews have then been complemented with an additional literature review aimed at identifying studies describing the **different actors (and their decisions) involved in the renovation process**. Context dimensions of the problematics and well-known existing issues of residential buildings investment in energy efficiency have been taken into account in the decision process, notably the effect of the type of ownership (landlord/tenant), the type of buildings (social housing, individual houses, etc.), and the type of renovation (e.g. standard renovation vs one shot deep renovation) on energy efficiency.

In parallel, the project team also completed a literature review on the **rebound effect** in residential buildings to increase the level of understanding around the consumption behaviour of key actors, notably the residents, after the renovation of the building has been made. The EEA's technical report on achieving energy efficiency through behaviour change (2013)[324] was consulted in order to determine the basis for evaluation regarding the rebound effect. A mix of qualitative and quantitative literature was selected based on the relevance of the articles to the following guiding research questions:

- What is the meaning of 'rebound effect' and what are the differences between 'direct', 'indirect', and 'economy-wide' rebound effect?
- What is the size of the rebound effect in the EU residential buildings sector?

[324] European Environment Agency (2013). Achieving energy efficiency through behaviour change: what does it take? EEA Technical Report No 5/2013.

- What are the factors affecting the rebound effect (e.g. energy prices, change in energy efficiency performance, energy performance level, income, demography and lifestyle, energy poverty)?
- Does the rebound effect influence the energy-saving potential in the residential sector?
- How do behaviours of people influence the size of the rebound effect in the residential sector? How can behavioural factors mitigate the rebound effect?

Finally, with the idea of mapping **how behavioural factors are considered into existing energy efficiency policies** in buildings, the project team reviewed the literature and existing assessments analysing how current European, national and local policy developments take or, on the contrary, do not take into account strategic behavioural factors, leading in some cases to ineffective policy or partial delivery of the expected results. The research questions that guided the review are the following:

- What are the energy efficiency policies and directives that consider behavioural factors?
- How are behavioural factors incorporated into the energy efficiency policies for buildings?
- Are the policies considering behavioural factors more effective than those that do not consider them?
- Are there successful examples at the national and/or local level that take into account the behaviour of actors such as owners and residents?
- What are the behavioural factors most commonly considered in energy efficiency policies for buildings?
- What are the factors that are overlooked in existing energy efficiency policies for residential buildings?

As part of this exercise, examples of **best practice initiatives** across Europe were collected with the idea of identifying options to develop innovative and effective policy mechanisms considering behavioural factors, which could complement or substitute existing policies. The best practice examples were collected with the help of the experts from the EIONET network[325] who responded to the questionnaire designed for the purpose by the project team. Additional examples were also collected through the literature review.

[325] The European Environment Information and Observation Network (EIONET) is a partnership network of the EEA and its 38 member and cooperating countries, including about 400 national institutions providing expertise in fields such as climate change adaptation, climate change mitigation, circular economy, sustainability transitions. More information is available at: https://www.eionet.europa.eu/

ANNEX – LITERATURE ON DRIVERS AND BARRIERS

Table 6.1 Identified literature on drivers and barriers

Driver of barrier	Reference	Geographical scope
Improved living conditions is a key driver for owners to implement EERMs	Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. (2011). *Barriers and drivers to energy-efficient renovation in the residential sector*. Empirical findings from five European countries. ECEEE Report.	EU
	Klöckner, C. A., & Nayum, A. (2016). Specific barriers and drivers in different stages of decision-making about energy efficiency upgrades in private homes. Frontiers in psychology, 7, 1362.	Norway
	Sustainable Energy Authority of Ireland, Behavioural insights on energy efficiency n the residential sector. Available at:https://www.seai.ie/publications/Behavioural-insights-on-energy-efficiency-in-the-residential-sector.pdf	Ireland
	Nair, G., Gustavsson, L., & Mahapatra, K. (2010). Factors influencing energy efficiency investments in existing Swedish residential buildings. Energy Policy, 38(6), 2956-2963.	Sweden
	Baumhof, R., Decker, T., Röder, H., & Menrad, K. (2018). *Which factors determine the extent of house owners' energy-related refurbishment projects? A Motivation-Opportunity-Ability Approach*. Sustainable cities and society, 36, 33-41.	Germany
	Druta, O., Schilder, F., & Lennartz, C. (2021). Home improvements in later life: competing policy goals and the practices of older Dutch homeowners. International Journal of Housing Policy, 1-21.	Netherlands
	Femenías, P., Mjörnell, K., & Thuvander, L. (2018). *Rethinking deep renovation: The perspective of rental housing in Sweden*. Journal of cleaner production, 195, 1457-1467.	Sweden
Reduced energy costs and increased energy efficiency	Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. American economic review, 93(5), 1449-1475.	NA
	Novemsky, N., & Kahneman, D. (2005). The boundaries of loss aversion. Journal of Marketing research, 42(2), 119-128.	NA
	Aravena, C., Riquelme, A., & Denny, E. (2016). *Money, comfort or environment? Priorities and determinants of energy efficiency investments in Irish households*. Journal of consumer policy, 39(2), 159-186.	Ireland
	Ademe. (2008)., *Observatoire permanent de l'Amélioration Energétique du Logement* (OPEN): 2007 campaign results	France
	Gram-Hanssen, K., Bartiaux, F., Jensen, O. M., & Cantaert, M. (2007). Do homeowners use energy labels? A comparison between Denmark and Belgium. Energy Policy, 35(5), 2879-2888.	Denmark Belgium
	Femenías, P., Mjörnell, K., & Thuvander, L. (2018). *Rethinking deep renovation: The perspective of rental housing in Sweden*. Journal of cleaner production, 195, 1457-1467.	Sweden

Social and environmental engagement	Mjörnell, K., Femenías, P., & Annadotter, K. (2019). *Renovation strategies for multi-residential buildings from the record years in Sweden—Profit-driven or socioeconomically responsible?*. Sustainability, 11(24), 6988.	Sweden
	Hartmann, A., Reymen, I. M., & Van Oosterom, G. (2008). *Factors constituting the innovation adoption environment of public clients*. Building research & information, 36(5), 436-449.	Netherlands
	Klöckner, C. A., & Nayum, A. (2016). *Specific barriers and drivers in different stages of decision-making about energy efficiency upgrades in private homes*. Frontiers in psychology, 7, 1362.	Norway
	Ameli, N. & Brandt, N., 2015. *Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes*. Environmental Research Letters 10 (2015) 044015.	EU
	Ipsos. 2018. Uncover the underlying motivations and barriers for energy efficient renovations: Report for European Climate Foundation. https://europeanclimate.org/wp-content/uploads/2019/11/12-03-19-uncover-the-underlying-motivations-and-barriers-for-energy-efficient-renovations.pdf (Viewed 2022-10-11)	EU
	Nair, G., Gustavsson, L., & Mahapatra, K. (2010). *Factors influencing energy efficiency investments in existing Swedish residential buildings*. Energy Policy, 38(6), 2956-2963.	Sweden
Who delivers information about EERMs	McMichael, M., & Shipworth, D. (2013). *The value of social networks in the diffusion of energy-efficiency innovations in UK households*. Energy Policy, 53, 159-168.	UK
	Ipsos. 2018. Uncover the underlying motivations and barriers for energy efficient renovations: Report for European Climate Foundation. https://europeanclimate.org/wp-content/uploads/2019/11/12-03-19-uncover-the-underlying-motivations-and-barriers-for-energy-efficient-renovations.pdf (Viewed 2022-10-11)	EU
	SEAI. *Behavioural insights on energy efficiency in the residential sector.* https://www.seai.ie/publications/Behavioural-insights-on-energy-efficiency-in-the-residential-sector.pdf (Viewed 2022-10-11)	Ireland
	Arning, K., Zaunbrecher, B.S. and Ziefle, M., 2019. The influence of intermediaries' advice on energy-efficient retrofit decisions in private households. ECEEE Summer Study Proceedings, June, pp. 1177-1188.	NA
	Owen, A., Mitchell, G. and Gouldson, A., 2014. Unseen influence: The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology. Energy Policy 73, pp. 169-179.	UK
	Wade, F., Hitchings, R. and Shipworth, M., 2016. Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom. Energy Research & Social Science 19, pp. 39-47.	
	Hrovatin, N., & Zorić, J. (2018). *Determinants of energy-efficient home retrofits in Slovenia: The role of information sources*. Energy and Buildings, 180, 42-50.	UK

	Allcott, H. (2011). Social norms and energy conservation. Journal of public Economics, 95(9-10), 1082-1095. Horne, C., & Familia, T. (2021). *Norms, Norm Sets, and Reference Groups: Implications for Household Interest in Energy Technologies*. Socius, 7, 23780231211039035. Haque, A. N., Lemanski, C., & de Groot, J. (2021). *Why do low-income urban dwellers reject energy technologies? Exploring the socio-cultural acceptance of solar adoption in Mumbai and Cape Town*. Energy Research & Social Science, 74, 101954. Palm, A. (2016). *Local factors driving the diffusion of solar photovoltaics in Sweden: A case study of five municipalities in an early market*. Energy Research & Social Science, 14, 1-12.	Slovenia US US India Sweden
Hassle factor	de Vries, G., Rietkerk, M., & Kooger, R. (2020). The hassle factor as a psychological barrier to a green home. Journal of Consumer Policy, 43(2), 345-352. DECC. (2013). *Removing the hassle factor associated with loft insulation*: Results of a behavioural trial. London: Department of Energy and Climate Change Allcott, H., & Mullainathan, S. (2010). Behavior and energy policy. Science, 327(5970), 1204-1205. DECC. (2011). Understanding Potential Consumer Response to the Green Deal. London: Department of Energy and Climate Change Hrovatin, N., & Zorić, J. (2018). *Determinants of energy-efficient home retrofits in Slovenia: The role of information sources*. Energy and Buildings, 180, 42-50. Judson, E. P., & Maller, C. (2014). *Housing renovations and energy efficiency: insights from homeowners' practices*. Building Research & Information, 42(4), 501-511. Abreu, M. I., de Oliveira, R. A., & Lopes, J. (2020). Younger vs. older homeowners in building energy-related renovations: Learning from the Portuguese case. Energy Reports, 6, 159-164. März, S. (2018). *Beyond economics—Understanding the decision-making of German small private landlords in terms of energy efficiency investment*. Energy Efficiency, 11(7), 1721-1743. Mjörnell et al Rethinking deep renovation: The perspective of rental housing in Sweden https://www.sciencedirect.com/science/article/abs/pii/S0959652617332766	NA UK NA UK Slovenia NA Portugal Germany Sweden

Financial benefits of EERM are not clear	Della Valle, N., & Bertoldi, P. (2021). Mobilizing citizens to invest in energy efficiency. EUR–Scientific and Technical Research Reports. Ispra: Joint Research Centre.	EU
	Kok, N., Miller, N., & Morris, P. (2012). *The economics of green retrofits*. Journal of Sustainable Real Estate, 4(1), 4-22.	NA
	Laibson, D. (1997). *Golden eggs and hyperbolic discounting.* The Quarterly Journal of Economics, 112(2), 443-478.	US
	International Energy Agency, 2020. Behavioural insights for demand-side energy policy and programmes. . https://userstcp.org/news/behavioural-insights-for-demand-side-energy-policy-and-programmes-report-published/	Global
	Jan Paul Baginski, Christoph Weber, *A consumer decision-making process? Unfolding energy efficiency decisions of German owner-occupiers*. HEMF Working Paper 08/2017. 2017.	Germany
	Femenías, P., Mjörnell, K., & Thuvander, L. (2018). *Rethinking deep renovation: The perspective of rental housing in Sweden*. Journal of cleaner production, 195, 1457-1467.	Sweden
	Hope, A. J., & Booth, A. (2014). *Attitudes and behaviours of private sector landlords towards the energy efficiency of tenanted homes*. Energy Policy, 75, 369-378.	UK
	März, S. (2018). *Beyond economics—Understanding the decision-making of German small private landlords in terms of energy efficiency investment*. Energy Efficiency, 11(7), 1721-1743.	Germany
	Nik, V. M., Mata, E., Kalagasidis, A. S., & Scartezzini, J. L. (2016). Effective and robust energy retrofitting measures for future climatic conditions—Reduced heating demand of Swedish households. Energy and Buildings, 121, 176-187	Sweden
Owners are often unsure of the outcome of EERMs	März, S. (2018). *Beyond economics—Understanding the decision-making of German small private landlords in terms of energy efficiency investment*. Energy Efficiency, 11(7), 1721-1743.	Germany
	Azizi, S., Nair, G., & Olofsson, T. (2020). *Adoption of Energy efficiency measures in renovation of single-family houses: A Comparative approach*. Energies, 13(22), 6042.	Sweden
Split incentive	CEPI 2010, Landlord/Tenant Dilemma,	EU
	Ameli, N. and Brandt, N., 2015. *Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes.* Environmental research letters 10 044015.	EU
	Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. (2011). Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report.	Germany, Switzerland, Italy, Spain and France
	Economidou, M., Sagaert, V., Laes, E., Wüstenberg, M., Kauppinen, J., & Puhakka, P. (2018). Energy Efficiency Upgrades in Multi-Owner Residential Buildings—Review of Governance and Legal Issues in 7 EU Member States. Publications Office of the European Union: Luxembourg.	France, UK & Scotland, Portugal Finland, Germany, Spain

	Castellazzi, L., Bertoldi, P., & Economidou, M. (2017). Overcoming the split incentive barrier in the building sector. Publications Office of the European Union, Luxembourg.	EU
Access to finance	Ameli, N. and Brandt, N., 2015. *Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes.* Environmental research letters 10 044015. Nair, G., Gustavsson, L., & Mahapatra, K. (2010). Factors influencing energy efficiency investments in existing Swedish residential buildings. Energy Policy, 38(6), 2956-2963. Wilson, C., Crane, L., & Chryssochoidis, G. (2015). Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. Energy Research & Social Science, 7, 12-22. Ameli and Brandt (2015). What Impedes Household Investment in Energy Efficiency and Renewable Energy? https://www.oecd-ilibrary.org/economics/what-impedes-household-investment-in-energy-efficiency-and-renewable-energy_5js1j15g2f8n-en	EU Sweden NA EU
The culture and social influence of the installer's workplace	Murtagh, N., Owen, A. M., & Simpson, K. (2021). What motivates building repair-maintenance practitioners to include or avoid energy efficiency measures? Evidence from three studies in the United Kingdom. Energy Research & Social Science, 73, 101943. Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. Journal of risk and uncertainty, 1(1), 7-59.	UK US
Limited knowledge of EERMs and lack of skilled workers	Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R. 2011. Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report. Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive science, 12(2), 257-285. Owen, A., Mitchell, G. and Gouldson, A., 2014. *Unseen influence: The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology.* Energy Policy 73, pp. 169-179.	Germany, Switzerland, Italy, Spain and France NA NA