NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTAMENT OF ENVIRONMENTAL SCIENCES AND ENGINEERING

HARD-TO-REACH ENERGY USERS IN JUST ENERGY TRANSITIONS

IDENTIFYING TARGET GROUPS AND PILOTING LOCAL ACTION

Miguel Macias Marques Sequeira

Master in Environmental Engineering

DOCTORATE IN ENVIRONMENT AND SUSTAINABILITY

NOVA University Lisbon

March 2025

DEPARTAMENT OF ENVIRONMENTAL SCIENCES AND ENGINEERING

HARD-TO-REACH ENERGY USERS IN JUST ENERGY TRANSITIONS

IDENTIFYING TARGET GROUPS AND PILOTING LOCAL ACTION

MIGUEL MACIAS MARQUES SEQUEIRA

Master in Environmental Engineering

Adviser: João Pedro Costa da Luz Baptista Gouveia,
Principal Researcher, NOVA School of Science and Technology, NOVA University Lisbon

Co-adviser: João Miguel Dias Joanaz de Melo,
Associate Professor with Habilitation, NOVA School of Science and Technology, NOVA University Lisbon

Examination Committee:

Chair: Maria Júlia Fonseca de Seixas,
Full Professor, NOVA School of Science and Technology, NOVA University Lisbon

Rapporteurs: Hélder Perdigão Gonçalves,
Coordinating Researcher, National Laboratory of Energy and Geology
Inês Almeida Dias Sobral de Campos,
Junior Researcher, Faculty of Sciences, University of Lisbon

Adviser: João Pedro Costa da Luz Baptista Gouveia,
Principal Researcher, NOVA School of Science and Technology, NOVA University Lisbon

Members: Aimee Ambrose,
Full Professor, Sheffield Hallam University, United Kingdom
Maria Júlia Fonseca de Seixas,
Full Professor, NOVA School of Science and Technology, NOVA University Lisbon

DOCTORATE IN ENVIRONMENT AND SUSTAINABILTY

NOVA University Lisbon
March 2025

Hard-to-reach energy users in just energy transitions: Identifying target groups and piloting local action

This work has been made possible by the financial support of the scholarship 2020.04774.BD from the Portuguese Foundation for Science and Technology (doi: 10.54499/2020.04774.BD).

ACKNOWLEDGMENTS

I would like to start by thanking my main supervisor Dr. João Pedro Gouveia. From our first meeting in 2020, he encouraged me to start this PhD journey, providing unwavering, round-the-clock support, advice, and critical insights which were fundamental for this thesis and for my professional and personal development. I also thank him for bringing me on board for multiple high-impact projects while always backing me up to explore my own ideas. It is an inspiration to be part of the research team led by João, investigating relevant environmental and social challenges and implementing meaningful actions.

I also thank my co-supervisor Prof. João Joanaz de Melo. Years after supervising my master's thesis, he demonstrated availability to once more supervise my work, contributing with relevant teachings and insights along the way. Joanaz has been a long-time mentor both at university and in environmental activism. A word of gratitude also to Prof. Aimee Ambrose and Prof. Francisco Ferreira who were members of the Thesis Evaluation Committee and spent some of their limited time reading my research and providing valuable feedback.

I am grateful to the Foundation for Science and Technology (FCT) for supporting my PhD scholarship (2020.04774.BD). I acknowledge FCT's support to CENSE (UIDB/04085/2020). I recognise the Associated Laboratory CHANGE (10.54499/LA/P/0121/2020).

A word of thank you also to the colleagues at CENSE and at the Environmental Sciences and Engineering Department at NOVA-FCT. In particular, I would like to thank the research team of CENSE's energy and climate group for the words of encouragement, exchange of experiences, and rich discussions. Furthermore, I highlight my appreciation of all the collaborative work and inspiring conversations with my peers and friends working in energy poverty topics, especially with my senior PhD colleagues Pedro Palma (without his proactivity, his belief in my ideas, and a couple of beers I would never have started this PhD journey) and Katherine Mahone,y and also with the more recent additions to the team Evandro Ferreira (whose technical skills support our ongoing research on energy communities), Carolina Castro, Inês Valente, and Salomé Bessa. I also thank all the colleagues, administrative staff, researchers, and professors involved in the Doctoral Program in Environment and Sustainability at NOVA-FCT.

Moreover, I would like to thank all the partners, stakeholders, experts, and citizens for their collaboration in multiple research projects for the past years. I recognise the inspirational collaboration with the colleagues from the International Energy Agency UsersTCP Task on Hard-To-Reach Energy Users. I also thank the partners from the EIT CLIMATE-KIC PAS2020 project (De Groene Grachten and E-Zavod), the interviewed experts, and the citizens that contributed to the development of the Green Menu digital one-stop shop. In addition, I thank the Transition Point consortium, namely the Calouste Gulbenkian Foundation for promoting and funding this project, ENA for the effort of on-the-ground implementation, and RNAE, and I also thank all the local organisations who do essential work and that agreed to spend some time talking with me about energy issues. In the context of the Transition Point's spin-off project "Prescribing a Comfortable Home", I acknowledge the participation of the Union of the Civil Parishes of Baixa da Banheira and Vale da Amoreira, of the USF Querer Mais, of S.Energia, and of other social support organisations.

A special word of gratitude to the local community from the Telheiras neighbourhood and to the Local Partnership of Telheiras who have, for many years and many struggles, placed tremendous faith in our ability to take energy into our own hands. Without the unwavering support of Luís Keel Pereira, Helena Martins, Bartolomeu Bernardes, and António Boucinha, we would not have gotten this far. A word of thanks also to all the energy community members that took a leap of faith and signed up for this innovative project - your belief, patience, and availability to this project is well recognised. I would also like to thank the Lumiar Civil Parish, in the persons of its President Dr. Ricardo Mexia and of its Board Member for Sustainability Mr. Rodrigo Benitez, for their long-lasting partnership on energy communities. I am also grateful to Coopérnico, especially Ana Rita Antunes and Luís Cachinho, for their support to this project, to the Energy Poverty Advisory Hub, and to the DUT Partnership Urban Doers programme.

I am thankful to many other organisations and individuals with whom I crossed paths during this PhD journey. I'm not able to mention all of them, but the opportunity to share experiences and connect with like-minded individuals in Portugal and beyond has been a source of immense inspiration. I’m grateful to the team at the environmental NGO GEOTA, to the EU Climate Pact coordinated by ZERO in Portugal, to the activists at the Jornada pela Democracia Energética, and to the Citizens Commissions project by Os230.

I'm thankful to my mother for all the unwavering support along the years and to all our family members and friends whose routine presence, conversations, and convivence are cherished.

Last but most important, I'm thankful beyond words to my girlfriend, fiancée, and soon-to-be wife Mafalda for our love of many years and for always being at my side, enabling, supporting, and encouraging me during this long, immersive, and often intense PhD journey, and to our beautiful son Tomás whose growing personality amazes me every day. This work would not have any meaning without you.

ABSTRACT

Energy lies at the heart of urgent transformations. Climate change and energy poverty are uttered global priorities. However, despite well-known solutions, energy transitions are not yet at the needed pace. Citizens have been pushed to the frontline with high hopes for their uptake of energy efficiency and renewable energy. Still, multi-faceted barriers stand in the way of participation. These are particularly stark for hard-to-reach energy users which can be broadly defined as those who are difficult to reach or hard to engage or motivate by policies and interventions. While this concept has attracted attention, it still lacks systematisation and operationalisation. Moreover, how to activate hard-to-reach groups remains a key research gap. Without faster, deeper, and broader adoption of energy efficiency and renewable energy, and more effective citizen engagement, energy transitions will remain off track.

In this context, this research has the goal of increasing knowledge on how to engage hard-to-reach energy users in just energy transitions. First, it systematises and characterises profiles that may be classified as hard-to-reach and estimates their size at multiple scales from the European to the national and local levels. Second, it operationalises the concept for the *ex-ante* assessment of energy policies and for the *ex-post* evaluation of on-the-ground projects. Third, action research is applied to three case-studies in Portugal, namely a digital one-stop shop for home renovation, a physical energy support one-stop shop, and a renewable energy community, for a closer look on approaches that seek to activate hard-to-reach groups. Fourth, recognising their common but ambiguous presence, it engages with local organisations to critically assess their roles as middle actors in energy transitions.

This research shows that hard-to-reach groups are significant at multiple scales, highlighting, for instance, low-income households, multi-family buildings, people with ill-health and disabilities, tenants, and micro-enterprises. It demonstrates that intersectionality compounds vulnerabilities and that variations exist across nations and regions. Data gaps are found for the most marginalised and the wealthiest profiles. This work argues that policymakers can still do much more to recognise hard-to-reach groups and to deploy targeted and tailored measures. Local action seems more effective at engaging hard-to-reach audiences, for instance, through trusted messengers, but has limitations on impact assessment and persistency.

Digital platforms can be useful tools in the energy transition toolbox but do not address hard-to-reach groups. Instead, greater potential is found in local actions; for instance, one-stop shops can deploy face-to-face support and energy communities can produce and share solar

power. Local stakeholders can play diverse roles, such as communicating with vulnerable households. However, many organisations face challenges and, if successful partnerships are to be established, dedicated funding and capacity building are a must. Local action relies heavily on the efforts of dedicated individuals and organisations, making their sustainability, upscaling, and replication challenging without stronger institutional backing at all levels of government.

Finally, this research's outputs are useful for policymakers, researchers, and practitioners working on energy transitions at multiple scales. A more sustainable, just, and democratic energy system is within reach, but it requires unprecedented commitment by all actors.

Keywords: just energy transitions, hard-to-reach energy users, energy policies, local action, digital tools, one-stop shop, renewable energy community, middle actors

RESUMO

A energia está no centro de uma transformação urgente onde as alterações climáticas e a pobreza energética são prioridades globais. No entanto, apesar das soluções serem já bem conhecidas, a transição energética não está ainda no ritmo necessário. Os cidadãos foram colocados na linha da frente com esperanças para o seu envolvimento na implementação de eficiência energética e energias renováveis. Ainda assim, barreiras multifacetadas impedem a participação na transição energética. Estas são particularmente graves para os utilizadores de energia difíceis de alcançar, amplamente definidos como aqueles que são difíceis de alcançar, envolver ou motivar por políticas e intervenções. Embora este conceito tenha atraído atenção, ainda carece de sistematização e operacionalização. Além disso, continua a haver uma lacuna de conhecimento sobre as formas mais eficazes de ativar os grupos difíceis de alcançar. Sem uma adoção mais rápida, profunda e ampla de eficiência energética e energias renováveis, e um envolvimento mais eficaz dos cidadãos, a transição energética permanecerá desalinhada.

Neste contexto, esta investigação tem como objetivo aumentar o conhecimento sobre como envolver os utilizadores de energia difíceis de alcançar em transições energéticas justas. Em primeiro lugar, sistematiza e caracteriza perfis de consumidores que podem ser classificados como difíceis de alcançar e estima a sua dimensão em múltiplas escalas, desde o nível europeu até ao nível nacional e local. Em segundo lugar, operacionaliza este conceito através da avaliação *ex ante* de políticas energéticas e através da avaliação *ex post* de projetos práticos. Em terceiro lugar, é conduzida investigação-ação em três casos-estudo em Portugal, nomeadamente uma *one-stop shop* digital para a renovação de casas, uma *one-stop shop* física de eficiência energética e uma comunidade de energia renovável, para uma análise detalhada de abordagens que procuram ativar grupos difíceis de alcançar. Em quarto lugar, reconhecendo a sua presença frequente, mas ambígua, este trabalho interage com organizações locais para avaliar o seu papel como intermediários na transição energética.

Esta investigação mostra que os grupos difíceis de alcançar são significativos a diversas escalas, destacando, por exemplo, as famílias de baixos rendimentos, os edifícios multifamiliares, as pessoas com problemas de saúde e deficiências, os inquilinos e as microempresas. Adicionalmente, demonstra que a interseccionalidade agrava vulnerabilidades e que existem variações entre países e regiões. Este trabalho encontra lacunas de dados nos perfis mais marginalizados e nos mais opulentos. Além disso, argumenta que os decisores políticos podem fazer muito mais para reconhecer os grupos difíceis de alcançar e para implementar medidas direcionadas e personalizadas. Os projetos locais parecem ser mais eficazes no envolvimento de grupos difíceis de alcançar, por exemplo, através de mensageiros de confiança, mas apresentam limitações em termos de avaliação de impactos e persistência.

As plataformas digitais podem ser ferramentas úteis para a transição energética, mas não respondem às necessidades dos grupos difíceis de alcançar. Em alternativa, esta investigação encontra maior potencial nas iniciativas à escala local. Por exemplo, as *one-stop shops* podem oferecer apoio energético personalizado e as comunidades de energia podem gerar e partilhar energia solar. As organizações locais podem desempenhar papéis diversos, como a comunicação com as famílias vulneráveis. No entanto, muitas organizações enfrentam desafios e, para estabelecer parcerias bem-sucedidas, é essencial existir financiamento e capacitação. A ação local depende, em grande parte, dos esforços de organizações e indivíduos motivados, o que torna a sua sustentabilidade, expansão e replicação desafiantes sem um apoio institucional mais forte a todos os níveis de governo.

Por último, os resultados desta investigação são úteis para os decisores políticos, investigadores e profissionais que trabalhem sobre transição energética às diversas escalas. Um sistema energético mais sustentável, justo e democrático é alcançável, mas exige um compromisso sem precedentes de todos os intervenientes.

Palavras-chave: transições energéticas justas, utilizadores de energia difíceis de alcançar, políticas energéticas, ação local, ferramentas digitais, *one-stop shop*, comunidade de energia renovável, intermediários

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND UNITS

BPIE	Buildings Performance Institute Europe
EE	Energy efficiency
EP	Energy poverty
EPAH	Energy Poverty Advisory Hub
EU	European Union
GHG	Greenhouse gas
GDP	Gross Domestic Product
HTR	Hard-to-reach
IEA	International Energy Agency
INE	Instituto Nacional de Estatística [Statistics Portugal]
IPCC	Intergovernmental Panel on Climate Change
NECP	National Energy and Climate Plan
NGO	Non-governmental organisation
OSS	One-stop shop
PV	Photovoltaic
REC	Renewable energy community
RES	Renewable energy sources
RQ	Research question
SDG	Sustainable Development Goal
SME	Small and medium enterprises
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Program
UNICEF	United Nations Children's Fund
WEF	World Economic Forum
WHO	World Health Organization
WWF	World Wide Fund for Nature
ktoe	kilotonne of oil equivalent
kWp	kilowatt-peak

Chapter 1.

INTRODUCTION

1.1 Crisis and transformation

As multiple crises unfold, synchronize, and amplify unendingly - pandemics, wars, climate change, inflation, and a myriad of other calamities - several researchers have started to speak of a global polycrisis (Lawrence *et al.*, 2024). A crisis is, by definition, fleeting, but it seems now to be a chronic state (Henig and Knight, 2023). Fernandes (2024) points out the capitalist system and its exploitation of labour, humans, and nature as a root cause, and Lawrence *et al.* (2024) blame neoliberal arrangements for removing social and environmental safeguards.

The scale, pace, and intensity of human activity are key drivers behind these shifts, linking to the stream of thought that classifies the current geological epoch as the Anthropocene (*e.g.*, Steffen *et al.*, 2004; Elhacham *et al.*, 2020). It is characterized by ecological overshoot with human consumption pushing past Earth's ability to regenerate (Ripple *et al.*, 2024). Richardson *et al.* (2023) warn that six out of nine planetary boundaries have been trespassed and that the Earth is now outside of the safe space for humanity (Figure 1.1). Year after year, the World Economic Forum (WEF, 2025) confirms environmental challenges as major global risks.

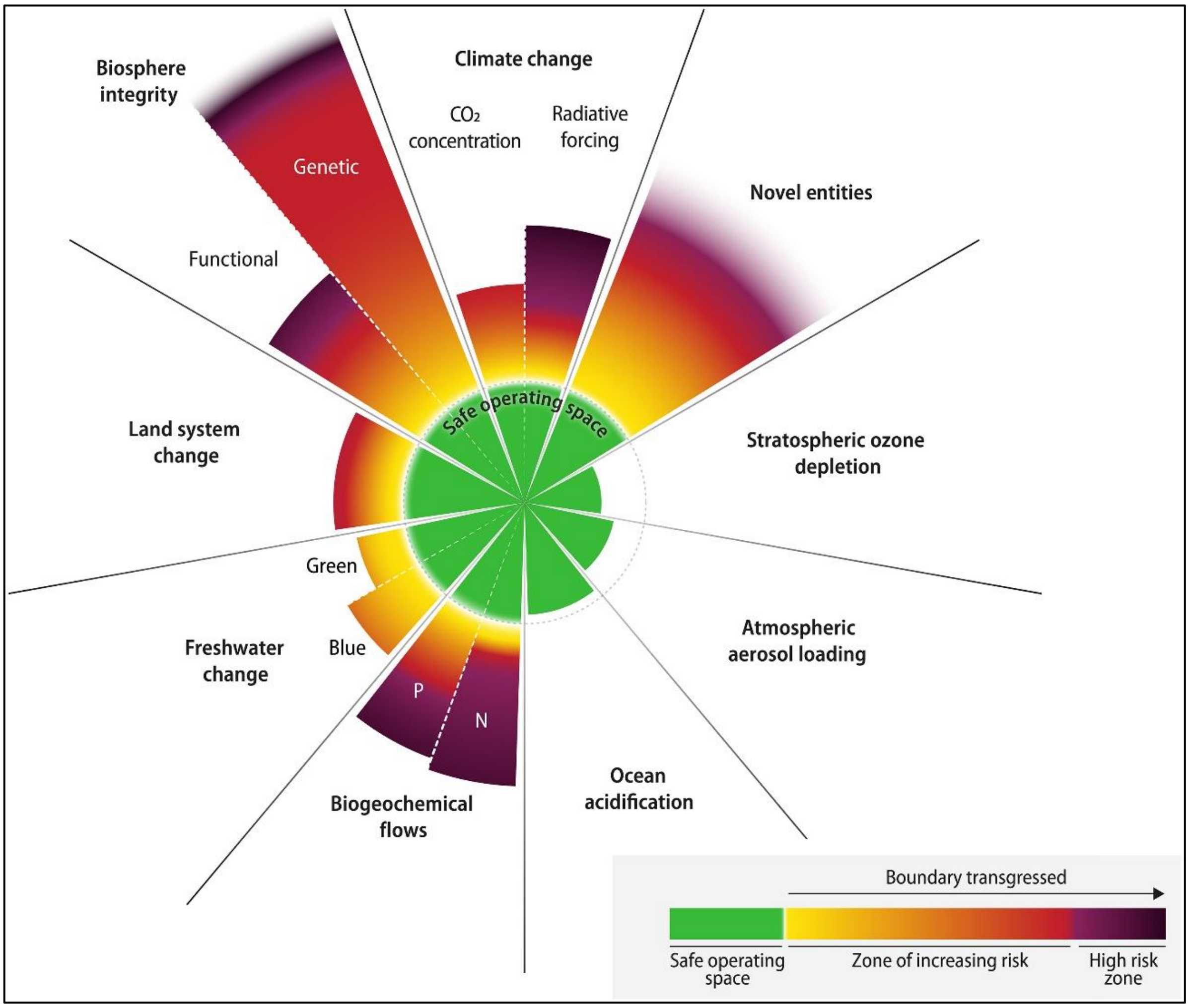


Figure 1.1 - The planetary boundaries framework (Richardson *et al.*, 2023).

The Intergovernmental Panel on Climate Change (IPCC, 2023, p. 4, p. 28), in its Sixth Assessment Report, firmly cemented that the human influence on climate change is “unequivocal” and that many climate modifications are “unprecedented”. Climate change is already playing a relevant role in weather extremes worldwide, with studies linking climate change to disastrous events (*e.g.*, Callaghan *et al.*, 2021; Cunningham *et al.*, 2024). The World Health Organization (WHO, 2021) singled out climate change as the largest health threat that humanity faces. It impacts health in multiple ways, *e.g.*, by increasing the risk of pandemics (Oliveira and Tegally, 2023) and exposing many people to unsafe heat levels (Lenton *et al.*, 2023).

The critical nature of this societal challenge for current and, especially, future generations has led many organizations, policymakers, and scientists to label it as the climate crisis – *e.g.*, United Nations Children’s Fund (UNICEF, 2021) – and as the climate emergency – *e.g.*, Ripple at al. (2020) – further sounding the alarm on the need for a watershed of climate action. More recently, Ripple *et al.* (2024, p. 812) warn of an "irreversible climate disaster" where the "fabric of life on Earth is imperilled". Climate tipping points, where small increases in global temperatures can lead to abrupt, self-perpetuating, and irreversible changes, are receiving increasing attention (Möller *et al.*, 2024). McKay *et al.* (2022) identify at least 16 of these subsystems, estimating that current warming levels already risk triggering multiple tipping points.

Anthropogenic climate change is, nonetheless, only one of the three intertwined environmental emergencies described by the United Nations Environment Program (UNEP, 2021), whereas widespread pollution and biodiversity decline are the two others. Biodiversity is key to sustain human societies - with over half of the global gross domestic product being moderately or highly dependent on nature - and every indicator that tracks biodiversity globally shows a decline (Obura *et al.*, 2023; WWF, 2024). Researchers have warned of a "sixth mass extinction" with land-use change, overharvesting, pollution, climate change, biological invasions, and coextinctions as key drivers of species losses (Penn and Deutsch, 2022; Strona and Bradshaw, 2022).

Deeply entangled with and exacerbated by environmental crises, inequality remains a rising and critical challenge (UNDESA, 2020; Millward-Hopkins, 2022). For the last two decades, income and wealth inequalities have increased within most countries and declined between countries (Chancel *et al.*, 2022). Currently, the richest 10% of the global population receives 52% of global income and own 76% of all wealth, while the poorest half earns 8.5% of income and owns 2% of wealth (Chancel *et al.*, 2022). Inequality is reflected in disparities in environmental impacts; Tian *et al.* (2024) show that the global top 10% and top 20% of consumers, from both developed and developing countries, bear most of the responsibility for ecological overshoot. For instance, these authors report that the world's wealthiest 10% was responsible for 43% of CO_2 emissions and the top 1% for 14%, while the bottom 50% contributed only 10%.

While they are the least responsible for these phenomena, vulnerable and poor populations worldwide will unequally shoulder the burden of their impacts (Dorninger *et al.*, 2021; Bastien-Olvera *et al.*, 2023). Meanwhile, global elites are purchasing real estate in perceived climate-safe zones (Millward-Hopkins, 2022). In this context, Wilkinson and Pickett (2024) point out that large income differences are a major social stressor, which increases anxiety, consumerism, and resistance against environmental policies.

Political polarization is also considered a critical socio-political issue, which has increased significantly since 2019, and is often antagonistic to environmental and climate policies (Falkenberg *et al.*, 2022). For instance, in the United Kingdom, right-wing populist politicians have used false premises to link net-zero policies to a cost-of-living crisis, framing climate action as too expensive and as an undemocratic pursuit imposed by a top-down elite (Atkins, 2022). Social media networks have amplified climate contrarian views, building on dissatisfaction and anxiety to fuel climate change denial (Maharasingam-Shah and Vaux, 2021). Climate change has thus been integrated into broader "culture wars" which seem to match with an uptick in the election of misogynist authoritarian leaders that disdain environmental policies (Kaul and Buchanan, 2023).

Being a rapid societal change, climate action creates adverse reactions in incumbent policymakers, industries, and businesses (Franta, 2021; Kenner and Heede, 2021). For instance, research has shown that fossil fuel companies knew about climate change for decades while actively working to deny it (Supran *et al.*, 2023). While their discourse has shifted, Li *et al.* (2022) argue that actions do not match pledges leading to accusations of greenwashing. Although the scientific consensus placed climate denialism on the back burner, proponents of climate delay argue for minimal action by shifting responsibilities, pushing for non-transformative solutions, emphasizing downsides, and surrendering to climate doom (Lamb *et al.*, 2020).

In the current polycrisis, the need for a profound socio-ecological transition is ever clearer. In his book "Designing Regenerative Cultures", Wahl (2016, p. 20) questions not only "how to become sustainable?" but also "why should we be sustained?" contemplating spiritual arguments for human and nonhuman survival. Reflecting on the vanishing of the whales, Moore (2021, p. 82) puts forward an answer: "It is worthy. That's the word. It is excellent. And so it must continue.". Main religions have targeted this spiritual void and called for global action, *e.g.*, the Encyclical Letter Laudato Si' of the Holy Father Francis on Care for Our Common Home (2015) and the Al-Mizan: A Covenant for the Earth of The Islamic Foundation for Ecology & Environmental Sciences (2024). Researchers have also strived to offer new models to guide humanity, for instance, Raworth's (2017) the Doughnut establishes the need to, simultaneously, ensure social foundations for wellbeing and safeguard Earth's systems. Still, Feola (2020) alerts that sustainability research has taken capitalism as implicit failing to account for the possibility that transitions may prompt fundamental changes in the capitalist system.

To simultaneously address diverse and intertwined global challenges, the United Nations' Agenda for 2030 established 17 Sustainable Development Goals (SDGs), stimulating action in critical areas for humanity and the planet (United Nations, 2015a). These include SDG 1 (end poverty in all its forms everywhere), SDG 3 (ensure healthy lives and promote well-being for all at all ages), SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all), SDG 10 (reduce inequality within and among countries), SDG 11 (make cities and human settlements inclusive, safe, resilient and sustainable), and SDG 13 (take urgent action to combat climate change and its impacts). Furthermore, building on the Universal Declaration of Human Rights (United Nations, 1948), the United Nations (UN Human Rights, 2021) has recognized that having a clean, healthy, and sustainable environment is a human right.

Regarding international collaboration on climate change, 196 parties signed the Paris Agreement in 2015, with the goal to limit global warming to well below 2°C by 2100, preferably to 1.5°C, compared to pre-industrial levels (United Nations, 2015b). World leaders have congregated year after year, but few progresses have been made, and the Conference of the Parties has been losing support even amongst climate advocates (Falkenberg *et al.*, 2022). A few researchers critique the lack of ambition of the target, stating that it tacitly accepts hundreds of millions of deaths and may trigger tipping points (Abbott *et al.*, 2023; Breyer *et al.*, 2023).

Despite political commitments, virtually every nation is off-track to meet the Paris Agreement, in a collective fiasco to bend the global emissions curve (Ripple *et al.*, 2024). Whilst the Covid-19 pandemic caused a 5.8% fall in global greenhouse gas (GHG) emissions in 2020, these have already rebounded and reached all-time records in 2024 in what is seen as a lost opportunity to hasten energy transitions (International Energy Agency (IEA), 2024a). Nahm *et al.* (2022) assess that the pandemic recovery packages from the 20 largest economies failed to 'build back better', with only 6% allocated to emissions cuts and almost 3% for polluting activities. This dramatic failure is not limited to climate action, as WWF (2024) foresees that over half of SGD targets for 2030 will be missed and that 30% of SDGs will be equal or worse than in 2015.

Current policies lead the world to a warming of 3.1ºC in 2100 (UNEP, 2024). The IEA (2023) warns that, to meet net-zero goals, investment in new coal, oil, and gas projects must halt, whilst Trout *et al.* (2022) state that 40% of already developed reserves ought to remain unextracted. In contrast, in 2023, global demand for coal, gas, and oil reached all-time records (IEA, 2024a). Under current trends, the chance of limiting global warming to 1.5ºC is virtually zero and the remaining carbon budget will be busted before 2030 (Lamboll *et al.*, 2023). Wynes *et al.* (2024) surveyed IPCC authors finding that 86% are sceptical that even the less ambitious 2ºC target will be met. Moreover, scientists are worried about a recent surge in temperatures, which could mean that the dynamics of the climate system are changing faster than anticipated (Schmidt, 2024). The year 2024 marked a grim milestone: the Earth's average temperature increased to more than 1.5ºC above pre-industrial levels for the first time (Tollefson, 2025).

After years of insufficient action, avoiding the worst effects of the climate crisis and meeting other SDGs requires an unprecedented transformation of the current paradigm (Fanning *et al.*, 2022; Andersen *et al.*, 2023). In a polycrisis, where solutions to one problem may exacerbate others, holistic policies need to target the root causes of multiple challenges (Richardson *et al.*, 2023). Halfway through to 2030, this struggle is half-lost, and the next five years will be decisive (Ripple *et al.*, 2024). Linkov *et al.* (2024, p. 1) draw concerning parallels between the Late Bronze Age Collapse and the current era and warn that civilizations can appear robust even when their foundations are eroding; still, these authors offer some hope: "civilization collapses are preventable; we are not necessarily destined to collapse".

1.2 Energy transitions

Energy is the linchpin of human societies. Fossil fuels still account for 77% of global primary energy consumption and the energy sector is the source of 85% of global greenhouse gas emissions (IEA, 2024a; Our World in Data, 2024a). While being an enabler of prosperity and human well-being, the current energy system is also a major part of social, environmental, and economic challenges. For instance, Sovacool *et al.* (2021) put the externalities of the global energy system at $11.6 trillion dollars - or around 29% of the global gross domestic product (GDP) in 2020.

Furthermore, energy poverty (EP) stands out as a multidimensional problem at a crossroads of environmental, economic, and social dimensions. From its inception in the United Kingdom, notably by Boardman (1991), the concept of EP, also referred to as fuel poverty, has grown into a consolidated scientific field and has gathered political momentum (Jiglau *et al.*, 2023). Many authors distinguish between EP in developed nations – attributed to drivers such as low incomes, energy-inefficient buildings and equipment, and high energy prices (*e.g.*, Siksnelyte-Butkiene *et al.*, 2021) – and EP in underdeveloped nations – where lack of access to adequate energy carriers has been seen as the key driver (*e.g.*, Bouzarovski and Petrova, 2015).

The European Union's (EU) Energy Efficiency Directive (Directive (EU) 2023/1791, p. 31) defines EP as "a household's lack of access to essential energy services, where such services provide basic levels and decent standards of living and health, including adequate heating, hot water, cooling, lighting, and energy to power appliances, in the relevant national context [...]". A few authors (*e.g.*, Mattioli *et al.*, 2018; Cludius *et al.*, 2024) have put forward the terminology of transport poverty. This analogous concept is defined in the EU's Social Climate Fund Regulation (2023, p. 10) as "[...] individuals' and households' inability or difficulty to meet the costs of private or public transport, or their lack of or limited access to transport needed for their access to essential socioeconomic services and activities, considering the national and spatial context".

At global scale, around 750 million people still lack access to electricity and more than 2 billion people still rely on polluting and unsafe fuels for cooking, mostly in developing countries, aggravating public health and disproportionately impacting women and children (IEA, 2024a). The EU's Energy Poverty Advisory Hub (EPAH, 2024a) lists a wide set of indicators to provide a more comprehensive understanding of EP considering the diversity amongst Member States. For instance, in 2023, 16% of the population (around 70 million people) lived in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor, 11% (48 million people) were unable to keep their home adequately warm, and 7% (31 million people) had arrears on utility bills. While traditionally associated with domestic heating and regarded as a winter phenomenon, more recently, cooling needs and summer EP have also attracted considerable attention (Cornelis, 2025). Several studies (*e.g.*, Liddel and Morris, 2010; Recalde *et al.*, 2019; Oliveras *et al.*, 2020) have linked EP and thermal discomfort with reduced physical and mental health and well-being and with increased mortality rates. These impacts are particularly severe for vulnerable and marginalised groups and may be exacerbated by climate change (Oliveras *et al.*, 2021; Choi *et al.*, 2023). The Covid-19 pandemic and the energy crisis have intensified EP vulnerability (Cuerdo-Vilches *et al.*, 2021; Carfora and Scandurra, 2024).

In this context, energy is at the top of the agenda, including to address the challenges of climate change mitigation and EP alleviation. The United Nations' Agenda for 2030 enshrined SDG 7 (affordable and clean energy) which is found to intersect with almost all other SDGs. Key targets include ensuring universal access to affordable, reliable and modern energy services, increasing substantially the share of renewable energy in the global energy mix, and doubling the global rate of improvement in energy efficiency. SDG 7 also calls for enhancing international cooperation in clean energy research and for expanding infrastructure and technologies to least developed countries (United Nations, 2015a).

Recently, several authors (*e.g.*, Kikstra *et al.*, 2021; Hickel and Slameršak, 2022) have warned about possible conflicts in meeting both challenges simultaneously, *i.e.*, reducing GHG emissions plus providing adequate levels of energy services to all, while stating it is possible to meet both ends. Rapid and equitable energy transitions can provide a series of cascading benefits, such as poverty alleviation, health improvements, reduced inequalities, job creation, resilient built environment, and restoration of ecosystems (Frischmann *et al.*, 2020; Pai *et al.*, 2021; Milner *et al.*, 2023). To accelerate energy transitions, Sovacool *et al.* (2025) distinguish incremental from radical innovation, ascertaining that the latter pushes past current systems' boundaries and may unlock transformative change.

Beyond other benefits, energy transitions may result in trillions of savings and be cost-effective, while providing economic growth (Way *et al.*, 2022; IEA, 2024a). For example, Kotz *et al.* (2024) show that already committed climate change-related economic damages by 2050 are six times larger than the costs required to limit global warming to 2ºC. Other authors disagree with "green growth" outlooks, seeing economic growth as a root cause of environmental degradation and researching post-growth and degrowth pathways (*e.g.*, Hickel *et al.*, 2021).

Vogel and Hickel (2023) provide a critique of green growth, stating that decoupling between emissions and growth in high-income countries falls far short of Paris-compliant rates. Other authors deliver similar criticism, for instance, Millward-Hopkins (2022) state that, if inequalities remain close to current levels while decent living is secured universally, energy consumption levels can be twice as high as in a more egalitarian world. On the other hand, if global energy use is reduced enough to ensure climate safety, but inequality remains as it is today, 4 billion people would not have access to essential energy services (Millward-Hopkins and Oswald, 2023). In contrast, to provide decent living standards for 8.5 billion people would require only 30% of current global resource and energy use (Hickel and Sullivan, 2024).

Project Drawdown (2020) argues that the world can reach drawdown – the future point in time when levels of GHG emissions stop climbing and start to steadily decline – mostly by scaling up off-the-shelf climate solutions. Following another approach, the IEA (2023) affirms that all technologies needed to achieve deep emissions cuts to 2030 are available, while the share of emissions reductions to 2050 from technologies still in the demonstration or prototype phase has fallen to 35%. The IPCC (2022) summarized key options for climate change mitigation according to their potential and costs (Figure 1.2). While there are no silver bullets, cross-sectoral profound improvements in energy efficiency (EE), including deep renovation of the building stock and equipment replacement, and massive deployment of renewable energy sources (RES), with solar and wind power at the helm, are seen as gatekeepers of energy transitions.

Albeit improvements in EE are generally a compulsory and desirable ingredient of energy transitions, it should be noted that a few authors have raised concerns regarding mainstream efficiency narratives (*e.g.*, Shove, 2018). These mainly deal with the threat of economy-wide rebound effects – where a significant proportion of the anticipated savings is eroded due to increased demand – and often advocate for a mindset shift towards energy sufficiency, conservation or frugality – which usually implies limiting energy use to a level of services that is consistent with equity, well-being, and environmental limits (Dablander *et al.*, 2025).

Other technological levers are also mentioned, such as digitalization, grids, flexibility, storage, demand-side management, artificial intelligence, and internet-of-things (*e.g.*, Sareen, 2021). Reaching 100% carbon-free electricity and decarbonising hard-to-abate sectors is a particularly complex challenge (Mai *et al.*, 2022), and technological solutions, such as nuclear energy, carbon capture, utilisation and storage, and green hydrogen are wished for in mitigation scenarios that perpetuate high levels of consumption (IEA, 2023).

Green hydrogen still faces significant economical, technical and environmental challenges, being relevant for industry and shipping but wholly unsuitable for the buildings sector (Rosenow, 2022; Tonelli *et al.*, 2023; Martin *et al.*, 2024). Ho (2023) argues that carbon dioxide removal is pointless until almost all emissions' sources have been eliminated. Nuclear power has seen rising interest in recent years, but Haywood *et al.* (2023) and Thellufsen *et al.* (2024)

argue that its high costs and long construction periods are a disadvantage in comparison with renewables (in addition to safety and waste concerns). Solar radiation modification is also being increasingly researched, involving the reflection of sunlight and control of global temperatures without reducing GHG emissions, but these are highly contested due to their inherent risks and their role in delaying effective climate mitigation (Sovacool *et al.*, 2022; Müller *et al.* 2024).

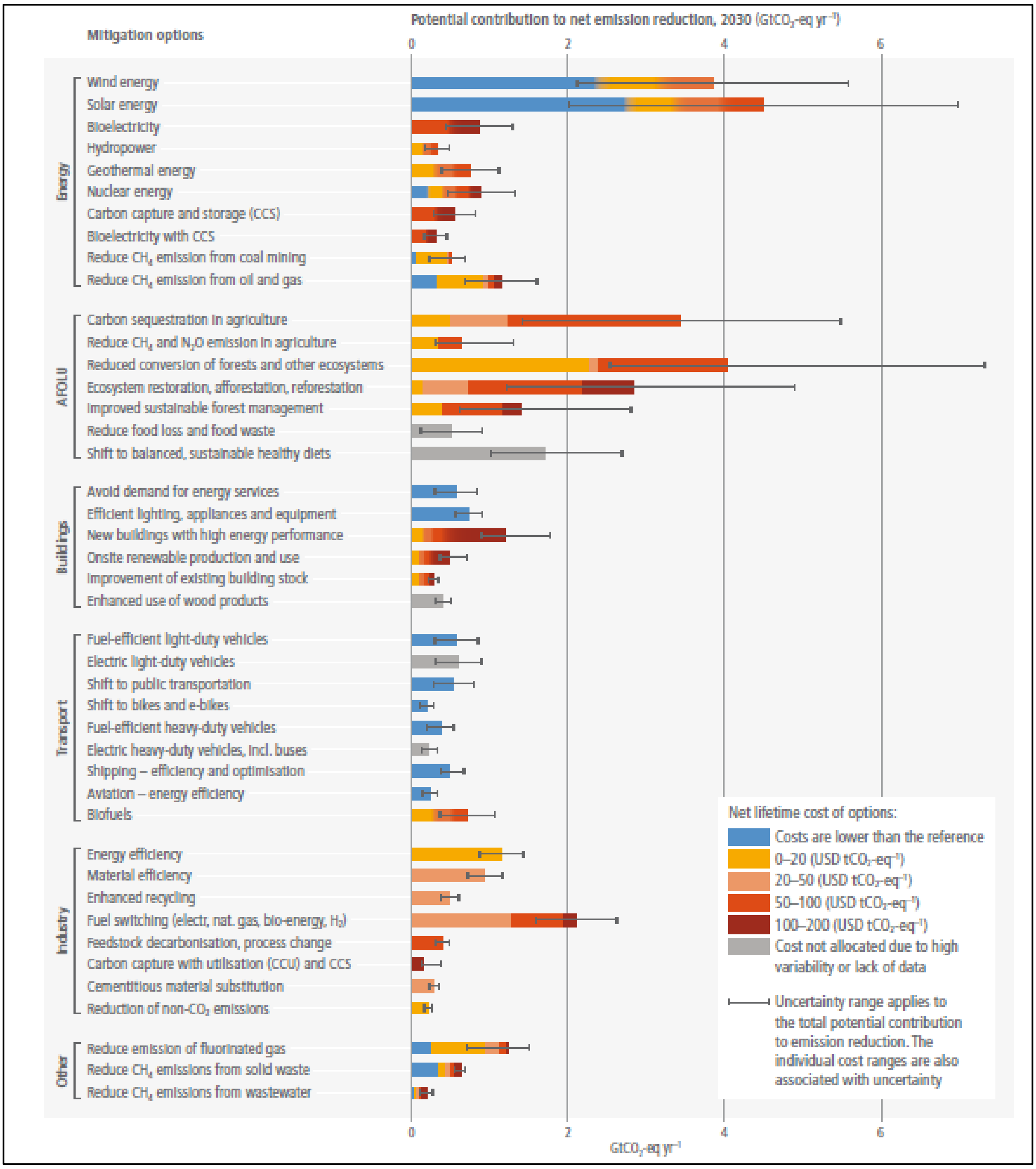


Figure 1.2 - Climate change mitigation options according to the IPCC Working Group III (IPCC, 2022).

The costs of renewable technologies have plummeted faster than expected, and these are now the most economical way of producing energy (Way *et al.*, 2022). Nevertheless, even "green" energy technologies, while being a majorly beneficial advance from fossil fuels, can have negative impacts. Utility-scale wind parks and solar farms are land-intensive and can threaten ecosystems, exclude local communities, entrench inequalities, and amplify authoritarian oppression (Rehbein *et al.*, 2020; Dunlap *et al.*, 2024; Sorman and Stock, 2024). Still, several authors find that the potential to generate energy in converted and low-conflict lands is larger than energy targets (Baruch-Mordo *et al.*, 2019; Kiesecker *et al.*, 2024). The building stock also holds significant potential for RES integration; for instance, Bódis *et al.* (2019) estimate that solar photovoltaic (PV) rooftop systems could meet up to 24% of the EU's electricity consumption. Another concern lies with the lifecycle impacts of technologies, such as electric vehicles, and the consequent rising demand for raw materials and critical minerals (IEA, 2023). Mining is unstainable on human timescales, and researchers have warned of the environmental impacts of a "green" extractivism agenda (Jowitt *et al.*, 2020; Maus and Werner, 2024).

In this context, public opposition to energy transition projects has emerged, which Susskind *et al.* (2022) pin on environmental concerns, unfair participation processes, failure to respect indigenous rights, health and safety concerns, and property value impacts, amongst other drivers. Resistance and contestation will likely grow as energy transitions accelerate. This challenge needs to be acknowledged in energy policies, including through coordinated planning of RES expansion and biodiversity conservation, stakeholder engagement, cross-sectoral improvements in EE, active citizen involvement in decision-making, and alleviation of EP.

1.3 Citizens in the spotlight

Climate action and energy transitions require buy-in from individuals across the globe (Andre *et al.*, 2024; Sovacool *et al.*, 2025). However, currently, human behaviours are driving ecological overshoot - through economic growth, marketing, and pronatalism - in what Merz *et al.* (2023, p. 1) call the "human behavioural crisis". The same authors explore how self-preserving human impulses (*i.e.*, seeking pleasure and avoiding pain, acquiring, amassing, and defending resources, displaying dominance, status or sex appeal, and procrastinating whenever an action does not have immediate benefits) have been hijacked by the economic system and are now a collective maladaptation. In this context, notwithstanding the importance of technological solutions, several authors argue that energy transitions will require profound changes in lifestyles, business models, and social norms across all sectors (Andersen *et al.*, 2023; Biely *et al.*, 2024).

For instance, the IEA's (2023) net zero pathway requires the active participation of citizens, with slightly more than half of cumulative emissions cuts up to 2050 being directly or indirectly linked to individual choices and behaviour changes. Similarly, the IPCC (2022) suggests that demand-side measures have the potential to reduce global GHG emissions in end-use sectors by 40%-70% by 2050. These reductions come mainly from three types of interventions: i) adoption of improved end-use technologies, ii) shifting activities toward less energy-intensive provisioning, and iii) avoiding certain activities or reducing service levels. A similar result was obtained by van Heerden *et al.* (2025) who estimate potential emissions reductions of 51%-85% in the building sector, by 2050, from reducing or changing activities, improving technological efficiency, and electrifying end uses. However, Geels (2023) warns that the achievement of this large potential is constrained by feasibility and implementation challenges and that, in the United Kingdom, technology adoption has accounted for most demand-side reductions in detriment of other types of interventions.

Normally, technology and behaviour uptake start with innovators and early adopters and only afterwards diffuses to other consumers (Biely *et al.*, 2024). However, energy technologies can take a long time from invention to commercialization and widespread adoption; Gross *et al.* (2018) researched 13 products and found this period to range from 20 to 70 years (for LCD TV and cars, respectively). In some cases, the process can be even slower, for instance, households started to be connected to electricity grids in the late 19th century, but it took over one hundred years for electricity to reach 90% of the global population. Other innovations have been deployed faster, for example, Facebook was created in 2004 and reached over three billion active users in 2023 (Statista, 2024), and COVID-19 vaccines were first administered in 2020 and covered 70% of the global population by 2024 (Our World in Data, 2024b). After a long period of technological development, solar power is now being deployed at an astounding speed and will dominate energy markets even without policy support (Nijsse *et al.*, 2023).

Analogue to climate research, social tipping points - broadly defined as nonlinear processes of transformative change in social systems - have recently attracted significant interest for their potential to trigger fast transitions (Milkoreit, 2023). This concept proposes that, as a belief or value spreads through a population, there is a threshold level for widespread adoption; this can occur after just 25% of a population has accepted the new norm (Merz *et al.*, 2023). Proponents of social tipping points mostly assume that these have desirable outcomes and can be intentionally triggered. In contrast, Milkoreit (2023) cautions against overusing the concept, considering that many social processes may not be prone to accelerated change. Other authors propose socio-technical tipping dynamics - bridging technological development with changes in values, norms or behaviours - which can take years to unfold (Sovacool *et al.*, 2025).

Several authors contest narratives that overemphasize the role of behaviour change in energy transitions. These narratives are often articulated by advocates of neoliberal environmentalism which frame individuals as directly responsible for tackling environmental and climate issues, including through lifestyle changes and the pursuit of an inner transition (Carvalho and Ferreira, 2024). In contrast, Lamb *et al.* (2020) consider that a focus on individual action obscures the influence of powerful organisations in constraining consumers' choices. Individuals are part of the energy system, and their behaviour is bound by its structures, norms, rules, and regulations (Biely *et al.*, 2024). While individual actions and behaviour change are indeed relevant, they should not be instrumentalised to shift responsibilities away from governments and businesses and should not distract from a much-needed systemic transformation.

Furthermore, significant scepticism of behavioural interventions persists, including due to difficulties in predicting effects and scalability and to their strong dependence on local context (Berger *et al.*, 2023). Through a meta-analysis, Bergquist *et al.* (2023) find that these approaches can increase pro-environmental behaviours by 2 to 12 percentage points compared to a baseline scenario. Sovacool *et al.* (2025) groups behaviour change interventions into major types, namely education and awareness, outreach and relationship building, social influence, nudges and behavioural insights, and incentives. Of these, social comparison and financial approaches seem to be amongst the most effective and information, awareness, and education amongst the least effective (Bergquist *et al.*, 2023; Merz *et al.*, 2023). Still., research has uncovered that income can be a significant determinant of behavioural change effectiveness, with lower income groups generally performing worst (Caballero and Ploner, 2022).

In addition, one must question if citizens are genuinely concerned about climate change and willing to take an active part in energy transitions. Andre *et al.* (2024) conducted a representative survey across 125 countries finding that 89% of the population demand intensified political action on climate change, 86% endorse pro-climate social norms, and 69% state a willingness to contribute with 1% of their personal income to this cause. Climate change is a relevant source of public concern and anxiety; for instance, Ballew *et al.* (2024) find that 16% of adults from the United States suffer from climate-induced psychological distress. The same authors report that people experiencing distress are more likely to engage in collective social, civic, and political actions.

It should be no surprise then that climate movements have gained momentum in recent years and are increasingly resorting to disruptive tactics. While their actions may be contested, Brehm and Gruhl (2024) and Ostarek *et al.* (2024) demonstrate that the overall effects of radical non-violent protests can be positive, including by reminding society of pressing issues and by leveraging support for more moderate groups. Putting all options on the table to address environmental and climate crises, Sovacool and Dunlap (2022) review 20 direct action tactics that have been used over time, ranging from more common-place civil disobedience and anti-authoritarian strategies to unsavoury and morally questionable sabotage and guerilla warfare.

Still, despite broad citizen support and rising demands from civil society, Geels (2023) contends that most citizens do not seem motivated for behaviour change. The same author suggests that this can be due to insufficient action by policymakers and/or due to consumers' reluctance to sacrifice convenience and comfort and to bear higher costs of low-carbon technologies. Andre *et al.* (2024) also find that citizens worldwide are in a state of pluralistic ignorance -

wherein individuals systematically underestimate the willingness of other citizens to act on climate change - which further hinders their engagement in energy transitions.

In this context, energy citizenship has emerged as a salient topic - stressing that citizens have important roles to play in energy transitions - including in key EU policy documents such as the European Green Deal and the European Climate Pact (European Commission, 2019, 2020a). Still, the concept has also been criticized for lacking a clear definition. Following, Debourdeau *et al.* (2024, p. 2) propose that energy citizenship can be "forms of civic involvement that pertain to the development of a more sustainable and democratic energy system" and that "it is an ideal that can be lived up to and realised to varying degrees, according to different framework conditions and states of empowerment". Biely *et al.* (2024) out-line three clusters of roles for citizens: technology adoption, lifestyle choices, and political action. Debourdeau *et al.* (2024) differentiate reformative from transformative citizenship and state that citizens can act individually, at household, organisational, and public level, and collectively, through organisations and social movements. In the energy crisis, Laakso *et al.* (2024) finds that households are treated both as active change agents - for instance, as energy savers, investors, adaptors, buyers, citizens, prosumers, preppers, and innovators - and as passive agents - for instance, as targets of advice, customers, victims, and recipients of support.

The expectations around citizen participation in energy transitions are crucial for the design of multi-scalar energy policies and interventions. These narratives should avoid one-dimensional consumer archetypes which neglect to account for diversity and for the drivers and barriers that shape engagement (Chadwick *et al.*, 2022). Figure 1.3 showcases a systematisation of influences that shape household adoption and rejection of energy technologies.

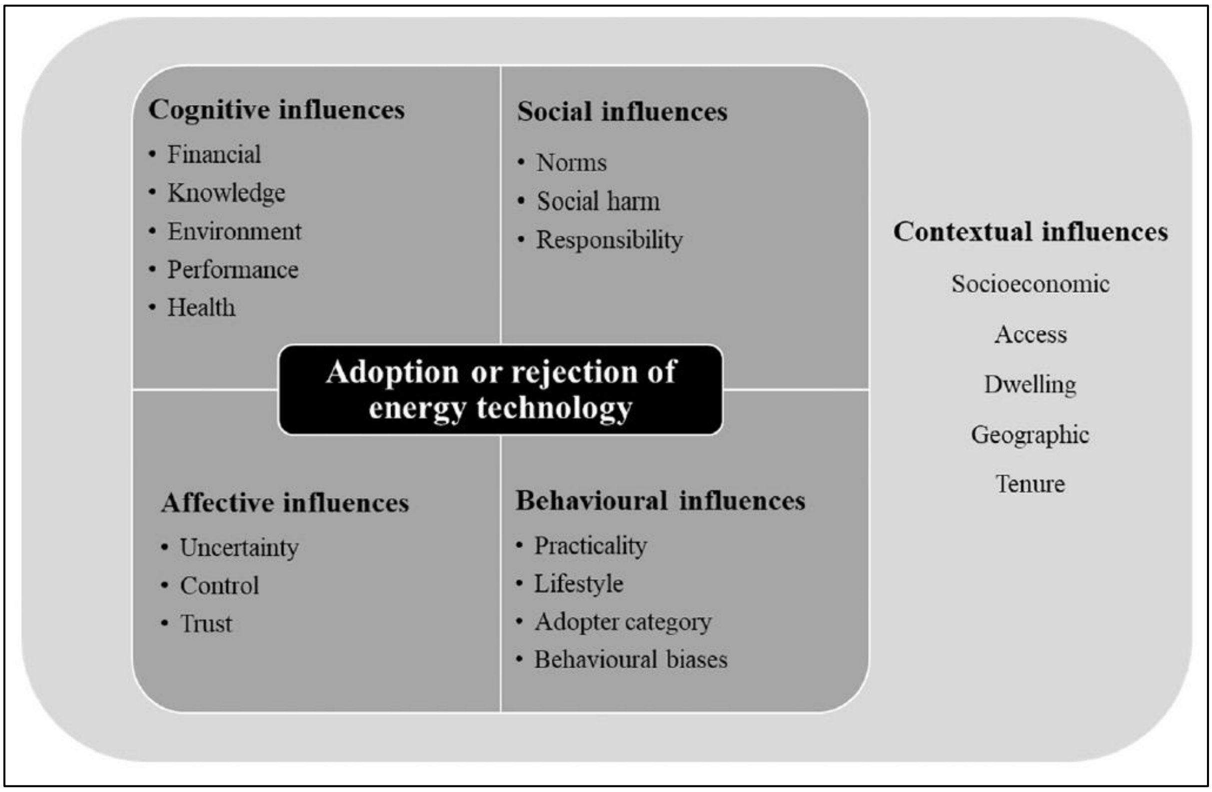


Figure 1.3 - Influences on household adoption or rejection of energy technologies (Chadwick *et al.*, 2022).

These challenges are particularly salient for hard-to-reach (HTR) energy users, which are broadly defined as those that, due to their vulnerabilities, circumstances, and/or characteristics, have so far been removed from energy transitions (Ambrose *et al.*, 2019a). Rotmann *et al.* (2020) label five major HTR groups: vulnerable households, high-income households, tenants and landlords, small and medium enterprises (SME), and commercial subsectors. Gender has also been identified as an important topic for energy research since gender inequalities and traditional gender roles influence EP vulnerability and HTR conditions (Habersbrunner *et al.*, 2024). The need for broad, fast, and extensive engagement in energy transitions has driven recent interest in the HTR concept.

Several authors (*e.g.*, Kelly and Pollitt, 2011; Rivas *et al.*, 2021) have highlighted the importance of local action to foster citizen engagement, particularly of HTR energy users. This includes interventions to improve energy performance, *e.g.*, by renovating buildings, replacing inefficient equipment, and integrating rooftop solar PV. Research on EP diagnosis and mitigation measures has also started to move to the local scale (*e.g.*, Palma and Gouveia, 2022). Local stakeholders are in a unique position to deliver on decarbonisation and EP goals, including by tailoring and targeting interventions to their local contexts (Berger *et al.*, 2023). Although local-scale action holds significant potential, Catney *et al.* (2014) warn against the assumption that it is inherently more democratic, just, or effective than actions taken at other scales. Furthermore, while recognising the drawbacks of megaprojects, Sovacool (2014) also acknowledges the need to manage the risks of polycentric approaches in energy transitions.

EPAH (2024b) puts forward recommendations for local-scale action, including EP diagnosis, awareness campaigns, behavioural change activities, one-stop shops (OSS), renewable energy communities (REC), home renovation, EE improvements, regulatory incentives, and financial mechanisms. The revised Energy Performance of Buildings Directive (Directive (EU) 2024/1275) calls for Member States to establish OSSs, defined as technical assistance facilities that target all actors involved in building renovations and that are easily accessible to the population, including vulnerable and energy-poor households.

While prosumers, *i.e.* consumers that produce and self-consume renewable energy (Campos and Marín-González, 2020), have been around for decades, more recently, community energy has also risen to prominence. Since 2018, the Renewable Energy Directive (Directive (EU) 2018/2001, p. 103), defines a REC as "a legal entity which [...] is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity". Furthermore, it states that REC shareholders or members are "natural persons, SMEs or local authorities, including municipalities" and that their primary purpose is to "provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits". Still, community energy is a highly diverse sector, with many types of actors and organisational forms, multiple sets of objectives and actions, and different strategies and technologies (Seyfang *et al.*, 2013).

Bottom-up community-led initiatives, also referred as grassroots or citizens' initiatives, can be important to promote change by kick-starting and enabling locally crafted solutions which are often driven by environmental and social benefits rather than by financial motives (Middlemiss and Parrish, 2009). Recently, the United Nations (2024) has acknowledged the role of the social and solidarity economy, for instance of non-governmental organisations (NGOs), in achieving SDG 7. Collective actions led by citizens across Europe are already contributing towards increased energy self-sufficiency, local sustainable development, and greater citizen engagement (Schwanitz *et al.*, 2023). Given the costs, organization capacity, and knowledge needed kick-star local action, it is important to prevent the exclusion of vulnerable households and communities (Campos *et al.*, 2020).

Finally, the envisioned role of citizens in energy transitions has led to the popularisation of discourses claiming energy democracy and energy justice. The former entails popular sovereignty and empowerment, participatory democratic governance, and civic ownership in energy systems (Szulecki, 2018; Stephens, 2019). The latter builds on existing formulations of environmental and climate justice, seeking to analyse current injustices and set remediation processes while emphasizing that those that are energy-poor, vulnerable, or HTR should also benefit from energy transitions (Sovacool and Dworkin, 2015; Jenkins *et al.*, 2016). Citizen-led collective actions deployed at local-scale are not a panacea nor a short- or medium-term replacement for commercial projects or governmental policies, but may hold the promise of more sustainable, just, and democratic energy systems (Schwanitz *et al.*, 2023).

1.4 Problem definition

Climate change and EP are high on the agenda worldwide. At this point, climate change causes and impacts have reached an overwhelming consensus (Lynas *et al.*, 2021; IPCC, 2023). Most solutions that curtail GHG emissions, while contributing towards several of the United Nation's SDGs (*e.g.*, by ensuring access to affordable and clean energy), are mature and well known (Frischmann *et al.*, 2020; IPCC, 2022; IEA, 2023). However, there is still an enormous gap between words and action - which Glavovic *et al.* (2022) label as a tragic rift in the science-society contract - including when it concerns energy transitions. For example, according to the IEA (2024b, 2024c), global EE progress (measured by the rate of change in primary energy intensity) is stuck at an improvement rate of 1% per year and must double by 2030. RES growth has surpassed expectations mainly due to strong deployment of solar power, but still falls short of the target of tripling installed capacity by 2030.

The EU has developed a solid policy framework for decarbonisation (*e.g.*, European Commission, 2019) and, more recently, for EP mitigation (*e.g.*, European Commission, 2023). There is overwhelming citizen support for energy transitions, *e.g.*, eight out of ten citizens agree with climate neutrality targets and over two-thirds have taken measures to reduce energy use at home (European Commission, 2024). However, progress towards SDGs, particularly SDG 7 (affordable and clean energy), has been insufficient in the EU (Eurostat, 2024). While EE and RES deployment has continued, current rates still fall short of 2030 goals and EP vulnerability has risen in recent years. Taking the example of EU Member State Portugal, its latest National Energy and Climate Plan (NECP) for 2030 advances challenging targets for GHG emissions reductions (55% reduction compared to 2005 levels by 2030 and climate neutrality by 2045), EE improvement (primary energy consumption below 16711 ktoe by 2030), and RES installation (51% share in gross final energy consumption in 2030), while also enshrining EP eradication as a critical objective of the country's energy transition (Portuguese Government, 2024a).

The European Commission (2019) has articulated the “energy efficiency first” principle in its European Green Deal legislative framework. More recently, EE also made it as a centrepiece of the European Commission's (2025) Action Plan for Affordable Energy, focused on lowering energy costs, completing the Energy Union, attracting investment and delivery, and being ready for crises. Beyond reduced energy demand and lower GHG emissions, EE can have multiple benefits across many different spheres, including on energy security and prices, macro-economy, poverty alleviation, health and well-being, employment, local air pollution, resource management, and disposable income (IEA, 2014). For instance, renovating the building stock can generate multiple social, environmental, and economic benefits, making the

European Renovation Wave strategy a crucial piece of the EU's climate neutrality and EP eradication goals (Shnapp *et al.*, 2020; European Commission, 2020b).

Even though EE is considered a win-win solution with tremendous potential, an EE gap, defined as the discrepancy between optimal and actual adoption of efficient technologies and practices (*e.g.*, Backlund *et al.*, 2012), persists with not enough progress at EU scale (Eurostat, 2024). Furthermore, the Buildings Performance Institute Europe (BPIE, 2024) finds that current annual building renovation rates remain far below the expectations of the European Renovation Wave. For example, in Portugal, annual renovation rates sit at around 1% per year, with deep energy renovations accounting for much less, and current investment levels are several orders of magnitude below what's needed to fully renovate the building stock by 2050 (Portuguese Government, 2021; Joanaz de Melo *et al.*, 2021; Palma *et al.*, 2022).

Deploying RES technologies, such as solar and wind power, is paramount for decarbonising current energy systems. RES technologies, prominently solar PV systems, are opening possibilities for the mainstreaming of decentralized small-scale electricity generation, in addition to, and/or in lieu of, centralized large-scale power plants (Roby and Dibb, 2019). Solar PV can be integrated into the built environment, for example, within urban boundaries, mitigating negative environmental impacts and enhancing local resilience (Freitas *et al.*, 2015). Rahdan *et al.* (2024) find that distributed solar PV can reduce the total costs of the EU's electricity system due to reduced peak demand and grid expansion. Moreover, citizens can become empowered and play a more active role within a decentralized energy system (*e.g.*, as prosumers or as energy community members), with Kampman *et al.* (2016) estimating that around half of the EU's households could produce renewable energy by 2050.

The European Commission (2022) recognises the potential of distributed RES generation, as exemplified by the REPowerEU Plan implemented in response to Russia's invasion of Ukraine and to the energy crisis. Taking the example of Portugal, the revised NECP has highly ambitious targets for solar PV generation, rising from around 5.2 GW in 2024 to 20.8 GW in 2030, including 5.5 GW of decentralised production by 2030 (Portuguese Government, 2024a). Despite falling technology costs, several obstacles block distributed RES generation. These include mismatched and unclear policies and regulations, licensing struggles, lack of awareness and knowledge, difficulties in involving citizens, lack of access to finance, grid capacity limitations, and organisational challenges (Horstink *et al.*, 2020; Bashi *et al.*, 2023; Energy Communities Repository, 2024). Krupnik *et al.* (2022) propose a research agenda for social sciences on RES, focusing on novel financial and organisational structures, democratisation of energy systems, geographies and scales of renewable energy, power dynamics and conflicts, social acceptance, and justice, equity, and societal inclusion, among other topics.

The European Pillar of Social Rights, jointly proclaimed by the European Parliament, the Council and the Commission in 2017, includes energy among the essential services which everyone is entitled to access (European Commission, 2021). Still, EP affects well over 35 million Europeans, with Eastern and Southern European countries particularly vulnerable (Maier and Dreoni, 2024). For instance, the Portuguese Government (2024b) estimates that up to 29% of Portugal's population - around three million people - may suffer from EP. To address this issue amid the energy crisis, existing policies promote consumer protection mechanisms and propose citizen involvement in deploying EE and RES as a key feature of just energy transitions.

However, significant segments of the population have been shown to be HTR with traditional energy policies, financing schemes, and business models (Ambrose *et al.*, 2019b). Likewise, research suggests that these consumer profiles will also be HTR with emerging social innovation approaches (*e.g.*, Hanke and Lowitzsch, 2020; Hall *et al.*, 2021). While establishing a research agenda, Sovacool (2014) called for the need to study the social groups that benefit from current energy systems and those that are usually excluded. A few authors (*e.g.*, Baker *et al.*, 2019) stress that it is not citizens and businesses themselves that are HTR, but it is policymakers, researchers, and practitioners who are not going the extra mile to deploy effective approaches. Indeed, not much progress is being made on HTR groups, due to their inherent complexity and to well-researched but persistent barriers, such as market failures and information gaps (Schleich and Gruber, 2008; Labanca *et al.*, 2015; Koch and Christ, 2018).

While the HTR concept has been put forward by several researchers across the Global North (*e.g.*, Ambrose *et al.*, 2019a; Ashby *et al.*, 2020; Rotmann *et al.*, 2020), the systematisation, characterisation, and quantification of the profiles that may fit into this broad framing can still be enhanced. Vulnerable households have been the focus of extensive research, for example, in the context of EP assessments (*e.g.*, Simcock *et al.*, 2021). On the other hand, high-income households have only recently received attention, partly because their intensive energy use implies a large scope for reductions (Ambrose *et al.*, 2024; Mundaca and Wamsler, 2025). The split incentives barrier, among other challenges, mean that the private rented sector is regularly considered as HTR (Papantonis *et al.*, 2022). In the non-residential sector, HTR groups typically include SMEs, where lack of knowledge and insufficient funds are important obstacles (Agrawal *et al.*, 2023). The HTR lens may be useful for a deep dive on the barriers hindering the participation of specific groups in energy transitions and as a tool to analyse and design multi-scalar policies and interventions to identify shortcomings and improvement opportunities.

While citizen engagement is essential, there is still a lack of understanding of how to activate them effectively and massively for energy transitions (Chilvers *et al.*, 2021). This stands particularly true for HTR energy users, who often require targeted and tailored policies and interventions (Mundaca *et al.*, 2023). Local-scale approaches aiming to leverage the largely unharvested EE and RES potential, such as OSS and REC, are still underexplored and poorly field-tested in the EU and in Portugal, which limits their latent contributions. Furthermore, their deployment, long-term sustainability, and transformational potential is contingent on multi-scalar regulatory support, funding streams, and social acceptance, among other factors (Caramizaru and Uihlein, 2020; Vogler and Kump, 2023).

Middle actors may serve as a bridge between policymakers and citizens, with local authorities and frontline organisations in the health, social, housing, and community sectors possibly well-placed to fulfil this role (*e.g.*, European Commission, 2023). However, local governments are understaffed, struggle with limited budgets, and have difficulties attracting professionals. Ancelle *et al.* (2022) estimate that, on average, 2.5 additional full-time positions are needed per municipality in the EU to support local energy transitions (for Portugal, this analysis corresponds to around nine additional full-time positions per municipality or to around one additional full-time position per civil parish). More research is still needed to better understand how to bring local stakeholders on-board as enablers of energy transitions.

The deployment of EE and RES is not happening fast enough, EP vulnerability is stagnating or worsening, and citizen participation in energy transitions is still lacking. The journey towards a future energy system anchored on energy justice and democracy is fundamentally off track. Researching the challenges faced by citizens and businesses - especially by those that are harder-to-reach - and addressing them through targeted and tailored policies and actions embedded at local scale may accelerate energy transitions and unlock their full potential.

1.5 Objective and research questions

Aiming to tackle the identified challenges, this research aims to increase knowledge on the topic of "how to engage HTR energy users in energy transitions". HTR energy users may represent a significant number of families and businesses, whose participation in energy issues is severely constrained by a wide range of vulnerabilities, circumstances and/or characteristics. Nevertheless, effectively engaging this heterogeneous audience, for instance, through targeted and tailored policies and interventions and through local-scale action, can be vital to foster just energy transitions.

This key objective can be further divided into four specific objectives: i) to systematise and characterise detailed HTR profiles in the EU context and to estimate the size of these groups at multiple scales (*i.e.*, EU, Member States, Municipal, and Sub-municipal), ii) to operationalise the HTR concept by assessing if and how current energy policies and on-the-ground interventions are inclusive of the specific needs of HTR audiences, iii) to pilot and explore real-world case studies of energy-related interventions aimed at engaging citizens and HTR groups in the context of Portugal and of the Lisbon Metropolitan Area, and iv) to critically assess the potential roles of local organisations as middle actors in energy transitions and the challenges and opportunities that these multi-stakeholder collaborations entail. Additionally, this research aims to produce useful theoretical and empirical knowledge for policymakers, researchers, and practitioners engaged in energy transitions at multiple scales.

The following research questions (RQ) were formulated to guide the research towards its goals:

- RQ1: Who might be classified as a hard-to-reach energy user in the European Union and what is the significance of these groups at multiple scales?
- RQ2: How do national energy and climate policies and local-scale interventions integrate the specific challenges and needs of hard-to-reach energy users?
- RQ3: How can digital tools and local-scale actions engage the hard-to-reach in energy initiatives and mitigate energy poverty?
- RQ4: What roles can local organisations play in energy transitions and what conditions must be met to foster effective collaborations?

1.6 Thesis outline

The thesis consists of seven chapters. Chapters 3 to 6 (except for chapter 3.3) are already published as scientific papers, book chapters, conference papers, or international reports. The thesis outline is as follows:

- Chapter 1: Introduction. Frames the context of ongoing energy transitions and the potential role of citizens. Introduces and briefly reviews key research concepts and defines the problems to be addressed, the research objectives and the four RQs.
- Chapter 2: Methodology. Reflects on the research's scientific disciplines and philosophical stances and acknowledges the researcher's positionality and motivation. Summarises and integrates the mixed methods applied in the research, combining theoretical, empirical, and action research approaches.
- Chapter 3: Gauging hard-to-reach energy users at multiple scales. Presents a deep dive on residential and non-residential HTR energy users, with a literature review and the definition of a theoretical framework. Uses secondary data sources to gauge HTR groups at multiple scales, namely for the EU, all 27 Member States, and at national and local levels in Portugal. This chapter addresses RQ1. References: Sequeira *et al.* (2024a), Sequeira and Gouveia (2023), and Sequeira and Gouveia (forthcoming).
- Chapter 4: Applying the hard-to-reach lens to assess policies and interventions. Operationalises the HTR concept for the evaluation of policies and interventions. Assesses *ex-ante* the NECPs of Portugal and Belgium and analyses *ex-post* two on-the-ground interventions in Portugal. This chapter addresses RQ2. References: Sequeira and Gouveia (2025), and Sequeira *et al.* (2021).
- Chapter 5: Fostering engagement through digital and community-based approaches. Presents two case-studies piloted in conjunction with the research, namely a digital OSS for home renovation in Portugal (case-study 1) and a solar REC in Lisbon (case-study

2). Assesses best practices and shortcomings. This chapter addresses RQ3 and RQ4. References: Sequeira and Gouveia (2022), and Sequeira *et al.* (2024b).

- Chapter 6: Exploring the roles of local organisations in energy transitions. Describes another case-study consisting of a mobile OSS for energy support in Setúbal (case-study 3). Presents results from interviews with local organisations and fosters a discussion on middle actors in energy transitions. This chapter addresses RQ3 and RQ4. References: Sequeira *et al.* (2024c).
- Chapter 7: Discussion and conclusions. Integrates the key outputs from all previous chapters to directly answer the RQs. Provides an overall discussion of the research work, concludes with final considerations, and identifies future research opportunities.

References

Abbott, B.W., Abrahamian, C., Newbold, N., Smith, P., Merritt, M., Sayedi, S.S., Bekker, J., *et al.* (2023). Accelerating the Renewable Energy Revolution to Get Back to the Holocene. Earth's Future, 11, e2023EF003639. https://doi.org/10.1029/2023EF003639

Agrawal, R., Tommasi, L.D., Lyons, P., Zanoni, S., Papagiannis, G.K., Karakosta, C., *et al.* (2023). Challenges and opportunities for improving energy efficiency in SMEs: learnings from seven European projects. Energy Efficiency, 16, 17. https://doi.org/10.1007/s12053-023-10090-z

Ambrose, A., Baker, W., Batty, E., and Hawkins, A. (2019a). Reaching the "Hardest to Reach" with energy advice: final report. Sheffield Hallam University, Centre for Regional Economic and Social Research. https://doi.org/10.7190/cresr.2019.8286642862

Ambrose, A., Baker, W., Batty, E., and MacNair Hawkins, A. (2019b). Focus Article: "I have a panic attack when I pick up the phone": experiences of energy advice amongst 'hard to reach' energy users. People, Place and Policy, 14(1). https://doi.org/10.3351/ppp.2019.3479427335

Ambrose, A., Castano Garcia, A., Hawkins, A., Parkes, S., and Arbell, Y. (2024). Uneven consumption and the work of being a high consumer. In Horne, R., *et al.* (Eds.) Post Carbon Inclusion: transitions built on justice. Bristol University Press: https://bristoluniversitypress.co.uk/post-carbon-inclusion

Ancelle, A., Bourgeois, M., and Joubert, J. (2022). Human capacity in local governments: The bottleneck of the building stock transition. Energy Cities policy paper. Available at: https://www.localstaff4climate.eu/the-study/

Andersen, A.D., Geels, F.W., Coenen, L., Hanson, J., Korsnes, M., Linnerud, K., *et al.* (2023). Faster, broader, and deeper! Suggested directions for research on net-zero transitions. Oxford Open Energy, 2, 1-7. https://doi.org/10.1093/ooenergy/oiad007

Andre, P., Boneva, T. 2, Chopra, F., and Falk, A. (2024). Globally representative evidence on the actual and perceived support for climate action. Nature Climate Change, 14, 253-259. https://doi.org/10.1038/s41558-024-01925-3

Ashby, K., Smith, J., Rotmann, S., Mundaca, L., and Ambrose, A. (2020). HTR Characteristics. HTR Annex by Users TCP by IEA: Wellington. https://doi.org/10.47568/3XR102

Atkins, E. (2022). 'Bigger than Brexit': Exploring right-wing populism and net-zero policies in the United Kingdom. Energy Research & Social Science, 90, 102681. https://doi.org/10.1016/j.erss.2022.102681

Backlund, S., Thollander, P., Palm, J., and Ottosson, M. (2012). Extending the energy efficiency gap. Energy Policy, 51, 392-396. http://dx.doi.org/10.1016/j.enpol.2012.08.042

Baker, K.J., Mould, R., Stewart, F., Restrick, S., Melone, H., and Atterson, B. (2019). Never try and face the journey alone: Exploring the face-to-face advocacy needs of fuel poor householders in the United Kingdom. Energy Research & Social Science, 51, 210–219. https://doi.org/10.1016/j.erss.2019.01.009

Ballew, M.T, Uppalapati, S.S., Myers, T., Carman, J., Campbell, E., Rosenthal, S.A., *et al.* (2024). Climate change psychological distress is associated with increased collective climate action in the U.S. npj Climate Action, 3, 88. https://doi.org/10.1038/s44168-024-00172-8

Baruch-Mordo, S., Kiesecker, J., Kennedy, C.M., Oakleaf, J.R., and Opperman, J.J. (2019). From Paris to practice: sustainable implementation of renewable energy goals. Environmental Research Letters, 14, 109501. https://doi.org/10.1088/1748-9326/ab39ae

Bashi, M.H., Tommasi, L.D., Cam, A.L., Relãno, L.S., Lyons, P., Mundó, J., *et al.* (2023). A review and mapping exercise of energy community regulatory challenges in European member states based on a survey of collective energy actors. Renewable and Sustainable Energy Reviews, 172, 113055. https://doi.org/10.1016/j.rser.2022.113055

Bastien-Olvera, B.A., Conte, M.N., Dong, X., Briceno, T., Batker, D., Emmerling, J., *et al.* (2023). Unequal climate impacts on global values of natural capital. Nature, 625, 722-727. https://doi.org/10.1038/s41586-023-06769-z

Berger, B., Ockenfels, A., and Zachmann, G. (2023). Behavioral science can aid household participation in gas savings. Joule 7, 1-12. https://doi.org/10.1016/j.joule.2022.12.009

Bergquista, M., Thiela, M., Goldberg, M.H., and van der Linden, S. (2023). Field interventions for climate change mitigation behaviors: A second-order meta-analysis. PNAS, 120, 13, e2214851120. https://doi.org/10.1073/pnas.2214851120

Biely, K., Sareen, S., de Vries, G., Chappin, E., Bauwens, T., and Montagnino, F.M. (2024). Understanding the embeddedness of individuals within the larger system to support energy transition. Sustainability Science, 19, 687-700. https://doi.org/10.1007/s11625-024-01493-7

Boardman, B. (1991). Fuel poverty: from cold homes to affordable warmth. Bellhaven, London.

Bódis, K., Kougias, I., Jäger-Waldau, A., Taylor, N., and Szabó, S. (2019). A high-resolution geospatial assessment of the rooftop solar photovoltaic potential in the European Union. Renewable and Sustainable Energy Reviews, 114, 109309. https://doi.org/10.1016/j.rser.2019.109309

Bouzarovski, S., and Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. Energy Research & Social Science, 10, 31-40. http://dx.doi.org/10.1016/j.erss.2015.06.007

BPIE (2024). Healthy Buildings Barometer 2024. How to deliver healthy, sustainable, and resilient buildings for people. Buildings Performance Institute Europe. Available at: https://healthybuildings.velux.com

Brehm, J., and Gruhl, H. (2024). Increase in concerns about climate change following climate strikes and civil disobedience in Germany. Nature Communications, 15, 2916. https://doi.org/10.1038/s41467-024-46477-4

Breyer, C., Keiner, D., Abbott, B.W., Bamber, J.L., Creutzig, F., Gerhards, C., *et al.* (2023). Proposing a 1.0°C climate target for a safer future. PLOS Climate, 2(6), e0000234. https://doi.org/10.1371/journal.pclm.0000234

Caballero, N., and Ploner, M. (2022). Boosting or nudging energy consumption? The importance of cognitive aspects when adopting non-monetary interventions. Energy Research & Social Science, 91, 102734. https://doi.org/10.1016/j.erss.2022.102734

Callaghan, M., Schleussner, C.-F., Nath, S., Lejeune, Q., Knutson, T. R., Reichstein, M., *et al.* (2021). Machine-learning-based evidence and attribution mapping of 100,000 climate impact studies. Nature Climate Change. https://doi.org/10.1038/s41558-021-01168-6

Campos, I., and Marín-González, E. (2020). People in transitions: Energy citizenship, prosumerism and social movements in Europe. Energy Research & Social Science, 69, 101718. https://doi.org/10.1016/j.erss.2020.101718

Campos, I., Pontes Luz, G., Marín-Gonzalez, E., Swantje, G., Hall, S., and Holstenkamp L. (2020). Regulatory challenges and opportunities for collective renewable energy prosumers in the EU. Energy Policy, 138, 111212. https://doi.org/10.1016/j.enpol.2019.111212

Caramizaru, A., and Uihlein, A. (2020). Energy communities: an overview of energy and social innovation. EUR 30083 EN. JRC119433. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-10713-2. https://doi.org/10.2760/180576

Carfora, A. and Scandurra, G. (2024). Boosting green energy transition to tackle energy poverty in Europe. Energy Research & Social Science, 110, 103451. https://doi.org/10.1016/j.erss.2024.103451

Carvalho, A., and Ferreira, V. (2024). Climate crisis, neoliberal environmentalism and the self: the case of 'inner transition'. Social Movement Studies, 23, 1, 1-18. https://doi.org/10.1080/14742837.2022.2070740

Catney, P., MacGregor, S., Dobson, A., Hall, S. M., Royston, S., Robinson, Z., *et al.* (2014). Big society, little justice? Community renewable energy and the politics of localism. Local Environment, 19:7, 715-730. https://doi.org/10.1080/13549839.2013.792044

Chadwick, K., Russell-Bennett, R., and Biddle, N. (2022). The role of human influences on adoption and rejection of energy technology: A systematised critical review of the literature on household energy transitions. Energy Research & Social Science, 89, 102528. https://doi.org/10.1016/j.erss.2022.102528

Chancel, L., Piketty, T., Saez, E., Zucman, G., *et al.* (2022). World Inequality Report 2022. World Inequality Lab. https://wir2022.wid.world/

Chilvers, J., Bellamy, R., Helen Pallett, H., and Hargreaves, T. (2021). A systemic approach to mapping participation with low-carbon energy transitions. Nature Energy 6, 250-259. https://doi.org/10.1038/s41560-020-00762-w

Choi, E.Y., Lee, H., and Chang, V.W. (2023). Cumulative exposure to extreme heat and trajectories of cognitive decline among older adults in the USA. J. Epidemiol Community Health, 77, 728-735. https://doi.org/10.1136/jech-2023-220675

Cludius, K., Noka, V., Unger, N., Delfosse, L., Dolinga, T., Schumacher, K., *et al.* (2024). Transport poverty: definitions, indicators, determinants, and mitigation strategies. Luxembourg: Publications Office of the European Union. https://doi.org/10.2767/0662480

Cornelis, M. (2025). Framing summer energy poverty: Insights and recommendations for a resilient future. Final report. European Commission: Directorate-General for Energy. Publications Office of the European Union. https://data.europa.eu/doi/10.2833/3135617

Cuerdo-Vilches, T., Navas-Martín, M. A., and Oteiza, I. (2021). Behavior Patterns, Energy Consumption and Comfort during COVID-19 Lockdown Related to Home Features, Socioeconomic Factors and Energy Poverty in Madrid. Sustainability, 13, 5949. https://doi.org/10.3390/su13115949

Cunningham, C.X, Williamson, G.J., and Bowman, D.M.J.S. (2024). Increasing frequency and intensity of the most extreme wildfires on Earth. Nature Ecology & Evolution, 8, 1420-1425. https://doi.org/10.1038/s41559-024-02452-2

Dablander, F., Hickey, C., Sandberg, M., Zell-Ziegler, C., and Grin, J. (2025). Embracing sufficiency to accelerate the energy transition. Energy Research & Social Science, 120, 103907. https://doi.org/10.1016/j.erss.2024.103907

Debourdeau, A., Schäfer, M., Pel, B., Kemp, R., and Vadovics, E. (2024). A conceptual typology of energy citizenship. Energy Research & Social Science, 117, 103720. https://doi.org/10.1016/j.erss.2024.103720

Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of energy from renewable sources (recast). Official Journal of the European Union. Available at: https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng

Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast). Official Journal of the European Union, L 231, 1-111. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (recast). Official Journal of the European Union. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401275&pk_keyword=Energy&pk_content=Directive

Dorninger, C., Hornborg, A., Abson, D. J., von Wehrden, H., Schaffartzik, A., Giljum, S., *et al.* (2021). Global patterns of ecologically unequal exchange: Implications for sustainability in the 21st century. Ecological Economics, 179, 106824. https://doi.org/10.1016/j.ecolecon.2020.106824

Dunlap, A., Sovacool, B.K., and Novaković, B. (2024). 'A Dead Sea of Solar Panels:' solar enclosure, extractivism and the progressive degradation of the California desert. The Journal of Peasant Studies. https://doi.org/10.1080/03066150.2024.2388051

Elhacham, E., Ben-Uri, L., Grozovski, J., M. Bar-On, Y. M., and Milo, R. (2020). Global human-made mass exceeds all living biomass. Nature, 588. https://doi.org/10.1038/s41586-020-3010-5

Encyclical Letter Laudato Si' of the Holy Father Francis on Care for Our Common Home (2015). Available at: https://www.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html

Energy Communities Repository (2024). Barriers and action drivers for the development of different activities by renewable and citizen energy communities. Available at: https://circabc.europa.eu/ui/group/8f5f9424-a7ef-4dbf-b914-1af1d12ff5d2/library/22055ff9-1f49-41f8-a321-cbf20ca3d316/details

EPAH (2024a). National Indicators Dashboard. Energy Poverty Advisory Hub. Available at: https://energy-poverty.ec.europa.eu/epah-indicators

EPAH (2024b). Handbook 3: A Guide to Implementing Energy Poverty Mitigation Actions. Energy Poverty Advisory Hub. Available at: https://energy-poverty.ec.europa.eu/observatory/publications/energy-poverty-advisory-hub-epah-handbook-3-guide-implementing-energy

European Commission (2019). The European Green Deal. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions. Brussels, 11.12.2019. COM(2019) 640 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640&from=EN

European Commission (2020a). European Climate Pact. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions. Brussels, 9.12.2020, COM(2020) 788 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A788%3AFIN

European Commission (2020b). A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions. Brussels, 14.10.2020, COM(2020) 662 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

European Commission (2021). The European Pillar of Social Rights Action Plan. Luxembourg: Publications Office of the European Union, 2021. https://doi.org/10.2767/89

European Commission (2022). REPowerEU Plan. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions. Brussels, 18.5.2022, COM(2022) 230 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483

European Commission (2023). Commission Recommendation (EU) 2023/2407 of 20 October 2023 on energy poverty. Official Journal of the European Union, L series. Available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302407

European Commission (2024). SPECIAL EUROBAROMETER 555: Europeans' attitudes towards EU energy policy. https://doi.org/10.2833/918644

European Commission (2025). Action Plan for Affordable Energy - Unlocking the true value of our Energy Union to secure affordable, efficient and clean energy for all Europeans. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions. Brussels, 26.2.2025, COM(2025) 79 final. Available at: https://energy.ec.europa.eu/publications/action-plan-affordable-energy-unlocking-true-value-our-energy-union-secure-affordable-efficient-and_en

Eurostat (2024). Sustainable development in the European Union Monitoring report on progress towards the SDGs in an EU context - 2024 edition. Luxembourg: Publications Office of the European Union. https://doi.org/10.2785/98370

Falkenberg, M., Galeazzi, A., Torricelli, M., Marco, N.D., Larosa, F., Sas, M., *et al.* (2022). Growing polarization around climate change on social media. Nature Climate Change, 12, 1114-1121. https://doi.org/10.1038/s41558-022-01527-x

Fanning, A.L., O'Neill, D.O., Hickel, J., and Roux, N. (2022). The social shortfall and ecological overshoot of nations. Nature Sustainability, 5, 26-36. https://doi.org/10.1038/s41893-021-00799-z

Feola, G. (2020). Capitalism in sustainability transitions research: Time for a critical turn? Environmental Innovation and Societal Transitions, 35, 241-250. https://doi.org/10.1016/j.eist.2019.02.005

Fernandes, S. (2024). "Just" Means "Just" Everywhere: How Extractivism Stands in the Way of an Internationalist Paradigm for Just Transitions. International Journal of Politics, Culture, and Society, 37, 493-511. https://doi.org/10.1007/s10767-024-09475-4

Franta, B. (2021): Weaponizing economics: Big Oil, economic consultants, and climate policy delay. Environmental Politics. https://doi.org/10.1080/09644016.2021.1947636

Freitas, S., Catita, C., Redweik, P., and Brito, M. C. (2015). Modelling solar potential in the urban environment: State-of-the-art review. Journal Renewable and Sustainable Energy Reviews, 41, 915-931. https://doi.org/10.1016/j.rser.2014.08.060

Frischmann C. J., Mehra M., Allard R., Bayuk K., Gouveia J. P., and Gorman M. R. (2020). Drawdown's "System of Solutions" Helps to Achieve the SDGs. In: Leal Filho W., Azul A., Brandli L., Lange Salvia A., Wall T. (eds) Partnerships for the Goals. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham. https://doi.org/10.1007/978-3-319-71067-9_100-1

Geels, F.W. (2023). Demand-side emission reduction through behavior change or technology adoption? Empirical evidence from UK heating, mobility, and electricity use. One Earth, 6, 4, 337-340. https://doi.org/10.1016/j.oneear.2023.03.012

Glavovic, B.C., Smith, T.F., and White, I. (2022) The tragedy of climate change science. Climate and Development, 14:9, 829-833. https://doi.org/10.1080/17565529.2021.2008855

Gross, R., Hanna, R., Gambhir, A., Heptonstall, P., and Speirs, J. (2018). How long does innovation and commercialisation in the energy sectors take? Historical case studies of the timescale from invention to widespread commercialisation in energy supply and end use technology. Energy Policy, 123, 682-699. https://doi.org/10.1016/j.enpol.2018.08.061

Habersbrunner, K., Ospina, M.N., Wieser, P., Kuschan, M., and Reichmann, F. (2024). Study on gender-disaggregated data on energy poverty: Final Study Report. The European Economic and Social Committee (EESC). https://doi.org/10.2864/44780

Hall, S., Anable, J., Hardy, J., Workman, M., Mazur, C., and Matthews, Y. (2021). Matching consumer segments to innovative utility business models. Nature Energy, 6, 349-361. https://doi.org/10.1038/s41560-021-00781-1

Hanke, F., and Lowitzsch, J. (2020). Empowering Vulnerable Consumers to Join Renewable Energy Communities – Towards an Inclusive Design of the Clean Energy Package. Energies, 13, 1615. https://doi.org/10.3390/en13071615

Haywood, L., Leroutier, M., and Pietzcker, R. (2023). Why investing in new nuclear plants is bad for the climate. Joule, 7, 1663-1678. https://doi.org/10.1016/j.joule.2023.07.006

Henig, D., and Knight, D.M. (2023). Polycrisis: Prompts for an emerging worldview. Anthropology Today, 39, 2. https://doi.org/10.1111/1467-8322.12793

Hickel, J., and Slameršak, A. (2022). Existing climate mitigation scenarios perpetuate colonial inequalities. Lancet Planet Health, 6, e628-e631. https://doi.org/10.1016/S2542-5196(22)00092-4

Hickel, J., and Sullivan, D. (2024). How much growth is required to achieve good lives for all? Insights from needs-based analysis. World Development Perspectives, 35, 100612. https://doi.org/10.1016/j.wdp.2024.100612

Hickel, J., Brockway, P., Kallis, G., Keyßer, L., Lenzen, M., Slameršak, A., *et al.* (2021). Urgent need for post-growth climate mitigation scenarios. Nature Energy. https://doi.org/10.1038/s41560-021-00884-9

Ho, D.T. (2023). Carbon dioxide removal is an ineffective time machine. Nature, 616. https://doi.org/10.1038/d41586-023-00953-x

Horstink, L., Wittmayer, J. M., Ng, K., Luz, G.P., Marín-González, E., Gährs, S., *et al.* (2020). Collective Renewable Energy Prosumers and the Promises of the Energy Union: Taking Stock. Energies, 13, 421. https://doi.org/10.3390/en13020421

IEA (2014). Capturing the Multiple Benefits of Energy Efficiency. International Energy Agency. www.iea.org

IEA (2023). Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach - 2023 Update. International Energy Agency. www.iea.org

IEA (2024a). World Energy Outlook 2024. International Energy Agency. www.iea.org

IEA (2024b). Energy Efficiency 2024. International Energy Agency. www.iea.org

IEA (2024c). Renewables 2024: Analysis and forecast to 2030. International Energy Agency. www.iea.org

IPCC (2022). Climate Change 2022: Mitigation of Climate Change. Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. ISBN 978-92-9169-160-9. https://www.ipcc.ch/report/ar6/wg3/

IPCC (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. Intergovernmental Panel on Climate Change, Geneva, Switzerland, pp. 1-34. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., and Rehnera, R. (2016). Energy justice: A conceptual review. Energy Research & Social Science, 11, 174-182. http://dx.doi.org/10.1016/j.erss.2015.10.004

Jiglau, G., Bouzarovski, S., Dubois, U., Feenstra, M., Gouveia, J.P., Grossmann, K., *et al.* (2023). Looking back to look forward: Reflections from networked research on energy poverty. iScience 26, 106083. https://doi.org/10.1016/j.isci.2023.106083

Joanaz de Melo, J., Sousa, M. J. F., Pereira, A. M., Fernandes, F., Galvão, A. and Grilo, J. (2021). Strategy for a sustainable decarbonization of the energy sector in Portugal: identification of priority policy measures. In: Mauerhof, V. (Ed), The Role of Law in Governing Sustainability, 81-99. Routledge. ISBN: 978-0-367-74632-2

Jowitt, S.M., Mudd, G.M., and Thompson, J.F.H. (2020). Future availability of non-renewable metal resources and the influence of environmental, social, and governance conflicts on metal production. Communications Earth & Environment, 1, 13. https://doi.org/10.1038/s43247-020-0011-0

Kampman, B., Blommerde, J., and Afman, M. (2016). The potential of energy citizens in the European Union. Delft, CE Delft, September 2016. Available at: https://cedelft.eu/publications/the-potential-of-energy-citizens-in-the-european-union/

Kaul, N., and Buchanan, T. (2023). Misogyny, authoritarianism, and climate change. Anal Soc Issues Public Policy, 23, 308-333. https://doi.org/10.1111/asap.12347

Kelly, S., and Pollitt, M. (2011). The Local Dimension of Energy. University of Cambridge, Electricity Policy Research Group. EPRG Working Paper 1103. Cambridge Working Paper in Economics 1114. https://doi.org/10.1017/CBO9780511996191.016

Kenner, D., and Heede, R. (2021). White knights, or horsemen of the apocalypse? Prospects for Big Oil to align emissions with a 1.5 °C pathway. Energy Research & Social Science, available online 15 April 2021, 102049. https://doi.org/10.1016/j.erss.2021.102049

Kiesecker, J.M., Evans, J.S., Oakleaf, J.R., Dropuljić, K.Z., Vejnović, I., Rosslowe, C., *et al.* (2024). Land use and Europe's renewable energy transition: identifying low-conflict areas for wind and solar development. Frontiers in Environmental Science, 12, 1355508. https://doi.org/10.3389/fenvs.2024.1355508

Kikstra, J. S., Mastrucci, Al., Min, J., Riahi, K., and Rao, N. D. (2021). Decent living gaps and energy needs around the world. Environmental Research Letters, 16, 9. https://doi.org/10.1088/1748-9326/ac1c27

Koch, J., and Christ, O. (2018). Household participation in an urban photovoltaic project in Switzerland: Exploration of triggers and barriers. Sustainable Cities and Society, 37, 420-426. https://doi.org/10.1016/j.scs.2017.10.028

Kotz, M., Levermann, A., and Wenz, L. (2024). The economic commitment of climate change. Nature, 628, 551-557. https://doi.org/10.1038/s41586-024-07219-0

Krupnik, S., Wagner, A., Vincent, O., Rudek, T.J., Wade, R., Misík, M., *et al.* (2022). Beyond technology: A research agenda for social sciences and humanities research on renewable energy in Europe. Energy Research & Social Science, 89, 102536. https://doi.org/10.1016/j.erss.2022.102536

Labanca, N., Suerkemper, F., Bertoldi, P., Irrek, W., and Duplessis, B. (2015). Energy efficiency services for residential buildings: market situation and existing potentials in the European Union. Journal of Cleaner Production, 109, 284-295. http://dx.doi.org/10.1016/j.jclepro.2015.02.077

Lamb, W. F., Mattioli, G., Levi, S., Roberts, J. R., Capstick, S., Creutzig, F., *et al.* (2020). Discourses of climate delay. Sustainability 3, 17, 1-5. https://doi.org/10.1017/sus.2020.13

Lamboll, R.D., Nicholls, Z.R.J, Smith, C.J., Kikstra, J.S., Byers, E., and Rogelj, J. (2023). Assessing the size and uncertainty of remaining carbon budgets. Nature Climate Change, 13, 1360-1367. https://doi.org/10.1038/s41558-023-01848-5

Laakso, S., Castellazzi, E., Matschoss, K., and Rinkinen, J. (2024). Agents of change or victims of transition? Media framings on household roles during the energy crisis. Sustainability Science, 19, 739-762. https://doi.org/10.1007/s11625-023-01434-w

Lawrence, M., Homer-Dixon, T., Janzwood, S., Rockstöm, J., Renn, O., and Donges, J.F. (2024). Global polycrisis: the causal mechanisms of crisis entanglement. Global Sustainability 7, e6, 1-16. https://doi.org/10.1017/sus.2024.1

Lenton, T.M., Xu, C., Abrams, J.F., Ghadiali, A., Loriani, S., Sakschewski, B., *et al.* (2023). Quantifying the human cost of global warming. Nature Sustainability, 6, 1237-1247. https://doi.org/10.1038/s41893-023-01132-6

Li, M., Trencher, G., and Asuka, J. (2022). The clean energy claims of BP, Chevron, ExxonMobil and Shell: A mismatch between discourse, actions and investments. PLoS ONE, 17(2), e0263596. https://doi.org/10.1371/journal.pone.0263596

Liddell, C., and Morris, C. (2010). Fuel poverty and human health: A review of recent evidence. Energy Policy, 38, 2987-2997. https://dx.doi.org/10.1016/j.enpol.2010.01.037

Linkov, I., Galaitsi, S.E., Trump, B.D., Pinigina, E., Rand K., Cline, E.H., and Kitsak, M. (2024). Are civilizations destined to collapse? Lessons from the Mediterranean Bronze Age. Global Environmental Change, 84, 102792. https://doi.org/10.1016/j.gloenvcha.2023.102792

Lynas, M., Houlton, B. Z., and Perry, S. (2021). Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature. Environmental Research Letters, 16, 114005. https://doi.org/10.1088/1748-9326/ac2966

Maharasingam-Shah, E., and Vaux, P. (2021). 'Climate Lockdown' and the Culture Wars: How COVID-19 sparked a new narrative against climate action. Institute for Strategic Dialogue. https://www.isdglobal.org/

Mai, T., Denholm, P., Brown, P., Cole, W.,Hale, E., Lamers, P., *et al.* (2022). Getting to 100%: Six strategies for the challenging last 10%. Joule 6, 1981-1994. https://doi.org/10.1016/j.joule.2022.08.004

Maier, S. and Dreoni, I. (2024). Who is "energy poor" in the EU. European Commission, JRC138418. https://publications.jrc.ec.europa.eu/repository/handle/JRC138418

Martin, P., Ocko, I.B., Esquivel-Elizondo, S., Kupers, R., Cebon, D., Baxter, T., and Hamburg, S.P. (2024). A review of challenges with using the natural gas system for hydrogen. Energy Sci. Eng., 12, 3995-4009. https://doi.org/10.1002/ese3.1861

Mattioli, G., Lucas, K., and Marsden, G. (2018). Reprint of Transport poverty and fuel poverty in the UK: From analogy to comparison. Transport Policy, 65, 114-125. https://doi.org/10.1016/j.tranpol.2017.07.007.

Maus, V., and Werner, T.T. (2024). Impacts for half of the world's mining areas are undocumented. Nature, 625, 26-29. https://doi.org/10.1038/d41586-023-04090-3

McKay, D.I.A., Staal, A. Abrams, J.F., Winkelmann, R., Sakschewski. B., Loriani, S., *et al.* (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points. Science, 377, 6611. https://doi.org/10.1126/science.abn7950

Merz, J.J., Barnard, P., Rees, W.E., Smith, D., Maroni, M., Rhodes, C.J., *et al.* (2023). World scientists' warning: The behavioural crisis driving ecological overshoot. Science Progress, 106(3), 1-22. https://doi.org/10.1177/00368504231201372

Middlemiss, L., and Parrish, B. D. (2009). Building capacity for low-carbon communities: The role of grassroots initiatives. Energy Policy, 38, 7559-7566. https://doi.org/10.1016/j.enpol.2009.07.003

Milkoreit, M. (2023). Social tipping points everywhere? Patterns and risks of overuse. WIREs Climate Change, 14(2), e813. https://doi.org/10.1002/wcc.813

Milner, J., Turner, G., Ibbetson, A., Colombo, P.E., Green, R., Dangour, A.D., *et al.* (2023). Impact on mortality of pathways to net zero greenhouse gas emissions in England and Wales: a multisectoral modelling study. Lancet Planet Health, 7, e128-e136. https://doi.org/10.1016/S2542-5196(22)00310-2

Millward-Hopkins, J. (2022). Inequality can double the energy required to secure universal decent living. Nature Communications, 13, 5028. https://doi.org/10.1038/s41467-022-32729-8

Millward-Hopkins, J., and Oswald, Y. (2023). Reducing global inequality to secure human wellbeing and climate safety: a modelling study. Lancet Planet Health, 7, e147-e154. https://doi.org/10.1016/S2542-5196(23)00004-9

Möller, T., Högner, A.E., Schleussner, C.-F., Bien, S., Kitzmann, N.H., Lamboll, R.D., *et al.*, (2024). Achieving net zero greenhouse gas emissions critical to limit climate tipping risks. Nature Communications, 15, 6192. https://doi.org/10.1038/s41467-024-49863-0

Moore, K.D. (2021). Earth's Wild Music: Celebrating and Defending the Songs of the Natural World. Counterpoint. ISBN 978-1-64009-530-4.

Müller, R.C., Kim, J.-S., Lee, H., Muri, H., Tjiputra, J., Yoon, J.-H., and Schaepman-Strub, G. (2024). Radiative forcing geoengineering under high CO2 levels leads to higher risk of Arctic wildfires and permafrost thaw than a targeted mitigation scenario. Communications Earth & Environment, 5, 180. https://doi.org/10.1038/s43247-024-01329-3

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., *et al.* (2023). Hard-to-Reach Energy Users: An ex-post cross-country assessment of behavioural-oriented interventions. Energy Research & Social Science, 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Mundaca, L., and Wamsler, C. (2025). Engaging high-income earners in climate action: Policy insights from survey experiments. Ecological Economics, 227, 108387. https://doi.org/10.1016/j.ecolecon.2024.108387

Nahm, J.M., Miller, S.M., and Urpelainen, J. (2022). G20's US$14-trillion economic stimulus reneges on emissions pledges. Nature, 603. https://doi.org/10.1038/d41586-022-00540-6

Nijsse, F.J.M.M., Mercure, J.-M., Ameli, N., Larosa, F., Kothari, S., Rickman, J., *et al.* (2023). The momentum of the solar energy transition. Nature Communications, 14, 6542. https://doi.org/10.1038/s41467-023-41971-7

Obura, D.O., DeClerck, F., Verburg, P.H., Gupta, J., Abrams, J.F., Bai, X., *et al.* (2023). Achieving a nature- and people-positive future. One Earth, 6. https://doi.org/10.1016/j.oneear.2022.11.013

Oliveira, T., and Tegally, H. (2023). Will climate change amplify epidemics and give rise to pandemics? Science, 381, eadk4500. https://doi.org/10.1126/science.adk4500

Oliveras, L., Artazcoz, L., Borrell, C., Palència, L., José López, M., Gotsens, *et al.* (2020). The association of energy poverty with health, health care utilisation and medication use in southern Europe. SSM - Population Health, 12, 100665. https://doi.org/10.1016/j.ssmph.2020.100665

Oliveras, L., Peralta, A., Palència, L., Gotsens, M., José López, M., Artazcoz, L., Borrell, C., and Marí-Dell'Olmo, M. (2021). Energy poverty and health: Trends in the European Union before and during the economic crisis, 2007-2016. Health & Place, 67, 102294. https://doi.org/10.1016/j.healthplace.2020.102294

Ostarek, M., Simpson, B., Rogers, C., and Ozden, J. (2024). Radical climate protests linked to increases in public support for moderate organizations. Nature Sustainability, 7, 1626-1632. https://doi.org/10.1038/s41893-024-01444-1

Our World in Data (2024a). Global primary energy consumption by source. Consulted in March 2025. Available at: https://ourworldindata.org/grapher/global-energy-substitution

Our World in Data (2024b). COVID-19 vaccination coverage worldwide. Consulted in January 2025. Available at: https://ourworldindata.org/grapher/covid-people-vaccinated-marimekko

Pai, S., Emmerling, J., Drouet, L., Zerriffi, H., and Jewell, J. (2021). Meeting well-below 2C target would increase energy sector jobs globally. One Earth 4, 1026–1036. https://doi.org/10.1016/j.oneear.2021.06.005

Palma, P., and Gouveia, J.P. (2022). Bringing Energy Poverty Research into Local Practice: Exploring Subnational Scale Analyses. EU Energy Poverty Advisory Hub. Directorate General for Energy and Geology. European Commission. Available at: https://energy-poverty.ec.europa.eu/observatory/publications/epah-bringing-energy-poverty-research-local-practice-exploring-subnational

Palma, P., Gouveia, J. P., and Barbosa, R. (2022). How much will it cost? An Energy Renovation Analysis for the Portuguese Dwelling Stock. Sustainable Cities and Society, 78, 103607. https://doi.org/10.1016/j.scs.2021.103607

Papantonis, D., Tzani, D., Burbidge, M., Stavrakas, V., Bouzarovski, S., and Flamos, A. (2022). How to improve energy efficiency policies to address energy poverty? Literature and stakeholder insights for private rented housing in Europe. Energy Research & Social Science, 93, 102832. https://doi.org/10.1016/j.erss.2022.102832

Penn, J.L., and Deutsch, C. (2022). Avoiding ocean mass extinction from climate warming. Science, 376, 6592, 524-526. https://doi.org/10.1126/science.abe9039

Portuguese Government (2021). Resolução do Conselho de Ministros n.º 8-A/2021 – Aprova a Estratégia de Longo Prazo para a Renovação dos Edifícios ["Resolution of the Council of Ministers no. 8-A/2021 – Approving the Long-term Strategy for Building Renovation"]. Diário da República, 1.ª série, 23. Available on: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/8-a-2021-156295372

Portuguese Government (2024a). Plano Nacional Energia e Clima 2021-2030 (PNEC2030): Atualização/Revisão ["National Energy and Climate Plan 2021-2030 (NECP2030): Update/Revision"]. Version of October 1, 2024. Available at: https://apambiente.pt/clima/plano-nacional-de-energia-e-clima-pnec

Portuguese Government (2024b). Resolução do Conselho de Ministros n.º 11/2024 de 8 de Janeiro – Estratégia Nacional de Longo Prazo para o Combate à Pobreza Energética 2023-2050 ["Resolution of the Council of Ministers no. 11/2024 of January 8 – National Long-term Strategy for Energy Poverty Mitigation 2023-2050"]. Diário da República, 1.ª série, 5. Available on: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/11-2024-836222486

Project Drawdown (2020). The Drawdown Review: Climate Solutions for a New Decade. Available at: https://www.drawdown.org/drawdown-review

Rahdan, P., Zeyen, E., Gallego-Castillo, C., and Victoria, M. (2024). Distributed photovoltaics provides key benefits for a highly renewable European energy system. Applied Energy, 360, 122721. https://doi.org/10.1016/j.apenergy.2024.122721

Raworth, K. (2017). A Doughnut for the Anthropocene: humanity's compass in the 21st century. The Lancet Planetary Health, 1, E48-E49. https://doi.org/10.1016/S2542-5196(17)30028-1

Recalde, M., Peralta, A., Oliveras, L., Tirado-Herrero, S., Borrell, C., Palència, L., *et al.* (2019). Structural energy poverty vulnerability and excess winter mortality in the European Union: Exploring the association between structural determinants and health. Energy Policy, 133, 110869. https://doi.org/10.1016/j.enpol.2019.07.005

Regulation (EU) 2023/955 of the European Parliament and of the Council of 10 May 2023 establishing a Social Climate Fund and amending Regulation (EU) 2021/1060. Official Journal of the European Union, L130/1. Available at: https://eur-lex.europa.eu/eli/reg/2023/955/oj/eng

Rehbein, J.A., Watson, J.E.M., Lane, J.L., Sonter, L.J., Venter, O., Atkinson, S.C., James R. and Allan, J.R. (2020). Renewable energy development threatens many globally important biodiversity areas. Global Change Biology, 26, 3040-3051. https://doi.org/10.1111/gcb.15067

Richardson, K., Steffen, W., Lucht, W. Bendtsen, J., Cornell, S.E., Donges, J.F., *et al.* (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9, eadh2458. https://doi.org/10.1126/sciadv.adh2458

Ripple, W.J., Wolf, C., Newsome, T.M., Barnard, P., and Moomaw, W.R. (2020). World scientists' warning of a climate emergency. BioScience, 70, 8-12. https://doi.org/10.1093/biosci/biz088

Ripple, W.J., Wolf, C., Gregg, J.W., Rockström, J., Mann, M.E., Oreskes, N., *et al.* (2024). The 2024 state of the climate report: Perilous times on planet Earth. BioScience, 0, 1-13. https://doi.org/10.1093/biosci/biae087

Rivas, S., Urraca, R., Bertoldi, P., and Thiel, C. (2021). Towards the EU Green Deal: Local key factors to achieve ambitious 2030 climate targets. Journal of Cleaner Production, 320, 128878. https://doi.org/10.1016/j.jclepro.2021.128878

Roby, H., and Dibb, S. (2019). Future pathways to mainstreaming community energy. Energy Policy, 135, 111020. https://doi.org/10.1016/j.enpol.2019.111020

Rosenow, J. (2022). Is heating homes with hydrogen all but a pipe dream? An evidence review. Joule, 6, 2219-2239. https://doi.org/10.1016/j.joule.2022.08.015

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., *et al.* (2020). Hard-to-Reach Energy Users: A Literature Review. User-Centred Energy Systems TCP - HTR Task. ISBN: 978-0-473-64983-8. https://userstcp.org/hard-to-reach-energy-users-task/

Sareen, S. (2021). Digitalisation and social inclusion in multi-scalar smart energy transitions. Energy Research & Social Science, 81, 102251. https://doi.org/10.1016/j.erss.2021.102251

Schleich, J., and Gruber, E. (2008). Beyond case studies: barriers to energy efficiency in commerce and the services sector. Energy Economics, 30, 449-464. https://doi.org/10.1016/j.eneco.2006.08.004

Schmidt, G. (2024). Climate models can't explain 2023's huge heat anomaly — we could be in uncharted territory. Nature, 627, 467. https://doi.org/10.1038/d41586-024-00816-z

Shnapp, S., Paci, D., and Bertoldi, P. (2020). Untapping multiple benefits: hidden values in environmental and building policies. Publications Office of the European Union. JRC120683. https://doi.org/10.2760/314081

Schwanitz, V.K., Wierling, A., Paudler, H.A., von Beck, C., Dufner, S., Koren, I.K., *et al.* (2023). Statistical evidence for the contribution of citizen-led initiatives and projects to the energy transition in Europe. Scientific Reports, 13, 1342. https://doi.org/10.1038/s41598-023-28504-4

Sequeira, M.M., Gouveia, J.P., and Palma, P. (2021). Subtask 2: Case Study Analysis – Portugal. UsersTCP Task on Hard-to-Reach Energy Users, International Energy Agency Technology Collaboration Programme. HTR Task: Lisbon, Portugal. https://doi.org/10.47568/3XR115

Sequeira, M.M., and Gouveia, J.P. (2022). A Sequential Multi-Staged Approach for Developing Digital One-Stop Shops to Support Energy Renovations of Residential Buildings. Energies, 15, 5389. https://doi.org/10.3390/en15155389.

Sequeira, M.M., and Gouveia, J.P. (2023). Non-residential hard-to-reach energy users: A vast audience forgotten by the energy transition? Meeting on Energy and Environmental Economics (ME3) conference proceedings, May 2023, Aveiro, Portugal. https://doi.org/10.48528/v3b3-fk78

Sequeira, M.M., Gouveia, J.P., and Melo, J.J. (2024a). (Dis)comfortably numb in energy transitions: Gauging residential hard-to-reach energy users in the European Union. Energy Research & Social Science, 115, 103612. https://doi.org/10.1016/j.erss.2024.103612

Sequeira, M.M., Ferreira, E., and Gouveia, J.P. (2024b). From the bottom-up: the development process and participants of the Telheiras Renewable Energy Community, Portugal. In Vañó, M.J.V., et al. (Eds), POWERCOOP - Comunidades Energéticas de Autoconsumo: Análisis Organizacional Desde una Perspectiva Jurídica, de Gestión y Tecnológica (pp. 137-158). Instituto Universitario de Economía Social, Cooperativismo y Emprendimiento (IUDESCOOP). ISBN 978-84-127263-9-8. Available at: https://www.powercoop.es/

Sequeira, M.M., Gouveia, J.P. and Melo, J.J. (2024c). Can local organizations act as middle actors in energy support? Exploring their functions, motivations, challenges, and needs. Energy Efficiency 17, 81. https://doi.org/10.1007/s12053-024-10262-5

Sequeira, M.M., and Gouveia, J.P. (2025). Assessing the inclusiveness of the draft updated National Energy and Climate Plans 2030 of Belgium and Portugal through a hard-to-reach energy users lens. In Brito, P.S., *et al.* (Eds) Insights into Energy Trends - Selected Papers from ICOWEFS 2024. Part of the book series: Green Energy and Technology. ISBN: 978-3-031-83810-1. Available at: https://link.springer.com/book/9783031838101

Sequeira, M.M., and Gouveia, J.P. (forthcoming). From the national to the local scale: Assessing data on hard-to-reach energy users at municipal and sub-municipal levels in Portugal.

Seyfang, G., Park, J. J., and Smith, A. (2013). A thousand flowers blooming? An examination of community energy in the UK. Energy Policy, 61, 977-989. http://dx.doi.org/10.1016/j.enpol.2013.06.030

Shove, E. (2018) What is wrong with energy efficiency? Building Research & Information, 46:7, 779-789. https://doi.org/10.1080/09613218.2017.1361746

Siksnelyte-Butkiene, I. Streimikiene, D., Lekavicius, V., and Balezentis, T. (2021). Energy poverty indicators: A systematic literature review and comprehensive analysis of integrity. Sustainable Cities and Society, 67, 102756. https://doi.org/10.1016/j.scs.2021.102756

Simcock, N., Jenkins, K.E.H, Lacey-Barnacle, M., Martiskainen, M., Mattioli, G., and Hopkins, D. (2021). Identifying double energy vulnerability: A systematic and narrative review of groups at-risk of energy and transport poverty in the global north. Energy Research & Social Science, 82, 102351. https://doi.org/10.1016/j.erss.2021.102351

Sorman, A.H., and Stock, R. (2024). Solar masculinities from the south: Patriarchal and ethnoreligious authoritarianism through solar infrastructures in Turkey and India. Energy Research & Social Science, 114, 103583. https://doi.org/10.1016/j.erss.2024.103583

Sovacool, B.K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Research & Social Science, 1, 1-29. http://dx.doi.org/10.1016/j.erss.2014.02.003

Sovacool, B.K., and Dworkin, M.H. (2015). Energy justice: Conceptual insights and practical applications. Applied Energy, 142, 435-444. http://dx.doi.org/10.1016/j.apenergy.2015.01.002

Sovacool, B.K., Kim, J., and Yang, M. (2021). The hidden costs of energy and mobility: A global meta-analysis and research synthesis of electricity and transport externalities. Energy Research & Social Science, 72, 101885. https://doi.org/10.1016/j.erss.2020.101885

Sovacool, B.K., and Dunlap, A. (2022). Anarchy, war, or revolt? Radical perspectives for climate protection, insurgency and civil disobedience in a low-carbon era. Energy Research & Social Science, 86, 102416. https://doi.org/10.1016/j.erss.2021.102416

Sovacool, B.K., Baum, C.M, and Low, S. (2022). Climate protection or privilege? A whole systems justice milieu of twenty negative emissions and solar geoengineering technologies. Political Geography, 97, 102702. https://doi.org/10.1016/j.polgeo.2022.102702

Sovacool, B.K., Geels, F.W., Andersen, A.D., Grubb, M., Jordan, A.J., Kern, F., *et al.* (2025). The acceleration of low-carbon transitions: Insights, concepts, challenges, and new directions for research. Energy Research & Social Science, 121, 103948. https://doi.org/10.1016/j.erss.2025.103948

Statista (2024). Number of monthly active Facebook users worldwide as of 4th quarter 2023. Consulted in January 2025. Available on: https://www.statista.com/statistics/264810/number-of-monthly-active-facebook-users-worldwide/

Steffen, W., Sanderson A., Tyson P. D., Jäger J., Matson P. A., Moore III, B., *et al.* (2004). Global Change and the Earth System: A Planet Under Pressure. Executive Summary. International Geosphere-Biosphere Program (IGBP). ISBN 3-540-40800-2. Available at: http://www.igbp.net/globalchange/greatacceleration.4.1b8ae20512db692f2a680001630.html

Stephens, J.C. (2019). Energy Democracy: Redistributing Power to the People Through Renewable Transformation. Environment: Science and Policy for Sustainable Development, 61:2, 4-13. https://doi.org/10.1080/00139157.2019.1564212

Strona, G., and Bradshaw, C.J.A. (2022). Coextinctions dominate future vertebrate losses from climate and land use change. Science Advances, 8, eabn4345. https://doi.org/10.1126/sciadv.abn4345

Supran, G., Rahmstorf, S., and Oreskes, N. (2023). Assessing ExxonMobil's global warming projections. Science, 379, 153. https://doi.org/10.1126/science.abk0063

Susskind, L., Chun, J., Gant, A., Hodgkins, C., Cohen, J., and Lohmar, S. (2022). Sources of opposition to renewable energy projects in the United States. Energy Policy, 165, 112922. https://doi.org/10.1016/j.enpol.2022.112922

Szulecki, K. (2018). Conceptualizing energy democracy. Environmental Politics, 2018, 27, 1, 21-41. https://doi.org/10.1080/09644016.2017.1387294

The Islamic Foundation for Ecology & Environmental Sciences (2024). Al-Mizan: A Covenant for the Earth. ISBN 978-1-7385385-1-5. Available at: https://www.almizan.earth/

Thellufsen, J.Z., Lund, H., Mathiesen, B.V., Østergaard, P.A, Sorknæs, P., Nielsen, S., *et al.* (2024). Cost and system effects of nuclear power in carbon-neutral energy systems. Applied Energy, 371, 123705. https://doi.org/10.1016/j.apenergy.2024.123705

Tian, P., Zhong, H., Chen, X., Feng, K., Sun, L., Zhang, N., *et al.* (2024). Keeping the global consumption within the planetary boundaries. Nature, 635, 625-630. https://doi.org/10.1038/s41586-024-08154-w

Tollefson, J. (2025). Earth shattered heat records in 2023 and 2024: is global warming speeding up? Nature, News Explainer, 06 January 2025. https://doi.org/10.1038/d41586-024-04242-z

Tonelli, D., Rosa, L., Gabrielli, P., Caldeira, K., Parente, A., and Contino, F. (2023). Global land and water limits to electrolytic hydrogen production using wind and solar resources. Nature Communications, 2023, 14, 5532. https://doi.org/10.1038/s41467-023-41107-x

Trout, K., Muttitt, G., Lafleur, D., de Graaf, T.V., Mendelevitch, R., Mei, L., and Meinshausen, M. (2022). Existing fossil fuel extraction would warm the world beyond 1.5 ◦C. Environmental Research Letters, 17, 064010. https://doi.org/10.1088/1748-9326/ac6228

UNDESA (2020). World Social Report 2020: Inequality in a rapidly changing world. United Nations Department of Economic and Social Affairs. ISBN 978-92-1-130392-6. https://www.un.org/development/desa/dspd/world-social-report/2020-2.html

UNEP (2021). Making Peace with Nature: A scientific blueprint to tackle the climate, biodiversity and pollution emergencies. United Nations Environment Programme. Available at: https://www.unep.org/resources/making-peace-nature

UNEP (2024). Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments. United Nations Environment Programme. Nairobi. https://doi.org/10.59117/20.500.11822/46404

UNICEF (2021). The Climate Crisis is a Child Rights Crisis: Introducing the Children's Climate Risk Index. United Nations Children's Fund. ISBN 978-92-806-5276-5. Available at: https://www.unicef.org/reports/climate-crisis-child-rights-crisis

United Nations (1948). Universal Declaration of Human Rights, Article 25(1). Available at: https://www.un.org/en/about-us/universal-declaration-of-human-rights

United Nations (2015a). Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015. Available at: https://sdgs.un.org/

United Nations (2015b). Paris Agreement. Available at: https://www.un.org/en/climatechange/paris-agreement

United Nations (2024). Promoting the social and solidarity economy for sustainable development. United Nations General Assembly. Seventy-ninth session, Agenda item 18 (k). https://digitallibrary.un.org/record/4009889

UN Human Rights (2021). Bachelet hails landmark recognition that having a healthy environment is a human right. Geneva, 8 October 2021. Available at: https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=27635&LangID=E

Van Heerden, R., Edelenbosch, O.Y., Daioglou, V., Le Gallic, T., Baptista, L.B., Di Bella, A., *et al.* (2025). Demand-side strategies enable rapid and deep cuts in buildings and transport emissions to 2050. Nature Energy. https://doi.org/10.1038/s41560-025-01703-1

Vogel, J., and Hickel, J. (2023). Is green growth happening? An empirical analysis of achieved versus Paris-compliant CO2–GDP decoupling in high-income countries. Lancet Planet Health, 7, e759-e769. https://doi.org/10.1016/S2542-5196(23)00174-2

Vogler, A., and Kump, B. (2023). (Too) high hopes? How Austrian energy community actors construct their roles in the energy transition. Sustainability Science, 19, 701-714. https://doi.org/10.1007/s11625-023-01433-x

Way, R., Ives, M.C., Mealy, P., and Farmer, J.D (2022). Empirically grounded technology forecasts and the energy transition. Joule 6, 2057-2082. https://doi.org/10.1016/j.joule.2022.08.009

WEF (2025). Global Risks Report 2025. World Economic Forum. ISBN: 978-2-940631-30-8. https://www.weforum.org/publications/global-risks-report-2025/

Whal, D.C. (2016). Designing Regenerative Cultures. Triarchy Press. ISBN 978-989-54746-0-8.

WHO (2021). COP26 special report on climate change and health: the health argument for climate action. World Health Organization. Advanced proof. ISBN 978-92-4-003672-7. Available at: https://www.who.int/publications/i/item/cop26-special-report

Wilkinson, R.G., and Pickett, K.E. (2024). Why the world cannot afford the rich. Nature, 627, 268-270. https://doi.org/10.1038/d41586-024-00723-3

WWF (2024). Living Planet Report 2024 – A System in Peril. WWF, Gland, Switzerland. ISBN: 978-2-88085-319-8. https://www.wwf.eu/?15334891/System-in-peril-Average-wildlife-populations-size-declined-by-73-in-just-50-years-warns-WWF

Wynes, S., Davis, S.J., Dickau, M., Ly, S., Maibach, E., Rogelj, J., *et al.* (2024). Perceptions of carbon dioxide emission reductions and future warming among climate experts. Communications Earth & Environment, 5, 498. https://doi.org/10.1038/s43247-024-01661-8

Chapter 2.

METHODOLOGY

2.1 Philosophical stance and positionality

This research is transdisciplinary, integrating social sciences, engineering, behavioural science, environmental studies, policy analysis, and participatory approaches to provide a comprehensive understanding of the topic at hand and to produce knowledge that pushes past the traditional boundaries of each discipline. Furthermore, it does not adhere to a single philosophy of science. Ontologically (*i.e.*, nature of reality), it follows Critical Realism (*e.g.*, Stutchbury, 2021) - not only describing the "reality" of HTR groups but also identifying and denouncing structural injustices, policy gaps, and implementation shortcomings as root causes that hinder their engagement. Epistemologically (*i.e.*, how knowledge is created), it is Constructivist and Pragmatic (*e.g.*, Kaushik and Walsh, 2019) - being action-oriented, deploying participatory approaches with stakeholders and citizens, finding "what-works-best" in solving real-world problems, delivering practical outcomes, and enhancing policymakers and practitioners' knowledge.

The opted stances are not without risks and limitations. For instance, in line with critical realism, it is acknowledged that the deep dive on HTR energy users is, to a certain degree, subjective and constructed by the researcher, and that reality cannot be unproblematically understood, characterised or measured (Stutchbury, 2021). Furthermore, constructivist approaches with stakeholders and citizens can be seen as intrusive and judgemental, especially by marginalised groups. Pragmatic on-the-ground research may be unsuccessful due to unforeseen reasons and unintended consequences (Rotmann *et al.*, 2025). However, failure is not necessarily a negative outcome and can inform future experiments (Heiskanen *et al.*, 2022).

It is also fundamental to reflect on axiology, referring to the values and ethical considerations that underpin the research. The position of scientists in society has long been the subject of heated debate. A more traditional stance holds that science should be limited to providing the best available evidence in objective and independent terms and, thus, be restricted from verbalizing opinions on values and political decisions (*e.g.*, McNutt, 2024). In this perspective, Büntgen (2024) dictates that climate science and climate activism should be clearly separated, as "scholars should not have a priori interests in the outcome of their studies". Still, other authors challenge this paradigm, arguing that science has never been value-free or free from moral, political, social, or otherwise ideological values (Schipper *et al.*, 2024). Fazey *et al.* (2020) propose transformational change for future knowledge systems that should be more collaborative, open, diverse, egalitarian, and should embrace values and systemic issues.

Given the current challenges, Ripple *et al.* (2024) stress that scientists have a moral obligation to alert humanity and to show leadership through action. Moreover, Hagedorn *et al.* (2019) side with young climate activists, stating that their goals are aligned with the best available evidence and that they deserve respect and support from the scientific community. Indeed, a growing number of researchers is reconciling scientific values with activism to advocate for policy changes and participate in social movements (Finnerty *et al.*, 2025). For instance, Dablander *et al.* (2024a) surveyed over 9000 researchers across 115 countries, observing that scientists whose research links with climate change are engaging in advocacy (57%), legal protests (37%), and civil disobedience (18%) while also adopting lifestyle changes.

Nevertheless, intellectual and practical barriers stand in the way of more extensive advocacy and activism, such as lack of knowledge, pre-established notions on the role of scientists, disagreements with activists' ideology and strategy, fear of losing credibility, and lack of skills, time, or opportunity (Dablander *et al.*, 2024b). Scientists may also fear judgement both due to inconsistencies between their own behaviour and advocacy and due to do-gooder derogation (Sparkman and Attari, 2020). There is widespread concern that advocacy may undermine public trust in scientists, which is challenged by Cologna *et al.* (2025) through a case of collective climate activism by researchers in Switzerland. Considering the challenges faced by academics when trying to "move from publications to public actions", Gardner *et al.* (2021) ask universities to stand up to defend protesting rights and to push back against threats to academic freedom.

This work adheres to the more flexible stance on the role of scientists in society where it is not possible to fully dissociate values from research. Decarbonisation, EP eradication, social justice, and democratic participation are naturally normative aims. Given the environmental and social crisis affecting current and future generations - and due to the researcher's engagement in on-the-ground action - it is recognised that there are "a priori interests in the research outcomes". Shannon-Baker (2023) and Finnerty *et al.* (2025) argue that reflecting on one's own positionality and motivations can enhance the credibility and depth of analysis while keeping them in check is fundamental to maintain rigour and trust in research outputs.

In this context, it should be noted, for instance, that the investigation on HTR groups is performed from an "easy-to-reach" privileged position (*i.e.*, the author is male, white, of Portuguese nationality, educated in environmental sciences and engineering, high-middle-class, and so on), which is reinforced by the positionality of the research's supervisors and host institution. Furthermore, the author was extensively involved in the three selected case-studies. Explicitly, as an active member of the CENSE NOVA-FCT team that developed the Green Menu digital OSS (case-study 1) and piloted the Transition Point mobile OSS (case-study 3). Admittedly, this degree of involvement can present a risk to the quality of the research, for example, if it leads to disregarding evidence contrary to the hoped-for conclusions; however, this risk can be managed by adhering to high standards of scientific rigour (Milkoreit, 2023). How to minimise bias is considered a key question for energy research (Sovacool, 2014).

The risk of bias is even greater for case-study 2 - the Telheiras/Lumiar Renewable Energy Community - and should be clearly framed to contextualise the research work. The author has lived in the Telheiras neighbourhood for most of his life and has a personal attachment to it. His master's thesis work, in 2015-2016, was an analysis of energy efficiency in the local commerce of Telheiras (Sequeira and Joanaz de Melo, 2020). This was also one of the projects evaluated *ex-post* during the current research. In 2020, the author joined a volunteer group of the Local Partnership of Telheiras (a network of local NGOs) called "Sustainable Telheiras" which was tasked with reflecting on and improving the neighbourhood's sustainability. This group came up with the "Network of Ideas" process to ask the community about priority actions and recruit volunteers for their co-creation (Sequeira and Mameri, 2022). In practice, this was a collection of ideas during a festival and an online form in September 2020.

The "Network of Ideas" process led to the embryonic formulation of the idea "let's produce renewable energy and share it among neighbours" and was followed by a brainstorming session, in September 2021, and by the launch of volunteer working group, in November 2021. This has since become a somewhat mythological origin story "the idea emerged from the local community", linking to an ongoing EU-wide "power to the people" narrative which swells up the role of citizens and communities in energy transitions (*e.g.*, Friends of the Earth Europe *et al.*, 2020). Although this rhetoric is useful for inspirational purposes, it should not distract from a rigorous and critical outlook on the role of RECs in energy transitions and on the limitations and severe obstacles that this social innovation still entails. In this context, for clarity and rigour, it should be mentioned that the original motto for the Telheiras/Lumiar REC came from the author (although two other ideas were somewhat aligned by asking to reduce the carbon footprint of the neighbourhood and to install solar panels in the rooftops of condominiums).

Furthermore, the author was the informal coordinator of the "energy community" volunteer group since its inception and is, nowadays, the formal coordinator of the Telheiras/Lumiar REC while also being one of the members of its pilot project for solar PV generation and sharing. Two of the founding members of the REC are the author's family members, most of the others are neighbours with whom he has developed a personal relationship during the long and strenuous journey of setting up the energy community. Meanwhile, over the years, the author has appeared as the public face of the project in multiple occasions (*e.g.*, short film[1], photo exhibition[2], podcast[3], and multiple events and media) while also participating in the national and EU movement pushing for citizen-led, inclusive, and democratic energy communities (*e.g.*, participation in the first edition of the Portuguese Citizens' Commission on Environment and Energy[4] and in the creation of a Portuguese Energy Democracy Network[5]). A lot of effort has

---

[1] Energy communities: The step towards energy democratisation. Available at: https://youtu.be/E1X7zNd09oQ?si=av8yrHaso4NgcbTu

[2] Powerful Encounters: Picturing an end to energy poverty. Community energy for everyone. Available at: https://friendsoftheearth.eu/powerful-encounters/exhibit/community-energy-for-everyone/

[3] Podcast Biosfera: How to create an energy community? Available at: https://open.spotify.com/episode/3MS0DV8PtFiARxZbEZW6uH

[4] Citizens Commissions. Energy and Environment Commission (11th Commission). Available at: https://www.os230.pt/comissao-dos-cidadaos/

[5] Portuguese Energy Democracy Network. Available at: https://democracia-energetica.pt/

gone into the Telheiras/Lumiar REC, not only by the author but by other people volunteering their own free time, which of course generates a desire for its success and replication.

Thus, the author's role in the Telheiras/Lumiar REC is at least two-fold - as researcher and as community member. It introduces bias but has the benefit of offering a unique insider’s perspective useful for enhancing policymakers, practitioners, and researchers' knowledge on the topic. Furthermore, over the years, the author has become involved in environmental activism, for instance, having leadership positions in a major Portuguese environmental NGO and being one of the EU Climate Pact Ambassadors in Portugal.

This multiplicity of roles and latent risk of conflicts of interest are not unheard of in science, of course. For instance, Fazey *et al.* (2020) suggest that science should evolve from just producing knowledge to creatively generating action-oriented wisdom. Garg (2024) calls for researchers and engineers to get involved in their local communities while arguing that the scientific method allows for biased and passionate people to objectively and systematically assess information and draw conclusions. Other researchers (*e.g.*, von Hellermann, 2021) have narrated in detail their own involvement in community-led climate action, exploring the few successes and the many failures of these bottom-up initiatives, while reflecting on what is considered as an enriching but also challenging experience - including due to the personal costs of striking a balance between family time, scientific research, and volunteer work.

Finally, several authors (*e.g.*, Milkoreit, 2023) find that hope, curiosity and excitement are common motivating emotions in science, especially in sustainability science, and that these may be both necessary and beneficial for conducting good science. The author's overall motivation for this research is, for example, explicitly formulated in a vision for Telheiras written in 2020: "A neighbourhood with a positive energy balance, which consumes efficiently and where energy poverty is not a reality, where energy is produced and managed locally by citizens through renewable sources with low environmental impact, with carbon neutrality being a vital objective to mitigate climate change. A more dynamic, resilient, sustainable, healthy and happy neighbourhood, with a democratic energy system that enhances the local economy, employment and financial stability of the community, ensures the satisfaction of the needs of future generations and creates better social relations between neighbours.". A utopia of course, but this motivation has fairly influenced the development of the research goals, questions, and outputs.

2.2 Synopsis of research methods

2.2.1 Overview

Overall, the research adopts a mixed methods approach to fulfil its goals and address the RQs. Mixed methods are defined by Tashakkori and Creswell (2007) as "research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry". The incorporation of quantitative and qualitative results leverages the individual strengths of each approach to provide a comprehensive understanding of a complex research problem. Hereby, Figure 2.1 synthetises and integrates the methodological steps applied in the thesis, focusing on the chapters with the main research contributions. In the figure, arrows indicate interconnections between chapters, which are explained in the notes.

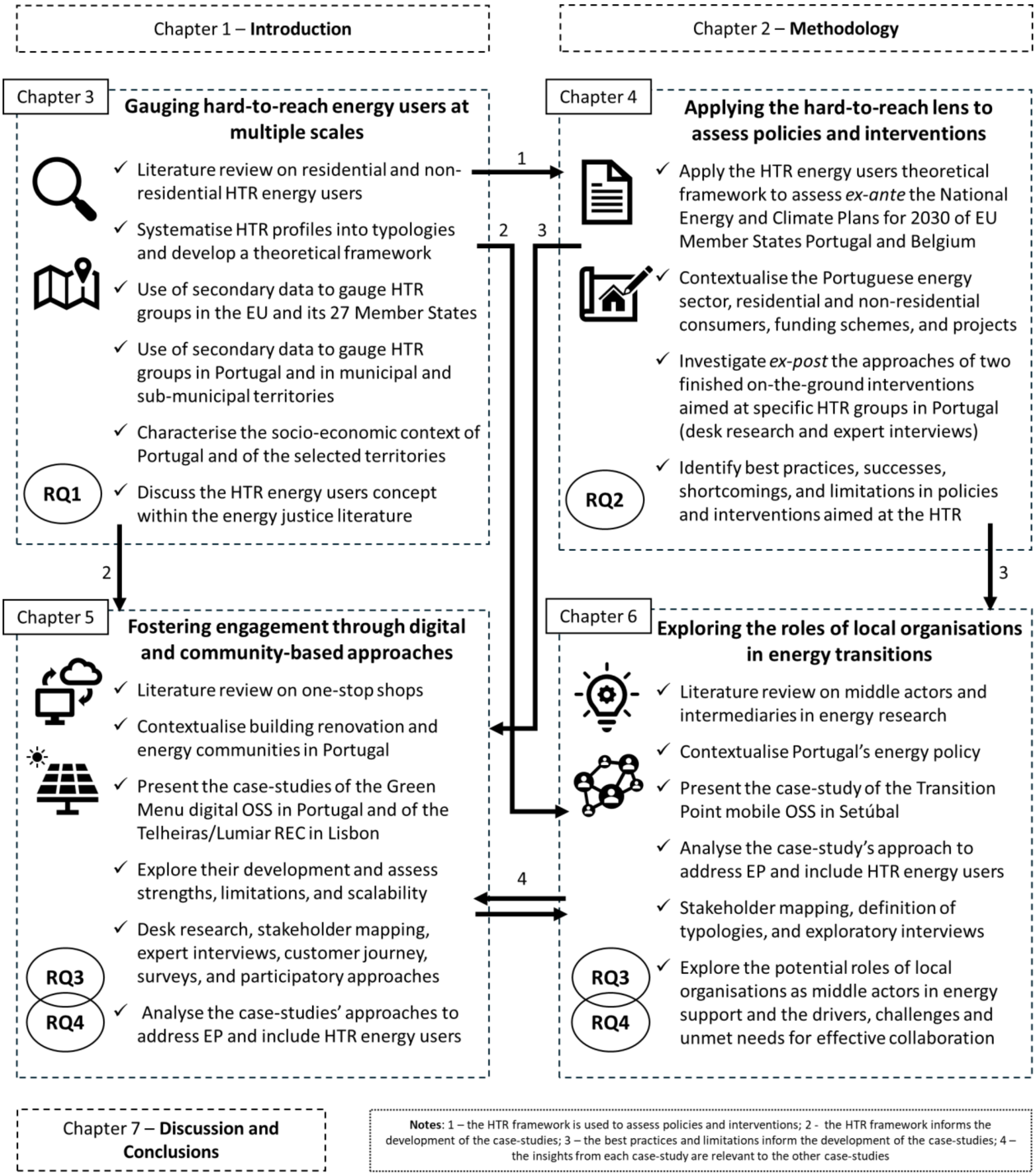


Figure 2.1 - Synthesis of research objectives and applied methods by chapter.

The methodology consists of three main blocks, namely i) literature review, ii) theory development on HTR energy users, its application to gauge the significance of HTR groups, and its operationalisation to assess national-scale energy and climate policies, and iii) case-study-based research in Portugal, namely the analysis of two previous projects aimed at HTR groups and the scientific support to the development of three projects, including desk research and a series of participatory methods with stakeholders, experts and citizens. Each method is described extensively in its respective chapter.

2.2.2 Literature review

First, a thorough literature review was performed to assess the state-of-the-art of the multiple topics that interlink with this research. This process followed the realist synthesis method (Pawson *et al.*, 2004) by identifying the key questions to be answered, drawing from a wide-ranging literature, and aiming for theoretical saturation in each topic. Relevant papers were collected following a combination of random, convenience, and snowball sampling.

Chapter 1 of the thesis introduces and briefly reviews the major themes of the research, such as energy justice and energy democracy, energy citizenship and HTR energy users, and local-scale approaches such as OSS and RECs, while providing a general contextualisation of the EU and Portuguese backgrounds. A more detailed review of specific topics is embedded in the remaining chapters, for instance, residential and non-residential HTR energy users are reviewed in chapter 3, OSS and RECs in chapter 5, and middle actors in energy transitions in chapter 6. A detailed analysis of major EU energy policies and of the Portuguese social and economic background, as well as of its energy system and key energy policies, measures and projects, is performed across several chapters. This assessment of the state-of-the-art was fundamental to inform the development of the next steps of the research in line with its objectives and RQs.

2.2.3 Theory development and application

Building on the broad HTR energy users definition proposed by Rotmann *et al.* (2020), on the five major groups identified by these authors, and on a wide-ranging literature review of diverse consumers' profiles, a theoretical framework for HTR energy users was designed (chapters 3.1 and 3.2). This theoretical framework provides a structure to organise, interpret, assess, and discuss data, which is substantiated with well-established research (Kivunja, 2018). It is based on the definition of several typologies for HTR energy users according to their characteristics and to the barriers that hinder their engagement in energy transitions.

Typologies are a well-established analytical tool including to form and refine concepts, draw out underlying dimensions, and create categories for classification and measurement (Collier *et al.*, 2012). One of the critiques of typologies-based research is that it may be unsophisticated and oversimplify reality - this is acknowledged in this thesis - however, if designed with rigor, typologies can provide a useful qualitative foundation for quantitative measurements. The proposed typologies are, of course, not "set in stone" and researchers can and should criticise, modify, and adapt the framework, for instance, to better reflect their specific contexts. Furthermore, the incidence of intersectionality - as the "insight that race, class, gender, sexuality, ethnicity, nation, ability, and age operate not as unitary, mutually exclusive entities, but rather as reciprocally constructing phenomena" (Collins, 2015) - is fully recognised in the research.

Although its limitations are acknowledged, the theoretical framework on HTR energy users was used as a foundation for several of the following steps of the research. To provide a quantitative dimension to the categorised typologies, a thorough assessment of the statistical data available in the Eurostat database was performed (chapters 3.1 and 3.2). A similar analysis of top-down indicators was performed by Gouveia *et al.* (2022, 2023) for national-scale EP assessment in EU Member States. Secondary data from Eurostat were collected and processed, and indicators were defined and selected, with the goal of assessing the size of specific HTR groups in the EU and in all its 27 Member States as a share of the total population and of the total number of businesses, for the residential and non-residential sectors, respectively. Furthermore, for the residential sector, a more detailed quantitative measurement was performed to pinpoint "priority" HTR groups that intersect at least two different typologies. Data gaps were identified and highlighted. This assessment allowed a deeper discussion on the role of HTR energy users in energy transitions and on how to foster the engagement of HTR groups.

In addition, the HTR energy users theoretical framework, including both its qualitative and quantitative outputs, was used as a lens for an *ex-ante* policy assessment of the NECP for 2030 of Portugal - as the main setting of the research - and of Belgium - as a contrasting case and as a testbed before expanding the analysis to other Member States, some of which still do not have their NECPs finalised (chapter 4.1). This exercise defined and applied keywords, representative of each HTR typology, to evaluate if and how these key policy documents explicitly target HTR groups and to map best practices and shortcomings according to each national context. A similar approach was employed by Vandyck *et al.* (2023) to understand if and how key EU energy policies explicitly recognise EP and the social implications of climate neutrality.

Finally, the theoretical framework was also transferred to the local level, namely for two municipalities and one civil parish in Portugal (chapter 3.3). In this case, secondary data from Statistics Portugal (INE) were collected and processed, mimicking what was previously performed at EU and national scales. A similar approach was developed by Gouveia *et al.* (2019) to map winter and summer EP vulnerability in Portuguese municipalities and civil parishes. This methodological step builds a bridge between the theoretical research on HTR groups, and the empirical and action research deployed at case-study level in Portugal. The quantitative assessment of HTR groups was performed for the case-studies' territories, namely the Setúbal and Lisbon Municipalities and the Lumiar Civil Parish.

2.2.4 Case-study-based research

Before delving into the case-studies, an additional step is worth mentioning, namely the *ex-post* assessment of on-the-ground interventions that explicitly aimed to engage HTR energy users (chapter 4.2). This work was performed in collaboration with the IEA's UsersTCP Task on Hard-To-Reach Energy Users and followed a theory of change approach proposed by Rotmann *et al.* (2021). It consists of a research framework called "The ABCDE Building Blocks of Behaviour Change" (Karlin *et al.*, 2021), which serves to evaluate interventions according to five dimensions: audience, behaviour, content, delivery, and evaluation. In Portugal, two already finished projects were evaluated, namely the LIGAR - Energy Efficiency for All project focused on vulnerable households in 10 selected areas of the Portuguese mainland (Horta *et al.*, 2019) and the Energy Efficiency in Telheiras' Traditional Commerce project focused on services and commerce small businesses in a specific neighbourhood of Lisbon (Sequeira and Joanaz de Melo, 2020). Applied methods included an extensive desk research process and interviews with experts (n=3) that had leading roles in the projects. This work was, on the one hand, informed by the literature review, and, on the other hand, provided key insights and recommendations for the more effective deployment of the three case-studies. The reports from eight Global North countries, spanning three continents, were integrated into a cross-country analysis of interventions targeted at HTR groups published by Mundaca *et al.* (2023).

While applying its methods and pursuing its objectives, this thesis overlapped the development of three on-the-ground pilot projects which became the research's case-studies. Even if the case-studies were selected through convenience sampling, these represent innovative approaches in Portugal and even in the EU and can be considered as paradigmatic cases (as defined by Flyvbjerg, 2006) whose insights can foster scientific development in their domains. The analysis of the case-studies follows a longitudinal approach across multiple points in time spanning years of research (Sovacool, 2014). Flyvbjerg (2006) breakdowns misunderstandings about case-study research, including that it is not possible to generalise from a single case - often case-studies are not aiming at statistical generalisation but instead look to explore a phenomenon in detail, provide context-specific insights, and contribute to scientific knowledge - and that case-studies contain verification bias and leave too much open for interpretation - bias is an inherent part of all research methods and can be reduced through rigorous methodologies and validation. Moreover, Sovacool (2014) highlights that striking a balance between depth - extensive research on a small sample - and breath - generalisation of insights beyond the case-studies - is a fundamentally open issue for energy research.

The case-studies are i) the Green Menu digital OSS developed for residential buildings renovation in Portugal, ii) the Telheiras/Lumiar REC established in Lisbon, Portugal, and iii) the Transition Point mobile OSS first piloted in Setúbal, Portugal (Figure 2.2).

Figure 2.2 - The case-studies: 1) top image - Green Menu virtual OSS, 2) bottom-left image - Transition Point mobile OSS, and 3) bottom-right image - Telheiras/Lumiar REC.

The Green Menu digital OSS for residential buildings renovation (case-study 1, further described in chapter 5.1) was developed in 2020, during the COVID-19 pandemic, as the key output of the European project PAS2020 (Pan-European Approach on Sustainable Heritage: Regeneration by a retrofitting economy) funded by the Climate-KIC's call for proposals to support post-COVID-19 green recovery[6]. In addition to CENSE NOVA-FCT, the partners were De Groene Grachten (The Netherlands) and E-Zavod (Slovenia). The Green Menu is a digital platform that provides integrated information to support the energy renovation of residential buildings in Portugal, including technical measures, calculation tools, funding schemes, and regulations. It features a 3D model of a typical building from Lisbon's historical areas. This

[6] The Portuguese Green Menu digital OSS for home renovation. Available at: https://www.menurenovacaoverde.pt/

digital OSS is currently being overhauled in the EU-funded LIFE project HORIS: Home Renovation Integrated Services (2023-2026)[7].

The Telheiras/Lumiar REC (case-study 2, further described in chapter 5.2) is a community-led initiative that first emerged in 2020 during a collection of ideas titled "Network of Ideas" which was promoted by the Local Partnership of Telheiras - a network of over 20 local NGOs - specifically by its "Sustainable Telheiras" working group[8]. In 2021, this idea started to be co-developed by a group of volunteers from the Telheiras neighbourhood which was coordinated by the author. In 2022, the Local Partnership of Telheiras and the Lumiar Civil Parish applied to the first round of EPAH's technical assistance, thereby receiving formal support from Coopérnico - Portugal's first and only renewable energy cooperative - and from CENSE NOVA-FCT. The collaboration between the partners allowed the planning of key aspects of the REC, leading to its implementation through the submission of the licensing application (in 2023), the installation of a pilot solar PV system with 7.15 kWp (in 2024), and the start of energy sharing amongst its 16 founding members including three energy-poor households (in 2025). The project's geographical scope is the Telheiras neighbourhood and the Lumiar Civil Parish where future solar PV installations are currently in planning stage. Since its beginning, the REC has also raised awareness and provided free counselling on energy issues.

The Transition Point mobile OSS (case-study 3, further described in chapter 6.1) stemmed from an initiative of the Calouste Gulbenkian Foundation that brought together the Energy and Environment Agency of Arrábida (ENA), the National Association of Energy and Environment Agencies (RNAE), and CENSE NOVA-FCT[9]. The partners developed an innovative OSS using a renovated shipping container to offer services to the general population, although with the specific aim of reaching vulnerable households, including advice on energy bills, information on energy efficiency, support on applications to public funds, and free energy audits. From February 2022 to September 2022, the container was in its pilot location - the Setúbal Municipality. This is the period of analysis that coincides with the research outputs depicted in this thesis. Nevertheless, Transition Point was latter piloted in two more municipalities in 2022 and 2023 (Sesimbra and Palmela) and replicated in four additional municipalities as part of the second round of EPAH's technical assistance in 2024 (Alcochete, Barreiro, Moita, and Montijo). In total, over 1000 families have been engaged by this OSS and, currently, two containers are available to deliver on-the-ground energy support.

Having briefly presented the three case-studies, the qualitative and quantitative approaches applied to fulfil the research objectives are described below. First, it should be noted that this

[7] LIFE HORIS. Available at: https://ieecp.org/projects/horis/
[8] Telheiras/Lumiar Renewable Energy Community. Available at: http://vivertelheiras.pt/certelheiras/en
[9] Transition Point mobile OSS. Available at: https://gulbenkian.pt/en/climate-and-ocean/transition-point/

component of empirical work adheres closely to action research methods. Greenwood and Levin (2011) define action research as "a set of collaborative ways of conducting social research that simultaneously satisfies rigorous scientific requirements and promotes democratic social change". The researchers work intimately with local stakeholders as full partners, utilising a range of techniques to solve real-world problems, produce actionable insights, and contribute to scientific knowledge. For instance, Berger *et al.* (2023) support this approach stating that trialling of energy-related behaviour change interventions should be directly accompanied by researchers. Whilst being participatory and iterative, action research limitations include that it can be very time consuming and context specific.

In line with action research principles, the author took part in numerous meetings with stakeholders and citizens during the development of the three case-studies. For instance, consortium meetings in the Transition Point OSS (case-study 3) included the regional energy agency responsible for the on-the-ground operationalisation of the project which enabled the continuous iteration and improvement of strategies to engage citizens in general and HTR groups in particular. In the four years of leading efforts to implement the Telheiras/Lumiar REC (case-study 2), there were multiple co-creation sessions with citizens, more than 30 meetings of the working group of volunteers, around 20 meetings with project partners, two general assemblies with energy community members, and multiple other events (Sequeira *et al.*, 2024a). As Greenwood and Levin (2011) state "in action research there is no substitute for learning by doing".

Still, the scientific support to the case-studies also included extensive desk research. For example, in the Green Menu OSS (case-study 1), a comprehensive assessment of EE and RES measures for Portuguese households was performed, together with the development of calculation tools (*e.g.*, for investment costs and energy savings) and the identification of specific funding schemes and regulation applicable to each measure. Furthermore, in the Transition Point OSS (case-study 3), an impact report was produced by the CENSE NOVA-FCT team which systematised key performance indicators, including theoretical estimates of triggered investment and energy savings, while providing actionable insights and contributing to scientific knowledge on OSS (Gouveia *et al.*, 2024). Finally, in the Telheiras/Lumiar REC (case-study 3), desk research included the supervision of the technical design of PV systems and energy sharing schemes (Ferreira *et al.*, 2024), the development of a financial and operational model, the definition of internal regulations, and the tailoring of approaches to engage vulnerable households; this work culminated in the publication of a practical guide for the development of RECs by citizens, associations, and local governments written collaboratively between researchers, local partners, and energy community members (Sequeira *et al.*, 2024b).

In addition, other approaches were deployed to fulfil the specific aims of each case-study. In the Green Menu OSS (case-study 1), a customer journey exercise - the series of touchpoints that customers go through before, during, and after building renovation (Becker *et al.*, 2020) -

was performed with project partners to identify the motivations and challenges of homeowners and to inform the design of the online platform. Surveys were conducted for the Green Menu OSS (case-study 1) - as a market consultation to gather feedback from end-users (n=91) - and for the Telheiras/Lumiar REC (case-study 2) - to characterise the working group volunteers, to assess their motivations, and to receive feedback on the process (n=9), and to characterise the households that signed up for the REC's pilot project, their drivers, and their EP vulnerability (n=22). The latter survey was replicated in the context of the open call for members of the second solar PV installation of the Telheiras/Lumiar REC, which received around 65 registrations, mostly from households but also from small businesses and condominiums. The surveys were part of the iteration process subjacent to the case-studies.

Importantly, all case-studies included stakeholders mapping, analysis, and engagement, following the approaches proposed by the Project Management Institute (2013). For the Green Menu OSS (case-study 1), stakeholder mapping focused on national, regional, and local organisations belonging to the building renovation ecosystem in Portugal. In contrast, in the Telheiras/Lumiar REC (case-study 2), key stakeholders were already identified and engaged through the Local Partnership of Telheiras, meaning that the project took advantage of an already established network. In the case of the Transition Point OSS (case-study 3), this exercise was narrowed down to local stakeholders, namely to public entities and social economy organisations, and was followed by a systematisation of key typologies. Still, a few authors (*e.g.*, Reed *et al.*, 2024) have begun to question the use of the term "stakeholder", considering that it reinforces systemic inequities and suggesting that research should instead focus on "the people, places, and species affected by decisions, interventions, projects, and issues".

Semi-structured exploratory interviews - a well-established method in energy research (*e.g.*, Mahoney *et al.*, 2024) - were deployed on two occasions. First, selected experts were interviewed on the state-of-the-art of residential buildings renovation in Portugal (n=11), aiming to gather information for the design of the Green Menu OSS (case-study 1). Second, in the aftermath of the Transition Point OSS (case-study 3) pilot in Setúbal, local stakeholders were invited for one-on-one exploratory interviews aiming to characterise the organisations and their target audiences, assess energy literacy, explore potential collaborative roles, and recognise drivers, barriers, and solutions for effective partnerships (n=34).

These interviews were relevant for the next stages of Transition Point, even inspiring a small spin-off project in the context of EPAH's technical assistances which brough together a local energy agency, social support organisations, a family health centre, and the local government to identify and support energy-poor households in Baixa da Banheira and Vale da Amoreira (Sequeira *et al.*, 2024c). Simultaneously, the research contributed to scientific knowledge on middle actors in energy transitions. When conducting interviews, Sovacool *et al.* (2014) argues that researchers should be wary of hidden underlying assumptions in their discourses which can eclipse alternative forms of knowledge. This research was mindful of this, focusing on "listening" to stakeholders' perspectives rather than "talking" about energy transitions.

2.2.5 Validation

Bringing it all together, the combination of theoretical and action research perspectives, the extensive case-study work, and the utilisation of mixed methods spanning a range of quantitative and qualitative approaches produced a vast yield of scientific and empirical outputs. These are integrated to address the research's objectives, directly answer the RQs, and foster a deeper discussion of the topics at hand.

The validation of the research's framing, methods, and results was safeguarded through experienced supervision, participation in international and national projects and networks, publication in high-impact peer-reviewed journals, and presentation in multiple international and national scientific conferences. Finally, the research directly engaged policymakers, practitioners, researchers, multi-sector stakeholders, journalists, and citizens hopefully delivering positive spill-over effects regarding energy transitions.

References

Becker, L., Jaakkola, E., and Halinen (2020), A. Toward a goal-oriented view of customer journeys. J. Serv. Manag., 31, 767–790. https://doi.org/10.1108/JOSM-11-2019-0329.

Berger, B., Ockenfels, A., and Zachmann, G. (2023). Behavioral science can aid household participation in gas savings. Joule 7, 1-12. https://doi.org/10.1016/j.joule.2022.12.009

Büntgen, U. (2024). The importance of distinguishing climate science from climate activism. npj Climate Action, 3, 36. https://doi.org/10.1038/s44168-024-00126-0

Collier, D., LaPorte, J., and Seawright, J. (2012). Putting Typologies to Work: Concept Formation, Measurement, and Analytic Rigor. Political Research Quarterly, 65(1) 217-232. https://doi.org/10.1177/1065912912437162

Collins, P.H. (2015). Intersectionality's Definitional Dilemmas. Annual Review of Sociology, 41. https://doi.org/10.1146/annurev-soc-073014-112142

Cologna, V., Freundt, J., Mede, N.G., Howe, L., Bertsou, E., Gloor, J., *et al.* (2025). How scientists' collective climate advocacy affects public trust in scientists and voting behavior. Environmental Research Letters, 20, 014043. https://doi.org/10.1088/1748-9326/ad984c

Dablander, F., Sachisthal, M.S.M., and Haslbeck, J.M.B. (2024a). Climate actions by climate and non-climate researchers. npj Climate Action, 3, 105. https://doi.org/10.1038/s44168-024-00187-1

Dablander, F., Sachisthal, M.S.M., Cologna, V., Strahm, N., Bosshard, A., Grüning, N.-M., *et al.* (2024b). Climate change engagement of scientists. Nature Climate Change, 14, 1033-1039. https://doi.org/10.1038/s41558-024-02091-2

Fazey, I., Schäpke, N., Caniglia, G., Hodgson, A., Kendrick, I., Lyon, C., *et al.* (2020). Transforming knowledge systems for life on Earth: Visions of future systems and how to get there. Energy Research & Social Science, 70, 101724. https://doi.org/10.1016/j.erss.2020.101724

Ferreira, E., Sequeira, M.M., and Gouveia, J.P. (2024). Sharing Is Caring: Exploring Distributed Solar Photovoltaics and Local Electricity Consumption through a Renewable Energy Community. Sustainability, 16, 2777. https://doi.org/10.3390/su16072777

Finnerty, S., Piazza, J., and Levine, M. (2025). Climate futures: Scientists' discourses on collapse versus transformation. British Journal of Social Psychology, 64, e12840. https://doi.org/10.1111/bjso.12840

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. Qualitative Inquiry, 12, 2, 219-245. https://doi.org/10.1016/10.1177/1077800405284363

Friends of the Earth Europe, REScoop.eu, and Energy Cities (2020). Community Energy: A Practical Guide to Reclaiming Power. Available at: https://friendsoftheearth.eu/publication/community-energy-guide/

Gardner, C.J, Thierry, A., Rowlandson, W., and Steinberger, J.K. (2021). From Publications to Public Actions: The Role of Universities in Facilitating Academic Advocacy and Activism in the Climate and Ecological Emergency. Frontiers in Sustainability, 2, 679019. https://doi.org/10.3389/frsus.2021.679019

Garg, A. (2024). Calling all scientists: show up in your local communities. Nature, 632, 955. https://doi.org/10.1038/d41586-024-02758-y

Gouveia, J.P., Palma, P., and Simões, S.G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187-201. https://doi.org/10.1016/j.egyr.2018.12.004

Gouveia, J.P., Palma, P., Bessa, S., Mahoney, K., and Sequeira, M. (2022). Energy Poverty National Indicators: Insights for a more effective measuring. Energy Poverty Advisory Hub. Directorate General for Energy. European Commission. Available at: https://energy-poverty.ec.europa.eu/observatory/publications/epah-energy-poverty-national-indicators-insights-more-effective-measuring

Gouveia, J.P., Bessa, S., Palma, P., Mahoney, K., and Sequeira, M. (2023). Energy Poverty National Indicators: Uncovering New Possibilities for Expanded Knowledge. Energy Poverty Advisory Hub. Directorate General for Energy. European Commission. Available at: https://energy-poverty.ec.europa.eu/observatory/publications/epah-report-energy-poverty-advisory-hub-national-indicators-uncovering-new

Gouveia, J.P., Mendes, M., Sequeira, M.M., and Palma, P. (2024). A New Way to Mitigate Energy Poverty: Lessons from the Transition Point 'One-Stop Shop' Pilot. Transition Point: Full Report. Published by the Calouste Gulbenkian Foundation (1st edition). Available on: https://gulbenkian.pt/en/publications/a-new-way-to-mitigate-energy-poverty-lessons-from-the-transition-point-one-stop-shop-pilot/

Greenwood, D.J., and Levin, M. (2011). Introduction to Action Research. Social Research for Social Change. Sage Research Methods 2nd edition. ISBN 9781412984614.

Hagedorn, G., Kalmus, P., Mann, M., Vicca, S., Van den Berge, J., van Ypersele, J.-P., Bourg, D., *et al.* (2019). Concerns of young protesters are justified. Science, 364, 6436. https://doi.org/10.1126/science.aax3807

Heiskanen, E., Happonen, J., Matschoss, K., and Mikkonen, I. (2022). Learning from failures - Encouraging lesson-sharing in the Finnish energy transition. Energy Research & Social Science, 90, 102676. https://doi.org/10.1016/j.erss.2022.102676

Horta, A., Gouveia, J. P., Schmidt, L., Sousa, J. C., Palma, P., and Simões, S. (2019). Energy poverty in Portugal: Combining vulnerability mapping with household interviews. Energy & Buildings, 203, 109423. https://doi.org/10.1016/j.enbuild.2019.109423

Karlin, B., Forster, H., Chapman, D., Sheats, J., and Rotmann, S. (2021). The Building Blocks of Behavior Change: A Scientific Approach to Optimizing Impact. Los Angeles, CA. See Change Institute.

Kivunja, C. (2018). Distinguishing between Theory, Theoretical Framework, and Conceptual Framework: A Systematic Review of Lessons from the Field. International Journal of Higher Education, 7, 6. https://doi.org/10.5430/ijhe.v7n6p44

Kaushik, V., and Walsh, C.A. (2019). Pragmatism as a Research Paradigm and Its Implications for Social Work Research. Social Sciences, 8(9), 255. https://doi.org/10.3390/socsci8090255

Mahoney, K., Lopes, R., Sareen, S., and Gouveia, J.P. (2024). Perceptions of competing agendas in car-bon neutrality policies in Portugal: Adverse impacts on vulnerable population groups. Energy Research & Social Science, 112, 103509. https://doi.org/10.1016/j.erss.2024.103509

McNutt, M. (2024). Science is neither red nor blue. Science, 386, 6723. https://doi.org/10.1126/science.adu4907

Milkoreit, M. (2023). Social tipping points everywhere? Patterns and risks of overuse. WIREs Climate Change, 14(2), e813. https://doi.org/10.1002/wcc.813

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., *et al.* (2023). Hard-to-reach en-ergy users: An ex-post cross-country assessment of behavioural-oriented interven-tions. Energy Research & Social Science 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Pawson, R., Greenhalgh, T., Harvey, G., and Walshe, K. (2004). Realist synthesis: an introduction. ESRC Research Methods Programme, University of Manchester, RMP Methods Paper 2/2004.

Project Management Institute (2013). A Guide to the Project Management Body of Knowledge (PMBOK® Guide), 5th ed., Project Management Institute, Inc.: Newtown Square, PA, USA, ISBN 978-1-935589-67-9.

Reed, M.S., Merkle, B.G., Cook, E.J., Hafferty, C., Hejnowicz, A.P., Holliman, R., *et al.* (2024). Reimagining the language of engagement in a post-stakeholder world. Sustainability Science, 19, 1481-1490. https://doi.org/10.1007/s11625-024-01496-4

Ripple, W.J., Wolf, C., Gregg, J.W., Rockström, J., Mann, M.E., Oreskes, N., *et al.* (2024). The 2024 state of the climate report: Perilous times on planet Earth. BioScience, 0, 1-13. https://doi.org/10.1093/biosci/biae087

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., *et al.* (2020). Hard-to-Reach Energy Users: A Literature Review. User-Centred Energy Systems TCP - HTR Task. ISBN: 978-0-473-64983-8. https://userstcp.org/hard-to-reach-energy-users-task/

Rotmann S., Mundaca L., Ashby K., O'Sullivan K., Karlin B., and H. Forster (2021). Subtask 2: Case Study Analysis Methodology - Template for National and Contributing Experts. Users TCP HTR Annex: Wellington. 16pp. https://userstcp.org/hard-to-reach-energy-users-task/

Rotmann, S., Ashby, K., Hogan, E., Saterson, M., Sullivan, L., and Kall, A.-S. (2025). Unintended Consequences - When well-intentioned energy interventions don't turn out the way they were intended. Subtask 2 Phase 2 HTR Task by Users TCP by IEA: Pūponga. 142pp. https://doi.org/10.47568/3XR144

Schipper, E.L.F., Maharaj, S.S., and Pecl, G.T. (2024). Scientists have emotional responses to climate change too. Nature Climate Change, 14, 1010-1012. https://doi.org/10.1038/s41558-024-02139-3

Sequeira, M., and Joanaz de Melo, J. (2020). Energy saving potential in the small business service sector: case study Telheiras neighborhood, Portugal. Energy Efficiency, 13(4), 551-569. https://doi.org/10.1007/s12053-020-09842-y

Sequeira, M.M., and Mameri, D. (2022). Can communities lead the way for socio-ecological urban transformations? The empiric experience of the "network of ideas" process in the Telheiras neighborhood, Portugal. Proceedings of the International Sustainable Development Research Society Conference 2022.

Sequeira, M.M., Ferreira, E., and Gouveia, J.P. (2024a). Promovendo a produção e partilha local de eletricidade: Uma análise detalhada da experiência da Comuni-dade de Energia Renovável de Telheiras em Portugal ["Promoting local electricity generation and sharing: A detailed analysis of the experience of the Telheiras Renewable Energy Community in Portugal"]. In Oliveira, F.P., and Chediek, J. (Eds), Comunidades de Energia ["Energy Communities"]. Almedina. ISBN 9789894021162. Available at: https://www.almedina.net/comunidades-de-energia-1719320486.html

Sequeira, M.M., Ferreira, E., Pereira, L.K., Cachinho, L., Martins, H., Gouveia, J.P., *et al.* (2024b). Practical guide: Development of renewable energy communities by citizens, associations, and local governments – The example of the Telheiras/Lumiar Renewable Energy Community. Portuguese and English versions. Available at: https://fireflyenergylab.com/research/publications/107

Sequeira, M.M., Sapatinha, M., Gouveia, J.P., Henriques, I.R., Camacho, S., Figueiredo, J., and Barroso, J. (2024c). Prescribing a comfortable home: Health, social support, and energy poverty at Baixa Banheira e Vale da Amoreira. Conference poster at the Portuguese Science Summit 2024. Porto, Portugal, July 2024. Available at: https://app.encontrociencia.pt/exhibitor/23372

Shannon-Baker, P. (2023). Philosophical underpinnings of mixed methods research in education. International Encyclopedia of Education (Fourth Edition), 380-389. https://doi.org/10.1016/B978-0-12-818630-5.11037-1

Sovacool, B.K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Research & Social Science, 1, 1-29. http://dx.doi.org/10.1016/j.erss.2014.02.003

Sparkman, G., and Attari, S.Z. (2020). Credibility, communication, and climate change: How lifestyle inconsistency and do-gooder derogation impact decarbonization advocacy. Energy Research & Social Science, 59, 101290. https://doi.org/10.1016/j.erss.2019.101290

Stutchbury, K. (2021). Critical realism: an explanatory framework for small-scale qualitative studies or an 'unhelpful edifice'? International Journal of Research & Method in Education, 45(2), 113-128. https://doi.org/10.1080/1743727X.2021.1966623

Tashakkori, A., and Creswell, J.W. (2007). Editorial: The New Era of Mixed Methods. Journal of Mixed Methods Research, 1, 3. https://doi.org/10.1177/2345678906293042

Vandyck, T., Valle, N.D., Temursho, U., and Weitzel, M. (2023). EU climate action through an energy poverty lens. Scientific Reports, 3, 6040. https://doi.org/10.1038/s41598-023-32705-2

von Hellermann, P. (2021). From Ecophany to Burnout? An Anthropologist's Reflections on Two Years of Participating in Council-Citizen Climate Governance in Eastbourne. World, 2, 521-537. https://doi.org/10.3390/world2040032

Chapter 3.

GAUGING HARD-TO-REACH ENERGY USERS AT MULTIPLE SCALES

3.1 (Dis)comfortably numb in energy transitions: Gauging residential hard-to-reach energy users in the European Union

This work is published in: Sequeira, M.M., Gouveia, J.P., and Melo, J.J. (2024). (Dis)comfortably numb in energy transitions: Gauging residential hard-to-reach energy users in the European Union. Energy Research & Social Science, 115, 103612. https://doi.org/10.1016/j.erss.2024.103612

Abstract

Hard-to-reach energy users – those who are difficult to reach, underserved, or hard to engage or motivate – are a vital concern for just energy transitions. Previous studies in the Global North have suggested three major residential groups, namely vulnerable households, high-income households, and tenants and landlords, for which one-size-fits-all policies have proven largely unsuccessful. Still, more research is needed to identify hard-to-reach groups and to understand households' decision-making processes. In this context, we review the literature to systematise a theoretical framework, proposing thirteen profiles for vulnerable households (low-income, low education, rural, multi-family, elderly, young, single parents, migrants, unemployed, ill-health and disabilities, ethnic minorities and indigenous groups, homeless and informal settlements, travellers and nomadic communities), two for high-income households (high-income, sumptuous spenders), and two for tenants and landlords (tenants, landlords). We select indicators to gauge these audiences in the European Union. Results suggest that a substantial share of households may be hard-to-reach, with several profiles (*e.g.*, low-income, tenants) individually accounting for 30% of the population. Relevant variations are found across Member States. Furthermore, a significant share of the population intersects at least two profiles, compounding the barriers to their engagement. These households require targeted and tailored policies and interventions to address their needs, which are broadly discussed. The hard-to-reach concept can be useful to inform policymakers and practitioners. Data gaps emerge for marginalised and wealthy groups. Heterogeneity and intersectionality add further complexity. Future research can fill these gaps while taking on multi-scalar, plural, and inclusive approaches to identify and engage hard-to-reach households.

Keywords: energy justice, energy policy, energy poverty, vulnerable households, high-income households, tenants and landlords

3.1.1 Introduction

Against the background of climate change, energy transitions are at the top of the agenda (IPCC, 2023). Notwithstanding the role of technology, energy transitions also demand the engagement of citizens (IEA, 2023). Simultaneously, several authors (*e.g.*, Okushima, 2021; Soergel *et al.*, 2021; Skjølsvold and Coenen, 2021; Mahoney *et al.*, 2024) have warned about risks in meeting potentially conflicting agendas of decarbonisation and poverty eradication while arguing for a well-balanced course of action. Energy poverty is a key concern, defined by the European Union's (EU) Energy Efficiency Directive as the "lack of access to essential energy services [...] caused by a combination of factors, including at least non-affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes". Its consequences on health and well-being can be particularly severe for vulnerable groups (Oliveras *et al.*, 2021; Clair and Baker, 2022).

The concept of hard-to-reach (HTR) energy users – broadly defined as those who are difficult to reach, underserved, or hard to engage or motivate by energy policies, programs, or interventions – has been receiving growing attention among researchers, policymakers, and practitioners (*e.g.*, Ambrose *et al.*, 2019a; Ambrose *et al.*, 2019b; Rotmann *et al.*, 2020; Mundaca *et al.*, 2023). It should be noted that the HTR terminology was already used in several areas – *e.g.*, poverty measurement (*e.g.*, UNECE, 2017, 2020, 2022), crime prevention (*e.g.*, Roberts, 2016), education, social services, and health (*e.g.*, Boag-Munroe and Evangelou, 2010; Shaghaghi *et al.*, 2011; Bonevski *et al.*, 2014; Liljas *et al.*, 2017) – before being applied to the energy field. For instance, UNECE (2020) refers to populations that are hard to sample, identify, find, contact, persuade, and interview. In this context, the Users-Centred Energy Systems Technology Collaboration Platform, working under the auspices of the International Energy Agency, launched the Task on Hard-To-Reach Energy Users aiming to identify, define, and prioritise HTR groups and to design, evaluate, and share strategies to engage them (UsersTCP, 2024).

The emergence of the HTR energy users concept stems from a stream of literature across a wide span of disciplines that challenges the assumption of energy users as one-dimensional rational agents, moved solely by economic and technical drivers, highlighting the existence of multiple characteristics, circumstances, vulnerabilities, preferences, cognitive routines, and belief systems, as well as cultural, social, and political factors, that influence engagement (Ambrose *et al.*, 2019b; Sovacool, 2014; Sovacool *et al.*, 2015). Rotmann *et al.* (2020) label five major HTR groups: vulnerable households (*e.g.*, low-income, elderly, single parents, among other subgroups), high-income households, tenants and landlords, commercial sub-sectors, and small and medium enterprises. The difficulty in reaching and engaging these groups in energy interventions seems to arise more from market, policy, and legislative failures than from technical barriers (Baker *et al.*, 2019; Raslan and Ambrose, 2022; Houghton *et al.*, 2023).

The engagement of HTR groups is crucial to achieve the goals of climate change mitigation and energy poverty alleviation but faces severe and persistent barriers. These are well-researched for vulnerable households and tenants, including split incentives, insufficient knowledge, high transaction costs, market fragmentation, shortage of finance, upfront costs, lack of information, competing priorities, and mistrust (Labanca *et al.*, 2015; Reames, 2016; Koch and Christ, 2018; Lukanov and Krieger, 2019). High-income households have not been extensively researched, but interest has risen recently (Otto *et al.*, 2019; Nielsen *et al.*, 2021;

Garcia *et al.*, 2021). Although barriers are known, several authors (*e.g.*, Sovacool, 2014; Chadwick *et al.*, 2022; Ring *et al.*, 2022) emphasise the need for an in-depth understanding of the decision-making processes of different energy users as a challenge for research.

Existing research finds that significant population groups are not reached with traditional one-size-fits-all policies and interventions (Gillard *et al.*, 2017; Ambrose *et al.*, 2019b; Ring *et al.*, 2022). Likewise, recent studies suggest that these consumer profiles will also be HTR to innovative approaches such as energy sharing and digitalisation (Hall *et al.*, 2021; Hanke *et al.*, 2021). In a just transition, all groups must participate, and the energy system fairly disseminates its benefits and costs while ensuring representative and impartial decision-making (Sovacool and Dworkin, 2015; Ring *et al.*, 2022). Aligned with the principle of "leaving no one behind", there is increasing pressure on policymakers and practitioners to find ways to engage the HTR; however, practical approaches are still under-researched (UNECE, 2022; Karlin *et al.*, 2022; Mundaca *et al.*, 2023). Mundaca *et al.* (2023) addressed this gap with an ex-post cross-country assessment of nineteen energy interventions that aimed explicitly or implicitly at engaging HTR groups. Poor targeting can also be due to a lack of disaggregated data (or insufficient operationalisation of existing data). Raslan and Ambrose (2022) and Houghton *et al.* (2023) highlight that establishing precise profiles of HTR households and tailoring approaches are key gaps to be filled by research.

The goals of this manuscript are i) to systematise a set of potential HTR profiles in the residential sector, ii) to suggest an indicator set and gauge the size of HTR groups in the EU-27 and its Member States (MS), iii) to evaluate the heterogeneity within groups and the intersectionality between groups, and iv) to derive insights for energy policies tailored to the needs of the HTR. While there is extensive work implicitly researching energy users that may be regarded as HTR, there is still scarce research explicitly conducted under this framing. Whereas most research on HTR energy users has remained broad and conceptual, the novelty of this manuscript lies in the systematisation and quantification of specific profiles of HTR households, which further advances this concept towards its operationalisation as a tool for the design of energy policies and interventions. To our knowledge, this is the first study to attempt this endeavour in the EU. Non-residential groups have been assessed by Sequeira and Gouveia (2023).

The structure of this manuscript is as follows. Section 3.1.2 reviews the state-of-the-art on HTR energy users, the criticism of the terminology, and its connection to energy justice. Section 3.1.3 lays out the methods. Section 3.1.4 details and discusses the outputs, including the theoretical framework, selection of indicators, analysis of results for the EU and its MS, and evaluation of intersectionality and heterogeneity for the EU. Section 3.1.5 derives implications for just energy policies and illustrates how to use our research for enhanced policy design. Section 3.1.6 assesses limitations and suggests perspectives for future research. Finally, section 3.1.7 concludes the work.

3.1.2 Literature review: Residential hard-to-reach energy users

In this literature review, we examine academic and grey literature from several interconnected strands of research – *e.g.*, energy poverty, clean energy uptake, and energy justice – that delve into the three residential HTR groups defined by Rotmann *et al.* (2020) – vulnerable households, high-income households, and tenants and landlords. A systematic review has already been performed by Rotmann *et al.* (2020). Furthermore, Ashby *et al.* (2020) have interviewed international experts regarding their perspectives on how to identify and engage HTR energy users in their countries.

Building on this work, our literature review follows the realist synthesis method (Pawson *et al.*, 2004) by identifying the question "who is considered as being a HTR energy user and for what reasons?" and drawing from a wide-ranging review of the literature – implicitly or explicitly reporting on HTR profiles – aiming for theoretical saturation in each defined profile (as also performed by Middlemiss, 2022). The realist synthesis approach is useful for reviewing evidence on complex social interventions, such as households' participation in energy transitions, aiming to explain how and why interventions work (or do not work) in specific contexts (Pawson *et al.*, 2004).

This literature review of relevant papers follows a combination of convenience and snowball sampling focused on HTR groups (*e.g.*, Garcia *et al.*, 2021; Simcock *et al.*, 2021), providing reasoning for the proposal of a theoretical framework. It is disaggregated according to characteristics found in the literature; for instance, UNECE's (2020) guide for measuring poverty stresses the need for disaggregation by income, gender, age, ethnicity, migratory status, disability, tenure status, employment status, educational level, and degree of urbanisation.

3.1.2.1 Hard-to-reach terminology

Although the HTR terminology is contested, it has long been applied to education, health, social services, and criminal justice, where authors have mapped inequalities and explored approaches for increased participation in support programmes (Boag-Munroe and Evangelou, 2010; Flanagan and Hancock, 2010; Shaghaghi *et al.*, 2011). For instance, in 1993, Griffiths *et al.* (1993) researched how to reach hidden populations of drug users, and in 1996, Shaw *et al.* (1996) used the term HTR to refer to homelessness and social welfare policies. Since the emergence of the concept, its meaning and intensity have varied widely between studies. For example, Liljas *et al.* (2017) reviewed barriers and strategies for engaging HTR older people in health promotion. Bonevski *et al.* (2014) reviewed challenges to sampling, recruitment, participation, and retention of socioeconomically disadvantaged persons. Researching an empirical case, Roberts (2016) detailed insights from a programme offering HTR young people a route back into employment and education. Finally, in an early recognition of both the vulnerable and the elites as being HTR, Atkinson and Flint (2003) suggested snowball sampling as a way of accessing groups that are typically impenetrable for social research.

In the context of the ongoing overhauling of the global energy system, the HTR terminology has made its way into the energy sector. Rotmann *et al.* (2020) provide the following definition – "a hard-to-reach energy user is any energy user from the residential & non-residential sectors, who uses any type of energy or fuel, and who is typically either hard-to-reach physically, underserved, or hard-to-engage or motivate in behaviour change, energy efficiency and demand response interventions that are intended to serve our mutual needs". This definition is purposely broad to avoid leaving out relevant groups. Furthermore, Ambrose *et al.* (2019a) argue that the HTR concept is context-specific and should not consist of a rigid list of target groups, highlighting a range of vulnerabilities, circumstances and/or characteristics that present barriers to participation in energy issues. Other terms used in the literature to describe the HTR include underserved, disadvantaged, hard-to-help, hidden, illegalised, stigmatised, under-represented, invisible, unchangeable, hard-to-count, hard-to-engage or motivate, understudied, hard-to-treat, hard-to-heat or cool, hard-to-decarbonise, and complex-to-decarbonise (Rotmann *et al.*, 2020; Houghton *et al.*, 2023). All these terms have their own critiques and challenges, for instance, for being too focused on research, on marginalised groups, on heating and cooling, or on decarbonisation.

We also acknowledge that the terminology of HTR energy users is subject to criticism. First, it can be considered as (deliberately) too broad, encompassing a wide range of users with distinct characteristics. Second, Baker *et al.* (2019) and Gillard *et al.* (2017) are critical of labelling individuals and grouping them into a limited number of archetypes, recognising issues of heterogeneity and intersectionality, and contesting that it excludes other information and reinforces biases. Furthermore, Houghton *et al.* (2023) prefer to use the term "complex" instead of "hard" to avoid a binary categorisation. Third, the literature mostly presupposes that engaging HTR households is mutually beneficial, neglecting to account for the fact that some families may have their reasons for wishing to avoid involvement (Boag-Munroe and Evangelou, 2010). Fourth, this concept can shift the focus away from the structural social, economic, and political norms that compound to make some households harder-to-reach than others (Gillard *et al.*, 2017; Simcock *et al.*, 2021; Alexandrescu *et al.*, 2021). It should be clearly stated that these groups may not be HTR in themselves, but the approaches currently used to engage them may not be adequate and should be improved (Baker *et al.*, 2019; Rotmann *et al.*, 2020).

While acknowledging these limitations, we argue that the HTR energy users concept can be useful for guiding the development of policies that foster just energy transitions. It clearly identifies population groups that are likely at risk of being left behind, highlights the multiple and distinct barriers that hinder engagement, and provides insights for targeted and tailored interventions. In this work, we follow the broad definition by Rotmann *et al.* (2020) to explore household profiles that may fit the HTR concept.

3.1.2.2 Vulnerable households

Vulnerable households are found by Rotmann *et al.* (2020) to be the most mentioned HTR group. In this regard, the European Commission (2016) states that vulnerability can be seen as a highly diverse, often hidden, and rapidly mutable condition that arises from personal and demographic characteristics, behavioural and situational drivers, deficiencies in access, and complex market features. Thus, it should be noted that HTR and vulnerable households are two different concepts with distinct definitions; in practice, these may often overlap on a case-by-case basis. Ambrose *et al.* (2019a) identified three dimensions of vulnerability: financial, health and capacity, and location. Building on these, Rotmann *et al.* (2020) added cultural issues, attitudinal barriers, gender, ethnicity, sexuality, timing, perceptions of relevance, and involvement methods.

A breath of research in the Global North has focused on the interactions between the energy system and specific vulnerable households' profiles (*e.g.*, Simcock *et al.*, 2021; Middlemiss, 2022; Sovacool *et al.*, 2022). Typically, these refer to people over a certain age, disabled or with long-term illnesses, low-income, single parents, rural, unemployed, and/or ethnic minorities (Middlemiss and Gillard, 2015; Baker *et al.*, 2019; Drehobl *et al.*, 2020). Going further, UNECE (2017) and Rotmann *et al.* (2020) report on marginalised groups, including illegal migrants, refugees, criminalised communities, ex-convicts, drug users, the homeless, and sex workers, among others. For some of these groups, energy research seems extremely scarce or even inexistent. Table 3.1 summarises the reasoning that may indicate a HTR nature for a set of vulnerable households' profiles.

Table 3.1 – Review of vulnerable households' reasons for potentially being HTR.

Proposed HTR profile	Reasoning to be considered HTR	Evidence
Low-income	Tend to spend a greater share of their income on energy leading to higher vulnerability to energy poverty. Additional vulnerabilities due to income instability and reliance on state benefits.	Anderson et al, 2012; Middlemiss and Gillard, 2015; Drehobl et al; 2020; Simcock *et al.*, 2021; Clair and Baker, 2022; Middlemiss, 2022; Chen et al, 2022
	Consistently less likely to invest in new technologies than the average household, even when the return on investment is in the short term.	Galvin and Sunikka-Blank, 2018; Lukanov and Krieger, 2019; Sovacool et al, 2022; Stewart, 2022
	Behavioural and informational barriers can lead to lack of awareness of interventions, even when financial support exists. Other barriers linked to home ownership, housing burdens, poverty stressors, chaotic lifestyles, lack of access to information technology, and social isolation.	Anderson et al, 2012; Mould and Baker, 2017; c; UNECE, 2022; Sovacool et al, 2022; Stewart, 2022
	Lack of peer diffusion effects in low-income areas hinders technology adoption.	Lukanov and Krieger, 2019; Stewart, 2022
Low education	Higher vulnerability to energy poverty compared with highly educated households.	Legendre and Ricci, 2015; Gouveia *et al.*, 2019
	Low awareness, lack of access to information, and poor energy literacy. Potentially insufficient literacy levels and/or digital skills to understand the intervention and apply to funding.	Hall *et al.*, 2021; UNECE, 2022; Sovacool *et al.*, 2022; Sequeira and Gouveia, 2022

	Less likely to adopt new technologies than highly educated households.	Lukanov and Krieger, 2019; Sovacool *et al.*, 2022
Rural	Mixed evidence regarding energy poverty vulnerability, but in some countries rural households face higher energy burdens than urban households. Potential vulnerabilities due to lack of employment, seasonal and part-time jobs, aging population, and more severe climate.	Roberts *et al.*, 2015; Ross *et al.*, 2018; MacDonald *et al.*, 2019; Gouveia *et al.*, 2019; Simcock *et al.*, 2021
	Geographical isolation, dispersion, and lack of available energy services. Limited offerings for interventions, lack of information about funding, and lack of trained contractors.	Ross *et al.*, 2018; Ashby *et al.*, 2020; UNECE, 2022
	Lack of access to gas and heating networks and reliance on expensive fuels. Use of unregulated and unreported energy carriers, such as biomass. In remote areas, issues of security of supply.	Roberts *et al.*, 2015; Simcock *et al.*, 2021; Stojilovska *et al.*, 2023
Multi-family	Evidence is not conclusive regarding energy poverty vulnerability in multi-family buildings, but some authors find a higher prevalence than in detached homes.	Clair and Baker, 2022
	Organizational barriers and highly fragmented ownership structures. Decisions on investment need to be approved by multiple owners and tenants, hindering whole building solutions.	Palm and Reindl, 2018; Baker *et al.*, 2019; Eisermann *et al.*, 2019; Moura and Brito, 2019; Rotmann *et al.*, 2020; Streimikiene and Balezentis, 2020; Raslan and Ambrose, 2022; Kraaijvanger *et al.*, 2023
	Multi-family buildings have been poorly addressed by policies, funding schemes, and market solutions. Most building professionals are not prepared for the complexity of condominiums.	Eisermann *et al.*, 2019; Moura and Brito, 2019; Streimikiene and Balezentis, 2020; Kraaijvanger *et al.*, 2023
Elderly	Elderly people living outside institutional homes are particularly vulnerable to energy poverty. Single or widowed female pensioners can be disadvantaged due to smaller pensions. They do not necessarily recognise their energy-poor situation and lack awareness about improvements.	Legendre and Ricci, 2015; Chard and Walker, 2016; Mould and Baker, 2017; Ambrose *et al.*, 2019b; Oliveras *et al.*, 2020; UNECE, 2020; Simcock *et al.*, 2021; Pais-Magalhães *et al.*, 2022
	Research finds that households whose family head is above 65 years old are less prone to invest in improving energy performance.	Abreu *et al.*, 2020; Sommerfeld *et al.*, 2017
	Limited information and poor trust in new technologies. Lack of energy literacy and poor digital skills. Limited capability to engage in the energy market and vulnerability to unethical marketing.	Chard and Walker, 2016; Willand and Horne, 2018; Simcock *et al.*, 2021; Bîrsănuc, 2022; UNECE, 2022; Zhen *et al.*, 2022
	Limited social interactions, lack of autonomy, and feelings of loneliness. Rigid lifestyles and higher amount of time spent at home leading to higher energy use.	Bîrsănuc, 2022; Jacques-Avinó, 2022; Zhen *et al.*, 2022
	Deteriorating health, illness, failing eyesight, loss of earing, and uncertainty over lifespan.	Willand and Horne, 2018; Simcock *et al.*, 2021; Bîrsănuc, 2022
Young	The available evidence is scarce but suggests that young adults face increased energy poverty vulnerability. Cultural norms consider acceptable for young people to inhabit low-quality housing. Lack of awareness of energy poverty.	Cauvain and Bouzarovski, 2016; Petrova, 2017; Kousis *et al.*, 2020; Nazarahari *et al.*, 2021; Castro and Gouveia, 2023
	Unstable and transient housing and employment patterns. Young adults regularly live in poor quality, privately rented, multioccupancy housing where bills are shared among multiple tenants.	Cauvain and Bouzarovski, 2016; Petrova, 2017
	Irregular incomes, shortage of funds, lack of experience and knowledge, and conflicting life priorities hinder energy interventions.	Groote *et al.*, 2016; Tod *et al.*, 2016; Mahapatra *et al.*, 2019; Abreu *et al.*, 2020
Single parents	Single parent households, most of which are headed by women, are more likely to suffer energy poverty. Women typically have lower	Legendre and Ricci, 2015; Mould and Baker, 2017; Galvin and Sunikka-Blank, 2018; UNECE, 2020; Sunikka-Blank and Galvin,

	incomes and smaller pensions due to structural disadvantages that deprive them of opportunities and of decent work.	2021; Chen *et al.*, 2022; Clair and Baker, 2022; EIGE, 2023
	Difficulty of maintaining a full-time job, economic precariousness, reliance on a single income to support children, and high dependency on state support. Little time available and other priorities, more time spent indoors, and lack of control over choices.	Bîrsănuc 2022; Jacques-Avinó *et al.*, 2022
	Entrenched gender inequality and socio-cultural norms on traditional gender roles place the decision-making on energy issues in the male sphere of interest, leading to low technology adoption rates in female-led households.	Groote *et al.*, 2016; Tjørring, 2016; Simcock *et al.*, 2021; Sovacool *et al.*, 2022; EIGE, 2023
Migrants	Scarce research is available, but migrants seem more vulnerable to energy poverty. Most affected are those born in low/middle income countries, asylum seekers, refugees, and illegal migrants, which are also vulnerable to discrimination.	Reames, 2016; Drehobl *et al.*, 2020; Oliveras *et al.*, 2020; Simcock *et al.*, 2021; Bouzarovski *et al.*, 2022; Clair and Baker, 2022
	Lower incomes and occupation of poor quality and rented dwellings resulting from residential segregation and job discrimination and leading to lower uptake of clean energy solutions.	Simcock *et al.*, 2021; Bouzarovski *et al.*, 2022; Jacques-Avinó *et al.*, 2022; Kraaijvanger *et al.*, 2023
	Migrant status generates concerns related to legal issues in their host country and to the provision of financial support for their family in the country of origin.	Jacques-Avinó *et al.*, 2022
	People with recent migrant background can face barriers due to being unfamiliar with the local language and other taken-for-granted competences (*e.g.,* communication with energy companies and applying to funding), leading to low levels of technology adoption.	Groote *et al.*, 2016; Lukanov and Krieger, 2019; Simcock *et al.*, 2021; Bouzarovski *et al.*, 2022
Unemployed	Unemployed people and people outside the workforce (*e.g.,* performing family and home care work) are likely to be more vulnerable to energy poverty.	Simcock *et al.*, 2021; Clair and Baker, 2022
	Additional vulnerabilities linked to precarious and low-wage employment, unstable household income, and performance of non-productive and unpaid work.	Simcock *et al.*, 2021; Clair and Baker, 2022; Bîrsănuc, 2022
	Less motivation to implement energy performance improvement measures.	Gouveia *et al.*, 2019; Rotmann *et al.*, 2020
Ill-health and disabilities	Energy poverty has consequences on physical and mental health and there is evidence that pre-existing health conditions and higher medical needs increase the likelihood of energy poverty.	Middlemiss and Gillard, 2015; Snell *et al.*, 2015; Oliveras *et al.*, 2020; Simcock *et al.*, 2021; Chen *et al.*, 2022; Clair and Baker, 2022; Jacques-Avinó *et al.*, 2022; Butler *et al.*, 2023a
	Disabilities and ill-health include a wide range of short-term, chronic, and terminal impairments, such as autism spectrum conditions, long-term health illness, mental health conditions, physical or mobility impairments, sensory impairments, and learning difficulties.	Ivanova and Middlemiss, 2021; Butler *et al.*, 2023a
	Dependence on healthcare and support services, lack of social relations, and moving limitations. Increased amount of time spent at home and higher energy needs (*e.g.,* room temperatures, energy intensive medical equipment, laundry).	Snell *et al.*, 2015; Chard and Walker, 2016; Middlemiss and Gillard, 2015; Oliveras *et al.*, 2020; Ivanova and Middlemiss, 2021; Simcock *et al.*, 2021; Bîrsănuc, 2022; Chen *et al.*, 2022; Jacques-Avinó *et al.*, 2022; Baltruszewicz *et al.*, 2023; Butler *et al.*, 2023a
	Households having a person with ill-health or disabilities often have lower income levels and different employment profiles than the general population.	Snell *et al.*, 2015; Mould and Baker, 2017; Simcock *et al.*, 2021

	Additional cognitive, sensory or communication impairments can make access to information and support difficult and hinder technology adoption. Reluctance to accept support except from trusted sources, such as family or social organisations, who may have limited knowledge themselves. Lack of recognition in energy policies.	Lukanov and Krieger, 2019; UNECE, 2020; Ivanova and Middlemiss, 2021; Chapman *et al.*, 2022
Ethnic minorities and Indigenous groups	Scarce research and data are available, but ethnic minorities seem more vulnerable to energy poverty. Global North studies point to higher vulnerability for people of colour (*e.g.,* Black or Hispanic in the US).	Reames, 2016; Churchill and Smyth, 2020; Oliveras *et al.*, 2020; Simcock *et al.*, 2021; Chen *et al.*, 2022; Clair and Baker, 2022
	Ethnic minorities in vulnerable neighbourhoods may be disengaged and uninformed, with little knowledge and trust of energy interventions. In a specific case, other authors have challenged this assumption uncovering ethnicity as a positive driver of uptake.	Reames, 2016; Churchill and Smyth, 2020; Bouzarovski *et al.*, 2022; Jacques-Avinó *et al.*, 2022; Owen *et al.*, 2023
	Ethnic minorities, Gypsies, Roma, and Indigenous communities suffer from an historical and structural pattern of marginalization, discrimination, institutional racism, and exclusion, which explains their lack of recognition in energy policies.	Churchill and Smyth, 2020; Alexandrescu *et al.*, 2021; UNECE, 2022; Ring *et al.*, 2022; Bouzarovski *et al.*, 2022; Butler *et al.*, 2023b
Homeless and informal settlements	Populations living in informal and illegal settlements are often perceived as problematic and may be treated as invisible or as criminals by policymakers.	Alexandrescu *et al.*, 2021; Ruiz-Rivas *et al.*, 2023
	Homeless persons, persons living in improper housing conditions (*e.g.* without doors or windows, no access to electricity, or presence of infestations), and persons living in illegal housing or with irregular connections to the grid may be unresponsive and distrustful of energy support while also perceiving little effect from interventions (or these would even be wholly non-applicable) especially as basic living conditions are of much greater worry.	Couvain and Bouzarovski *et al.*, 2016; Mould and Baker, 2017; UNECE, 2017; Rotmann *et al.*, 2020; Bîrsănuc, 2022; Jacques-Avinó *et al.*, 2022; Ruiz-Rivas *et al.*, 2023
Travellers and nomadic communitie s	Traveller communities can face restrictions over energy suppliers and heating systems, leaving them reliant on more expensive tariffs and fuels and more susceptible to energy poverty. Low literacy levels, language barriers, isolation from support services, transience between locations, mistrust in authorities, non-eligibility to support schemes, and discrimination may pose further barriers.	Forster *et al.*, 2019; Butler *et al.*, 2023b

3.1.2.3 High-income households

A particularity of the HTR energy users concept by Rotmann *et al.* (2020) is the inclusion of other groups beyond the often-mentioned vulnerable households, namely high-income households. This perspective is uncommon but not unique, for instance, in 2001, Atkinson and Flint (2003) placed vulnerable households and elites under the umbrella of HTR. High-income households have been receiving increasing attention, and the HTR lens can provide a comprehensive reframing of their role in energy transitions. This is relevant particularly as income and wealth inequality have been increasing, enabling high-wealth individuals' influence to grow (Galvin and Sunikka-Blank, 2018; Oswald *et al.*, 2020).

A few authors note that the top income groups should be disaggregated, highlighting variations in the energy use patterns of the top 20%, top 10%, top 1%, and even top 0.1% or top 0.01% (Sommer and Kratena, 2017; Oswald *et al.*, 2020; Barros and Wilk, 2021; Nielsen *et al.*, 2021). These have disproportionate energy use and carbon footprints, for instance, the top quintile of income in the EU-27 is responsible for 37% of emissions, the top 10% for 27% of emissions, and the top 1% for 6% of emissions (Sommer and Kratena, 2017; Ivanova and Wood, 2020). Going further, Barros and Wilk (2021) suggest that billionaires have thousands of times higher carbon footprints than average citizens. Their growing number jeopardises the remaining global carbon budget (Gossling and Humpe, 2023). A wide range of terminologies is used in the literature to refer to this subgroup which lies at the top of the social ladder regarding income and wealth levels - *e.g.*, super-rich, high consumers, millionaires, billionaires, and super-affluent (Otto *et al.*, 2019; Wiedmann *et al.*, 2020; Garcia *et al.*, 2021). Since the commonality in these studies appears to be the sumptuous consumption of energy-intensive luxury goods and services, we have derived the term "sumptuous spenders" to refer to this subgroup. Table 3.2 summarises the reasoning that may indicate an HTR profile for high-income groups.

Table 3.2 – Review of high-income households' reasons for potentially being HTR.

Proposed HTR profile	Reasoning to be considered HTR	Evidence
High-income	Use more energy even, mostly due to air travel and motor vehicles followed by housing. Housing is an area of high consumption due to ownership and occupancy of larger homes, multiple residences, multiple sets of energy intensive equipment, and luxury items.	Otto *et al.* 2019; Ivanova and Wood, 2020; Oswald *et al.*, 2020; Rotmann *et al.*, 2020; Nielsen *et al.*, 2021; Garcia *et al.*, 2021; Cass *et al.*, 2022; Baltruszewicz *et al.*, 2023
	Inequalities within countries are significative and undermine public consensus on the energy transition. Higher income households drive consumption norms across the population by setting societal material aspirations, particularly for the middle class.	Sovacool, 2014; Galvin and Sunikka-Blank, 2018; Otto *et al.*, 2019; Wiedmann *et al.*, 2020; Barros and Wilk, 2021; Garcia *et al.*, 2021; Oxfam, 2021; Nielsen *et al.*, 2021
	High-income households can easily invest in energy interventions and may disproportionately benefit from support. However, this evidence appears to tail off at the upper-middle income groups, suggesting that more affluent brackets are less likely to be persuaded by energy savings.	Nielsen *et al.*, 2021; Cass *et al.*, 2022; Sovacool *et al.*, 2022; Stewart, 2022
	Little incentive to reduce their energy use since they can afford higher expenditure and are less vulnerable to price hikes, making price mechanisms and taxes ineffective.	Kenner, 2015; Garcia *et al.*, 2021; Cass *et al.*, 2022
Sumptuous spenders	One of the most hidden groups regarding income, lifestyles, resource use, consumption patterns, mobility, and social networks. Data is scarce due to under-representation in national and global analysis, difficulty in recruitment, data privacy laws, accounting tricks, and vested ownership.	Sommer and Kratena, 2017; Otto *et al.* 2019; Oswald *et al.*, 2020; Barros and Wilk, 2021; Nielsen *et al.*, 2021
	Highest energy footprints, mostly from transportation and yachting followed by ownership of multiple large houses. No incentive to moderate consumption as they take for granted energy-intensive lifestyles. First adopters of energy-intensive innovations that can later massify.	Kenner, 2015; Galvin and Sunikka-Blank, 2018; Barros and Wilk, 2021; Markard *et al.*, 2023; Oswald *et al.*, 2023; Starr *et al.*, 2023
	Exert disproportionate power through policymaking and investment. They can use their wealth to bypass policies aiming at	Kenner, 2015; Oswald *et al.*, 2023; Oxfam, 2023; Starr *et al.*, 2023

	reducing energy use. Billionaires are twice as likely as the average investor to invest in polluting industries.	
	Affluent people can more easily disconnect themselves and adapt to climate change.	Kenner, 2015; Otto *et al.* 2019; Barros and Wilk, 2021

3.1.2.4 Tenants and landlords

The third major residential HTR group mentioned by Rotmann *et al.* (2020) are tenants and landlords. While some authors may place tenants under vulnerable households in other contexts, such as energy poverty assessment (*e.g.*, Middlemiss and Gillard, 2015), this separate classification reflected in the HTR framing highlights the specific nature of the overarching challenges that both tenants and landlords face when acting to improve energy performance. Tenants and vulnerable households will occasionally overlap on a case-by-case basis.

Some authors consider households living in the private-rented sector arguably the hardest group to reach in energy policies, mainly due to the split incentives dilemma where neither the tenant nor the landlord is motivated to invest in energy performance (*e.g.*, Petrova, 2017). Social housing, where the landlord is a single organisation, could present a different situation altogether, with an easier-to-reach profile if sufficient funds were allocated (European Commission, 2020a; Houghton *et al.*, 2023). People living in rented houses can be quite heterogeneous, *e.g.*, varying levels of income, types of contracts (or lack thereof), and rental durations, and often experience split incentives and other constraints (Ástmarsson *et al.*, 2013; Ambrose, 2015; Bouzarovski *et al.*, 2022). Landlords can be a similarly diverse group (Ambrose and McCarthy, 2019). Table 3.3 summarises the characteristics that may indicate an HTR profile for tenants and landlords.

Table 3.3 – Review of tenants' and landlords' reasons for potentially being HTR.

Proposed HTR profile	Reasoning to be considered HTR	Evidence
Tenants	Studies find that tenants are more vulnerable to energy poverty. Evidence that poor housing conditions are prevalent in rented homes, especially those for low-income households, and that vulnerable families are more likely to be tenants.	Ambrose, 2015; Legendre and Ricci, 2015; Drehobl *et al.*, 2020; UNECE, 2020; Simcock *et al.*, 2021; Chen *et al.*, 2022; Clair and Baker, 2022
	Split incentives: tenants are not property owners and do not have direct influence over decisions. This challenge is particularly acute for low-income tenants since these have the least choice over properties and the least agency to improve conditions.	Bird and Hernández, 2012; Ástmarsson *et al.*, 2013; Ambrose, 2015; Ambrose and McCarthy, 2019; Bouzarovski *et al.*, 2022; Raslan and Ambrose, 2022
	Tenants often face home insecurity making high upfront investment risky. While transience in rental markets has been marked as a barrier, it can also encourage improvements as new tenants can demand higher standards. However, tenants rarely factor-in energy costs in their decision.	Bird and Hernández, 2012; Ambrose, 2015; Ambrose and McCarthy, 2019; Jacques-Avinó, 2022; Raslan and Ambrose, 2022
	Other barriers, such as limited tenants' rights, absence of minimum energy performance standards, and power imbalances, are relevant	Ambrose, 2015; Middlemiss and Gillard, 2015; Longhurst and Hargreaves, 2019; Rotmann *et al.*,

	depending on audience segment and building type. Fear, embarrassment, and stigma can also stand between a tenant and support.	2020; Simcock *et al.*, 2021; Raslan and Ambrose, 2022
	For illegal or informal shared housing, where tenants have reduced housing rights, no control over energy services, and more pressing priorities, data is unavailable in most countries. Typically, these include students, young adults, and vulnerable persons, such as newly released from prison, leaving the care system, with mental health or substance misuse problems, homeless, new immigrants, and asylum seekers. Stigma and lack of capabilities deters tenants from complaining.	Cauvain and Bouzarovski, 2016; Mould and Baker, 2017; Petrova, 2017; Kousis *et al.*, 2020
Landlords	Split incentives: the landlord does not pay for energy and has few incentives to invest.	Bird and Hernández, 2012; Ástmarsson *et al.*, 2013; Ambrose, 2015; Ambrose and McCarthy, 2019; Bouzarovski *et al.*, 2022; Raslan and Ambrose, 2022
	Landlords are less likely to invest in energy performance than owner-occupiers or social housing providers. Landlords are less likely to dedicate time to gain knowledge on interventions and support schemes. Tenants are unable to carry out formalities that must be done by landlords.	Ambrose, 2015; Reames, 2016; Sommerfeld *et al.*, 2017; Galvin and Sunikka-Blank, 2018; Jacques-Avinó *et al.*, 2022; Sovacool *et al.*, 2022; Kraaijvanger *et al.*, 2023
	Market factors, where high demand and low supply leave tenants in a weak position, provide little incentive to invest in more than cosmetic repairs. Landlords also mention the weakness of the housing market and low rental yields as a barrier. Cultural factors may emerge where poorly performing properties are the norm leading to a lack of incentive to provide better quality.	Ambrose, 2015; Petrova, 2017; Ambrose and McCarthy, 2019

3.1.2.5 A case of energy injustice

Sovacool and Dworkin (2015) define energy justice as an energy system that fairly disseminates the benefits and costs of energy services and has representative and impartial decision-making. Most authors delve into energy justice by accounting for three tenets: distributional, recognitional, and procedural (Jenkins *et al.*, 2016). While this is not consensual and may fail to incorporate more plural perspectives (Sovacool *et al.*, 2017; Wang and Lo, 2021; Sovacool *et al.*, 2023), we apply this three-pronged lens to the HTR concept.

First, distributional justice recognises the unequal allocation of energy-related benefits and ills (Sovacool and Dworkin, 2015; Jenkins *et al.*, 2016). We argue that vulnerable households and tenants bear the brunt of energy poverty, exacerbated by intersectional vulnerabilities, while high-income households overconsume (Oswald *et al.*, 2020; Baltruszewicz *et al.*, 2023; Ruiz-Rivas *et al.*, 2023). Furthermore, vulnerable families are often excluded from the opportunities to benefit from energy transitions (Sommerfeld *et al.*, 2017; Hanke et al, 2021; Butler *et al.*, 2023b). Policies that require upfront costs or do not consider the needs of vulnerable households may prove regressive in numerous ways (Stewarts, 2022; Millward-Hopkins and Johnson, 2023).

Second, recognition justice states that all individuals must be fairly represented and offered complete and equal political rights (Jenkins *et al.*, 2016). From this perspective, an HTR profile can be seen as a lack of recognition of their attributes, limiting policy effectiveness, eroding public support, and harming marginalised groups (Starr *et al.*, 2023). Vulnerable households are often addressed through general communication that does not match their needs (Hanke *et al.*, 2021). Grossmann and Trubina (2021) add that vulnerable households experience dignity violations in the form of disrespect, humiliation, shame, stigma, and dependence.

Third, procedural justice relates to the decision-making processes, manifesting as equitable procedures and non-discriminatory participation (Sovacool and Dworkin, 2015; Jenkins *et al.*, 2016). The perspectives of less powerful HTR groups, such as vulnerable households and tenants, are often underrepresented in policies, with barriers such as insufficient access to information and decider bias contributing to unfair policy outcomes (Sovacool, 2014; Ivanova and Middlemiss, 2021; Sovacool *et al.*, 2023). For instance, the barriers to disabled people's participation are manifold, including that they may be dependent on others to represent their interests (Gillard *et al.*, 2017). In contrast, high-income households are better represented in governance circles while having more power to challenge undesired outcomes (Kenner, 2015; Starr *et al.*, 2023).

The persistence of these inequities points towards the need for specific mechanisms to accelerate energy transitions while acting on the injustices identified (Sovacool *et al.*, 2022; Kraaijvanger *et al.*, 2023). Currently, energy policies often rely on top-down and one-size-fits-all approaches targeted at the average consumer (Snell *et al.*, 2015; Garcia *et al.*, 2021; Bouzarovski *et al.*, 2022). Several authors (*e.g.*, Walker and Day, 2012; Snell *et al.*, 2015; Cauvain and Bouzarovski, 2016; Ivanova and Middlemiss, 2021) argue for improved recognition and engagement of HTR groups, implying that structural and targeted policies are needed.

3.1.3 Methods and data selection

The methodological approach consists of i) proposal of a theoretical framework for residential HTR energy users, ii) selection of an indicator set for the EU and its MS, iii) assessment of results to gauge the size of potential HTR groups in the EU's population, and iv) evaluation of the heterogeneity within groups and of the intersectionality across groups.

3.1.3.1 Proposing a theoretical framework for residential hard-to-reach energy users

First, we build on the literature review to systematise a theoretical framework for residential HTR energy users. In this context, the theoretical framework provides a structure to organise, interpret, assess, and discuss data, substantiating it with well-established research (Kivunja, 2018). This framework considers the literature review of socio-economic, demographic, and other characteristics that can act as markers of HTR profiles by hindering the identification and engagement of specific household types and slowing the uptake of interventions.

The framework intentionally highlights a single characteristic for each profile, drawing on the commonalities uncovered in the literature. Therefore, it does not consider the heterogeneity within profiles, where people have distinct experiences even if they share a prominent characteristic, nor the intersectionality between profiles, where people have more than one characteristic at once. This is addressed in subsection 3.1.3.4. The terminologies used to describe HTR profiles align with those employed by the sources from which the evidence was collected.

3.1.3.2 Selecting an indicator set

We operationalise the proposed theoretical framework by selecting a set of indicators for the EU-27 (reported in Eurostat as a geographical entity "EU-27 from 2020") and for its 27 current MS. We thoroughly analysed the Eurostat database to compile and process a basket of indicators relevant to each proposed HTR profile (this analysis was concluded in December 2023). These rely on publicly available secondary data in the Eurostat database (*e.g.*, income and living conditions statistics, labour force surveys, and demographic data). Data processing included extracting from the Eurostat database, calculating indicators based on two or more datasets, and normalising results to the total population of the EU and its MS. Appendix A presents the entire basket of indicators, their respective sources, and the data processing methods used. A similar operationalisation of existing statistics has been performed to assess energy poverty, including by the EU Energy Poverty Advisory Hub (Thomson *et al.*, 2017; Gouveia *et al.*, 2022; Gouveia *et al.*, 2023).

For each proposed HTR profile, a main indicator was selected from the surveyed basket based on the following five sequential prioritisation criteria: i) data is collected annually, ii) data is available for the last 10-year period (from 2013 to 2022), iii) data is reported for all MS, iv) its relevance to each HTR profile while avoiding co-linearity, and v) when multiple relevant indicators are available at EU-level the highest value for 2022 is chosen to include the broadest number of persons possible in each HTR group. Nevertheless, other relevant indicators from Eurostat (*e.g.*, modules collected every 3 or 6 years and thematic ad-hoc modules collected only once or in longer-term periods) are also discussed.

For specific profiles without data in Eurostat, other data sets and proxy indicators are shown when possible (European Commission, 2020b; Altrata, 2023; Capgemini, 2023; FEANTSA and The Abbé Pierre Foundation, 2023). These do not have the same comprehensiveness and standardisation as the Eurostat database, and mostly report on the European continent rather than just on the EU and its MS. Thus, proxy data were not included in the side-by-side normalised cross-country assessment performed with the Eurostat-based indicators; these are nonetheless assessed in the results and discussion section.

3.1.3.3 Assessing results for the European Union and its Member States

The selected indicator set is applied to the EU-27 and its current MS for the ten years between 2013 and 2022 to gauge the size of potential HTR groups. The analysis focuses on the EU-27, highlighting the need to recognise and target specific types of households through European energy policy. The diversity between MS is illustrated by the countries with the maximum and minimum values, as a share of the total population, for each profile in 2022. The limitations of the indicators are critically assessed, including by comparing the results with other datasets. Appendix A presents the results for all MS for the years 2013 and 2022. The Supplementary Materials in Appendix A include additional visualisations of the results for each HTR profile and country, which can be useful to inform policymakers and practitioners.

3.1.3.4 Evaluating heterogeneity and intersectionality

To address the inherent heterogeneity within HTR profiles and intersectionality between HTR profiles (Sunikka-Blank and Galvin, 2021), we return to our full indicator basket and to the Eurostat database to search for one-on-one combinations of HTR profiles (*e.g.*, low-income x elderly, rural x tenants, migrants x low education, and so on). It is not possible to extract data from Eurostat for several matchups, pointing towards data gaps in specific household types. When data were available, we followed the selection, processing, and prioritisation criteria described in subsection 3.1.3.2. It should be noted that the indicators previously selected from the basket and those used for the combination of HTR profiles may not coincide due to a lack of data availability. The indicators used to evaluate heterogeneity and intersectionality are compiled in Appendix A. Results are shown as the share of the total EU-27 population that compounds two HTR profiles in 2013 and 2022, allowing the identification of key target groups for policy intervention. The Supplementary Materials in Appendix A include the analysis of intersectionality for all EU-27 countries.

3.1.4 Results and discussion

3.1.4.1 Theoretical framework for residential hard-to-reach energy users

Building on multi-disciplinary literature, we propose a theoretical framework for residential HTR energy users, visually showcased in Figure 3.1. This framework aims to structure and guide our subsequent work by providing clearly defined HTR profiles while avoiding intersectionality at this stage. It includes thirteen vulnerable households' profiles, although frequent overlapping is likely on a case-by-case basis. As suggested by Sommer and Kratena (2017), we subdivided the high-income group into two profiles, as considerable differences between them were found in the literature. Tenants and landlords appear as a single profile for each group with specific overarching barriers. However, the rented sector is heterogeneous and vulnerable tenants (combining the profiles of vulnerable households and tenants) deserve further attention (Ambrose, 2015).

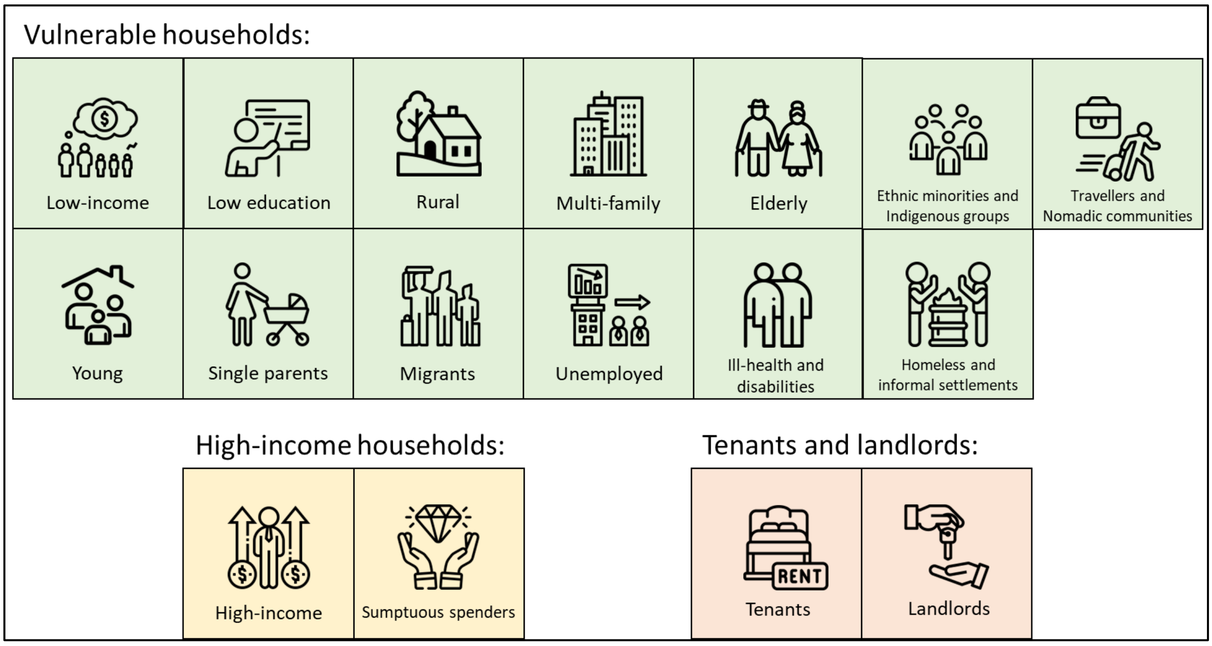


Figure 3.1 – Proposed theoretical framework for residential hard-to-reach energy users.

Notably, although sex is the most basic demographic data shown in the EU-level Eurostat database and a prevalent topic across the literature (*e.g.*, Sovacool, 2014; Fraune, 2015; Feenstra and Clancy, 2020), we did not define gender-based HTR profiles. This merits a clear justification. On the one hand, it would be unreasonable to consider half of the population as being HTR due to gender – even if Tjørring (2016) uncovered cultural norms that place energy issues in the male sphere of interest in the Danish context and Boag-Munroe and Evangelou (2010) find that traditional views of masculinity are often antithetical to asking for support. On the other hand, any attempt to go beyond the binary male/female division is hindered by lack of data and would intersect with other HTR profiles (*e.g.*, by looking at income, employment, education, and age from a gendered perspective), as shown by EIGE (2023) who maps gender inequalities in the EU. Poverty assessment by gender has met similar difficulties, and the usefulness of the term "female-headed household" has been questioned (UNECE, 2015). Nevertheless, a gendered analysis is relevant and can be the object of future work.

3.1.4.2 Indicator set

The proposed theoretical framework is operationalised for the EU-27 and its MS. For this purpose, a set of indicators was selected to gauge the size of potential HTR groups while exploring data availability and mapping data gaps. The proposed indicators, following the criteria established in Section 3.1.3, are shown in Table 3.4. In this table, we also briefly justify our choice of indicators, namely stating when it was the only strictly relevant indicator fully available for the ten years and for all MS ("single indicator"), when it represented the highest value for the HTR profile among available and relevant indicators ("highest value"), and when it was chosen as a proxy indicator from a different source than Eurostat since data in Eurostat were not found ("proxy indicator"); this process is fully fleshed out in the following subsections. The complete list of indicators for each profile and the data processing methods are detailed in Appendix A. All indicators are normalised to the total population of the EU-27 and of each MS.

Table 3.4 – Proposed indicator set for residential HTR energy users in the European Union.

HTR profile	Proposed indicator	Justification	Reference
Low-income	Population at-risk-of-poverty after deducting housing costs (cut-off point: 60% of median equivalised income after social transfers)	Highest value	Eurostat, 2023a
Low education	Population aged 15 to 64 years old with less than primary, primary, and lower secondary education (levels 0-2)	Single indicator	Eurostat, 2023b, Eurostat, 2023c
Rural	Population by degree of urbanisation – Rural	Single indicator	Eurostat, 2023d
Multi-family	Population by dwelling type - Flat	Highest value	Eurostat, 2023d
Elderly	Population aged 65 years old or over living alone or living as a couple	Single indicator	Eurostat, 2023c; Eurostat, 2023e
Young	Population aged 18-34 years old not living with their parents	Single indicator	Eurostat, 2023c; Eurostat, 2023f
Single parents	Population living in a household composed of a single person with dependent children	Single indicator	Eurostat, 2023g
Migrants	Population by country of birth - Foreign country	Highest value	Eurostat, 2023c; Eurostat, 2023h
Unemployed	Population aged 20 to 64 years old that is unemployed	Highest value	Eurostat, 2023c; Eurostat, 2023i
Ill-health	Population aged 16 years old or over having a long-standing illness or health problem	Highest value	Eurostat, 2023c; Eurostat, 2023j
Ethnic minorities and Indigenous groups	No data available from Eurostat; a proxy indicator was collected from other sources reporting on the Roma population in Europe	Proxy indicator	European Commission, 2020b
Homeless and informal settlements	No data available from Eurostat; a proxy indicator was collected from other sources reporting on people experiencing homeless in Europe	Proxy indicator	FEANTSA and The Abbé Pierre Foundation, 2023
Travellers and Nomadic communities	No data available in Eurostat; no proxy indicators found	-	-

High-income	Population having income of 160% of median income or more	Highest value	Eurostat, 2023k
Sumptuous spenders	No data available from Eurostat; proxy indicators were collected from other sources reporting on high-net-worth individuals in Europe	Proxy indicator	Altrata, 2023; Capgemini, 2023
Tenants	Population by tenure status – Tenant	Upper boundary	Eurostat, 2023l
Landlords	No data available in Eurostat; no proxy indicators found	-	-

One of the challenges of finding indicators for HTR groups is that they lack recognition, are underrepresented in official statistics, and data neglects some of the hardest-to-reach groups UNECE (2017, 2020). Gouveia *et al.* (2022, 2023) extensively reviewed energy poverty and HTR-related statistics, exposing data collection procedures' weaknesses and indicators' strengths and limitations. While the Eurostat database is largely harmonised, differences remain in the designs, definitions, and processes across countries and timescales; furthermore, several data points are marked as estimated, unreliable, or provisional (Sareen *et al.*, 2020). Still, most HTR profiles presented a straightforward choice of indicators due to established criteria and limited data.

There is also a potential criticism regarding our rough quantification of HTR profiles as a percentage of the population (which is the dataset publicly available in Eurostat) instead of as a percentage of households. Intra-household dynamics could mean that one household member would fit into one of the suggested HTR profiles while others would not. This limitation does not apply to HTR profiles based on location, buildings, and household composition. The need to conduct a thorough analysis of intra-household data has also been ascertained by UNECE (2020). This analysis can be pursued using primary statistical data from EU and national statistical offices, although this will require micro-data access.

<u>Vulnerable households</u>

For the "low-income" HTR profile, numerous indicators paint a multidimensional picture of the risk-of-poverty in the EU (Eurostat, 2023a, 2023m, 2023n, 2023o, 2023p). However, it should be cautioned that relative poverty thresholds are essentially arbitrary and often a better measure of income inequality (UNECE, 2017; Gouveia *et al.*, 2022). Another limitation is that these do not include income as informal work, begging or donations (UNECE, 2020). In the EU, the poverty line is usually set to 60% of the national median equivalised income (Eurostat, 2023n); however, since price levels tend to be more similar across countries than income, this implies different cost of living values, hindering comparisons between MS (UNECE, 2020).

Social exclusion considers dimensions beyond income, including labour market participation, educational opportunities, health and disability, access to healthcare, public services and essential infrastructure, and social, political, and civic engagement (UNECE, 2022). Indeed, social exclusion is a broader concept than income; thus, it would intersect with other profiles (it has also only been available since 2015) (Eurostat, 2023m). Social transfers aim to compensate for lack of income and try, but often fail, to prevent persons from falling into poverty (Middlemiss and Gillard, 2015; UNECE, 2020; Eurostat, 2023o); thus, they were included in the selected indicator. Finally, UNECE (2020) finds that accounting for housing costs can provide valuable insights, corroborating our final choice of indicator being the population at-risk-of-poverty after deducting housing costs (Eurostat, 2023a). An indicator reporting the persistent risk-of-poverty is also available, shedding light on this most vulnerable segment (Eurostat, 2023p).

Regarding the "low education" HTR profile, only one EU-level standardised dataset was found, where the option reporting on the lowest education level was selected (less than primary, primary and lower secondary education) (Eurostat, 2023b). Still, differences may exist between countries due to different levels of mandatory education and competencies developed during enrolment. A single EU-level dataset accounted for the "rural" HTR profile, dividing the population as living in urban areas, towns or suburbs, and rural areas – the latter option being selected (Eurostat, 2023d). Its weakness is that it does not allow for asserting remoteness, which is a significant factor for a potential HTR profile. The "multi-family" profile refers to the population living in flats, as described by the selected dataset, which also distinguishes those living in buildings with ten or more dwellings (Eurostat, 2023d).

Eurostat collects demographic data by age segment (Eurostat, 2023c). However, following other research, for the "elderly" HTR profile, we focus only on households that are composed of one adult aged 65 years and over and households that are composed of two adults aged 65 years and over, therefore excluding those living in institutional homes or living with their kin (Pais-Magalhães *et al.*, 2022; Eurostat, 2023e). A similar procedure was used for the "young" HTR profile, following the age brackets suggested by Petrova (2017) and considering only young adults not living with their parents (Eurostat, 2023f).

For the "single parents" HTR profile – defined as a parent not living with a partner and bearing responsibilities for raising a child (UNECE, 2020) – only one EU-level dataset was found, which reports on household composition (Eurostat, 2023g). Although data is available on households consisting of a single person, the vulnerability comes from the additional factor of parenthood (Galvin and Sunikka-Blank, 2018). This indicator does not inform on the number of children, which could also be interesting (UNECE, 2020).

The proposed "migrants" HTR profile is particularly complex. First, migratory status is usually defined by distinguishing between native-born and foreign-born persons (UNECE, 2020). This indicator is selected considering the broader barriers to migrants' participation (Eurostat, 2023h). For a more refined analysis, the data can be disaggregated by country of birth. However, the option to separate migrants born in EU and non-EU countries has only been available since 2017. Alternatively, building on the assertion that migrants from low- and medium-income countries potentially present a harder-to-reach profile (Oliveras *et al.*, 2020;

Jacques-Avinó, 2022), it is also possible to disaggregate according to the level of human development of the country of birth (Eurostat, 2023q). This provides only a statistical likelihood since immigrants from a given country may have different characteristics and may develop their own economic, educational, and social status.

Relevant data also reports on the length of the stay in the host country by quantifying recent migrants (Eurostat, 2023r), with these deemed as potentially more vulnerable (Simcock *et al.*, 2021). On the other hand, the prevalence of second-generation migrants, defined as native-born persons with at least one foreign-born parent, and where cultural factors, trust, discrimination, and language may still pose a barrier (Churchill and Smyth, 2020; Bouzarovski *et al.*, 2022), is not systematically collected and was only the target of an ad-hoc module in 2014 (Eurostat, 2019). Data on the permits for subsidiary protection or refugee status is available (Bouzarovski *et al.*, 2022; Eurostat, 2023s). Finally, data on illegal migration is reported as third-country nationals found to be illegally present each year (only available since 2021), which is naturally an underestimate (Eurostat, 2023t).

The "unemployed" HTR profile reflects the classification by employment status as a vulnerability factor that emerged in the literature review (Simcock *et al.*, 2021). EU-level data allows the quantification of persons from 20 to 64 years old in several employment situations, namely unemployment, long-term unemployment, underemployment, working part-time, and outside the labour force (Eurostat 2023i, 2023u, 2023v). Following the criteria established, the general unemployment indicator was selected. The other options present additional layers of the problem, and outside the labour force can encompass an extensive range of situations.

Data on the health conditions of the EU population is extensively collected, providing several options of indicators to represent the "ill-health and disabilities" HTR profile. Following the criteria of gauging the highest value, the indicator showcasing people aged 16 or over having a long-standing illness or health problem was chosen (Eurostat, 2023j). Other relevant indicators collected annually include the self-perceived health status and the self-perceived long-standing limitations in usual activities due to health problems (Eurostat, 2023w, 2023x). It should be noted that the concept of disability is broad and does not fully overlap with ill-health (Ivanova and Middlemiss, 2021). Thorough EU-level data collection on specific signs of illness (depressive symptoms and bodily pain) was performed in 2014 and 2019, while data collection on disability status, longstanding health problems, and longstanding difficulties in basic activities was conducted as an ad-hoc module in 2012 (Eurostat, 2015a, 2015b, 2015c, 2022, 2023y). Although health is relevant for the conceptualisation of HTR households, in practice, its relevance will vary because ill-health can be a transitory condition and, if chronic, may be associated with disability or advanced age.

Notably, no indicators in Eurostat were found to match the profiles "ethnic minorities and indigenous groups", "homeless and informal settlements", and "travellers and nomadic communities", pointing towards data gaps in these often-marginalised HTR groups. Data on ethnicity and indigenous groups is not commonly collected in the EU. Furthermore, ethnic identity is multidimensional, including ancestry, cultural origins, nationality, race, colour, minority status, tribe, language, and religion; thus, international comparability is low (UNECE, 2020). Country of birth is often used as a proxy, including in energy research, but it may be a weak indicator for ethnicity and is unsuitable for indigenous groups (Groote *et al.*, 2016; UNECE, 2020). The Fundamental Rights Agency carries out research on vulnerable groups, such as ethnic minorities, descendants of immigrants, LGBTI, and Roma, among others; however, these are not systematic or quantitative. The European Commission's (2020b) Roma strategic framework reports on the Roma population in Europe. FEANTSA and The Abbé Pierre Foundation (2023) report on people experiencing homelessness. These may be used as proxy indicators but do not fully encompass the HTR profiles defined and lack comparability with the standardised Eurostat database.

High-income households

Besides the general disaggregation of income by quintiles or deciles, there is surprisingly little data available on the high-income population, as also reported by Baltruszewicz *et al.* (2023). For the "high-income" HTR profile, only one EU-level standardised dataset was found, reporting the share of people with income above a certain threshold (Eurostat, 2023k). The highest threshold available (160% of median or mean income) was chosen, and, like the procedure for the "low-income" profile, the median was selected. As with relative poverty metrics, this threshold is essentially arbitrary, reporting more on income inequality than on high income or wealth per se.

Notably, no indicators in Eurostat were found to match the profile "sumptuous spenders", pointing towards data gaps in this elusive group. Seeking potential proxy indicators, data were collected from international sources that report on the high-net-worth population in Europe (Altrata, 2023; Capgemini, 2023). Still, these do not have the same level of standardisation and comparability of the Eurostat database.

Tenants and landlords

The "tenants" HTR profile attempts to capture the overarching effects of housing tenure on households' agency to implement energy interventions. Thus, the selected indicator showcases the share of the population living in rented houses, regardless of their income, rent level, or being public housing or privately rented (Eurostat, 2023l). Tenants can also be divided into those paying rent at market prices and those having rent at reduced price or free, with the latter potentially having more income to pay for other necessities than the former (UNECE, 2020). Finally, no data is available in Eurostat regarding "landlords", and no proxy indicator was found to report on this profile.

3.1.4.3 Results for the European Union and its Member States

This subsection shows the results of applying the selected indicators to the EU-27 and its MS. Data were collected from Eurostat for the ten years between 2013 and 2022 to assess macro trends (Figure 3.2). The results for the complete basket of indicators are shown in Appendix A. To illustrate the variability between MS, Figure 3.3 showcases the range of values for each profile considering the highest and lowest data points among Member States in the year 2022. Results for all 27 current MS are shown in the Supplementary Materials, enabling an in-depth national-scale analysis of HTR profiles, which can be useful for future research and policymaking. As explained in section 3.1.3, HTR profiles for which there is no available data in Eurostat are not shown in the figures due to their lack of comparability, being nonetheless presented and discussed in this section.

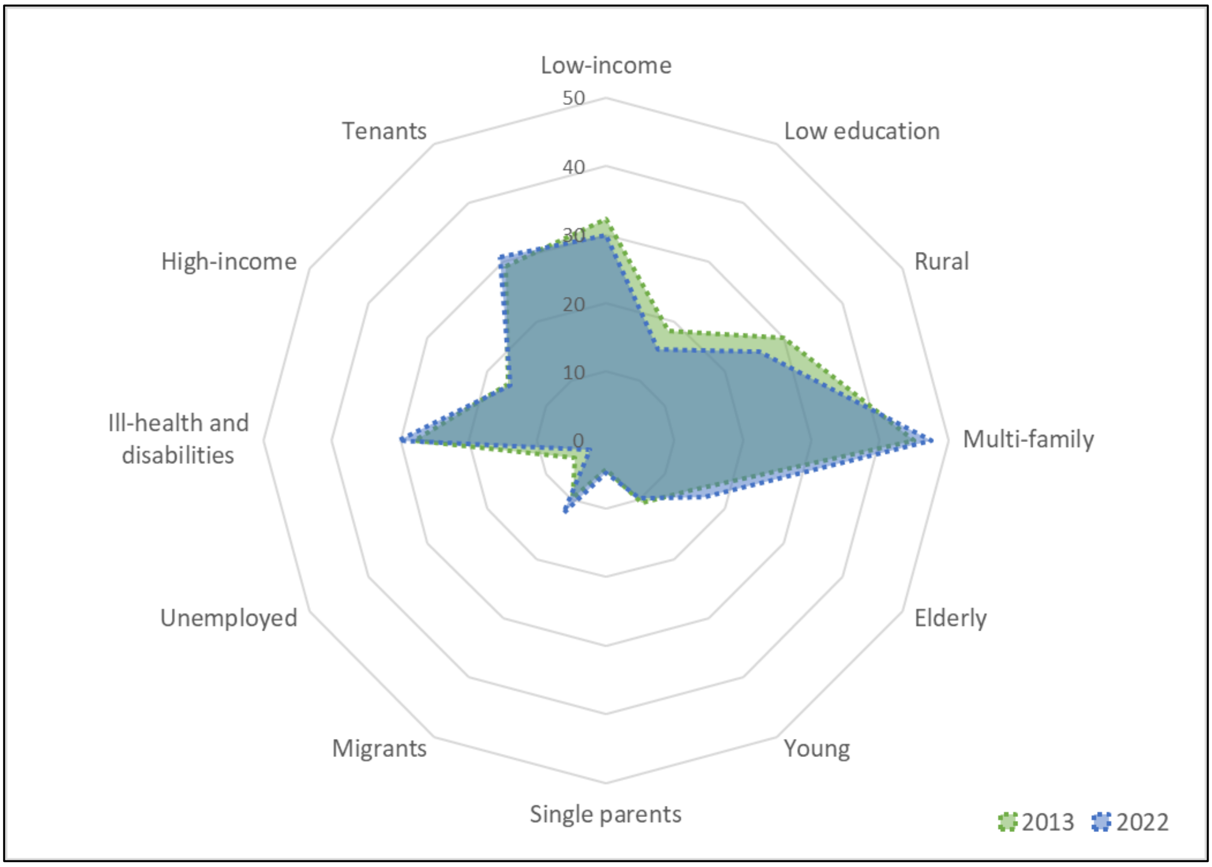


Figure 3.2 – Share of the systematised HTR profiles in the total EU-27 population.

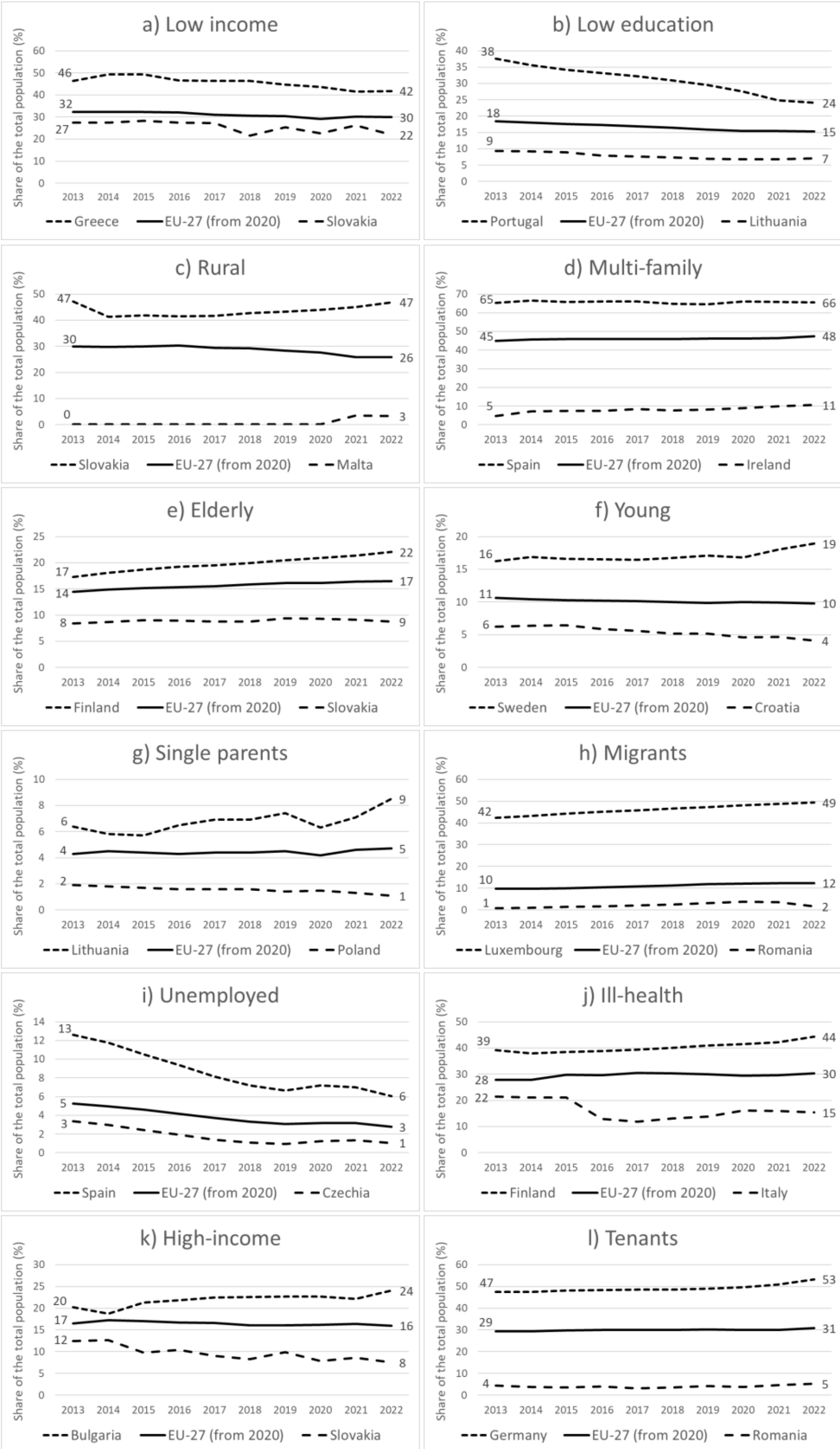


Figure 3.3 – Evolution of proposed HTR profiles in the EU-27 and range between Member States.

Vulnerable households

The largest group identified is the "multi-family" profile, accounting for 48% of the EU population and highlighting the role of fragmented ownership and organisational barriers where the need for multiple homeowners, tenants, and landlords to agree on investment decisions hinders the uptake of whole-building interventions (Baker *et al.*, 2019; Rotmann *et al.*, 2020). Of these, slightly more than half live in buildings with more than ten flats, where these barriers may be more severe. The size of this group is significant in most MS. Still, variations are noted, as illustrated by Ireland and Spain, with 11% and 66% of their population living in flats, respectively.

The "low-income" profile suggests that up to 30% of the EU population may be at greater risk of energy poverty while experiencing a lack of financial capacity and other barriers to adopting energy interventions (Galvin and Sunikka-Blank, 2018; Simcock *et al.*, 2021). However, if other indicators were to be selected, for instance, not including housing costs, this value would be reduced to about half at EU-scale. Since both these indicators are a better metric for income inequality than for absolute low income, the results should be critically assessed as significative differences are to be expected between countries, even if the data may look similar (UNECE, 2017; Gouveia *et al.*, 2022). For example, according to this indicator, Romania and the Netherlands present similar levels of low-income population (32% of the total population); however, in 2022, the monthly minimum wage was 2-3 times lower in absolute values and in purchasing power standards, respectively, in the former compared to the latter (Eurostat, 2024).

Following, the "ill-health and disabilities" HTR profile also represents up to 30% of the EU population with higher vulnerability to energy poverty, dependence on healthcare services, and cognitive, sensory, or communication impairments (Ivanova and Middlemiss, 2021; Chapman *et al.*, 2022; Jacques-Avinó *et al.*, 2022). Data on disabilities is only available for 2012 when around 14% of the EU population had disability status (only accounting for those aged 15 years old and over). More specific health issues, such as self-perceived bad health, severe bodily pain, and depressive symptoms, are reported for less than 10% of the EU population. For the selected indicator, data varies among MS, as illustrated by Italy and Finland, with only 15% and more than 40% of their population suffering from a long-standing illness or health problem, respectively.

At the EU level, ill-health shows a growing trend that may be linked to an aging population with potential impacts on energy use (Zhen *et al.*, 2022). The "elderly" HTR profile accounts for 17% of the population (up from 14% in 2013); according to the literature, these households may be less prone to invest in improving energy performance (Abreu *et al.*, 2020). Data is relatively homogenous, with the elderly living alone or as a couple representing 9% to 22% of the MS's population in 2022.

Around one-quarter of the population lives in a rural settlement, where barriers such as lack of available services and use of unregulated energy carriers may impact the adoption of energy interventions (Ashby *et al.*, 2020; Stojilovska *et al.*, 2023). Nevertheless, it should be noted that results may lack comparability across countries due to different definitions of rural areas (Roberts *et al.*, 2015). For the last 10-year period, the rural population appears to have slightly decreased at the EU level, with significant differences in trends and values among MS.

While EU education levels have risen in the past 10-year period, the suggested "low education" HTR profile still accounts for 15% of the population in 2022, potentially with lower literacy levels and a lack of knowledge on energy issues (Legendre and Ricci, 2015). Significant differences exist across countries, with the share of the population in the lowest education bracket ranging from 7% to 24% in 2022 for Lithuania and Portugal, respectively.

Over the past decade, migration fluxes led to an increase in the "migrants" profile, which accounts for 12% of the EU population. Of these, at least half were born in non-EU countries, and a quarter were born in countries with low or medium levels of human development; these can be more susceptible to language barriers and concerns about legal status (Oliveras *et al.* 2020; Simcock *et al.*, 2021; Jacques-Avinó *et al.*, 2022). Particularly vulnerable groups, such as refugees, illegal immigrants, and recent immigrants, represented a small share of the EU population – around 0.4%, 0.1%, and 1.5%, respectively – but these are not negligible, being among the hardest-to-reach groups (Bouzarovski *et al.*, 2022). The share of migrants in the national population varies considerably, with Western European and Nordic countries presenting higher values and Eastern European countries presenting lower values.

The dynamics of an aging population also mean that the share of the suggested "young" profile has reduced in the past decade. Young adults living without their parents account for around 10% of the EU population; these can be vulnerable due to unstable and transient housing and employment patterns (Petrova, 2017). Nordic countries seem to have a higher share of young adults living independently, while Southern Europe and Eastern Europe countries have lower values. The HTR profiles "single parents" and "unemployed" each represent less than 5 % of the EU population. Simultaneously, around 12% of the EU population is outside the labour force; this employment status might be associated with the additional risk of energy poverty (Clair and Baker, 2022).

Finally, no data can be ascertained from Eurostat regarding the profiles "ethnic minorities and indigenous groups", "homeless and informal settlements", and "travellers and nomadic communities". However, other sources attempt to shed light on these groups. For instance, the European Commission (2020b) estimates that between 10 and 12 million Roma live in Europe – equivalent to up to 2.7% of the EU's population (the source reports on Europe, not only in the EU) – facing discrimination and exclusion. Still, this represents only a portion of a much broader population profile. While focusing only on the most visible forms of homelessness and not considering informal or illegal settlements, FEANTSA and The Abbé Pierre Foundation (2023) estimate that a minimum of 895 thousand people is homeless in Europe – equivalent to at least 0.2% of the EU's population (the source reports on Europe, not only on the EU). For the "travellers and nomadic communities", no data could be ascertained from Eurostat or from other proxies.

High-income households

Like the "low-income" profile, the "high-income" results can be seen as a measure of income inequality and not as absolute high income, and any comparisons should be critically assessed. For instance, Ivanova and Wood (2020) report that as much as 36% of Luxembourg's households can be classified as being in the top 10% of high emitters within the EU, while in Croatia, only 1% would be classified as such; however, our indicator does not show this situation presenting similar values for both countries. At the EU level, this profile may account for up to 16% of the total population (alternatively, using the mean would suggest 13%), where price signals and cost savings may be ineffective drivers (Kenner, 2015; Garcia *et al.*, 2021; Cass *et al.*, 2022).

For the elusive "sumptuous spenders" HTR group, Capgemini (2023) estimates that 5.6 million people in Europe can be classified as high net worth individuals with over one million dollars in wealth in 2022 – this would be equivalent to around 1.3% of the EU's population (the source reports on Europe, not only on the EU). In addition, Altrata (2023) estimates that around 100 thousand individuals in Europe can be classified as ultra-high net worth individuals with over 30 million dollars in wealth – this would be equivalent to about 0.02% of the EU's population (the source reports on Europe, not only on the EU).

Tenants and landlords

At the EU level, tenants represent 31% of the population, pointing towards the need to address the split incentives problem (Ambrose, 2015). Of these, around one-third pay rent at market price while the remaining have reduced or free rent. The general trend for the EU shows an increase in the population living in rented houses, which Galvin and Sunikka-Blank (2018) pin on increasing economic inequality and neoliberal policies. Variation is considerable among MS, with Eastern European countries having larger shares of homeownership (*e.g.*, less than 5% of the population in Romania rents their home) compared with Western and Northern European countries (*e.g.*, half of the population in Germany rents their home). As mentioned, we did not find Eurostat statistical data or any proxy indicators referring to landlords in the European context.

3.1.4.4 Heterogeneity and intersectionality

Up to this point, we have purposely omitted the heterogeneity within HTR profiles and the intersectionality of multiple vulnerabilities, characteristics, and circumstances in the individuals and households belonging to HTR profiles. Considerable heterogeneity between nations, regions, and households will exist, particularly since the HTR concept is context-specific (Ambrose *et al.*, 2019a; Middlemiss, 2022). Furthermore, there is an emerging literature on intersectionality, which avoids focusing on one characteristic and instead explores several intersecting features (Sunikka-Blank and Galvin, 2021). Energy poverty research has moved in this direction, seeking to cross-examine and combine various dimensions to assess vulnerabilities across countries and regions (Longhurst and Hargreaves, 2019; Chen *et al.*, 2022; Middlemiss, 2022; Gouveia *et al.*, 2023).

Following, tables 3.5 and 3.6 present the results from the one-on-one combinations of HTR profiles for the years 2013 and 2022, respectively. These are shown as a share of the total EU-27 population. This process allows the identification of key groups that compound multiple HTR characteristics, and that may require targeted energy policies and interventions.

Table 3.5 – One-on-one combinations of HTR profiles as a share of the total EU-27 population (2013).

EU-27, 2013	Low-income	Low education	Rural	Multi-family	Elderly	Young	Single parents	Migrants	Unemployed	Ill-health (...)	High-income	Tenants
Low income		5%	11%	8%	5%	2%	2%	3%	2%	4%	-	8%
Low education			10%	-	6%	2%	0%	4%	2%	-	1%	-
Rural				6%	4%	3%	-	1%	1%	10%	3%	-
Multi-family					-	-	-	-	-	-	-	-
Elderly						-	-	1%	0%	9%	2%	3%
Young							-	1%	1%	2%	-	-
Single parents								-	0%	-	-	2%
Migrants									1%	3%	-	5%
Unemployed										1%	-	-
Ill-health (...)											-	7%
High-income												-
Tenants												

Table 3.6 – One-on-one combinations of HTR profiles as a share of the total EU-27 population (2022).

EU-27, 2022	**Low-income**	**Low education**	**Rural**	**Multi-family**	**Elderly**	**Young**	**Single parents**	**Migrants**	**Unemployed**	**Ill-health (…)**	**High-income**	**Tenants**
Low income		4%	8%	9%	6%	2%	2%	4%	1%	5%	-	8%
Low education			7%	-	5%	2%	0%	5%	1%	8%	1%	-
Rural				4%	4%	2%	-	1%	1%	10%	3%	-
Multi-family					-	-	-	-	-	-	-	-
Elderly						-	-	2%	0%	10%	2%	4%
Young							-	2%	1%	2%	-	-
Single parents								-	0%	-	-	3%
Migrants									1%	3%	-	8%
Unemployed										1%	-	-
Ill-health (…)											-	7%
High-income												-
Tenants												

A significant share of the EU population intersects low incomes with living in rural settlements, in multi-family buildings, and/or being a tenant; all these aspects can compound to further hinder the uptake of interventions. Furthermore, where low incomes are prevalent, a range of other stressors often aggravate, including physical and mental health problems, social isolation, discrimination, crime, substance abuse, and poor housing (Anderson *et al.*, 2012; Mould and Baker, 2017; Lukanov and Krieger, 2019). Rural households can become even harder-to-reach when geographical isolation intersects with low education levels and ill-health (Ross *et al.*, 2018; Gouveia *et al.*, 2019); our analysis shows that a significant share of the population compounds these vulnerabilities. Nonetheless, national-scale assessments can miss regional differences, as Simcock *et al.* (2021) argue that vulnerability varies widely across rural areas.

Chard and Walker (2016) report enormous heterogeneity across the elderly regarding income, health, mobility, aspirations, and outlook, which may influence their capability and willingness to engage. Regarding the level of income, in 2022, 6% of the EU population combined "elderly" with "low income", and 2% combined "elderly" with "high income", illustrating the inherent diversity in this group. There is a significant overlap between advanced age and aggravating health problems, which merits particular attention. Disabilities include a vast range of impairments which can change over time, may or may not demand specific energy needs, and may intersect with other vulnerabilities, such as struggling to secure stable employment (Snell *et al.*, 2015; Middlemiss, 2022).

An undifferentiated view of immigrants' neglects to account for trends in specific communities while not considering relevant intersections with low education levels and tenure status (Bouzarovski *et al.*, 2022). The former is illustrated by Jacques-Avinó *et al.* (2022), who noted different responses to energy-saving interventions from immigrants according to their country of origin; suggesting how intersections between migratory status and ethnicity can make households HTR. A relevant share of the EU population lives as a tenant while intersecting migratory status and/or ill-health and disabilities; research has shown that the barriers in the private rented sector can be exacerbated for vulnerable tenants who are in a weaker bargaining position (Petrova, 2017; Bouzarovski *et al.*, 2022; Ambrose and McCarthy, 2019).

Heterogeneity and intersectionality are also present for smaller HTR groups, for instance, a single-parent household may compound vulnerabilities related to gender, low incomes, tenure status, and ethnicity, which may accentuate the HTR profile (Sunikka-Blank and Galvin, 2021). However, data gaps hinder a more comprehensive analysis across HTR profiles, prominently regarding the population living in multi-family buildings, single-parents, and tenants. As previously mentioned, very scarce data is collected on higher-income population segments. Heterogeneity may also be present in this group, with a few authors stating that some of the wealthiest persons actively engage in energy-related causes while still using excessive amounts of energy (Otto *et al.*, 2019; Barros and Wilk, 2021).

3.1.5 Implications for just energy policies

3.1.5.1 Targeting vulnerable households

Our research has shown that different profiles of HTR households account for a significant share of the EU population and that a relevant subset compounds at least two vulnerabilities; these can be at increased risk of being left behind in energy transitions. Currently, most approaches have proven largely inadequate in identifying and supporting these households, lacking the cultural sensitivity and accessibility needed, for instance, on formal requirements (*e.g.*, excluding migrant populations and those living in informal housing), upfront investment (*e.g.*, excluding those on low incomes or in unstable housing or employment situations), and engagement methods (*e.g.*, often requiring digital and other taken-for-granted skills thereby excluding groups with advanced aged or low education levels) (Anderson *et al.*, 2012; Mould and Baker, 2017; Bouzarovski *et al.*, 2022). Even programmes providing full financial support, can meet barriers such as distrust, information gaps, and split incentives between tenants and landlords (Reames, 2016, Stewart, 2022).

Several authors argue for policies and interventions targeted and tailored to specific groups that acknowledge their needs (Gouveia *et al.*, 2019; Lukanov and Krieger, 2019; Jacques-Avinó, 2022). These imply proactive action, as opposed to relying on individuals taking the initiative, and there needs to be a better understanding of how different types of households become aware of schemes, why they get involved, and what barriers they must overcome (Sovacool, 2014; Chard and Walker, 2016; Willand and Horne, 2018; Owen *et al.*, 2023).

In this context, the importance of local scale action has been highlighted (Gillard *et al.*, 2017; Zhen *et al.*, 2022; Mundaca *et al.*, 2023). A few lessons can be learned from the experience of conducting poverty surveys with HTR groups, where traditional methods had to be adapted, and from the extensive work of health and social services professionals (Boag-Munroe and Evangelou, 2010; UNECE, 2020, 2022). These find that enhancing trust and accessibility is key, for instance, by providing culturally appropriate materials in several languages that can meet the needs of migrants, ethnic minorities, persons with ill-health and disabilities, among others. Tailoring policies and interventions to specific vulnerable groups requires consultation with the populations or their representatives at all stages (Simcock *et al.*, 2021). Several authors argue for a community-based approach (*e.g.*, Reames, 2016; Horta *et al.*, 2019; Sequeira and Melo, 2020), which can make use of trusted middle actors, enhancing targeting, awareness, and uptake of interventions by vulnerable groups.

Energy-related support to vulnerable households must often be delivered face-to-face and in-home, as studies show that the provision of advice by phone or online is insufficient for groups with low literacy levels or advanced age, among others (Forster *et al.*, 2019; Sequeira and Gouveia, 2022; Butler *et al.*, 2023a). Butler *et al.* (2023b) underline the need for training, support, and supervision of organisations that interact with HTR groups, addressing both energy and cultural awareness and reducing biases. UNECE (2020) argues for the recruitment of peers from the community or from the target group to conduct fieldwork. This approach has been employed in energy support; for instance, in the United States, Reames (2016) reports on the hiring of all African American staff to foster trust among residents.

Nevertheless, even targeted policies can involve trade-offs. For instance, associated with the decision to support one group of households over others or with the provision of support to all people from a potentially vulnerable profile (*e.g.*, for being elderly, disabled, or migrant) while neglecting to consider the diversity of cases and the intersection with other vulnerabilities and amending factors (Legendre and Ricci, 2015; Chard and Walker, 2016). Addressing vulnerable households often requires working case-by-case, and a poorly targeted policy or intervention can be ineffective and waste limited funds; more research is needed to inform on effective designs (Pillai *et al.*, 2021; Owen *et al.*, 2023).

3.1.5.2 Targeting high-income households

While reaching vulnerable households is key for just energy transitions, Otto *et al.* (2019) and Oswald *et al.* (2023) argue that policies are also needed to target the opposite end of the social ladder. Reducing excess consumption in high-income families may be the most efficient and equitable approach to curb energy demand (Garcia *et al.*, 2021; Cass *et al.*, 2022; Büchs *et al.*, 2023). Furthermore, behaviour change in this group has downstream benefits, inspiring the consumption patterns of the population (Otto *et al.*, 2019). The common feature of high-income households is that costs are not a constraint to energy use. The degree of disproportionate energy use is, therefore, not only a function of income but also of mentality. Measures to deal with this need a different focus, and current energy policies have mostly neglected high-income households (Ivanova and Wood, 2020; Garcia *et al.*, 2021).

Nevertheless, there are ways in which policymakers might be able to target excessive consumption while mitigating unintended consequences for vulnerable households (Oswald *et al.*, 2020; Cass *et al.*, 2022). To achieve this goal, we first alert to the persisting lack of data on high-income households, as we were only able to gauge the share of the EU population having income above a certain level which may or may not translate into excessive energy use.

Oxfam (2023) calls for increasing taxation on the top 1% and proposes major taxes on highly energy-intensive luxury consumption, such as SUVs, mega-yachts, private jets, and space tourism. Other authors also argue for progressive taxation and redistribution policies, simultaneously targeting overconsumption and poverty (Sunikka-Blank and Galvin, 2021; Büchs *et al.*, 2023; Gossling and Humpe, 2023). For instance, Oswald *et al.* (2023) argue for luxury-focused taxation as an effective method to reduce emissions, which can recycle revenues for retrofitting homes. Complementary to taxation, François *et al.* (2023) draw on historical cases to suggest caps on wealth and income as a tool to decrease inequality.

Decision makers can guide, constrain, or outright ban potentially unsustainable energy-intensive innovations through precautionary policies, as exemplified with space tourism by Markard *et al.* (2023). Furthermore, interventions explicitly targeting the wealthiest could include obligatory installation of renewable energy, taking advantage of their capability to meet requirements (Otto *et al.*, 2019). Perhaps more unconventional, Barros and Wilk (2021) suggest public shaming to pressure sumptuous spenders by creating socially acceptable limits and punishing violators.

While multiple sources call for energy policies to effectively target HTR high-income households, these are hampered by several barriers. First, is the very realisation among policy makers that the wealthy must be limited in their energy use, which can be seen as an affront to personal freedom; second, increasingly polarised political environments in which these policies cannot be proposed; third, ineffective policy designs that fail to meet their goals (Nielsen *et al.*, 2021; Büchs *et al.*, 2023; Gossling and Humpe, 2023). Finally, policies targeted at high-income households are bound to meet resistance because there are strong ties between the wealthy and the political elites (Otto *et al.*, 2019; Wiedmann *et al.*, 2020; Oswald *et al.*, 2023).

3.1.5.3 Targeting tenants and landlords

Energy policies have so far neglected to provide a definitive response to the challenges of the rented sector (Ambrose, 2015), which accounts for around 30% of the EU population. In a review of policies in Global North countries, Bouzarovski *et al.* (2023) found scarce examples of specialised support for tenants and landlords. The same authors report that most policies focus on technical and financial measures, with a limited number involving behaviour change and energy conservation. Ambrose (2015) argues for policies that consider landlords' perspectives and that raise awareness among landlords and tenants.

Cauvain and Bouzarovski (2016) list a few examples of interventions aimed at the improvement of energy performance in rented houses, for instance, including the energy performance certificate as a condition, promoting systematic programmes of inspection, grants, support, and voluntary accreditation, and adopting minimum energy performance standards. In the United States, Reames (2016) reports on the use of a discount incentive for landlords to renovate their houses, which also provides tenants with a reasonable bargain for intervention.

Nevertheless, most authors admit that no single policy can overcome split incentives and that neither regulatory mechanisms, information instruments, nor incentive schemes are sufficient on their own (Ástmarsson *et al.*, 2013; Ambrose and McCarthy, 2019). Thus, these authors propose a package approach tailored to specific segments of the private rented market, including legislative changes, institutional support, financial incentives, and dissemination of information. Finally, tenants and landlords should be involved in formulating, designing, and implementing EU and national policies through a mediated discussion to address their respective needs (Bouzarovski *et al.*, 2023).

3.1.5.4 Using the hard-to-reach framework for policy design

Clear, informative, and measurable EU and national-scale knowledge on HTR groups can be highly relevant for designing policies, as well as for ex-ante and ex-post evaluations of their outcomes towards just transitions. If effective multi-scalar policies and interventions are to be deployed, policymakers and practitioners must first know their audiences well and recognise the specific challenges hindering engagement in energy transitions. Furthermore, acknowledging intra-group diversity and inter-group overlap is important to pinpoint key groups and efficiently allocate funds while avoiding falling into stereotypes and stigma (Ambrose, 2015; Forster *et al.*, 2019; Butler *et al.*, 2023b).

For instance, when launching a national-scale funding scheme for building renovation, policymakers can leverage on our framework, indicators, and results to be aware of the specificities of their target population and ask fundamental questions such as “Does this funding meet the upfront cash needs of low-income households which represent a significant share of our population? Is it inclusive towards people with advanced age and/or low educational levels? Is it available in several languages and with culturally appropriate materials so that our immigrant communities and/or ethnic minorities can apply? Does it tackle head-on the split incentives challenges in the private rental sector? Are service providers and installers ready to implement these interventions in rural and remote areas?", among others. When piloting energy efficiency or renewable energy actions to increase citizen engagement in energy transitions, practitioners should raise similar questions according to their regional and local contexts, for example "Are there trusted intermediaries in place to ensure that our actions reach people with ill-health and disabilities? Is our message applicable to people in homeless situations or inhabiting informal housing? Do we have the necessary buy-in to engage with Indigenous communities?", among others. Key questions that should also be raised by policymakers include "Do our policies call upon high-income households to take responsibility and reduce sumptuous energy use? Is the allocation of public funding having regressive effects and further increasing inequalities in the uptake of energy interventions?".

Still, more important than systematising and quantifying HTR profiles per se, it is to emphasise that dealing with these households requires targeted and tailored approaches, often deployed on a case-by-case basis. More important than assessing intersectionality in deterministic terms, it is to create the local capacity to take this into account for each household through flexible, responsive, and dynamic interventions (Reames, 2016; Millward-Hopkins and Johnson, 2023). Engaging the HTR requires more holistic and people-centred policies that break silos spanning areas such as energy, family, social security, health, housing, labour, and migration (Middlemiss and Gillard, 2015; Jacques-Avinó *et al.*, 2022). While much more needs to be done to ensure that HTR energy users are not left out of the energy transition, existing research already sheds light on effective mechanisms to target different types of households.

3.1.6 Limitations and future work

Our work has delved into largely uncharted territory, and there are inherently some associated limitations. First, although we strived to include different streams-of-though in the literature review, other sources could have provided different evidence. Second, limitations exist in the statistics publicly available from the Eurostat database, as described by Gouveia *et al.* (2022), including the data collection methods themselves, missing or unreliable data, and lack of comparability. Third, statistics do not cover the whole population due to sampling methods that exclude the most vulnerable and wealthiest groups (UNECE, 2017, 2020; Otto *et al.*, 2019). Fourth, the selection of indicators to gauge HTR groups in the EU and its MS is exploratory, and the results should be seen in each national context considering heterogeneity and intersectionality. Fifth, the discussion of approaches to target HTR groups does not intend to be comprehensive, merely paving the way for future research.

Our work on HTR energy users opens a wide space for further interdisciplinary and multi-scalar research. First, we join other authors in arguing for the need to collect and analyse data at the national, regional, and local scales to inform tailored solutions (Bîrsănuc, 2022; Chen *et al.*, 2022; Houghton *et al.*, 2023). The collection procedures should be established in statistical offices, and data gaps should be closed (UNECE, 2017; Ring *et al.*, 2022). Second, heterogeneity and intersectionality merit further research by disaggregating and exploring the variables that may lead to an increase or decrease in the vulnerabilities, characteristics and conditions that suggest an HTR profile (Middlemiss, 2022; Baltruszewicz *et al.*, 2023). Third, more research is still needed to understand the drivers and barriers that impact the participation of HTR groups. These can include empirical case studies, adopting human-centred approaches and working alongside members from the target groups (Sovacool, 2014; Chapman *et al.*, 2022; Budworth, 2023).

3.1.7 Conclusions

Throughout this work, we have contributed to the advancement of the concept of HTR energy users – building on the seminal review by Rotmann *et al.* (2020) – with a focus on the EU and its MS. Our review synthesises the challenges to identifying, communicating, and engaging with three major groups, namely vulnerable households, high-income households, and tenants and landlords. We critically assess the usefulness of the HTR concept while framing the participation of these groups in energy transitions as a necessity for its completeness and a matter of justice.

Following, we propose a theoretical framework and select an indicator set, including thirteen HTR profiles for vulnerable households (low-income, low education, rural, multi-family, elderly, young, single parents, migrants, unemployed, ill-health and disabilities, ethnic minorities and indigenous groups, homeless and informal settlements, and travellers and nomadic communities), two profiles for high-income households (high-income and sumptuous spenders), and two profiles for tenants and landlords (tenants and landlords). This framework does not intend to 'write in stone' a rigid list of HTR profiles nor to define a fixed set of indicators; these are context-specific and should reflect national, regional, and local dynamics. The results are discussed for the EU and its MS, identifying key target groups for energy policies and mapping persistent data gaps. Furthermore, we take our indicator set a step further to evaluate the heterogeneity and intersectionality in HTR profiles, highlighting groups which compound at least two HTR characteristics. Finally, our research provides insights for improved targeting and tailoring of policies and interventions that meet the needs of the HTR.

Considering the criticism and limitations of this work, the following insights can be summarised:

i) There are multiple and distinct barriers to HTR groups participation in energy transitions, and these are often specific to the characteristics of each HTR profile.

ii) At EU-level the systematised profiles individually account for significant shares of the population – *e.g.*, "low-income", "ill-health and disabilities", and "tenants" profiles individually represent around 30% of the EU population – which are likely not being properly included in energy transitions, with wide-ranging variations among MS.

iii) There is a lack of standardised data on the most vulnerable and marginalised groups and on the most wealthy and powerful groups, while more detailed and open-access datasets could allow a refined analysis of other HTR profiles.

iv) Reality is more complex than theory, and the heterogeneity within HTR profiles and the intersectionality between HTR profiles will likely aggravate the challenges of deploying just energy policies.

v) The HTR nature of the mapped household profiles demands targeted and tailored energy policies and interventions to address their often very specific needs.

vi) Existing research points towards the important role of local-scale community-based social, technical, and financial support for vulnerable households, stringent taxation, caps, mandates, and bans for high-income households, and a package of regulations, information, and incentives for tenants and landlords.

Increasingly, energy transitions are being seen as more than average energy users adopting reasonable and cost-effective technologies and behaviours. This leads to a necessary reflection on the ones left behind, comfortably or harmed, by one-size-fits-all approaches – the hard-to-reach. In this work, we suggest that involving HTR households is key for just energy transitions, ensuring that the vulnerable and often marginalised also benefit from existing solutions and that the wealthy and often powerful contribute their fair share.

Our proposed theoretical framework and indicator set can serve as a decision-making tool to guide the development of multi-scalar, targeted, and tailored energy policies and interventions that foster just energy transitions while also being useful for ex-post analysis of their effects. Policy is about choices, and science is most useful to policy when it helps to set priorities. We hope this work offers useful insights to recognise and address the needs of HTR groups. Successfully reaching and engaging the hard-to-reach is urgent and vital to materialise the multiple benefits of energy transitions.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia & João Joanaz de Melo: Writing – review & editing, Validation, Supervision, Conceptualisation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103612.

References

Abreu, M.A., Oliveira, R.A.F., and Lopes, J. (2020). Younger vs. older homeowners in building energy-related renovations: Learning from the Portuguese case. 6th International Conference on Energy and Environment Research, ICEER 2019, 22–25 July, University of Aveiro, Portugal. Energy Reports, 6, 159-164. https://doi.org/10.1016/j.egyr.2019.08.036

Alexandrescu, F., Anghel, I.-M., Adorjáni, J., Stefanescu, L., Pop, A., and Mihai, A. (2021). On the path of evictions and invisibilization: Poor Roma facing climate vulnerability. Cities, 114, 103201. https://doi.org/10.1016/j.cities.2021.103201

Altrata (2023). World Ultra Wealth Report 2023. Retrieved from https://altrata.com/reports/world-ultra-wealth-report-2023

Ambrose, A. (2015). Improving energy efficiency in private rented housing: what makes landlords act? Indoor and Built Environment, 24 (7), 913-924. Retrieved from https://shura.shu.ac.uk/9866/7/Ambrose_-_IBE_paper_v4_-_final.pdf

Ambrose, A., and McCarthy, L. (2019). Taming the 'masculine pioneers'? Changing attitudes towards energy efficiency amongst private landlords and tenants in New Zealand: A case study of Dunedin. Energy Policy, 126, 165–176. https://doi.org/10.1016/j.enpol.2018.11.018

Ambrose, A., Baker, W., Batty, E., and Hawkins, A. (2019a). Reaching the "Hardest to Reach" with energy advice: final report. Sheffield Hallam University, Centre for Regional Economic and Social Research. https://doi.org/10.7190/cresr.2019.8286642862

Ambrose, A., Baker, W., Batty, E., and MacNair Hawkins, A. (2019b). Focus Article: "I have a panic attack when I pick up the phone": experiences of energy advice amongst 'hard to reach' energy users. People, Place and Policy, 14(1). https://doi.org/10.3351/ppp.2019.3479427335

Anderson, W., White, V., and Finney, A. (2012). Coping with low incomes and cold homes. Energy Policy, 49, 40-52. https://doi.org/10.1016/j.enpol.2012.01.002

Ashby, K., Smith, J., Rotmann, S., Mundaca, L., and Ambrose, A. (2020). HTR Characteristics. HTR Annex by Users TCP by IEA: Wellington. https://doi.org/10.47568/3XR102

Ástmarsson, B., Jensen, P.A., and Maslesa, E. (2013). Sustainable renovation of residential buildings and the landlord/tenant dilemma. Energy Policy, 63, 355–362. http://dx.doi.org/10.1016/j.enpol.2013.08.046

Atkinson, R. and Flint, J. (2003). Accessing Hidden and Hard-to-Reach Populations: Snowball Research Strategies. Social Research Update, 33. University of Surrey. Retrieved from: https://sru.soc.surrey.ac.uk/SRU33.html

Baker, K.J., Mould, R., Stewart, F., Restrick, S., Melone, H., and Atterson, B. (2019). Never try and face the journey alone: Exploring the face-to-face advocacy needs of fuel poor householders in the United Kingdom. Energy Research & Social Science, 51, 210–219. https://doi.org/10.1016/j.erss.2019.01.009

Baltruszewicz, M., Steinberger, J.K., Paavola, J., Ivanova, D., Brand-Correa, L., and Owen, A. (2023). Social outcomes of energy use in the United Kingdom: Household energy footprints and their links to well-being. Ecological Economics, 205, 107686. https://doi.org/10.1016/j.ecolecon.2022.107686

Barros, B., and Wilk, R. (2021). The outsized carbon footprints of the super-rich, Sustainability: Science, Practice and Policy, 17:1, 316-322. https://doi.org/10.1080/15487733.2021.1949847

Bird, S., and Hernández, D. (2012). Policy options for the split incentive: Increasing energy efficiency for low-income renters. Energy Policy, 48, 506–514. http://dx.doi.org/10.1016/j.enpol.2012.05.053

Bîrsănuc, E. (2022). Mapping gendered vulnerability to energy poverty in Romania. Applied Spatial Analysis and Policy. https://doi.org/10.1007/s12061-022-09442-6

Boag-Munroe, G., and Evangelou, M. (2010). From hard to reach to how to reach: A systematic review of the literature on hard-to-reach families. Research Papers in Education, 27:2, 209-239. https://doi.org/10.1080/02671522.2010.509515

Bonevski, B., Randell, M., Paul, C., Chapman, K., Twyman, L., Bryant, J., Brozek, I., and Hughes, C. (2014). Reaching the hard-to-reach: a systematic review of strategies for improving health and medical research with socially disadvantaged groups. BMC Medical Research Methodology, 14:42. https://doi.org/10.1186/1471-2288-14-42

Bouzarovski, S., Burbidge, M., and Stojilovska, A. (2023). Deliverable 2.6 Report on Energy Poverty in the PRS – Overview & Framework. University of Manchester, United Kingdom: ENPOR Project. Retrieved from www.enpor.org

Bouzarovski, S., Burbidge, M., Sarpotdar, A., and Martiskainen, M. (2022). The diversity penalty: Domestic energy injustice and ethnic minorities in the United Kingdom. Energy Research & Social Science, 91, 102716. https://doi.org/10.1016/j.erss.2022.102716

Büchs, M., Cass, N., Mullen, C., Lucas, K., and Ivanova, D. (2023). Emissions savings from equitable energy demand reduction. Nature Energy, 8, 758–769. https://doi.org/10.1038/s41560-023-01283-y

Budworth, P. (2023). Care, comfort, and capacity: The importance of being flexible in research with Disabled and chronically ill people. SSM - Qualitative Research in Health, 4, 100352. https://doi.org/10.1016/j.ssmqr.2023.100352

Butler, D., Steadman, L., Jackson, M., Stockton, H., and Smith, P. (2023a). Taking the Temperature of NG6: A review of how NG6 is delivering warm and safe homes, and what more can be done for vulnerable and terminally ill people. National Energy Action. Retrieved from https://www.nea.org.uk/publications/taking-the-temperature-of-ng6/

Butler, D., Nuttall, E., Stockton, H., and Storey, N. (2023b). Plugged In: Strengthening Energy Advice and Support for Gypsies, Travellers, Roma and Nomadic Communities – Final Report. National Energy Action. Retrieved from https://www.nea.org.uk/researchpolicy/gypsies-travellers-roma-nomadic-communities/

Capgemini (2023). World Wealth Report 2023 – Wealth Management. Retrieved from https://www.capgemini.com/insights/research-library/world-wealth-report/

Cass, N., Lucas, K., Adeel, M., Anable, J., Buchs, M., Lovelace, R., Morgan, M. and Mullen, C. (2022). Curbing excess: high energy consumption and the fair energy transition. Centre for Research into Energy Demand Solutions. Oxford, UK. ISBN: 978-1-913299-14-9. Retrieved from https://www.creds.ac.uk/publications/curbing-excess-high-energy-consumption-and-the-fair-energy-transition/

Castro, C.C., and Gouveia, J.P. (2023). Students' perception of energy poverty—A comparative analysis between local and exchange university students from Montevideo, Lisbon, and Padua. Front. Sustain. Cities, Sec. Urban Energy End-Use, 5. https://doi.org/10.3389/frsc.2023.1114540

Cauvain, J., and Bouzarovski, S. (2016). Energy vulnerability in multiple occupancy housing: a problem that policy forgot. People, Place and Policy, 10/1, 88-106. https://doi.org/10.3351/ppp.0010.0001.0007

Chadwick, K., Russell-Bennett, R., and Biddle, N. (2022). The role of human influences on adoption and rejection of energy technology: A systematised critical review of the literature on household energy transitions. Energy Research & Social Science, 89, 102528. https://doi.org/10.1016/j.erss.2022.102528

Chapman, M., Gilbertson, J., Bradley, J., Damm, C., Farnsworth, V., Ferguson, A., Owen, A., Stafford, B., Taylor, B., Tod, A., and Wolstenholme, D. (2022). Being Warm Being Happy: Understanding factors influencing adults with learning disabilities being warm and well at home with inclusive research. People, Place and Policy, 16/2, 193-215. https://doi.org/10.3351/ppp.2022.2942847959

Chard, R., and Walker, G. (2016). Living with fuel poverty in older age: Coping strategies and their problematic implications. Energy Research & Social Science, 18, 62-70. http://dx.doi.org/10.1016/j.erss.2016.03.004

Chen, C., Greig, J., Nelson, H, and Li, F. (2022). When disadvantage collides: The concentrated effects of energy insecurity and internet burdens in the United States. Energy Research & Social Science, 91, 102713. https://doi.org/10.1016/j.erss.2022.102713

Churchill, S.A., and Smyth, R. (2020). Ethnic diversity, energy poverty and the mediating role of trust: Evidence from household panel data for Australia. Energy Economics, 86, 104663. https://doi.org/10.1016/j.eneco.2020.104663

Clair, A., and Baker, E. (2022). Cold homes and mental health harm: Evidence from the UK Household Longitudinal Study. Social Science & Medicine, 314, 115461. https://doi.org/10.1016/j.socscimed.2022.115461

Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast). Official Journal of the European Union, L231, 1-111. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

Drehobl, A., Ross, L., and Ayala, R. (2020). How High Are Household Energy Burdens? An Assessment of National and Metropolitan Energy Burden across the United States. ACEEE - American Council for an Energy-Efficient Economy. Retrieved from https://www.aceee.org/research-report/u2006

EIGE (2023). Gender Equality Index 2023: Towards a green transition in transport and energy. European Institute for Gender Equality. Luxembourg: Publications Office of the European Union. https://doi.org/10.2839/64810

Eisermann, M., Maurer, C., and Turner, I. (2019). Boosting energy retrofits in condominiums: Approaches for local authorities to facilitate change. Interreg North-West Europe ACE-Retrofitting and Energy Cities. ISBN 978-2-490384-11-2. Retrieved from https://energy-cities.eu/publication/boosting-energy-retrofits-in-condominiums/

European Commission (2016). Consumer vulnerability across key markets in the European Union. Final report, January 2016. Retrieved from https://ec.europa.eu/info/files/consumer-vulnerability-report_en

European Commission (2020a). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives. Brussels, 14.10.2020, COM(2020) 662 final. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

European Commission (2020b). Communication from the Commission to the European Parliament and the Council. A Union of Equality: EU Roma strategic framework for equality, inclusion and participation. Brussels, 7.10.2020, COM(2020) 620. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0620

Eurostat (2015a). Population by sex, age and disability status. HLTH_DPEH005. Last update: 18/05/2015. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_DPEH005

Eurostat (2015b). Population by sex, age, disability status and having a longstanding health problem. HLTH_DPEH050. Last update: 18/05/2015. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_DPEH050

Eurostat (2015c). Population by sex, age, disability status and having a longstanding difficulty in basic activities. HLTH_DPEH060. Last update: 18/05/2015. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_DPEH060

Eurostat (2019). Population by sex, age, migration status, country of birth and country of birth of parents. LFSO_14PCOBP. Last update: 28/03/2019. Accessed: 21/12/2023. https://doi.org/10.2908/LFSO_14PCOBP

Eurostat (2022). Severity of bodily pain by sex, age and educational attainment level. HLTH_EHIS_PN1E. Last update: 22/03/2022. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_EHIS_PN1E

Eurostat (2023a). At-risk-of-poverty rate after deducting housing costs by age and sex. ILC_LI45. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LI45

Eurostat (2023b). Population by educational attainment level, sex and age (%) - main indicators. EDAT_LFSE_03. Last update: 14/09/2023. Accessed: 21/12/2023. https://doi.org/10.2908/EDAT_LFSE_03

Eurostat (2023c). Population on 1 January by age and sex. DEMO_PJAN. Last update: 28/09/2023. Accessed: 21/12/2023. https://doi.org/10.2908/DEMO_PJAN

Eurostat (2023d). Distribution of population by degree of urbanisation, dwelling type and income group - EU-SILC survey. ILC_LVHO01. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LVHO01

Eurostat (2023e). Distribution of population aged 65 and over by type of household - EU-SILC survey. ILC_LVPS30. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LVPS30

Eurostat (2023f). Share of young adults aged 18-34 living with their parents by age and sex - EU-SILC survey. ILC_LVPS08. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LVPS08

Eurostat (2023g). Distribution of population by household type and income group - EU-SILC survey. ILC_LVPS02. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LVPS02

Eurostat (2023h). Population on 1 January by age group, sex and country of birth. MIGR_POP3CTB. Last update: 28/11/2023. Accessed: 21/12/2023. https://doi.org/10.2908/MIGR_POP3CTB

Eurostat (2023i). Unemployment by sex and age – annual data. UNE_RT_A. Last update: 14/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/UNE_RT_A

Eurostat (2023j). People having a long-standing illness or health problem, by sex, age and labour status. HLTH_SILC_04. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_SILC_04

Eurostat (2023k). Share of people having income greater or equal to specific national thresholds by age and sex. ILC_DI20. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_DI20

Eurostat (2023l). Distribution of population by tenure status, type of household and income group - EU-SILC survey. ILC_LVHO02. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LVHO02

Eurostat (2023m). Persons at risk of poverty or social exclusion by age and sex. ILC_PEPS01N. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_PEPS01N

Eurostat (2023n). At-risk-of-poverty rate by poverty threshold, age and sex - EU-SILC and ECHP surveys. ILC_LI02. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LI02

Eurostat (2023o). At-risk-of-poverty rate before social transfers (pensions excluded from social transfers) by poverty threshold, age and sex - EU-SILC and ECHP surveys. ILC_LI10. Last update: 19/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LI10

Eurostat (2023p). Persistent at-risk-of-poverty rate by sex and age - EU-SILC and ECHP surveys. ILC_LI21. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/ILC_LI21

Eurostat (2023q). Population on 1 January by age group, sex and level of human development of the country of birth. MIGR_POP8CTB. Last update: 05/10/2023. Accessed: 21/12/2023. https://doi.org/10.2908/MIGR_POP8CTB

Eurostat (2023r). Recent immigrants by sex, age and country of birth. LFST_RIMGPCGA. Last update: 14/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/LFST_RIMGPCGA

Eurostat (2023s). All valid permits by reason, length of validity and citizenship on 31 December of each year. MIGR_RESVALID. Last update: 19/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/MIGR_RESVALID

Eurostat (2023t). Third country nationals found to be illegally present - annual data (rounded). MIGR_EIPRE. Last update: 06/11/2023. Accessed: 21/12/2023. https://doi.org/10.2908/MIGR_EIPRE

Eurostat (2023u). Long-term unemployment by sex - annual data. UNE_LTU_A. Last update: 14/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/UNE_LTU_A

Eurostat (2023v). Supplementary indicators to unemployment - annual data. LFSI_SUP_A. Last update: 14/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/LFSI_SUP_A

Eurostat (2023w). Self-perceived health by sex, age and degree of urbanisation. HLTH_SILC_18. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_SILC_18

Eurostat (2023x). Self-perceived long-standing limitations in usual activities due to health problem by sex, age and labour status. HLTH_SILC_06. Last update: 15/12/2023. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_SILC_06

Eurostat (2023y). Current depressive symptoms by sex, age and income quintile. HLTH_EHIS_MH1I. Last update: 16/06/2023. Accessed: 21/12/2023. https://doi.org/10.2908/HLTH_EHIS_MH1I

Eurostat (2024). Monthly minimum wages - bi-annual data. EARN_MW_CUR. Last update: 31/01/2024. Accessed: 08/03/2024. https://doi.org/10.2908/EARN_MW_CUR

FEANTSA and The Abbé Pierre Foundation (2023). Eight Overview of Housing Exclusion in Europe – 2023. Retrieved from https://www.feantsa.org/en/report/2023/09/05/report-8th-overview-of-housing-exclusion-in-europe-2023

Feenstra, M., and Clancy, J. (2020). A View from the North: Gender and Energy Poverty in the European Union. In: Clancy J., Özerol G., Mohlakoana N., Feenstra M., Sol Cueva L. (eds) Engendering the Energy Transition. https://doi.org/10.1007/978-3-030-43513-4_8

Flanagan, S.M., and Hancock, B. (2010). 'Reaching the hard to reach' - lessons learned from the VCS (voluntary and community Sector). A qualitative study. BMC Health Services Research, 10:92. https://doi.org/10.1186/1472-6963-10-92

Forster, N., Hodgson, P., and Bailey, C. (2019). Energy advice for Traveller Communities in the context of ethnic and spatial premiums: 'paying the price' for other people's choices. Journal of Poverty and Social Justice, 27 (1), 61-78. https://doi.org/10.1332/175982718x15451316707778

François, M., Wilmars, S.M., and Maréchal, K. (2023). Unlocking the potential of income and wealth caps in post-growth transformation: A framework for improving policy design. Ecological Economics, 208, 107788. https://doi.org/10.1016/j.ecolecon.2023.107788

Fraune, C. (2015). Gender matters: Women, renewable energy, and citizen participation in Germany. Energy Research & Social Science, 7, 55-65. http://dx.doi.org/10.1016/j.erss.2015.02.005

Galvin, R., and Sunikka-Blank, M. (2018). Economic Inequality and Household Energy Consumption in High-income Countries: A Challenge for Social Science Based Energy Research. Ecological Economics, 153, 78–88. https://doi.org/10.1016/j.ecolecon.2018.07.003

Garcia, A.C., Ambrose, A., Hawkins, A., and Parkes, S. (2021). High consumption, an unsustainable habit that needs more attention. Energy Research & Social Science, 80, 102241. https://doi.org/10.1016/j.erss.2021.102241

Gillard, R., Snell, C., and Bevan, M. (2017). Advancing an energy justice perspective of fuel poverty: Household vulnerability and domestic retrofit policy in the United Kingdom. Energy Research & Social Science, 29, 53–61. http://dx.doi.org/10.1016/j.erss.2017.05.012

Gossling, S., and Humpe, A. (2023). Millionaire spending incompatible with 1.5 ºC ambitions. Cleaner Production Letters, 4, 100027. https://doi.org/10.1016/j.clpl.2022.100027

Gouveia, J.P., Palma, P., and Simões, S.G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187-201. https://doi.org/10.1016/j.egyr.2018.12.004

Gouveia, J.P., Palma, P., Bessa, S., Mahoney, K., and Sequeira, M. (2022). Energy Poverty National Indicators: Insights for a more effective measuring. Energy Poverty Advisory Hub. Directorate General for Energy. European Commission. Retrieved from https://energy-poverty.ec.europa.eu/discover/publications/publications/energy-poverty-national-indicators-insights-more-effective-measuring_en

Gouveia, J.P., Palma, P., Bessa, S., Mahoney, K., and Sequeira, M. (2023). Energy Poverty National Indicators: Uncovering New Possibilities Expanded Knowledge. Energy Poverty Advisory Hub. Directorate General for Energy. European Commission. Retrieved from https://energy-poverty.ec.europa.eu/discover/publications/publications/epah-report-energy-poverty-advisory-hub-national-indicators-uncovering-new-possibilities-expanded_en

Griffiths, P., Gossop, M., Powis, B., and Strang, J. (1993). Reaching hidden populations of drug users by privileged access interviewers: methodological and practical issues. Addiction, 88, 1617-1626. https://doi.org/10.1111/j.1360-0443.1993.tb02036.x

Groote, O.D., Pepermans, G., and Verboven, F. (2016). Heterogeneity in the adoption of photovoltaic systems in Flanders. Energy Economics, 59, 45-57. http://dx.doi.org/10.1016/j.eneco.2016.07.008

Grossmann, K., and Trubina, E. (2021). How the Concept of Dignity Is Relevant to the Study of Energy Poverty and Energy Justice. Frontiers in Sustainable Cities, 3, 644231. https://doi.org/10.3389/frsc.2021.644231

Hall, S., Anable, J., Hardy, J., Workman, M., Mazur, C., and Matthews, Y. (2021). Matching consumer segments to innovative utility business models. Nature Energy, 6, 349-361. https://doi.org/10.1038/s41560-021-00781-1

Hanke, F., Guyet, R., and Feenstra, M. (2021). Do renewable energy communities deliver energy justice? Exploring insights from 71 European cases. Energy Research & Social Science, 80, 102244. https://doi.org/10.1016/j.erss.2021.102244

Horta, A., Gouveia, J.P., Schmidt, L., Sousa, J.C., Palma, P., and Simões, S. (2019). Energy poverty in Portugal: Combining vulnerability mapping with household interviews. Energy & Buildings, 203, 109423. https://doi.org/10.1016/j.enbuild.2019.109423

Houghton, E., Kelly, L., Raslan, R., and Cui, C. (2023). Defining and identifying complex-to-decarbonise homes and retrofit solutions - Research report. Department for Energy Security and Net Zero, Government of the United Kingdom. Retrieved from: https://www.gov.uk/government/publications/defining-and-identifying-complex-to-decarbonise-homes

IEA (2023). Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach (2023 update). International Energy Agency. Retrieved from https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

IPCC (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. Intergovernmental Panel on Climate Change, Geneva, Switzerland, pp. 1-34. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Ivanova, D., and Middlemiss, L. (2021). Characterizing the energy use of disabled people in the European Union towards inclusion in the energy transition. Nature Energy, 6, 1188–1197. https://doi.org/10.1038/s41560-021-00932-4

Ivanova, D., and Wood, R. (2020). The unequal distribution of household carbon footprints in Europe and its link to sustainability. Global Sustainability 3, e18, 1–12. https://doi.org/10.1017/sus.2020.12

Jacques-Avinó, C., Peralta, A., Carrere, J., Marí-Dell'Olmo, M., Benach, J., and López, M. (2022). Qualitative evaluation of an intervention to reduce energy poverty: Effects perceived by participants according to typologies of social vulnerability. Energy Policy, 167, 113006. https://doi.org/10.1016/j.enpol.2022.113006

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., and Rehnera, R. (2016). Energy justice: A conceptual review. Energy Research & Social Science, 11, 174-182. http://dx.doi.org/10.1016/j.erss.2015.10.004

Karlin, B., Rotmann, S., Ashby, K., Mundaca, L., Butler, D., Sequeira, M.M., Gouveia, J.P., Palma, P., Realini, A., and Maggiore, S. (2022). Process matters: Assessing the use of behavioural science methods in applied behavioural programmes. European Council for an Energy Efficient Economy 2022 Summer Study on Energy Efficiency (ECEEE 2022). Retrieved from https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2022/4-monitoring-and-evaluation-for-a-wise-just-and-inclusive-transition/process-matters-assessing-the-use-of-behavioural-science-methods-in-applied-behavioural-programmes/

Kenner, D. (2015). Inequality of overconsumption: The ecological footprint of the richest. GSI Working Paper 2015/2. Cambridge: Global Sustainability Institute, Anglia Ruskin University. Retrieved from https://whygreeneconomy.org/wp-content/uploads/2015/11/Inequality-of-overconsumption.-The-ecological-footprint-of-the-richest-Dario-Kenner.pdf

Kivunja, C. (2018). Distinguishing between Theory, Theoretical Framework, and Conceptual Framework: A Systematic Review of Lessons from the Field. International Journal of Higher Education, 7, 6. https://doi.org/10.5430/ijhe.v7n6p44

Koch, J., and Christ, O. (2018). Household participation in an urban photovoltaic project in Switzerland: Exploration of triggers and barriers. Sustainable Cities and Society, 37, 420-426. https://doi.org/10.1016/j.scs.2017.10.028

Kousis, I., Laskari, M., Ntouros, V., Assimakopoulos, M., and Romanowicz, J. (2020). An analysis of the determining factors of fuel poverty among students living in the private-rented sector in Europe and its impact on their well-being. Energy Sources, Part B: Economics, Planning, and Policy, 15:2, 113-135. https://doi.org/10.1080/15567249.2020.1773579

Kraaijvanger, C.W., Verm, T., Doorn, N., and Goncalves, J.E. (2023). Does the sun shine for all? Revealing socio-spatial inequalities in the transition to solar energy in The Hague, The Netherlands. Energy Research & Social Science, 104, 103245. https://doi.org/10.1016/j.erss.2023.103245

Labanca, N., Suerkemper, F., Bertoldi, P., Irrek, W., and Duplessis, B. (2015). Energy efficiency services for residential buildings: market situation and existing potentials in the European Union. Journal of Cleaner Production, 109, 284-295. http://dx.doi.org/10.1016/j.jclepro.2015.02.077

Legendre, B., and Ricci, O. (2015). Measuring fuel poverty in France: Which households are the most fuel vulnerable? Energy Economics, 49, 620–628. http://dx.doi.org/10.1016/j.eneco.2015.01.022

Liljas, A. E. M., Walters, K., Jovicic, A., Iliffe, S., Manthorpe, J., Goodman, C., and Kharicha, K. (2017). Strategies to improve engagement of 'hard to reach' older people in research on health promotion: a systematic review. BMC Public Health, 17:349. https://doi.org/10.1186/s12889-017-4241-8

Longhurst, N., and Hargreaves, T. (2019). Emotions and fuel poverty: The lived experience of social housing tenants in the United Kingdom. Energy Research & Social Science, 56, 101207. https://doi.org/10.1016/j.erss.2019.05.017

Lukanov, B.R., and Krieger, E.M. (2019). Distributed solar and environmental justice: Exploring the demographic and socio-economic trends of residential PV adoption in California. Energy Policy, 134, 110935. https://doi.org/10.1016/j.enpol.2019.110935

MacDonald, S., Winner, B., Smith, L., Juillerat, J., and Belknap, S. (2019). Bridging the rural efficiency gap: expanding access to energy efficiency upgrades in remote and high energy cost communities. Energy Efficiency, 13, 503–52. https://doi.org/10.1007/s12053-019-09798-8

Mahapatra, K., Mainali, B., and Pardalis, G. (2019). Homeowners' attitude towards one-stop-shop business concept for energy renovation of detached houses in Kronoberg, Sweden. 10th International Conference on Applied Energy (ICAE2018), 22-25 August 2018, Hong Kong, China. Energy Procedia, 158, 3702-3708. https://doi.org/10.1016/j.egypro.2019.01.888

Mahoney, K., Lopes, R. Sareen, S., Gouveia, J.P. (2024) Perceptions of competing agendas in carbon neutrality policies in Portugal: Adverse impacts on vulnerable population groups. Energy Research & Social Science, 112, 103509. https://doi.org/10.1016/j.erss.2024.103509.

Markard, J., Wells, P., Yap, X., and van Lente, H. (2023). Unsustainabilities: A study on SUVs and Space Tourism and a research agenda for transition studies. Energy Research & Social Science, 106, 103302. https://doi.org/10.1016/j.erss.2023.103302

Middlemiss, L. (2022). Who is vulnerable to energy poverty in the Global North, and what is their experience? WIREs Energy Environ, 11, e455. https://doi.org/10.1002/wene.455

Middlemiss, L., and Gillard, R. (2015). Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor. Energy Research & Social Science, 6, 146–154. http://dx.doi.org/10.1016/j.erss.2015.02.001

Millward-Hopkins, J., and Johnson, E. (2023). Distributing less, redistributing more: Safe and just low-energy futures in the United Kingdom. Energy Research & Social Science, 95, 102915. https://doi.org/10.1016/j.erss.2022.102915

Mould, R., and Baker, K.J. (2017). Documenting fuel poverty from the householders' perspective. Energy Research & Social Science, 31, 21–31. http://dx.doi.org/10.1016/j.erss.2017.06.004

Moura, R., and Brito, M.C. (2019). Prosumer aggregation policies, country experience and business models. Energy Policy, 132, 820-830. https://doi.org/10.1016/j.enpol.2019.06.053

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., Gouveia, J.P., Palma, P., Realini, A., Maggiore, S., and Feenstra, M. (2023). Hard-to-Reach Energy Users: An ex-post cross-country assessment of behavioural-oriented interventions. Energy Research & Social Science, 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Nazarahari, A., Ghotbi, N., and Tokimatsu, K. (2021). Energy Poverty among College Students in Japan in a Survey of Students' Knowledge, Attitude and Practices towards Energy Use. Sustainability, 13, 8484. https://doi.org/10.3390/su13158484

Nielsen, K.S., Nicholas, K.A., Creutzig, F., Dietz, T., and Stern, P.C. (2021). The role of high-socioeconomic-status people in locking in or rapidly reducing energy-driven greenhouse gas emissions. Nature Energy, Perspective. https://doi.org/10.1038/s41560-021-00900-y

Okushima, S. (2021). Energy poor need more energy, but do they need more carbon? Evaluation of people's basic carbon needs. Ecological Economics, 187, 107081. https://doi.org/10.1016/j.ecolecon.2021.107081

Oliveras, L., Artazcoz, L., Borrell, C., Palència, L., José López, M., Gotsens, M., Peralta, A., and Marí-Dell'Olmo, M. (2020). The association of energy poverty with health, health care utilisation and medication use in southern Europe. SSM - Population Health, 12, 100665. https://doi.org/10.1016/j.ssmph.2020.100665

Oliveras, L., Peralta, A., Palència, L., Gotsens, M., José López, M., Artazcoz, L., Borrell, C., and Marí-Dell'Olmo, M. (2021). Energy poverty and health: Trends in the European Union before and during the economic crisis, 2007-2016. Health & Place, 67, 102294. https://doi.org/10.1016/j.healthplace.2020.102294

Oswald, Y., Millward-Hopkins, J., Steinberger, J.K., Owen, A., and Ivanova, D. (2023). Luxury-focused carbon taxation improves fairness of climate policy. One Earth 6, 884–898. https://doi.org/10.1016/j.oneear.2023.05.027

Oswald, Y., Owen, A., and Steinberger, J.K. (2020). Large inequality in international and intranational energy footprints between income groups and across consumption categories. Nature Energy, 5, 231–239. https://doi.org/10.1038/s41560-020-0579-8

Otto, I.M., Kim, K.M., Dubrovsky, N., and Lucht, W. (2019). Shift the focus from the super-poor to the super-rich. Nature Climate Change, 9, 82–87. https://doi.org/10.1038/s41558-019-0402-3

Owen, A., Middlemiss, L., Brown, D., Davis, D., Hall, S., Bookbinder, R., Brisbois, M.C., Cairns, I., Hannon, M., and Mininni, G. (2023). Who applies for energy grants? Energy Research & Social Science, 101, 103123. https://doi.org/10.1016/j.erss.2023.103123

Oxfam (2023). Survival of the Richest: How we must tax the super-rich now to fight inequality. Oxfam briefing paper: January 2023. Retrieved from https://www.oxfam.org/en/research/survival-richest

Oxfam International and the Institute for European Environmental Policy (2021). Carbon Inequality in 2030. https://doi.org/10.21201/2021.8274

Pais-Magalhães, V., Moutinho, V., and Robaina, M. (2022). Is an ageing population impacting energy use in the European Union? Drivers, lifestyles, and consumption patterns of elderly households. Energy Research & Social Science, 85, 102443. https://doi.org/10.1016/j.erss.2021.102443

Palm, J., and Reindl, K. (2018). Understanding barriers to energy-efficiency renovations of multifamily dwellings. Energy Efficiency, 11, 53-65. https://doi.org/10.1007/s12053-017-9549-9

Pawson, R., Greenhalgh, T., Harvey, G., and Walshe, K. (2004). Realist synthesis: an introduction. ESRC Research Methods Programme, University of Manchester, RMP Methods Paper 2/2004.

Petrova, S. (2017). Encountering energy precarity: Geographies of fuel poverty among young adults in the UK. Transactions of the Institute of British Geographers, 43, 17-30. https://doi.org/10.1111/tran.12196

Pillai, A., Reaños, M.T., and Curtis, J. (2021). An examination of energy efficiency retrofit scheme applications by low-income households in Ireland. Heliyon, 7, e08205. https://doi.org/10.1016/j.heliyon.2021.e08205

Raslan, R., and Ambrose, A. (2022). Solving the difficult problem of hard to decarbonize homes. Nature Energy, 7, 675–677. https://doi.org/10.1038/s41560-022-01075-w

Reames, T.G. (2016). A community-based approach to low-income residential energy efficiency participation barriers. Local Environment, 21, 12, 1449-1466. https://doi.org/10.1080/13549839.2016.1166567

Ring, M., Wilson, E., Ruwanpura, K. N., and Gay-Antaki, M. (2022). Just energy transitions? Energy policy and the adoption of clean energy technology by households in Sweden. Energy Research & Social Science, 91, 102727. https://doi.org/10.1016/j.erss.2022.102727

Roberts, D., Vera-Toscano, E., and Phimister, E. (2015). Fuel poverty in the UK: Is there a difference between rural and urban areas? Energy Policy, 87, 216–223. http://dx.doi.org/10.1016/j.enpol.2015.08.034

Roberts, W. (2016). Engaging hard to reach young people through sport. Published by the Berkeley Foundation. https://doi.org/10.13140/RG.2.2.20582.52804

Ross, L., Drehobl, A., and Stickles, B. (2018). The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency. ACEEE – American Council for an Energy-Efficient Economy. Retrieved from https://www.aceee.org/research-report/u1806

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., Chester, M., Karlin, B., Ashby, K., Butler, D., and Chambers, J. (2020). Hard-to-Reach Energy Users: A Literature Review.

User-Centred Energy Systems TCP - HTR Task. ISBN: 978-0-473-64983-8. Retrieved from https://userstcp.org/hard-to-reach-energy-users-task/

Ruiz-Rivas, U., Tirado-Herrer, S., Castano-Rosa, R., and Martínez-Crespo, J. (2023). Disconnected, yet in the spotlight: Emergency research on extreme energy poverty in the Canada Real informal settlement, Spain. Energy Research & Social Science, 102, 103182. https://doi.org/10.1016/j.erss.2023.103182

Sareen, S., Thomson, H., Tirado Herrero, S., Gouveia, J.P., Lippert, I., and Lis, A. (2020). European energy poverty metrics: Scales, prospects and limits. Global Transitions, 2, 26-36. https://doi.org/10.1016/j.glt.2020.01.003

Sequeira, M., and Melo, J.J. (2020). Energy saving potential in the small business service sector: case study Telheiras neighborhood, Portugal. Energy Efficiency, 13, 551-569. https://doi.org/10.1007/s12053-020-09842-y

Sequeira, M.M., and Gouveia, J.P. (2022). A Sequential Multi-Staged Approach for Developing Digital One-Stop Shops to Support Energy Renovations of Residential Buildings. Energies 2022, 15, 5389. https://doi.org/10.3390/en15155389

Sequeira, M.M., and Gouveia, J.P. (2023). Non-residential hard-to-reach energy users: A vast audience forgotten by the energy transition? 8th Meeting on Energy and Environmental Economics, Aveiro University, Portugal. https://doi.org/10.48528/v3b3-fk78

Shaghaghi, A., Bhopal, R.S., Sheikh, A. (2011). Approaches to Recruiting 'Hard-To-Reach' Populations into Research: A Review of the Literature. Health Promot Perspect., 20;1(2), 86-94. https://doi.org/10.5681/hpp.2011.009

Shaw, I., Bloor, M., Cormack, R., and Williamson, H. (1996). Estimating the Prevalence of Hard-to-Reach Populations: The Illustration of Mark-Recapture Methods in the Study of Homelessness. Social Policy & Administration, 3, 1, 69-85. https://doi.org/10.1111/J.1467-9515.1996.TB00482.X

Simcock, N., Jenkins, K.E.H, Lacey-Barnacle, M., Martiskainen, M., Mattioli, G., and Hopkins, D. (2021). Identifying double energy vulnerability: A systematic and narrative review of groups at-risk of energy and transport poverty in the global north. Energy Research & Social Science, 82, 102351. https://doi.org/10.1016/j.erss.2021.102351

Skjølsvold, T.M., and Coenen, L. (2021). Are rapid and inclusive energy and climate transitions oxymorons? Towards principles of responsible acceleration. Energy Research & Social Science, 79, 102164. https://doi.org/10.1016/j.erss.2021.102164

Snell, C., Bevan, M., and Thomson, H. (2015). Justice, fuel poverty and disabled people in England. Energy Research & Social Science, 10, 123-132. http://dx.doi.org/10.1016/j.erss.2015.07.012

Soergel, B., Kriegler, E., Bodirsky, B.L., Bauer, N., Leimbach, M., and Popp, A. (2021). Combining ambitious climate policies with efforts to eradicate poverty. Nature Communications, 12:2342. https://doi.org/10.1038/s41467-021-22315-9

Sommer, M., and Kratena, K. (2017). The Carbon Footprint of European Households and Income Distribution. Ecological Economics, 136, 62–72. http://dx.doi.org/10.1016/j.ecolecon.2016.12.008

Sommerfeld, J., Buys, L., Mengersen, K., and Vine, D. (2017). Influence of demographic variables on uptake of domestic solar photovoltaic technology. Renewable and Sustainable Energy Reviews, 67, 315-323. http://dx.doi.org/10.1016/j.rser.2016.09.009

Sovacool, B.K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Research & Social Science, 1, 1-29. http://dx.doi.org/10.1016/j.erss.2014.02.003

Sovacool, B.K., and Dworkin, M.H. (2015). Energy justice: Conceptual insights and practical applications. Applied Energy, 142, 435-444. http://dx.doi.org/10.1016/j.apenergy.2015.01.002

Sovacool, B.K., Barnacle, M.L., Smith, A., and Brisbois, M.C. (2022). Towards improved solar energy justice: Exploring the complex inequities of household adoption of photovoltaic panels. Energy Policy, 164, 112868. https://doi.org/10.1016/j.enpol.2022.112868

Sovacool, B.K., Bell, S.E., Daggett, C., Labuski, C., Lennon, M., Naylor, L., Klinger, J., Leonard, K., and Firestone, J., (2023). Pluralizing energy justice: Incorporating feminist, anti-racist, Indigenous, and postcolonial perspectives. Energy Research & Social Science, 97, 102996. https://doi.org/10.1016/j.erss.2023.102996

Sovacool, B.K., Burke, M., Baker, L., Kotikalapudi, C.K., and Wlokas, H. (2017). New frontiers and conceptual frameworks for energy justice. Energy Policy, 105, 677–691. http://dx.doi.org/10.1016/j.enpol.2017.03.005

Sovacool, B.K., Ryan, S.E., Stern, P.C., Janda, K., Rochlin, G., Spreng, D., Pasqualetti, M.J., Wilhite, H., and Lutzenhiser, L. (2015). Integrating social science in energy research. Energy Research & Social Science, 6, 95-99. http://dx.doi.org/10.1016/j.erss.2014.12.005

Starr, J., Nicolson, C., Ash, M., Markowitz, E.M., and Moran, D. (2023). Assessing U.S. consumers' carbon footprints reveals outsized impact of the top 1%. Ecological Economics, 205, 107698. https://doi.org/10.1016/j.ecolecon.2022.107698

Stewart, F. (2022). Friends with benefits: How income and peer diffusion combine to create an inequality "trap" in the uptake of low-carbon technologies. Energy Policy, 163, 112832. https://doi.org/10.1016/j.enpol.2022.112832

Stojilovska, A., Dokupilová, D., Gouveia, J.P., Bajomi, A.Z., Tirado-Herrero, S., Feldmár, N., Kyprianou, I., and Feenstra, M. (2023). As essential as bread: Fuelwood use as a cultural practice to cope with energy poverty in Europe. Energy Research & Social Science, 97, 102987. https://doi.org/10.1016/j.erss.2023.102987

Streimikiene, D., and Balezentis, T. (2020). Willingness to Pay for Renovation of Multi-Flat Buildings and to Share the Costs of Renovation. Energies, 13, 2721. https://doi.org/10.3390/en13112721

Sunikka-Blank, M., and Galvin, R. (2021). Single parents in cold homes in Europe: How intersecting personal and national characteristics drive up the numbers of these vulnerable households. Energy Policy, 150, 112134. https://doi.org/10.1016/j.enpol.2021.112134

Thomson, H., Bouzarovski, S., and Snell, C. (2017). Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data. Indoor and Built Environment, 26(7), 879–901.https://doi.org/10.1177/1420326X17699260

Tjørring, L. (2016). We forgot half of the population! The significance of gender in Danish energy renovation projects. Energy Research & Social Science, 22, 115–124. http://dx.doi.org/10.1016/j.erss.2016.08.008

Tod, A.M., Nelson, P., Cronin de Chavez, A., Homer, C., Powell-Hoyland, V., and Stocks, A. (2016). Understanding influences and decisions of households with children with asthma regarding temperature and humidity in the home in winter: a qualitative study. BMJ Open, 6, 009636. https://doi.org/10.1136/bmjopen-2015-009636

UNECE (2017). Guide on Poverty Measurement. United Nations Economic Commission for Europe. Retrieved from https://unece.org/statistics/publications/guide-poverty-measurement

UNECE (2020). Poverty Measurement: Guide to Data Disaggregation. United Nations Economic Commission for Europe. ISBN 978-92-1-117260-7. Retrieved from https://unece.org/statistics/publications/poverty-measurement-guide-data-disaggregation

UNECE (2022). Approaches to Measuring Social Exclusion. Prepared by the UNECE Task Force on the Measurement of Social Exclusion. United Nations Economic Commission for Europe. ISBN 978-92-1-117283-6. Retrieved from https://unece.org/statistics/publications/approaches-measuring-social-exclusion

Users TCP - IEA Technology Collaboration Programme (2024). UsersTCP Hard-to-Reach Energy Users. Accessed in March 2024: https://userstcp.org/hard-to-reach-energy-users-task/

Walker, G., and Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. Energy Policy, 49, 69-75. https://doi.org/10.1016/j.enpol.2012.01.044

Wang, X., and Lo, K. (2021). Just transition: A conceptual review. Energy Research & Social Science, 82, 102291. https://doi.org/10.1016/j.erss.2021.102291

Wiedmann, T., Lenzen, M., Keyßer, L.T., and Steinberger, J.K. (2020). Scientists' warning on affluence. Nature Communications, 11:3107. https://doi.org/10.1038/s41467-020-16941-y

Willand, N., and Horne, R. (2018). "They are grinding us into the ground" – The lived experience of (in)energy justice amongst low-income older households. Applied Energy, 226, 61-70. https://doi.org/10.1016/j.apenergy.2018.05.079

Zhen, H., Long, Y., Wood, R., Moran, D., Zhang, Z., Meng, J., Feng, K., Hertwich, E., and Guan, D. (2022). Ageing society in developed countries challenges carbon mitigation. Nat. Clim. Chang. 12, 241–248. https://doi.org/10.1038/s41558-022-01302-y

3.2 Non-residential hard-to-reach energy users: A vast audience forgotten by the energy transition?

This work is published in: Sequeira, M.M., and Gouveia, J.P. (2023). Non-residential hard-to-reach energy users: A vast audience forgotten by the energy transition? Meeting on Energy and Environmental Economics (ME3) conference proceedings, May 2023, Aveiro, Portugal. https://doi.org/10.48528/v3b3-fk78

Abstract

In the context of ongoing energy transitions, the concept of hard-to-reach energy users has been receiving growing attention. Hard-to-reach audiences are usually those who are hard to engage in energy-related interventions, with five major groups mentioned in the literature: vulnerable households, high-income households, tenants and landlords, small and medium enterprises, and commercial subsectors. In this paper, we focus our approach on non-residential hard-to-reach energy users since scarce research has been conducted on these audiences thus far. The specific needs of these vast groups have also been largely neglected by most energy policies and financing schemes. Our approach includes four steps: i) conducting a literature review, ii) proposing a non-residential hard-to-reach framework, iii) selecting a indicator set for the European Union, iv) assessing the size of these audiences in the European Union and its Member States. Key audiences identified included small and medium enterprises and micro-enterprises – characterized by size – and wholesale trade, retail trade, food services, accommodation, offices, and other activities – characterized by subsector of activity. Although data limitations are a key concern, we find that small and medium enterprises and micro-enterprises are vast audiences, comprising 99.8% and 93.5% of all enterprises in the European Union in 2020; while this percentage varies among Member States these groups are very significant. Efforts to more effectively reach these groups should focus on targeted and tailored interventions, including by focusing on the local-scale and by engaging with trusted middle actors. We hope this work sheds a light on traditionally forgotten groups in the European energy transition and that it contributes to the design of energy policies that more effectively reach the hard-to-reach.

Keywords: small and medium enterprises, commercial and services sector, European Union

3.2.1 Introduction

To address the key challenges of climate change and energy poverty, energy transitions are at the top of the agenda. An energy transition as pursued by the European Commission places the active engagement of citizens and businesses at the centre. Against a backdrop of insufficient action, the concept of hard-to-reach (HTR) energy users has been applied to the energy sector and is receiving growing attention both in scientific literature and policy development. The HTR concept has long been used in several areas outside energy, particularly in social services, education, crime prevention, and health. According to Ambrose *et al.* (2019), this concept may be context specific and should not consist of a single list of target groups. This term has its critiques and challenges. While some authors argue that it puts emphasis on policymakers and providers for failing to engage with the HTR, others say it shifts the blame to the individuals (Ambrose *et al.*, 2019).

In the context of the International Energy Agency UsersTCP Task on Hard-To-Reach Energy Users, Rotmann *et al.* (2020) state that "a hard-to-reach energy user is any energy user from the residential & non-residential sectors, who uses any type of energy or fuel, and who is typically either hard-to-reach physically, underserved, or hard-to-engage or motivate in behaviour change, energy efficiency and demand response interventions that are intended to serve our mutual needs". HTR energy users, due to their vulnerabilities, circumstances and/or characteristics, have so far been removed from engaging in the energy transition (Ambrose *et al.*, 2019). They may represent a large percentage of the energy users and their active participation is crucial to achieve climate change mitigation.

Although the HTR definition is purposely broad, five different groups have been highlighted by Ashby *et al.* (2020) and Rotmann *et al.* (2020): i) vulnerable households (including low income and energy poor), ii) high income households, iii) renters and landlords (residential and non-residential), iv) commercial sub-sectors, and v) small and medium enterprises (SMEs). A well-established literature has researched the key barriers across a variety of HTR audiences, underlining competing priorities, financial considerations, mistrust, market failures such as split incentives, and informational barriers (Ashby *et al.*, 2020). In the European Union (EU), these groups may consume a significant share of energy, since they likely represent a relevant share of the residential sector and of the services and commerce sector. Lack of data hinders a more detailed analysis of energy use in HTR groups.

We find that the concept of HTR audiences, as applied to the energy area, is relatively novel, with scarce scientific research conducted under this umbrella, particularly in the EU and for the non-residential sector. Whereas most research on HTR energy users has remained of conceptual and qualitative nature, the novelty of this paper lies in the operationalization of the concept through the systematization of key non-residential profiles, the proposal of an indicator set, and its application to the EU and its Member States. Although our work focuses on the EU, we suggest that the approach can be adapted to other contexts, while being suitable for national and sub-national analysis

This paper is structured as follows. Section 3.2.2 summarizes the methods and data selection criteria. Section 3.2.3 exposes the existing literature on non-residential HTR audiences while fleshing out the key barriers to their engagement in. Section 3.2.4 presents the main results of the work, namely the proposal of a framework for non-residential HTR energy users, the selection of an indicator set for the EU, and the assessment of the size of these audiences. Section 3.2.5 discusses the results while also deriving policy implications for the effective engagement of HTR energy users. Section 3.2.6 concludes the paper and lays out a research agenda for further work.

3.2.2 Methods and data selection

The methods of this paper follow a four-step approach. First, a literature review was conducted on HTR energy users, focusing on the non-residential sector and on the relevant barriers to their engagement. Second, based on the literature review, potential HTR audiences were systematized and a framework for non-residential HTR energy users was proposed. The goal was to detail the two groups mentioned by, *e.g.*, Rotmann *et al.* (2020), while avoiding intersecting them at this stage.

Third, the Eurostat database was explored with the goal of finding suitable indicators to quantify the systematized HTR audiences in the EU and its Member States. Key criteria for data selection included the availability of data for the whole period of 2011 to 2020 and the availability of data for the EU-27 (from 2020) group and for all current Member States. The original data was adjusted in order to be shown as a percentage of the total number of enterprises. The main data set used was from the Structural Business Statistics (SBS), including "number of enterprises" (SBS_SC_SCA_R2) according to the enterprises' size and activity sector (Eurostat, 2022). Data on the "value added" and "persons employed" according to the enterprises' size and to activity sector was also analysed (Eurostat, 2022).

Fourth, after the data selection and extracted, these indicators were analysed to assess the size of non-residential HTR audiences in the EU, as well as their evolution from 2011 to 2020 and their variation among Member States by looking at the minimum and maximum values for the EU-27 (from 2020) country group. These results fed the discussion of the paper and paved the way for a future research agenda on the topic of HTR energy users.

3.2.3 Literature review: Non-residential hard-to-reach audiences

Rotmann *et al.* (2020) found a lack of literature on non-residential energy users, stating that this sector could almost be categorized as HTR in its entirety (excluding large enterprises and potentially offices which have been the focus of more research and policies). The same authors subdivide this sector in two broad groups, namely SMEs and commercial, which often overlap.

SMEs are defined by the European Commission (2020) as enterprises with less than 250 employees and an annual turnover of less than 50 million euro. Even if SMEs account for 99% of all businesses in the world and contribute significantly for energy use, research on their role in the energy transition is still scarce. Large companies, energy-intensive industries, and the public sector should theoretically be easier to reach by energy policies since they have facilitated access to finance and expertise, their number is small, and organizational structures are well-defined (Schlomann and Schleich, 2015). Conversely, SMEs engagement in energy issues through traditional policies and measures is seriously hindered by a wide range of barriers and vulnerabilities, such as lack of knowledge and shortage of funds (Sequeira and Melo, 2020). While common challenges affect most SMEs, the diversity of activities performed can lead to strikingly different energy use profiles and to a high degree of individuality (Sequeira and Melo, 2020). Cunha *et al.* (2020) found that the majority of SMEs in Portugal has never conducted an energy audit and do not have an energy manager. Likewise, Rotmann *et al.* (2020) found that the decision-making processes in SMEs are much more akin to those of households than they are to large enterprises. These authors call for research on different SME subsectors, that would enable to identify targeted solutions for individual business types.

Among main energy users, the services and commerce sector has the least amount of data available. This sector encompasses different subsectors (*e.g.*, offices, retail, food services, health care), with quite unique energy needs and uses, even if they are sometimes housed in relatively similar spaces (Rotmann *et al.*, 2020). Energy performance varies widely, with larger corporations and offices usually scoring higher, but there is few research on energy use and occupant behaviour in non-residential buildings. Therefore, general energy policies and support mechanisms often do not cater to the needs of this heterogenous and complex HTR audience (Henriques and Catarino, 2016).

3.2.4 Results

3.2.4.1 Proposing a framework for non-residential hard-to-reach energy users

Based on the literature review and on data availability, potentially HTR audiences of the non-residential sector were systematized in Figure 3.4. The inclusion of offices as a HTR audience is not consistent across the literature, with some authors finding them easier to engage.

Figure 3.4 – Proposed framework for systematized non-residential HTR audiences.

3.2.4.2 Selecting an indicator set for the European Union

Table 3.7 shows the selected indicators for the systematized non-residential HTR audiences in the EU. The selection of indicators was conditioned by the striking lack of data on enterprises at EU scale.

Table 3.7 – Selected indicators for non-residential HTR audiences in the EU.

Audience	Selected indicator	Method
SMEs	No. of enterprises by size class - Less than 250 employees	Adjusted
Micro-enterprises	No. of enterprises by size class - Less than 10 employees	Adjusted
Wholesale trade	No. of enterprises - Wholesale trade, except of motor vehicles	Adjusted
Retail trade	No. of enterprises - Retail trade, except of motor vehicles	Adjusted
Accommodation	No. of enterprises - Accommodation	Adjusted
Food services	No. of enterprises - Food and beverage service activities	Adjusted
Offices	No. of enterprises - Information and communication + Real estate activities + Administrative and support service activities	Calculated & adjusted
Other activities	No. of enterprises - Professional, scientific and technical activities	Adjusted

3.2.4.3 Assessing the size of hard-to-reach audiences in the European Union

Figure 3.5 showcases the results for the selected indicators aiming to assess the size of the systematized non-residential HTR audiences in the EU, as a percentage of the total number of enterprises. Notably, SMEs and micro-enterprises represent around 99.8% and 93.5% of enterprises, respectively. While these segments account for the vast majority of enterprises by number, SMEs and micro-enterprises represent 53% and 19% of value added and 64% and 29% of persons employed, respectively.

Offices was the fastest growing activity from 2011 to 2020, representing around 17% of enterprises in 2020 and presenting a mostly uniform energy consumption profile, which is considered easier to reach by, *e.g.*, Rotmann *et al.* (2020). Activities such as retail, wholesale, and food services showed a relative downward trend from 2011 to 2020 in. These can present vastly different firmographics and energy use patterns even if they are often housed in similar spaces. Finally, "other activities" is a tremendously heterogeneous group which often presents very specific energy use characteristics.

Note that these indicators paint an average picture for the EU; there will be considerable variation between Member States. Table 3.8 showcases this variation by providing the minimum and maximum value, as percentage of total enterprises, and the respective Member State. SMEs and micro-enterprises represent the vast majority of enterprises in all Member States. Regarding the types of activities, differences can be found reflecting specific national contexts (*e.g.*, retail trade ranges from 5% of enterprises in Slovenia to 28% in Bulgaria). Nevertheless, we find that these audiences are significant in most Member States and that a more detailed national-scale analysis should be pursued.

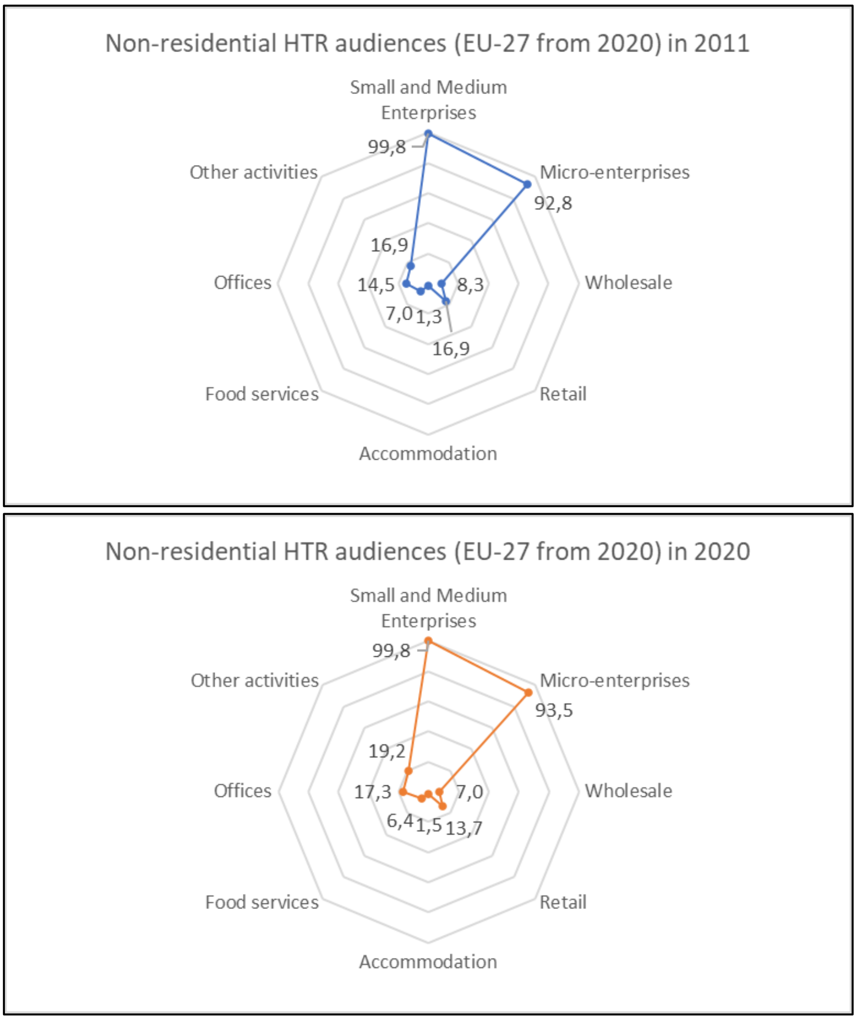


Figure 3.5 – Non-residential HTR audiences in the EU as a percentage of the total number of enterprises.

Table 3.8 – Variation among Member States for systematized non-residential HTR audiences.

HTR audiences	**2011** (% of total enterprises)			**2020** (% of total enterprises)		
	Min.	EU-27	Max.	Min.	EU-27	Max.
SMEs	99.5 (LU)	99.8	99.9 (PT)	99.5 (LU)	99.8	99.9 (GR)
Micro-enterprises	87.0 (LU)	92.8	96.0 (SK)	84.4 (DE)	93.5	97.4 (SK)
Wholesale trade	5.7 (IE)	8.3	13.3 (SK)	4.4 (HU)	7.0	10.1 (IT)
Retail trade	6.3 (SI)	16.9	32.1 (BG)	5.2 (SI)	13.7	27.9 (BG)
Accommodation	0.5 (BE)	1.3	4.9 (AT)	0.6 (BE)	1.5	4.8 (AT)
Food services	2.2 (LT)	7.0	10.7 (ES)	1.8 (LT)	6.4	10.7 (GR)
Offices	5.4 (GR)	14.5	27.0 (DK)	7.0 (GR)	17.3	30.2 (DK)
Other activities	10.4 (CY)	16.9	26.9 (NL)	13.6 (RO)	19.2	30.3 (NL)

3.2.5 Discussion

Through this work, we do not intend to "write in stone" a rigid list of HTR audiences – a concept subject to criticism for being too broad – nor to define a fixed set of indicators (constrained due to lack of data availability). This is a highly context-specific concept that should reflect national and local dynamics. In contrast, we operationalized the HTR terminology aiming at sparking a discussion on the need to recognize the specific characteristics and needs of significant segments of the non-residential sector which are considered important for the energy transition. Following, we suggest that these might make them difficult to engage while we highlight their lack of recognition in traditional energy-related interventions. The results of this work can be relevant to inform the design of effective tailored and targeted policies and programs that target non-residential HTR audiences.

In this context, its highly relevant to assess effective interventions to engage with HTR audiences. Mundaca *et al.* (2023) have reviewed 19 case-studies in 8 countries that have (implicitly or explicitly) targeted residential and non-residential HTR groups, finding that proper mapping of audiences, definition of behaviours, design of content, effective delivery of the intervention, and conduction of an ex-post evaluation are key to determine their success. In particular, Sequeira *et al.* (2021) analysed a case-study in Portugal that targeted SMEs of the services and commerce sector, arguing for the importance of action at local-scale with the involvement of trusted community middle actors to provide both technical and financial support.

3.2.6 Conclusions

In this work we have explored the HTR energy users concept in the EU, particularly looking at the non-residential sector and finding that the SME group represents over 99% of all enterprises in the EU with the hardest-to-reach segment of micro-enterprises accounted for around 93%. The relative importance of specific subsectors varies among Member States and this should be subjected to further analysis –data limitation is a key concern. While the concept of energy poverty is not easily transferred to the non-residential sector, the term energy burden (used in the United States) can be useful to conceptualize the challenges related to energy costs in the non-residential sector. Considering the ongoing energy crisis, non-residential HTR audiences may be at exacerbated risk of increased energy burdens which may affect businesses viability in often already constrained sectors of activity. Thus, we hope that this paper offers a useful approach to recognize the HTR nature of specific audiences in energy policies. After gauging at the potential size of HTR audiences, we argue that the next step is to propose effective approaches to reach the HTR.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia: Writing – review & editing, Validation, Supervision, Conceptualisation.

References

Ambrose, A., Baker, W., Batty, E., and MacNair Hawkins, A. (2019). Focus Article: "I have a panic attack when I pick up the phone": experiences of energy advice amongst 'hard to reach' energy users. People, Place and Policy, 14(1). https://doi.org/10.3351/ppp.2019.3479427335

Ashby, K., Smith, J., Rotmann, S., Mundaca, L., and Ambrose, A. (2020). HTR Characteristics. HTR Annex by Users TCP by IEA: Wellington. https://doi.org/10.47568/3XR102

Cunha, P., Almeida Neves, S., Cardoso Marques, A., and Serrasqueiro, Z. (2020). Adoption of energy efficiency measures in the buildings of micro-, small and medium-sized Portuguese enterprises. Energy Policy, 146, 111776. https://doi.org/10.1016/j.enpol.2020.111776

European Commission (2020). User guide to the SME definition. Luxembourg: Publications Office of the European Union. https://doi.org/0.2873/255862

Eurostat (2022). Structural Business Statistics (SBS). Update: 27/10/2022. Consulted: 13/12/2022.

Henriques, J., and Catarino, J. (2016). Motivating towards energy efficiency in small and medium enterprises. Journal of Cleaner Production, 139, 42-50. http://dx.doi.org/10.1016/j.jclepro.2016.08.026

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., *et al.* (2023). Hard-to-Reach Energy Users: Lessons from the assessment of nineteen energy behaviour change programmes across eight countries.

Rotmann S., Mundaca L., Castaño-Rosa R., O'Sullivan K., Ambrose A., Butler D., *et al.* (2020). Hard-to-Reach Energy Users: A critical review of audience characteristics and target behaviours. User-Centred Energy Systems TCP - HTR Annex: Wellington. 250pp. https://userstcp.org/task/hard-to-reach-energy-users/

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

Sequeira, M., and Melo, J.J. (2020). Energy saving potential in the small business service sector: case study Telheiras neighborhood, Portugal. Energy Efficiency, 13, 551-569. https://doi.org/10.1007/s12053-020-09842-y

Sequeira, M.M., Gouveia, J.P. and Palma, P. (2021). Case Study Analysis – PORTUGAL. HTR Task Users TCP by IEA: Lisbon. 38pp. https://doi.org/10.47568/3XR115

3.3 From the national to the local scale: Assessing data on hard-to-reach energy users at municipal and sub-municipal levels in Portugal

This work is under development: Sequeira, M.M., and Gouveia, J.P. (forthcoming). From the national to the local scale: Assessing data on hard-to-reach energy users at municipal and sub-municipal levels in Portugal.

Abstract

Climate change and energy poverty are high on the European Union's agenda, but the social aspects of energy transitions still receive scarce attention. In this context, hard-to-reach energy users, those who are difficult to reach or engage, are a growing concern. Previous research has reviewed and gauged these users' profiles in the European Union and its Member States. Top-down statistics can be useful for informing national policy, including pinpointing priority groups and proposing targeted measures. Nevertheless, energy efficiency and renewable energy measures are mostly implemented locally, and knowledge of the specific challenges of each territory is fundamental. Here, we explore available datasets to assess residential and non-residential hard-to-reach groups in Portugal at municipal and sub-municipal levels. Results can be insightful for the design of local energy plans and on-the-ground interventions. If citizens' and businesses' involvement is hoped for in energy transitions, then policies and actions should be devised accordingly.

Index Terms: Consumer behaviour, Demography, Public policy, Social groups, Social sciences

3.3.1 Introduction

Through the European Green Deal, the Fit-for-55 Package, and the REPowerEU Plan, the European Union (EU) has been increasingly emphasising energy transitions to mitigate climate change, enhance energy security, and, more recently, improve competitiveness. Member States have been mandated to raise their ambition for greenhouse gas emissions reduction, energy efficiency improvement, and renewable energy integration, including in their updated National Energy and Climate Plans for 2030. Addressing energy poverty and ensuring citizen participation are mentioned as paramount.

Thus, the social aspects of energy transitions are fundamental – *e.g.*, the responsibility for adopting energy efficiency and renewable energy is often placed on consumers, among other roles (Laakso *et al.*, 2024). These are frequently regarded as one-dimensional agents which adopt technologies and behaviours based on rational criteria such as cost-effectiveness. However, citizens are highly dependent on the structural conditions that may support or hinder the adoption of specific measures (Hansen and Aagaard, 2025).

In contrast, many authors have been applying social sciences to energy research to identify the panoply of socio-economic, demographic, behavioural, political, and cultural factors that shape energy transitions (Sovacool, 2014). The hard-to-reach (HTR) energy users concept emerges from this stream of thought, being broadly defined as those who are difficult to reach or engage by energy policies and interventions (Ambrose *et al.*, 2019).

Several authors have called for more local action to increase the breadth and speed of adopting energy technologies and behaviours, with a growing responsibility for local governments, energy agencies, frontline workers, and other local stakeholders (Wehden *et al.*, 2025). For instance, local-scale approaches, such as one-stop shops and renewable energy communities, are being proposed and explored throughout the EU to engage citizens, including HTR groups, and to mitigate energy poverty (Mello *et al.*, 2024; Croon *et al.*, 2025). Just energy transitions imply the fair distribution of harms and benefits, the recognition of energy users' needs, and the full participation in decision-making processes; all of these might not be naturally occurring features of energy policies and interventions even if they are deployed at a local scale (Rios-Ocampo *et al.*, 2025).

This research builds on previous work that expanded the theoretical knowledge on HTR energy users and explored datasets to gauge the significance of these groups in the EU and its 27 Member States. Its main goal is to transfer the HTR concept to the local level in Portugal – *i.e.*, at municipal and sub-municipal (civil parish) levels - with practical implications for the design of local energy plans and on-the-ground actions.

3.3.2 Theoretical background

3.3.2.1 Theoretical framework on hard-to-reach energy users

Working under the auspices of the International Energy Agency's Technology Collaboration Programme Users TCP Task on Hard-To-Reach Energy Users, Rotmann *et al.* (2020) proposed a definition for HTR energy users while suggesting that vulnerable households, high-income households, tenants and landlords, small and medium enterprises, and commercial subsectors can be regarded as the major HTR groups. Building on this work, Sequeira *et al.* (2023, 2024) systematised typologies that may be considered as HTR, leading to the formulation of a theoretical framework on HTR energy users (Figure 3.6).

In addition, Mundaca *et al.* (2023) used the HTR concept for an ex-post assessment of 19 interventions across eight Global North countries to assess their successes and limitations in targeting HTR groups. Finally, Sequeira and Gouveia (2025) used the HTR framework to evaluate ex-ante the National Energy and Climate Plans for 2030 of EU Member States Belgium and Portugal for their inclusiveness of HTR profiles.

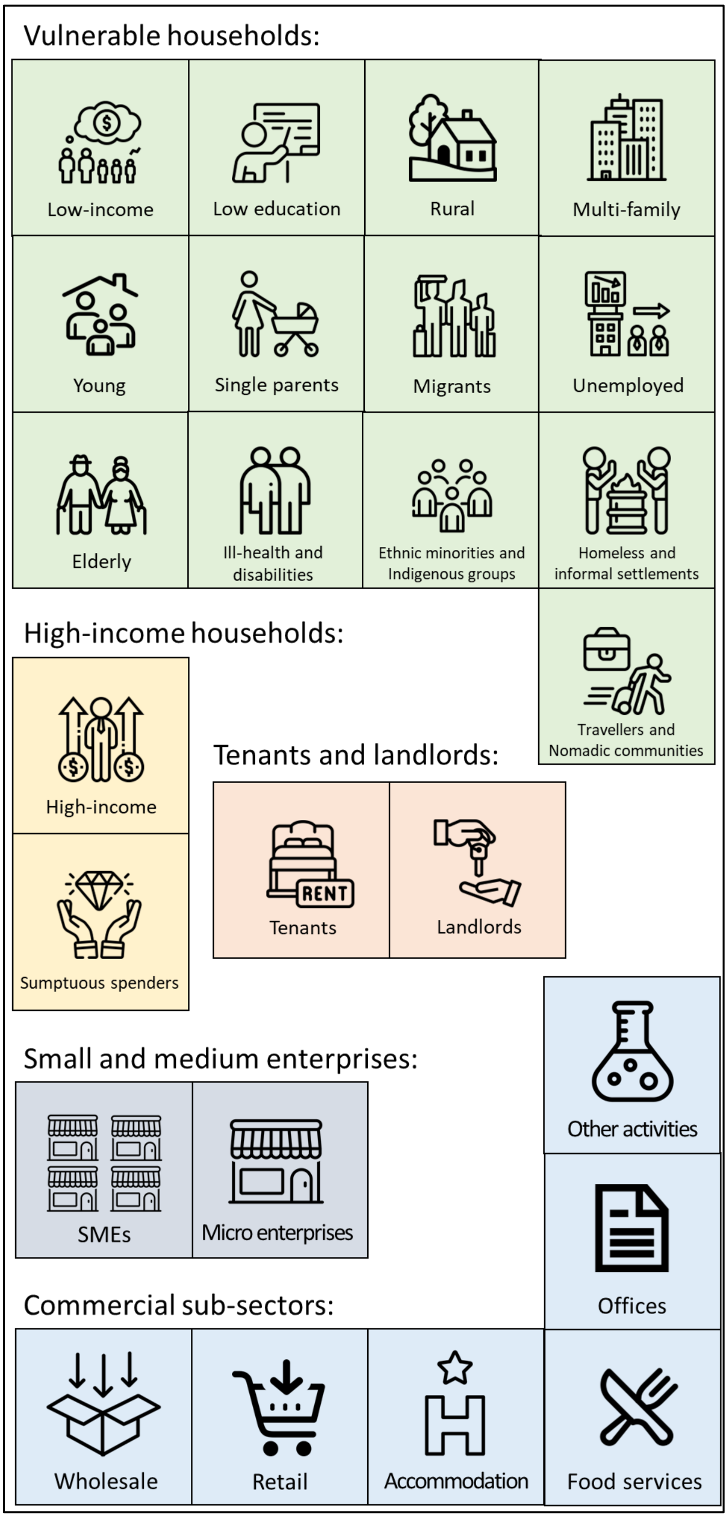


Figure 3.6 - Hard-to-reach energy users framework (adapted from Sequeira *et al.*, 2023,2024).

3.3.2.2 National-level results for Portugal

The HTR framework was used as a guide for exploring EU-level datasets (*i.e.*, Eurostat), providing an estimate of the size of HTR groups, and identifying data gaps (Sequeira *et al.*, 2023, 2024). For Portugal, national-scale results are shown in Figures 3.7 and 3.8 for the residential and non-residential sectors, respectively.

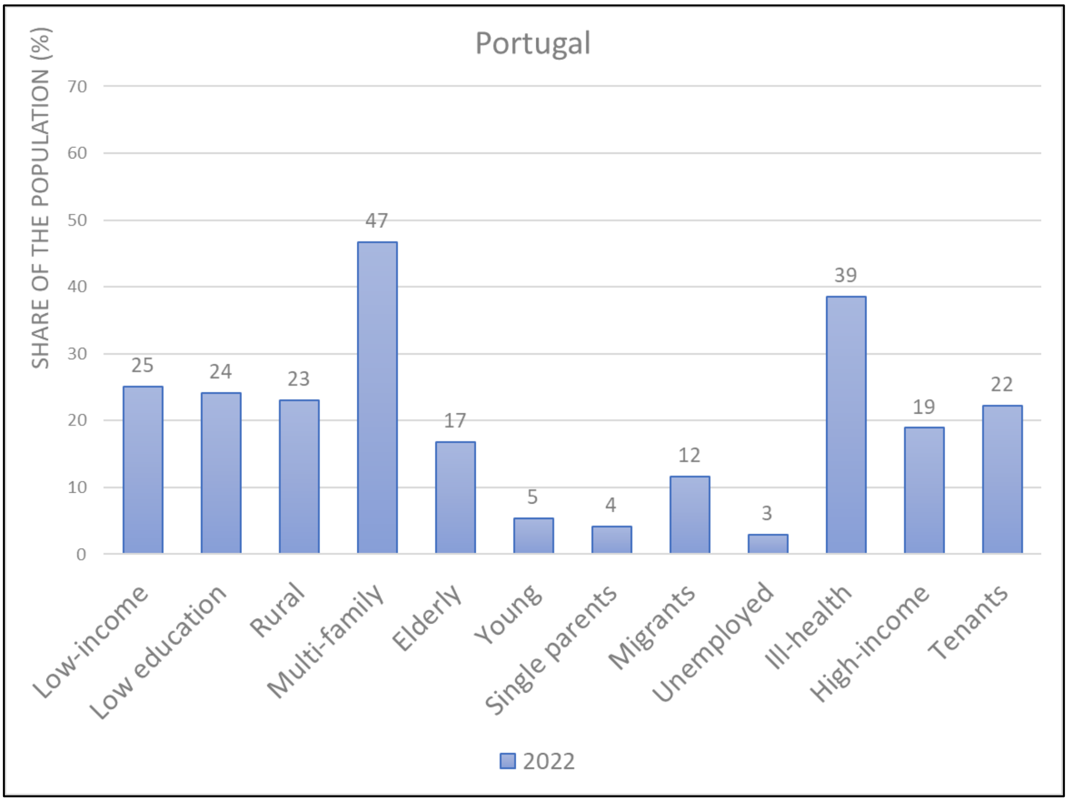


Figure 3.7 - Residential HTR groups in Portugal in 2022 (adapted from Sequeira *et al.*, 2024).

This top-down research maps priority groups that should not be forgotten or left behind in the design of national-level policies. For instance, policymakers in Portugal should pay close attention to the fact that a significant share of households have low incomes and low education levels, that the population is aging with ill-health and disabilities being a relevant factor, that almost half of households live in multi-family buildings but that rural households are also noteworthy, and that the business sector is mainly comprised of micro-enterprises operating in diverse economic sectors.

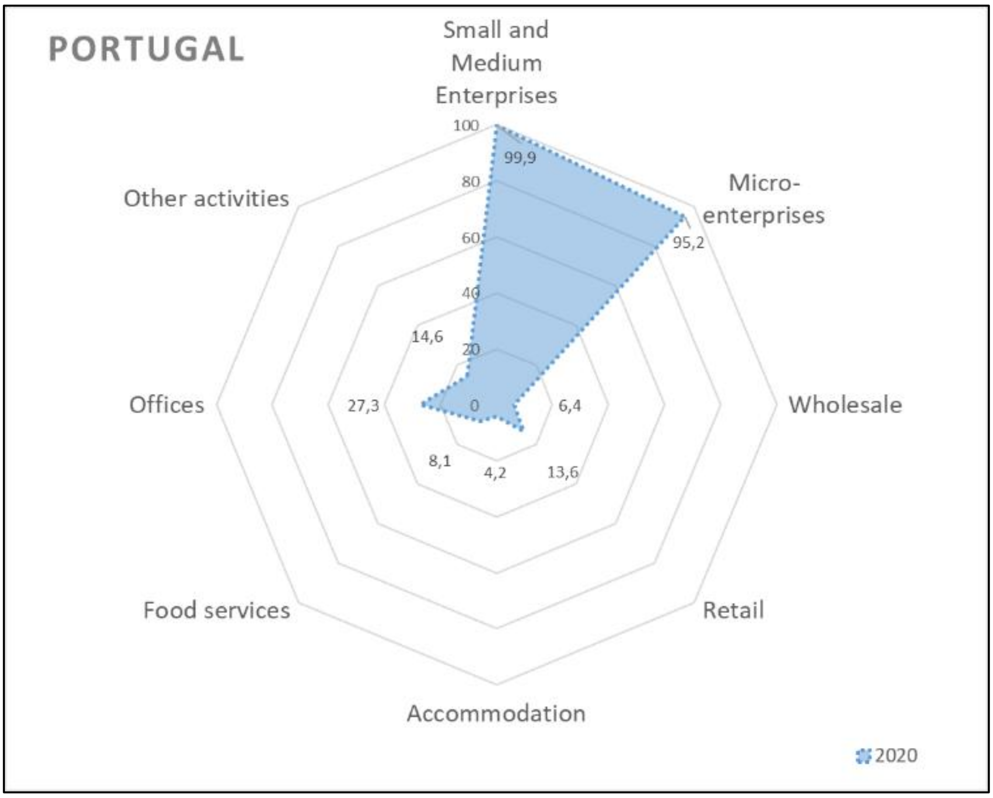


Figure 3.8 - Non-residential HTR groups in Portugal in 2020 (adapted from Sequeira *et al.*, 2023).

3.3.3 Methods and data sources

3.3.3.1 Geographical scope and socio-economic context

This research focuses on Portugal, providing a contrasting approach to the one presented by Sequeira *et al.* (2023, 2024) regarding national-scale data analysis. Furthermore, it takes a deep dive into local scale indicators. This second step focuses on two municipalities – Lisbon and Setúbal, both located in the Lisbon Metropolitan Area – and one sub-municipal administrative area – the Lumiar Civil Parish, located within the Lisbon Municipality. The choice of these locations was based on convenience criteria, linking to ongoing on-the-ground projects which can benefit from the analysis of local energy consumers as their primary target audience.

Situated in Southern Europe, Portugal has a population of around 10 million people and 1.5 million enterprises are registered in its territory (Portugal Statistics, 2025). The country has published a National Strategy to Combat Poverty 2021-2030, recognising that around 2 million people still suffer from poverty or social exclusion (Portuguese Government, 2021). The Action Plan for 2022-2025 highlights priority groups, such as children, youth, elderly, disabled, and migrants (Portuguese Government, 2023). Energy poverty is endemic in Portugal, being the focus of the National Long-Term Strategy to Combat Energy Poverty 2023-2050 (Portuguese Government, 2024). This document estimates that up to 29% of the population is in energy poverty – around 3 million people – while prioritising energy performance of housing, universal access to essential energy services, integrated territorial action, and knowledge and informed action.

Setúbal is in the southern region of the Lisbon Metropolitan Area, boasting a population of around 120 thousand people and with almost 16 thousand enterprises registered (Portugal Statistics, 2025). For the 2015-2016 period, the local organisations partaking in the Setúbal Social Partnership ("Rede Social de Setúbal") diagnosed key social issues, namely the persistence of situations of poverty and social exclusion, the insufficient health response, the lack of resources, employment and housing, and the insufficient collaboration between institutions (Setúbal Social Partnership, 2013). It also designed a Social Development Plan, calling for reinventing social responses beyond relief measures, reinforcing infrastructure, improving sustainability, and fostering social cohesion (Setúbal Social Partnership, 2014).

Setúbal is a signatory of the Covenant of Mayors, having developed a Sustainable Energy Action Plan with four pillars, namely increasing energy efficiency in the municipality and in the private sector, creating carbon sinks and increasing the exploitation of renewable energy, implementing a sustainable mobility plan, and informing, raising awareness, educating, and training the population and specific target groups (Setúbal Municipality, 2021). In 2022, a pilot project tested a mobile one-stop shop to support the general population, especially energy-poor families (Calouste Gulbenkian Foundation, 2025).

Lisbon is the capital of Portugal, with a population of almost 546 thousand people; of these, 46 thousand people inhabit Lumiar, one of its most populous civil parishes (Portugal Statistics, 2025). Around 141 thousand businesses are registered in Lisbon; data at the civil parish level is unavailable (Portugal Statistics, 2025). For the 2015-2016 period, the local organisations participating in the Lisbon Social Partnership ("Rede Social de Lisboa") diagnosed key intervention areas, including healthy city, growing with opportunities (focused on children), from vulnerability to inclusion (with homeless as a key focus), cultural diversity (acknowledging migration fluxes), active aging (recognising the elderly), and quality of social and health services (Lisbon Social Partnership, 2016a). Furthermore, the organizations of the Lumiar Parish Social Committee identified substance abuse and aging as priority challenges while also recognising the relatively high social capital of the territory (Lisbon Social Partnership, 2016b).

More recently, in 2024, Lisbon's social challenges were portraited by the local branch of the European Anti-Poverty Network (EAPN, 2024a), calling for a new generation of policies to tackle intergenerational poverty, for schools to consider linguistic diversity, for greater diversification of professional training, for regulating abusive practices in rental contracts, and for investing in anti-racism training. EAPN Portugal (2024b) pinpointed specific issues for Lumiar, including the multiple origins of poverty, the significant number of young residents but also the aging population, the extensive social disparities in income levels and the concentration of vulnerabilities in specific communities, the presence of informal housing, the higher levels of education but marked by contrasts between areas, and the relevant share of unemployed youth.

Lisbon is a signatory of the Covenant of Mayors, and it is one of the cities in the EU Mission for 100 climate-neutral and smart cities by 2030. It has a Climate Action Plan for 2030, which embraces the challenges of climate neutrality, climate adaptation, and energy poverty eradication (Lisbon Municipality, 2021). Lisbon has recently published a Climate City Contract for 2030 with 130 actions for climate mitigation and adaptation (Lisbon Municipality, 2024). It seeks to increase energy efficiency, including renovating buildings, and to integrate renewable energy, including installing solar photovoltaic panels. In Lumiar, since 2021, an energy community has been trying to bring together citizens, associations, and the civil parish to invest, produce, and share solar energy while engaging vulnerable households (Viver Telheiras, 2025).

Finally, in the energy poverty vulnerability index developed by Gouveia *et al.* (2019), Setúbal and Lisbon rank 296 and 298 (winter vulnerability) and 257 and 307 (summer vulnerability), respectively, out of 308 Portuguese municipalities, showcasing a relatively low vulnerability. Lumiar ranks 3089 and 3086 for winter and summer out of 3092 civil parishes in Portugal. This index merges an energy performance gap with the population's adaptative capacity. Thus, the average value for a given territory, particularly those with large populations, can hide the presence of communities severely affected by energy poverty while balancing out the presence of households that overconsume. Energy poverty vulnerability is aggravated by the poor conditions of buildings – the share in need of repair is 36% in Portugal, 34% in Setúbal, 39% in Lisbon, and 23% in Lumiar – by the absence of heating – 30% of households in Portugal, 37% in Setúbal, 30% in Lisbon, and 21% in Lumiar – and by the number of people without air conditioning – 82% of the population in Portugal, 77% in Setúbal, 77% in Lisbon, and 67% in Lumiar (Portugal Statistics, 2025).

3.3.3.2 Data collection and processing

Data collection from the database of Portugal Statistics ("Instituto Nacional de Estatística – INE") followed the HTR energy users framework by Sequeira *et al.* (2023, 2024) as a guide, seeking to identify all related statistics for shedding light on the size of HTR profiles. Relevant statistics were collected from Portugal Statistics for each HTR typology, with the Census 2021 proving particularly useful due to the breadth and granularity of data (Portugal Statistics, 2025). Data processing and indicator selection were performed according to Sequeira *et al.* (2023, 2024), who used Eurostat data, including the normalization of the data to the total population or to the total number of businesses. However, for this research's purpose, priority was also given to indicators that could be assessed at all scales of analysis – national, municipal, and sub-municipal.

3.3.4 Results and discussion

3.3.4.1 Residential sector

Table 3.9 presents the effort to quantify residential HTR energy users for the residential sector in Portugal, in the two target municipalities (Setúbal and Lisbon) and in the sub-municipal territory (Lumiar), providing valuable insights into the characteristics of the local population. At-risk of poverty indicators are not collected at municipal or sub-municipal level, which leaves income as the sole source of data (but also not available at civil parish level). The national census process also does not collect data regarding ethnic minorities, nomad communities, highly wealthy individuals, or landlords.

Table 3.9 - Residential HTR groups for selected locations.

HTR profile	Proxy indicator description	Portugal	Setúbal Municipality	Lisbon Municipality	Lumiar Civil Parish	Unit	Year
Low income	Share of fiscal households reporting less than 10,000 euro of gross annual income	31.1%	28.7%	29.1%	Not available	% of fiscal households	2022
Low education	Share of the population with only primary education or with no formal education	34.5%	30.0%	25.5%	20.4%	% of the population	2021
Rural	Share of the population living in places with less than 2,000 inhabitants	37.5%	22.8%	0.0%	0.0%	% of the population	2021
Multi-family	Share of the population living in buildings constructed for more than one dwelling	51.6%	69.8%	94.5%	97.5%	% of the population	2021
Elderly	Share of the population living in households where all members are 65 years old or more	17.0%	20.2%	19.7%	18.7%	% of the population	2021
Young	Share of the population aged between 15 and 34 years old that live alone	0.9%	1.0%	2.3%	1.9%	% of the population	2021
Single parents	Share of the population living in a single-parent household	5.6%	6.6%	6.6%	6.2%	% of the population	2021
Migrants	Share of the population that was born in a foreign country	10.5%	12.8%	16.8%	13.0%	% of the population	2021
Unemployed	Share of the population that is unemployed	3.8%	4.2%	4.1%	3.0%	% of the population	2021

Ill-health and disabilities	Share of the population with at least one physical or cognitive limitation	43.7%	44.0%	39.4%	34.3%	% of the population	2021
Ethnic minorities & Indigenous groups	No data available	-	-	-	-	-	-
Homeless & informal settlements	Share of the population which is identified as homeless	0.02%	0.02%	0.06%	0.00%	% of the population	2021
Travellers & nomadic communities	No data available	-	-	-	-	-	-
High-income	Share of fiscal households reporting more than 32,500 euro of gross annual income	16.3%	19.7%	27.3%	Not available	% of fiscal households	2022
Sumptuous spenders	No data available	-	-	-	-	-	-
Tenants	Share of the population living in a rented dwelling	21.2%	23.9%	41.5%	24.9%	% of the population	2021
Landlords	No data available	-	-	-	-	-	-

More important than going through the differences between territories is to explore targeted and tailored measures to ensure inclusiveness towards HTR groups in local energy policies and in on-the-ground actions. For instance:

- Low-income households may require up-front financing for efficient equipment and renewable energy.
- People with low education levels may need simplified information and advice on energy bills and public funds.
- Multi-family buildings may need mediation, *e.g.*, by condominium managers, for whole building measures.
- Elderly people may need support regarding digital tools and novel technologies.
- Young people may respond better to social media campaigns and gamification.
- Single parents, mostly women, may lack time for energy issues and require support in specific schedules.
- Migrants may need information in their language and communication should be culturally sensitive.
- People with ill health and disabilities may require intermediation from already trusted frontline workers.

- Homeless people need extensive housing, employment, and social support beyond the scope of the energy area.
- High-income households can be persuaded to be the first adopters of efficient equipment and renewable energy.
- Tenants and landlords might aim for shared responsibility models that surpass split incentives.

3.3.4.2 Non-residential sector

Table 3.10 presents the effort to quantify non-residential HTR energy users for the residential sector in Portugal and in the two target municipalities (Setúbal and Lisbon). Notably, it was not possible to find data on enterprises at a lower resolution than the municipal level. Relevant insights can include:

- Small and medium enterprises may benefit from free or low-cost energy audits programs.
- Micro-enterprises may require upfront financial support in addition to the provision of technical expertise.
- Commercial sub-sectors often present heterogeneous energy uses, which may require very specific measures.

Table 3.10 - Non-residential HTR groups for selected locations.

HTR profile	Proxy indicator description	Portugal	Setúbal Municipality	Lisbon Municipality	Lumiar Civil Parish	Unit	Year
Small and medium enterprises	Share of enterprises classified as small and medium enterprises (less than 250 employees)	99.9%	99.9%	99.7%	Not available	% of enterprises	2023
Micro enterprises	Share of enterprises classified as micro-enterprises (less than 10 employees)	96.0%	96.8%	94.9%	Not available	% of enterprises	2023
Wholesale	Share of enterprises whose activity is wholesale trade (except of motor vehicles)	4.0%	3.5%	3.2%	Not available	% of enterprises	2023
Retail	Share of enterprises whose activity is retail trade (except of motor vehicles)	8.2%	7.7%	5.8%	Not available	% of enterprises	2023
Accommodation	Share of enterprises whose activity is accommodation	3.4%	2.1%	4.3%	Not available	% of enterprises	2023

Food services	Share of enterprises whose activity is food services or similar	4.9%	6.5%	4.7%	Not available	% of enterprises	2023
Offices	Share of enterprises whose activity is information and communication, real estate, consultancy, or administrative	33.1%	38.0%	49.8%	Not available	% of enterprises	2023
Other services	Share of enterprises whose activity is classified as arts and sports or as other services	8.2%	9.6%	8.1%	Not available	% of enterprises	2023

3.3.5 Conclusions

This work provided an in-depth multi-scalar analysis of HTR groups in Portugal. Its novelty lies in the application of the HTR concept at a local scale, which can be insightful for the design of local energy plans and on-the-ground interventions. Although statistical data is useful for these purposes, it should not be forgotten that, even if an HTR profile seems to be only a small share of total energy users, leaving them behind in energy transitions has a tremendous impact on the lives of families and the resilience of businesses.

Without targeted and tailored actions, the engagement of these groups in Portugal is severely constrained, leading to a slower pace of technologies and behaviours adoption (impacting decarbonisation goals) and to energy justice concerns where certain groups may see their situation worsen (vulnerable groups may become more exposed to energy poverty). In contrast, others continue to overconsume (high-income groups adopt energy-intensive habits). The local scale seems like a proper arena for reaching the HTR.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia: Writing – review & editing, Validation, Supervision.

References

Ambrose, A., Baker, W., Batty, E., and Hawkins, A. (2019). Reaching the "Hardest to Reach" with energy advice: final report. Sheffield Hallam University, CRESR. https://doi.org/10.7190/cresr.2019.8286642862

Calouste Gulbenkian Foundation (2025). Transition Point: Pilot project to combat energy poverty in Portugal. Available on: https://gulbenkian.pt/en/climate-and-ocean/transition-point/

Croon, T.M., Maghsoudi Nia, E., He, S., Qian, Q.K., Elsinga, M.G., Hoekstra, J.S.C.M., *et al.* (2025). Energy coaching and 'fix team' retrofitting to mitigate energy poverty: An ex-post analysis of treatment and interaction effects. Energy Research & Social Science, 119, 103807. https://doi.org/10.1016/j.erss.2024.103807

EAPN Portugal (2024a). Lisbon Social Portrait: From census to consensus. ISBN: 978-989-35489-5-0. Available on: https://observatorio-lisboa.eapn.pt/destaque/retrato-social-de-lisboa-do-censo-aos-consensos/

EAPN Portugal (2024b). Thinking Lumiar: Experimental thought exercise. Available on: https://observatorio-lisboa.eapn.pt/destaque/pensar-lumiar/

Gouveia, J.P., Palma, P., and Simões, S.G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187-201. https://doi.org/10.1016/j.egyr.2018.12.004

Hansen, A.R., and Aagaard, L.K. (2025). Uncovering energy flexibility of everyday rhythms and routines in households with real-time electricity pricing. Energy Efficiency, 18, 6. https://doi.org/10.1007/s12053-024-10291-0

Laakso, S., Castellazzi, E., Matschoss, K., and Rinkinen, J. (2024). Agents of change or victims of transition? Media framings on household roles during the energy crisis. Sustainability Science, 19, 739-762. https://doi.org/10.1007/s11625-023-01434-w

Lisbon Municipality (2021). Lisbon Climate Action Plan 2030. Available on: https://amensagem.pt/wp-content/uploads/2021/08/PAC_LISBOA_2030_Relatorio.pdf

Lisbon Municipality (2024). Lisbon Climate City Contract 2030. Available on: https://netzerocities.app/resource-4423

Lisbon Social Partnership (2016a). Social Diagnosis of Lisbon 2015-2016. Available on: https://www.am-lisboa.pt/451600/1/008956,000511/index.htm

Lisbon Social Partnership (2016b). Social Diagnosis of Lisbon 2015-2016 – Portrait of the Lumiar Civil Parish. Available on: https://www.am-lisboa.pt/452000/1/,000555/index.htm

Mello, J., Villar, J. Bessa, R.J. Antunes, A.R., and Sequeira, M.M. (2024). Decarbonized and Inclusive Energy: A Two-Fold Strategy for Renewable Energy Communities. IEEE Power and Energy Magazine, 22, 4. https://doi.org/10.1109/MPE.2024.3396442

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., *et al.* (2023). Hard-to-reach energy users: An ex-post cross-country assessment of behavioural-oriented interventions. Energy Research & Social Science, 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Portugal Statistics (2025). Statistical database. INE – Instituto Nacional de Estatística. Consulted in February 2025. Available on: www.ine.pt

Portuguese Government (2021). Resolution of the Council of Ministers no. 184/2021: National Strategy to Combat Poverty 2021-2030. Diário da República, 1.ª série, 251. Available on: https://diariodarepublica.pt/dr/legislacao-consolidada/resolucao-conselho-ministros/2021-863010347

Portuguese Government (2023). Action Plan for 2022-2025 of the National Strategy to Combat Poverty. Available on: https://www.portugal.gov.pt/pt/gc23/comunicacao/documento?i=plano-de-acao-20222025-da-estrategia-nacional-de-combate-a-pobreza

Portuguese Government (2024). Resolution of the Council of Ministers no. 11/2024: National Long-term Strategy to Combat Energy Poverty 2023-2050". Diário da República, 1.ª série, 5. Available on: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/11-2024-836222486

Rios-Ocampo, M.A., Romero, J.C., Centeno, E., and Mora, S. (2025). A just energy transition is not just a transition: Framing energy justice for a quantitative assessment. Energy Research & Social Science, 119, 103900. https://doi.org/10.1016/j.erss.2024.103900

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., *et al.* (2020). Hard-to-Reach Energy Users: A Literature Review. IEA UsersTCP - HTR Task. ISBN: 978-0-473-64983-8. Available on: https://userstcp.org/hard-to-reach-energy-users-task/

Sequeira, M.M., and Gouveia, J.P. (2023). Non-residential hard-to-reach energy users: A vast audience forgotten by the energy transition? ME3 conference, Portugal. https://doi.org/10.48528/v3b3-fk78

Sequeira, M.M., and Gouveia, J.P. (2025). Assessing the inclusiveness of the draft updated National Energy and Climate Plans 2030 of Belgium and Portugal through a hard-to-reach energy users lens. In Brito, P.S., *et al.* (Eds) Insights into Energy Trends - Selected Papers from ICOWEFS 2024. Part of the book series: Green Energy and Technology. ISBN: 978-3-031-83810-1. Available at: https://link.springer.com/book/9783031838101

Sequeira, M.M., Gouveia, J.P., and Melo, J.J. (2024). (Dis)comfortably numb in energy transitions: Gauging residential hard-to-reach energy users in the European Union. Energy Research & Social Science, 115, 103612. https://doi.org/10.1016/j.erss.2024.103612

Setúbal Municipality (2021). Setúbal Sustainable Energy Action Plan. Available on: https://www.setubalambiente.pt/wp-content/uploads/2021/05/PAES_Setubal_Final.pdf

Setúbal Social Partnership (2013). Social Diagnosis – Social Action Area. Available on: https://www.mun-setubal.pt/rede-social-de-setubal

Setúbal Social Partnership (2014). Setúbal Social Development Plan. Available on: https://www.mun-setubal.pt/rede-social-de-setubal

Sovacool, B.K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Research & Social Science, 1, 1-29. https://doi.org/10.1016/j.erss.2014.02.003

Viver Telheiras (2025). Telheiras/Lumiar Renewable Energy Community. https://vivertelheiras.pt/certelheiras/en

Wehden, S., Janda, K.B., Jansen, J., and Creutzig, F. (2025). Local climate action from the middle-out: the social potential of craft guilds to facilitate low-carbon installations in Germany. Energy Efficiency, 18, 2. https://doi.org/10.1007/s12053-024-10287-w

Chapter 4.

APPLYING THE HARD-TO-REACH LENS TO ASSESS POLICIES AND INTERVENTIONS

4.1 Assessing the inclusiveness of the draft updated National Energy and Climate Plans 2030 of Belgium and Portugal through a hard-to-reach energy users lens

This work is published in: Sequeira, M.M., and Gouveia, J.P. (2025). Assessing the inclusiveness of the draft updated National Energy and Climate Plans 2030 of Belgium and Portugal through a hard-to-reach energy users lens. In Brito, P.S., *et al.* (Eds) Insights into Energy Trends - Selected Papers from ICOWEFS 2024. Part of the book series: Green Energy and Technology. ISBN: 978-3-031-83810-1. https://doi.org/10.1007/978-3-031-83811-8_6

Abstract

The European Union's energy strategy vows to strive for a fair transition where no one is left behind. Hard-to-reach energy users encompass residential and non-residential groups generally neglected by energy policies. National Energy and Climate Plans (NECP) for 2030 are a key instrument currently being updated by the Member States. In this context, we aim to put the commitment to a just transition to the test by applying a hard-to-reach energy users framework to the draft updated NECPs of Belgium and Portugal. While vulnerable households are mentioned in the plans through tailored and targeted measures, specific profiles such as rural households, migrants, people with ill-health, and other marginalized groups seem to be overlooked, particularly in the Portuguese case. The need to address excessive energy consumption of high-income households has been the focus of recent research. Still, Belgium's NECP scantily mentions this group, which is absent in Portugal's NECP. Specific schemes for the renovation of rented homes are presented in both NECPs but with a much greater level of detail in Belgium's one. Small and medium enterprises represent most businesses and are mentioned in the NECPs, while a much smaller focus is given to micro-enterprises. Commercial subsectors seem to be adequately mentioned, although activities such as food services do not attract much attention. We conclude by arguing that, even if some promising examples can be found, policymakers can do more to ensure the engagement of hard-to-reach groups in the energy transition.

Keywords: Energy transition, energy policy, vulnerable households, NECP

4.1.1 Introduction

The European Union (EU) has vowed to be a leader in climate change mitigation, foreseeing a net reduction of greenhouse gas emissions of at least 55% in 2030 com-pared to the 1990 baseline (European Commission, 2021). This goal is to be achieved by raising the share of renewable energy in the EU's overall energy consumption to 42.5% and improving energy efficiency to reduce final energy consumption at the EU level by 11.7%. Recognizing the different responsibilities and needs of specific population groups, the European Green Deal emphasizes a just transition where no one is left behind (European Commission, 2019).

In this context, the concept of hard-to-reach (HTR) energy users has been gaining attention from researchers, policymakers, and practitioners, broadly described as residential and non-residential energy users that have so far been neglected by energy policies and interventions (Rotmann *et al.*, 2020). Five major HTR groups are identified in the literature, namely vulnerable households, high-income households, tenants and landlords, small and medium enterprises, and commercial subsector. A few authors have endeavoured to establish more precise residential and non-residential HTR profiles (Sequeira and Gouveia, 2023; Sequeira *et al.*, 2024).

Due to multiple and persistent barriers, the involvement of HTR groups in the energy transition has been slow, hindering both the success and fairness of this societal transformation. A recent stream of literature has argued for targeted and tailored energy policies that recognize the characteristics and needs of HTR households and businesses and detail concrete approaches to surpass these challenges (Mundaca *et al.*, 2023).

A key research question with practical policy-oriented implications is to assess if current energy policies are being inclusive towards HTR energy users and to what extent. In this work, we explore the draft updated National Energy and Climate Plans (NECP) for 2030 of EU Member States Belgium and Portugal for mentions of HTR groups regarding just energy transitions and targeted and tailored measures. By applying an HTR energy users framework to these policy documents, which are currently being revised by Member States, we aim to identify forgotten groups at risk of being left behind by the EU's energy transition.

4.1.2 Methods

4.1.2.1 National Energy and Climate Plans 2030 of Belgium and Portugal

In the EU, the NECPs outline the Member States' 10-year strategic plans for the energy and climate area, addressing five key dimensions, namely decarbonization, energy efficiency, energy security, internal energy market, and research, innovation, and competitiveness (European Commission, 2024). Member States were required to submit their NECPs by December 2019, taking into consideration the European Commission's assessment of their draft version. A progress report on the implementation of the NECPs is due every two years.

In 2023, Member States were mandated to update their NECPs in line with the EU's revised energy and climate targets for 2030. The draft versions were due to be submitted in June 2023, and the European Commission published its assessment and issued recommendations to raise ambition in December 2023. Member States must submit their final NECPs by June 2024. For an improved development and implementation of the NECPs, Member States were required to consult stakeholders in the drafting and finalization process.

Belgium and Portugal submitted their draft updated NECPs per the European Commission's timeline (Government of Belgium, 2023; Government of Portugal, 2023). These countries have similar population levels, but present markedly different climates and socio-economic conditions (€117 and €83 per capita for Portugal and Belgium, respectively). Furthermore, Portugal and Belgium have distinct primary energy mixes (64% and 75% of fossil fuels in the energy mix for Portugal and Belgium, respectively), greenhouse gas emissions levels (86 and 35 Mt CO2, for Belgium and Portugal, respectively), and energy poverty problems (6% and 21% of the population unable to heat their homes in Belgium and Portugal, respectively). Thus, these two contrasting countries were selected for methodological testing purposes, and future work will analyse the NECPs of all Member States. The NECP of Belgium consists of 758 pages, while the Portuguese one has only 238 pages. These countries are in the revision process of their NECPs, making the current analysis valuable and timely.

4.1.2.2 Hard-to-reach energy users' framework

In this work, we use the HTR energy users framework developed by Sequeira *et al.* (2024) for the residential sector and by Sequeira and Gouveia (2023) for the non-residential sector (Figure 4.1). These authors built on the existing scientific literature on major HTR groups to further define specific HTR profiles. Furthermore, they operationalized using existing standardized statistical data to gauge the significance of these audiences at the EU and Member State scale. This framework is now applied to assess if energy policies are i) recognizing the relevance of HTR groups for just energy transitions and ii) defining targeted and tailored measures that meet the needs of specific HTR profiles.

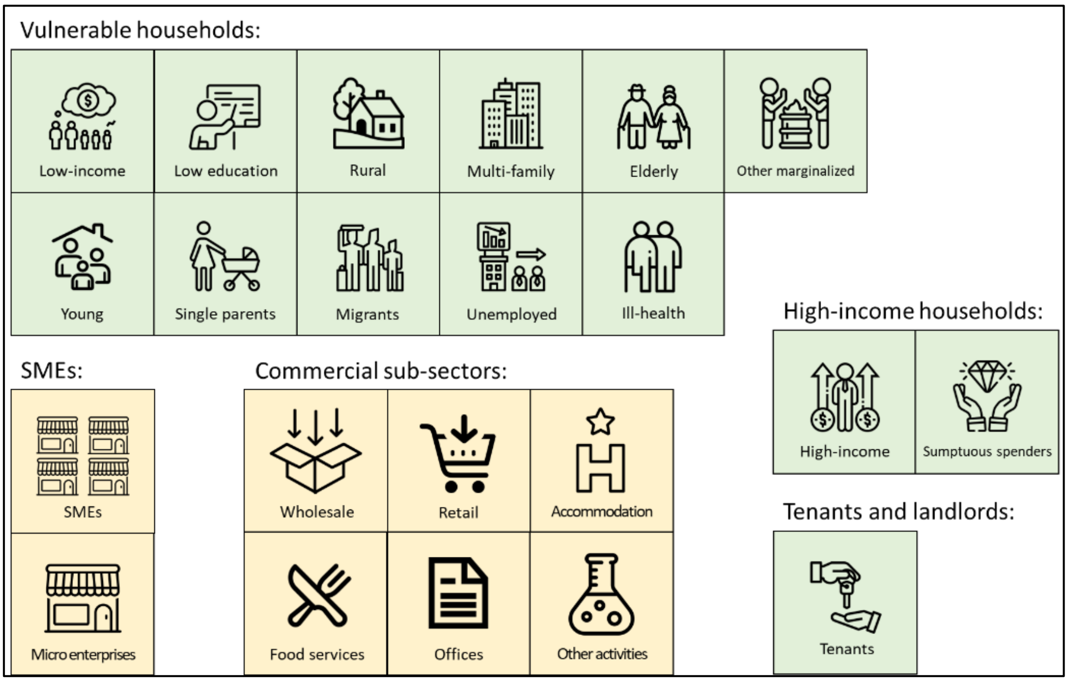


Figure 4.1 - Hard-to-reach energy users framework (adapted from Sequeira and Gouveia, 2023, and Sequeira *et al.*, 2024).

4.1.2.3 Assessing energy policy through a hard-to-reach lens

Considering the HTR energy users framework, the NECPs of Belgium and Portugal were scanned for mentions of HTR groups. To perform this task, representative keywords were selected for each HTR profile, as presented in Tables 4.1 and 4.2 for the residential and non-residential sectors, respectively. Only the successful keywords are shown since a wide range of other keywords was tested during this process. Furthermore, the sections where the keywords were found were read in detail to understand the context in which HTR groups were mentioned.

The goal was to identify the approaches to recognizing and engaging these HTR groups in the energy transition as being "energy users" and not in other roles. Thus, several topics were deemed out-of-scope for this assessment (*e.g.*, international climate finance, vulnerable nature, climate adaptation, and green jobs, among others).

Table 4.1 - Keywords to scan the NECPs for mentions of HTR profiles (residential sector).

HTR group	HTR profile	Keywords
Vulnerable households	Low-income	Low/lower/lowest income, poor socio-economic
	Low education	Low skilled, info-exclusion
	Rural	Rural, remote
	Multi-family	Apartment, multi-dwelling, condominium
	Elderly	Elderly, older, aged 65 and over
	Young	Young adults/people
	Single parents	Single parents/households/mothers, divorced
	Migrants	Migrants, intercultural
	Unemployed	Unemployed, not currently working
	Ill-health	Poor health, disabilities, illness, health problems
	Other marginalized	-
High-income households	High-income	Higher/highest income
	Sumptuous spenders	-
Tenants and landlords	Tenants	Tenant, rental stock
	Landlords	-

Table 4.2 - Keywords to scan the NECPs for mentions of HTR profiles (non-residential sector).

HTR group	HTR profile	Keywords
Small and medium enterprises	SMEs	SME, small and medium-sized enterprises
	Micro-enterprises	Micro-enterprises, small business
Commercial sub-sectors	Wholesale	Depot, distribution sector
	Retail	Retail, shop, shopping, trade, commerce
	Accommodation	Horeca, hotel, tourism sector
	Food services	Horeca
	Offices	Office
	Other activities	Sports, care, laundry, hospital

Figure 4.2 showcases the matrix used to apply the HTR energy users framework to the draft updated NECPs. Each cell represents the assessment of one HTR profile for a given country NECP. The share of the HTR profile as a percentage of the population or of the number of enterprises for the residential and non-residential sectors, respectively, was retrieved from Sequeira and Gouveia (2023) and Sequeira *et al.* (2024). The number of mentions in the draft updated NECP only encompasses the topics that are considered in the scope of this work, namely just energy transitions and energy poverty and several types of targeted and tailored measures.

Finally, each cell is given a colour that considers both the number of mentions and the representativeness of the HTR profile in the total population or number of enterprises of the country. This is done by dividing the number of mentions by the share of the population or enterprises; if the result is larger than 0 and smaller than 0.5, a yellow colour is attributed; if it is equal or greater than 0.5, a green colour is attributed. The cell is shown as red if the HTR profile is not mentioned in the NECP.

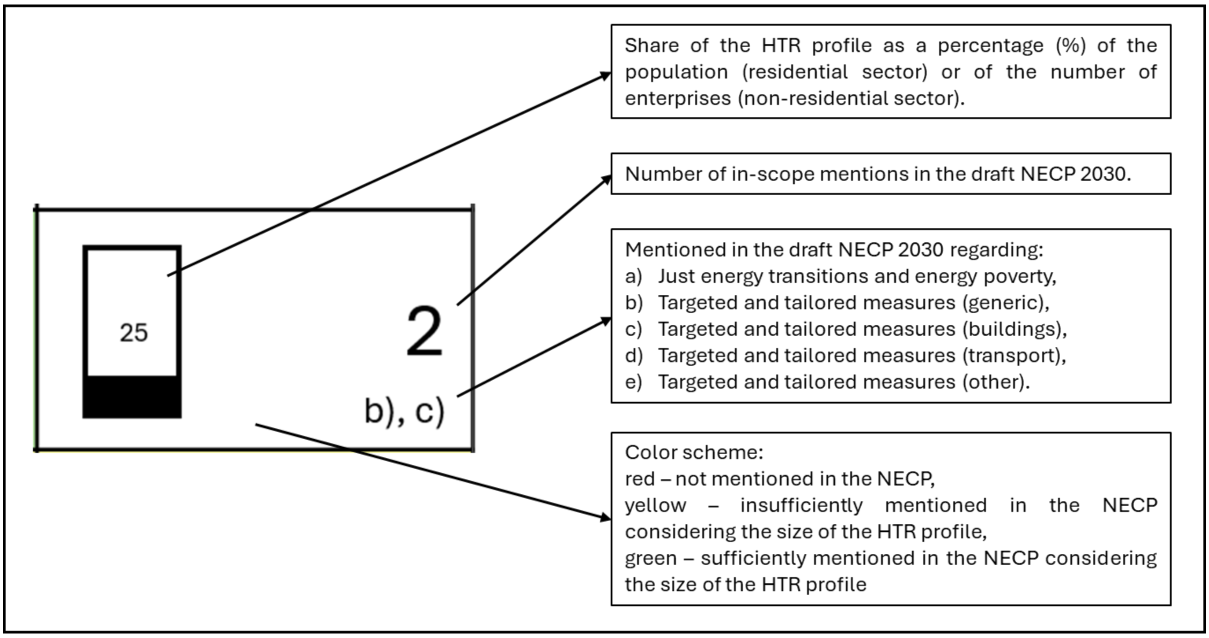


Figure 4.2 - Assessment matrix for the application of the HTR framework to the NECPs.

4.1.3 Results and discussion

4.1.3.1 Residential sector

For the residential sector, the assessment of the draft NECPs of Belgium and Portugal using the HTR framework is shown in Figure 4.3. The NECP of Belgium seems to perform better than the Portuguese, partially because of its greater level of detail.

The low-income HTR profile is mentioned in both NECPs, although insufficiently in the Portuguese case, given the sheer size of this target group. For Belgium, the NECP establishes the need for a just energy transition that mitigates energy poverty and shares the benefits of clean energy. Targeted measures include specialised support and dedicated financing for low-income households to renovate their houses and install solar panels. The Portuguese NECP only mentions low-income households two times. Nevertheless, it includes targeted measures describing on-the-ground support and dedicated financing of home renovation interventions.

HTR profile \ Member State	Belgium	Portugal
Low income	29 24 a), b), c)	25 2 b), c)
Low education	13 1 b)	24 1 b)
Rural	15 4 a), d)	23 1 e)
Multi-family	22 25 a), c)	47 3 c), d)
Elderly	18 13 a), c), d)	17 0
Young	12 14 a), b), c), d)	5 4 a), b), d)
Single-parents	6 9 a), c)	4 0

HTR profile \ Member State	Belgium	Portugal
Migrants	18 2 b), c)	12 0
Unemployed	2 2 b)	3 0
Ill-health	22 5 a), c), d)	39 1 c)
Other marginalized	? 0	? 0
High-income	11 2 a), c)	19 0
Sumptuous spenders	? 0	? 0
Tenants	28 25 a), c)	22 1 c)

Figure 4.3 - Mentions of residential HTR profiles in the NECPs of Belgium and Portugal.

Even though a relevant share of each country's population has low education levels and might potentially be more challenging to reach with energy interventions due to energy and digital illiteracy, this is not adequately considered in the NECPs. The Portuguese NECP mentions the need to provide support to people in a situation of info-exclusion. At the same time, the Belgian NECP argues for the promotion of the social inclusion of low-skilled people.

Regarding rural areas, most measures in the NECPs focus on stimulating socio-economic development and do not specifically mention rural households. These can be considered HTR due to geographical isolation, lack of available services, and use of unregulated energy carriers. The Belgian NECP states the need to involve rural people in energy policymaking while providing targeted measures for households' transport energy use. The Portuguese NECP only presents one measure focused on improving grid access to remote populations.

Interventions in multi-family buildings are hindered by ownership and organizational challenges. Belgium's NECP recognizes this well, providing specific financial and technical support schemes for renovating apartment buildings, including through the involvement of co-owners associations in the process. While in Portugal, almost half of the population lives in apartments, this target group is scantily mentioned, stating only the need to develop reference buildings and a single measure for installing electric vehicle charging stations in condominiums.

Elderly people living alone or as a couple can be particularly susceptible to energy poverty while being harder-to-reach with energy interventions. The Belgian NECP recognizes this exacerbated vulnerability and designs tailored measures such as loans for renovating homes (older homeowners typically do not have access to traditional bank credits) and lower prices for public transport fares. This target group is not mentioned in Portugal's NECP, even if it represents a significant population share.

Both NECPs adequately mention young people. Young adults living independently (the indicator depicted in the table) can be considered HTR due to unstable and transient housing and employment. In Portugal, this group is much less significant than in Belgium. Both NECPs mention the need to engage with youth for a just energy transition while providing measures to improve energy literacy, promote behavioural change, and increase public transportation use.

The increased vulnerability to energy poverty in single-parent households is well described in Belgium's NECP, which also frames the gender dimension of this issue. Migrants can be considered HTR due to language barriers and lack of skills to navigate the energy market in the host country. In Belgium, migrants account for almost one-fifth of the total population, and their active participation in the energy transition is vital. However, these groups are only mentioned two times in the NECP regarding general measures to promote social inclusion and foster the engagement of intercultural stakeholders. Unemployment rates have been dropping around Europe, and Belgium's NECP includes only a few mentions of this group. In contrast, Portugal's NECP does not recognize the need to engage with households matching the profiles of single parents, migrants, and the unemployed.

Research has uncovered a bi-directional relationship between energy poverty and ill-health (Ivanova and Middlemiss, 2021). This is recognized in both NECPs, describing measures to protect consumers with health problems and proposing measures for enhanced access to public transport. Other marginalized groups, such as the homeless, ethnic minorities, indigenous people, and criminalized populations, among others, have historically been left out of energy policies; the assessed NECPs are no exception to this trend.

While energy poverty has been identified as a key issue for just energy transitions, attention is also growing to the opposite side of the social ladder and issues of excess energy use (Gossling and Humpe, 2023). The Belgian NECP timidly recognises this issue, ascertaining different responsibilities and outcomes for higher and lower income households and foreseeing stricter measures for high-income households to renovate their buildings. Portugal's NECP does not mention high-income households. Not mentioned in both NECPs is the narrower high-income group described as sumptuous spenders whose energy use largely surpasses the average household due to luxury consumption.

Finally, the private rental sector can be considered one of the harder-to-reach due to split incentives between landlords and tenants and other barriers. With more than one-quarter of households living in rented homes, Belgium's NECP recognizes the increased risk of energy poverty for tenants and defines measures to facilitate renewable energy sharing and energy renovation while seeking to protect tenants from rent increases. While Portugal's NECP mentions the need to rehabilitate social housing, it only mentions tenants once regarding a program to renovate privately owned housing, which is subsequently made available at affordable rent.

4.1.3.2 Non-residential sector

For non-residential HTR profiles, the assessment of the NECPs of Belgium and Portugal using the HTR energy users framework is shown in Figure 4.4.

Small and medium enterprises represent the overwhelming majority of enterprises in Belgium and Portugal, where barriers such as lack of knowledge, financing difficulties, and other priorities may hinder the uptake of energy interventions; these challenges are particularly severe in micro-businesses. Given the sheer size of these groups, it can be considered that they could be more extensively mentioned in the NECPs, particularly in the Portuguese one. Nevertheless, the plans frame the need to support smaller businesses in the energy transition while providing a few targeted and tailored measures, such as carrying out energy audits (with or without support depending on the size of the enterprise), implementing interventions with short payback times (mandatory), installing renewable energy systems, establishing awards for outstanding enterprises, withdrawing the use of F-gases, among others.

Commercial sub-sectors include a heterogeneous range of activities and services often neglected in energy policies. For the Belgian and Portuguese NECPs, this does not seem to be the case. A set of targeted measures is in place for the improvement of the energy performance of wholesale, such as capacity building and electrification of transport, and of retail, such as raising awareness on the need to close doors in heated or cooled establishments, replacing refrigeration equipment with more efficient ones, and promoting water efficiency. The need to improve energy performance in the tourism sector is extensively mentioned in the Portuguese NECP, with measures targeting buildings and transport, reflecting the sector's importance in the national context. Food services, such as restaurants and bars, are only mentioned in the Belgian NECP, where they are aggregated with the accommodation sector. The need to renovate office buildings is mentioned in both NECPs. The other activities profile encompasses sports, health, laundry, and other services, some of which are mentioned in the NECPs, including, for instance, through targeted measures for sports buildings in the Belgian plan.

HTR profile \ Member State	Belgium	Portugal
Small and medium enterprises	99,9 33 a), b), c), d), e)	99,9 6 b)
Micro-enterprises	96 2 d), e)	95 1 a)
Wholesale	7 5 d), e)	6 3 b), d)
Retail	11 10 c), e)	14 6 a), c)
Accommodation	1 1 c)	4 7 a), b), c), d)
Food services	7 1 c)	8 0
Offices	20 8 c), d)	27 3 a), c)
Other services	24 25 c)	15 5 a), c)

Figure 4.4 - Mentions of non-residential HTR profiles in the NECPs of Belgium and Portugal.

4.1.4 Conclusions

In this research, we have performed a cross-evaluation of the NECPs of Belgium and Portugal by applying an HTR energy users framework to scan for specific mentions of HTR households and businesses and understand the extent of their inclusion. NECPs are the key energy and climate policy instruments for the EU Member States, outlining the country's strategy until 2030. These are currently being updated, and it is critical to provide science-based recommendations that can contribute to their revision process. The following insights can be summarized:

i) Vulnerable households and energy poverty are mentioned in Belgium's and Portugal's NECPs, but specific HTR profiles are often overlooked. For both countries, these include people with low education levels, rural households, migrants, people with ill health, and other marginalized groups. The Portuguese NECP does not adequately mention other relevant groups, such as elderly people, multi-family buildings, single parents, and the unemployed. Recognition of these HTR groups can be improved, and more targeted and tailored measures can be outlined.

ii) High-income households are timidly mentioned in Belgium's NECP and completely overlooked in the Portuguese one. In line with recent research, this implies that more attention needs to be drawn to the issue of excessive energy consumption, mainly due to luxury consumption, if a just energy transition is to be enabled.

iii) Due to split incentives and other challenges, the rented building stock has historically been considered harder to reach. A relevant share of Belgium's population lives in a rented home. The NECP outlines targeted and tailored measures so tenants and landlords can find ways to improve energy performance. The Portuguese NECP does not adequately mention this issue.

iv) Small and medium enterprises represent over 99% of enterprises in both countries. The NECPs provide targeted measures to protect businesses from high energy prices and support them during the energy transition. Nevertheless, micro-enterprises where the challenges are particularly severe are scarcely mentioned.

v) The commercial/services sector is highly heterogeneous, with a wide range of activities and energy use patterns being considered HTR. Both NECPs adequately mention different subsectors within this group, establishing targeted measures. Specific subsectors, such as food services, seem to attract less attention.

While promising examples of recognition of HTR groups and targeted and tailored measures can be found, we argue that policymakers can do much more to ensure that energy policies really promote an ambitious, fast, and just energy transition that leaves no one behind.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia: Writing – review & editing, Validation, Supervision, Conceptualisation.

References

European Commission (2019). The European Green Deal. Brussels, 11.12.2019. COM(2019) 640 final.

European Commission (2021). 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality. Brussels, 14.7.2021. COM(2021) 550 final.

European Commission (2024). National energy and climate plans: EU countries' 10-year national energy and climate plans for 2021-2030. https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en

Gossling, S., and Humpe, A. (2023). Millionaire spending incompatible with 1.5 ºC ambitions. Cleaner Production Letters, 4, 100027. https://doi.org/10.1016/j.clpl.2022.100027

Government of Belgium (2023). Draft update of the Belgian National Energy and Climate Plan. Available at: https://commission.europa.eu/publications/belgium-draft-updated-necp-2021-2030_en

Government of Portugal (2023). Draft National Energy and Climate Plan 2021-2030 (NECP 2030): Update/Revision. Available at: https://commission.europa.eu/publications/portugal-draft-updated-necp-2021-2030_en

Ivanova, D., and Middlemiss, L. (2021). Characterizing the energy use of disabled people in the European Union towards inclusion in the energy transition. Nature Energy, 6, 1188–1197. https://doi.org/10.1038/s41560-021-00932-4

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., Gouveia, J.P., Palma, P., Realini, A., Maggiore, S., and Feenstra, M. (2023). Hard-to-Reach Energy Users: An ex-post cross-country assessment of behavioural-oriented interventions. Energy Research & Social Science, 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., Chester, M., Karlin, B., Ashby, K., Butler, D., and Chambers, J. (2020). Hard-to-Reach Energy Users: A Literature Review. User-Centred Energy Systems TCP - HTR Task. ISBN: 978-0-473-64983-8.

Sequeira, M.M., and Gouveia, J.P. (2023). Non-residential hard-to-reach energy users: A vast audience forgotten by the energy transition? 8th Meeting on Energy and Environmental Economics, Aveiro University, Portugal. https://doi.org/10.48528/v3b3-fk78

Sequeira, M.M., Gouveia, J.P., and Melo, J.J. (2024). (Dis)comfortably numb in energy transitions: Gauging residential hard-to-reach energy users in the European Union. Energy Research & Social Science, 115, 103612. https://doi.org/10.1016/j.erss.2024.103612

4.2 UsersTCP Task on hard-to-reach energy users: Case study analysis - Portugal

This work is published in: Sequeira, M.M., Gouveia, J.P., and Palma, P. (2021). Subtask 2: Case Study Analysis – Portugal. UsersTCP Task on Hard-to-Reach Energy Users, International Energy Agency Technology Collaboration Programme. HTR Task: Lisbon, Portugal. https://doi.org/10.47568/3XR115.

Preface

This report was developed under the 'Users Technology Collaboration Programme (TCP) by the International Energy Agency (IEA) Task on Hard-to-Reach (HTR) Energy Users'. The Task aims to provide country participants with the opportunity to share and exchange successful approaches identifying and better engaging HTR energy users. Under the Task, HTR energy users are broadly defined as 'any energy user from the residential and non-residential sectors, who uses any type of energy or fuel, and who is typically either hard-to-reach physically, underserved, or hard to engage or motivate in behaviour change, energy efficiency and demand-side interventions'.

Outcomes from the Task indicate that HTR energy users involve, for example, renters and landlords; low- and high-income households; the MUSH (municipalities, universities, schools, and hospitals) sector; small to medium enterprises / businesses (SMEs / SMBs); and people exposed to intersecting and compounding vulnerabilities based on factors such as age, race, gender, minority status, geographic, linguistic, technological or social isolation.

The case studies presented in this report aim to offer insights into programmes that aim to better engage HTR energy users in Portugal. Particular attention is given to design, implementation and behaviour change aspects. Other country case studies developed under the Task also include: Aotearoa New Zealand, Canada, Italy, the Netherlands, Sweden, the UK and the U.S.

We would like to thank all participating countries, their authors, and the interviewees who provided insights into their programmes targeting the HTR. I would like to particularly like to thank our National Experts and any national experts who undertook peer reviews.

All case studies can be found on the project's website.

Dr Sea Rotmann

Task Leader, Users TCP by IEA Task on HTR Energy Users

Wellington, September 2021

4.2.1 Country background: Portugal

Portugal is located in the Iberian Peninsula, in the southwest region of Europe. Historically, Portugal has suffered from a high external energy dependency of around 90%, as no fossil fuel production occurs in the country. However, the last decades saw a sudden increase in endogenous energy supply, mainly due to the investment in renewable energy sources, which brought down energy dependency to 72% in 2019. From 2005 to 2014, primary energy consumption registered a downward trend of around 2.3% per year due to the combined effects of the economic crisis, technological evolution, and modest energy efficiency policies. From 2015 to 2019, energy use increased almost 5%, signalling the slight rebound and stabilisation that followed the country's economic recovery (DGEG, 2020).

In 2019, transportation accounted for 36% of Portugal's final energy consumption, the country's most significant energy-consuming sector. The building sector represented 31% of energy use (17% from households and 14% from services). Finally, industry accounted for 29% of energy consumption (DGEG, 2020). Although no official data is available regarding Small and Medium Enterprises (SMEs), estimates indicate that industrial SMEs may represent 9% of national gross energy consumption, while service sector SMEs may account for 15% of total electricity consumption (Sequeira, 2016; Reuter *et al.*, 2021).

The Covid-19 pandemic crisis has had a tremendous impact on Portugal's everyday life and economic activities, leading to temporary shifts in energy consumption patterns. The national GDP is estimated to have fallen 7.6% on a year-on-year basis (INE, 2021). In 2020, primary energy consumption decreased 8.5% from 2019 levels (DGEG, 2021). For example, with the country on full lockdown in April 2020, compared with April 2019, private vehicles' fuel consumption was halved, while services and residential electricity use was reduced by 43% and increased by 31%, respectively (Portuguese Energy Observatory, 2020). Data from April 2021 suggests a tentative return to pre-pandemic normality regarding energy consumption patterns (Portuguese Energy Observatory, 2021a).

Portuguese buildings generally have low energy performance with a high incidence of problems, such as lack of thermal comfort, indoor air pollution, leakages, and humidity (Gouveia and Palma, 2019). Around two-thirds of the building stock predates energy performance regulations, and, according to the Portuguese long-term building renovation strategy, virtually 100% of existing buildings will need to be renovated by 2050 (Portuguese Government, 2021a). However, currently, energy renovation rates remain very low, with deep renovation estimated to occur in only around 0.01% of buildings annually, far below the values expected in the European Renovation Wave (INE, 2020; European Commission, 2020a). In addition, Portuguese buildings' energy use will likely be impacted by a changing climate, and Portugal has been pointed out as one of the European countries most vulnerable to climate change (EEA, 2017; Figueiredo *et al.*, 2020).

Regarding residential buildings, energy use in Portuguese households is the second-lowest per capita in the European Union (EU) (Eurostat, 2020). Although climate, culture and other country-specific factors play a role, research has uncovered systemic energy performance gaps and underconsumption in the Portuguese residential sector (Palma *et al.*, 2019; Horta *et al.*, 2019). In addition, based on the energy performance certificates available, around 70% of Portugal's close to 6 million dwellings are inefficient compared to current standards (C class or lower; Portuguese Energy Observatory, 2021b). Electricity is the primary energy source in households, followed by biomass, respectively 43% and 29% of consumption (DGEG, 2020). Main energy end-uses include cooking (39%), water heating (24%), space heating (22%), and electric appliances (11%; INE and DGEG, 2011). Energy-saving potential for Portugal's residential sector has been estimated at 50% of current consumption (Melo *et al.*, 2019).

Regarding non-residential buildings, public or private, data is still scarce in Portugal. Compared with the residential sector, the energy performance certificates available present a slightly improved picture, with around 43% of certified services buildings with a B-class or above (Portuguese Energy Observatory, 2021c). Electricity is the largest energy source for services, accounting for over 60% of consumption (DGEG, 2020). Non-residential buildings include a wide array of activities which further constrains in-depth analysis.

Portugal is committed to the global challenge of climate change, being a signatory of the Paris Agreement and following the directives emanated at EU level. The Carbon Neutrality Roadmap 2050 charts the long path towards full decarbonisation by 2050 (Portuguese Government, 2019). Buildings, end-users, and citizens are essential for the energy transition, and the roadmap sets urban renovation, energy efficiency, renewables integration, and energy poverty mitigation as key priorities. Furthermore, the National Energy and Climate Plan 2030 is the main policy instrument for the current decade and establishes the measures needed to keep the country in line with its long-term goals (Portuguese Government, 2020). Key targets for 2030 include a 45-55% reduction in greenhouse gas emissions from 2005 levels, a 47% share of renewable sources in final energy use and a 35% reduction in primary energy use.

4.2.1.1 Energy poverty in Portugal

Energy poverty is a multidimensional, severe societal problem in Portugal that negatively impacts public health and well-being, as well as the pursuit of overarching social, environmental, and economic goals (Portuguese Government, 2021b). It can be defined as the inability or difficulty to maintain an adequate level of essential household energy services and has some of its root causes in a combination of factors as low incomes, poor buildings energy performance and high energy prices, among others (adapted from Portuguese Government, 2021b). EU-SILC proxy indicators illustrating the situation in the country report:

i) 18.9% of households are unable to keep their home adequately warm (4th highest in the EU and well above the average of 6.9% in 2019),

ii) 35.7% of the population live in houses not comfortable cooled in summer (2nd highest and above the EU average of 20.9% in 2012), and

iii) 24.4% of the population live in dwellings with the presence of leak, damp or rot (2nd highest and above the EU average of 12.7% in 2019; Eurostat, 2021a; Eurostat, 2021b; Eurostat, 2021c).

According to the index developed by OPENEX (2019), Portugal is the fourth-worst EU country regarding domestic energy poverty. Gouveia *et al.* (2019) has explored the phenomenon for all its civil parish regions, both for winter and summer.

Electricity prices for Portuguese households in the second half of 2020 are in line with the EU average, whereas natural gas prices are above; however, purchasing power in Portugal is significatively lower than in other Member States with comparable energy prices (Eurostat, 2021d; Eurostat, 2021e; Eurostat, 2021f). The country's Gini coefficient reveals significant income disparities, and 16.2% of citizens are at risk of poverty (INE and PORDATA, 2021a). The recently released national Energy Poverty Mitigation Draft Strategy for 2021 to 2050, currently awaiting its final version, estimates that around 7% of the population may suffer from severe energy poverty, with up to 22% suffering from moderate energy poverty (Portuguese Government, 2021b). Covid-19 may have exacerbated existing social inequalities, possibly increasing energy poverty vulnerability in Portugal (Horta and Schmidt, 2021).

4.2.2 Portuguese hard-to-reach energy users

Until recently, scientific knowledge on energy poverty and vulnerable energy users was scarce in Portugal. In the past few years, however, these topics have received more attention from researchers, practitioners, and policymakers (*e.g.*, Gouveia and Seixas, 2016; Simões *et al.*, 2016; Gouveia, 2017; Gouveia *et al.*, 2018a; Horta and Sousa, 2018; Gouveia *et al.*, 2019; Horta *et al.*, 2019; and Portuguese Government, 2021b). In contrast, the concept of hard-to-reach (HTR) energy users is novel in Portugal, with virtually no research conducted explicitly under this umbrella. Nevertheless, HTR energy users, as broadly defined by Ambrose *et al.* (2019a) and extensively reviewed by Rotmann *et al.* (2020), may represent a large and growing percentage of the Portuguese population and their participation in a citizen-centred, local-scale, sustainable and inclusive energy transition is crucial to achieve the twin goals of decarbonisation and energy poverty alleviation.

Despite their importance to overall societal aims, engaging with HTR energy users has been slow due to numerous and wide-ranging barriers (Backlund *et al.*, 2012; Ambrose *et al.*, 2019a). These include key challenges such as split incentives, insufficient knowledge, high transaction costs, market fragmentation, shortage of finance, lack of information, competing priorities, and mistrust of energy providers (Schleich and Gruber, 2008; Labanca *et al.*, 2015).

To better target the HTR, the first step should be to identify and characterise this remarkably heterogeneous group of residential and non-residential energy users in the specific Portuguese context. It is essential to understand their unique perspectives regarding behavioural change, energy efficiency, building renovation, renewable energy, demand flexibility, and the gaps and barriers that hinder their involvement in the energy transition. This is a prerequisite for developing tailor-made and context-specific measures that effectively target HTR energy users from the national to the local scale. The following analysis presents a first exploratory attempt at identifying and estimating some Portuguese audiences, who might potentially be HTR energy users, in the residential and non-residential buildings sector.

4.2.2.1 Residential sector

HTR households can be considered as those facing a wide range of vulnerabilities and whose circumstances or characteristics present severe barriers to engage in energy issues (Ambrose *et al.*, 2019a). Considering the Portuguese population of 10.3 million people, corresponding to around 4.1 million families, a few national-scale socio-economic indicators can be used to explore this concept (INE and PORDATA, 2020). These tentative proxy indicators are shown individually in Table 4.3, although, in the real world, vulnerabilities can often be hidden or add up, and regional differences should also be accounted for. The rationale is explained below.

Table 4.3 - Indicators relevant for the identification and characterisation of HTR households.

Indicator	Number of families	Share of families (%)	Number of people	Share of population (%)	Reference year, source
Natural gas social tariff recipients	55 281	1.3	-	-	2021 (DGEG and Portuguese Government, 2021)
Total electricity social tariff recipients:	797 337	19.2	-	-	
- Due to income	398 364	9.6	-	-	2020 (Portuguese Government, 2021b)
- Due to social assistance	203 539	4.9	-	-	
- Due to income plus social assistance	150 001	3.6	-	-	
Family income < 5 000 €	677 673	12.5*	-	-	2019 (AT/MF and PORDATA, 2021)
Family income level 5 001 - 10 000 €	1 446 100	26.7*	-	-	
Family income level 10 001 - 19 000 €	1 625 421	30.5*	-	-	
Family income level 50 001 - 250 001 €	309 435	5.7*	-	-	
Family income level > 250 001 €	4 180	0.1*	-	-	
Population at risk of poverty (income below 6 480 € after social transfers)	-	-	1 666 381	16.2	2019 (INE and PORDATA, 2021a)

Population with severe housing deprivation conditions	-	-	473 170	4.6	2020 (INE and PORDATA, 2021b)
Elderly (>65 years old) living alone	-	-	513 200	5.0	2019 (INE and PORDATA, 2020)
Families with representative > 65 years old	1 445 000	34.8	-	-	
Families with representative < 34 years old	368 900	8.9	-	-	
Single-parent families	470 654	11.3	-	-	2020 (INE and PORDATA, 2021c)
Single-parent families led by women	398 572	9.6	-	-	
Migrant population with legal status	-	-	604 140	5.9	2019 (INE *et al.*, 2020)
Unemployed population	-	-	350 900	6.8**	2020 (INE and PORDATA 2021d)
Population with social pension of old age or disability below minimum wage	-	-	1 614 171	18.1***	2019 (ISS/MTSSS and PORDATA, 2020)
Families with children receiving social assistance	820 330	19.8	-	-	2020 (II/MTSSS & PORDATA, 2021)
Adult population without formal education	-	-	478 300	5.6***	2020 (INE and PORDATA, 2021e)
Adult population with education below the 12th grade (current mandatory minimum)	-	-	4 894 200	55.0***	
Families living in rented dwellings	1 067 841	25.7	-	-	2011 (INE and PORDATA, 2015)
Families in informal dwellings	6 612	0.2	-	-	
Families living in social housing	112 188	2.7	-	-	2015 (INE, 2016)
Population living in settlements with fewer than 2 000 inhabitants	-	-	4 124 307	40.1	2011 (INE and PORDATA, 2018)
Population living in settlements with fewer than 10 000 inhabitants	-	-	6 055 272	58.9	

Notes: *Considering a total number of 5 408 288 fiscal families (AT/MF and PORDATA, 2021); **Official unemployment rate in 2020 (INE and PORDATA, 2021d); ***Considering adult population of 8 898 924 people (INE and PORDATA, 2020).

The selected indicators, based on Ambrose *et al.* (2019b), Ashby *et al.* (2020), and Rotmann *et al.* (2020), among other relevant literature (*e.g.*, Gouveia *et al.*, 2019), showcase a wide array of population profiles that may be associated with potential situations of vulnerability and HTR energy users. For example, the Energy Social Tariff is a social support scheme to increase vulnerable consumers' access to essential energy services (Martins *et al.*, 2019). It is currently given to around 19% of Portuguese families, which can be considered HTR due to their low income and/or need for social assistance.

Using only lower gross incomes as a generic metric, it is noteworthy that around 70% of Portuguese fiscal families are in the bottom four tax levels, substantially below family average net income of €34,000 per year (INE and PORDATA, 2021a). These families' engagement in energy issues is hindered by their lack of investment capability. Around 16.2% of the population is still at risk of poverty, and, according to the draft of the National Energy Poverty Strategy, up to 29% of people may suffer from energy poverty (Portuguese Government, 2021b). In contrast, the top three tax levels (high-income) only account for 5.8% of families.

Age can be an important factor in the households' capability to participate in energy issues. In Portugal, there is a high share of families whose head of household is above 65 years old and, according to some research (*e.g.*, Abreu *et al.*, 2020), less prone to invest in improving energy performance. On the other hand, younger and more recent families can experience a shortage of funds, lack of knowledge and conflicting life priorities, even if they seem more inclined to act, particularly, to improve their children' comfort and health (Mahapatra *et al.*, 2019). These two situations can account for almost half of Portuguese families. Moreover, elderly people living alone are particularly vulnerable to energy poverty issues (Ambrose *et al.*, 2019b).

Context-specific characteristics such as single-parent families and migrant status may be associated with an HTR condition, with strong links to broader gender and ethnic inequalities (Feenstra and Clancy, 2020; Churchill and Smyth, 2020). Other vulnerabilities such as unemployment, child-related social support, and dependence on very low income from pensions due to old age, disabilities, or illness can also hinder households' ability to engage in energy issues. In addition, higher education levels are widely considered an enabler of engagement (Hall *et al.*, 2021). However, in Portugal, more than half of the adult population has an education level below the 12th grade (current mandatory minimum).

Although the share of the population living in rented dwellings, social housing, and informal settlements in Portugal is low compared to other EU countries, these can be particularly HTR regarding energy issues. While the share of rented dwellings sits at 26%, it reaches 40% for population below 60% of median equivalised income (Eurostat, 2021g). People living in rented houses can be quite heterogeneous – *e.g.*, with varying levels of income, types of contracts (or lack thereof), and rental durations, including specific subgroups such as dislocated students. They may experience split incentives where neither the renter nor the landlord invests in energy performance (Bouzarovski *et al.*, 2020). Social housing, governed by a single organisation, could present a different situation altogether, with an easier-to-reach profile if sufficient funds were to be allocated (European Commission, 2020a). Finally, informal settlers, illegal migrants, and stigmatised and criminalised people (*e.g.*, the homeless) are also mentioned as HTR by Rotmann *et al.* (2020); these are hard to account for in Portugal.

Around 90% of Portuguese residential buildings are designed to accommodate only one or two families (INE, 2012). However, 46% of citizens currently live in apartments, while 54% live in single-family houses (Eurostat and PORDATA, 2020). The adoption of building renovation and renewable energy measures can be complex in multi-family buildings where decisions and investment need to be approved by multiple house owners (Eisermann *et al.*, 2019).

Almost 60% of Portuguese citizens live in less-densely populated settlements, such as suburbs and rural areas, which could make them HTR due to geographical isolation and lack of available services, as also reported by Ashby *et al.* (2020), and due to the use of unregulated and unreported energy carriers. In Portugal, around half of the population aged between 16 and 74 years old has below-basic digital skills, women being five percentage points behind men, which can hinder their participation in an increasingly digital energy system (Eurostat, 2021h). The Portuguese Energy Services Regulator (ERSE, 2020) ranked residential energy literacy levels at 43 out of 100 points, highlighting higher values among male consumers between 36 and 55 years old, with at least ten years of education, who are responsible for managing their family's energy bills.

In summary, the Portuguese residential sector showcases a wide range of structural socio-economic vulnerabilities, low education levels, dependence on social assistance, gender and ethnic inequalities, low housing quality, and widespread energy poverty. The lower-income factor alone may deem two in every three households as HTR with traditional energy policies and measures; other vulnerabilities and circumstances will significantly add to this problem.

4.2.2.2 Non-residential sector

SMEs are defined by the European Commission (2020b) as enterprises with less than 250 employees and an annual turnover of less than 50 million euro. These enterprises are described as HTR energy users by Ashby *et al.* (2020) and Rotmann *et al.* (2020); however, research on their role in the energy transition is still scarce. Large companies, energy-intensive industries and the public sector should theoretically be easier to reach by traditional energy policies since they have facilitated access to finance and expertise, their number is small, and organisational structures are well-defined (Schlomann and Schleich, 2015). Considering the universe of 1.3 million enterprises in Portugal, SMEs account for a staggering 99.9% of enterprises, employ 77% of private-sector workers, and generate 56% of business revenues (INE and PORDATA, 2021f). Table 4.4 presents further details on Portuguese SMEs.

Table 4.4 - Portuguese SMEs according to their number of employees.

Type of enterprise	Number	Share of total enterprises (%)	Reference year, source
Micro enterprises (less than 10 employees)	1 281 857	96.0	2019 (INE and PORDATA, 2021f)
Small enterprises (10-49 employees)	44 492	3.3	
Medium enterprises (50-249 employees)	7 300	0.5	
Total SME (less than 250 employees)	1 333 649	99.9	

Portuguese SMEs can be disaggregated by economic activity, as shown in Figure 4.5. Significant shares of these activities, *e.g.*, retail, food services, education, and health, take place either in commercial, mixed-use or residential buildings. The Portuguese Energy Services Regulator (ERSE, 2020) ranked businesses' energy literacy levels at 50 out of 100 points, slightly above the score for households, highlighting that it was higher among enterprises with over 10 employees and higher revenues. Considering the share of micro-enterprises, at least 96% of Portuguese business might be deemed HTR energy users. Their engagement in energy issues through traditional policies and measures is seriously hindered by a wide range of barriers and vulnerabilities, such as lack of knowledge and shortage of funds, as described in Portugal by Brazão and Melo (2012) for industrial SMEs and Sequeira and Joanaz de Melo (2020) for service sector SMEs.

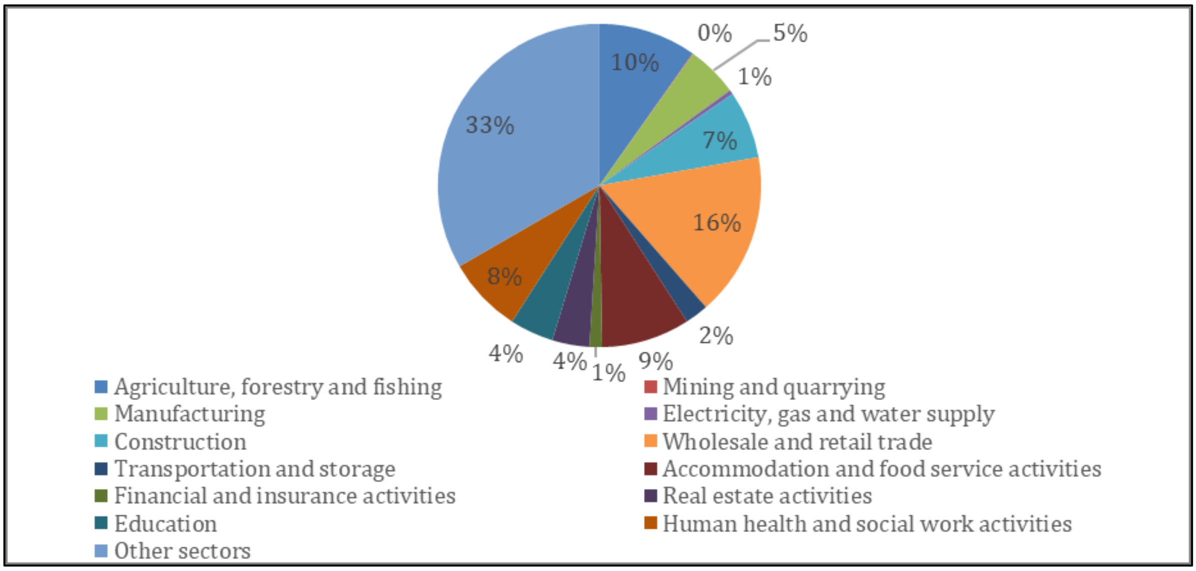


Figure 4.5 - Share of SMEs according to economic activity in 2019 (adapted from INE and PORDATA, 2021f).

4.2.2.3 Targeting and engaging the hard-to-reach

Whilst stressing the importance of increasing energy efficiency in buildings, the Portuguese Carbon Neutrality Roadmap and the Long-Term Strategy for Buildings Renovation acknowledge the need for addressing energy poverty, *i.e.*, vulnerable HTR energy users, but do not advance any specific measures for their identification, targeting and support. The National Energy and Climate Plan 2030 paved the way for the development of a National Energy Poverty Strategy. In the draft version of this instrument, the Portuguese Government (2021b) foresees energy efficiency vouchers (Vouchers Eficiência programme) for energy-poor households, and support of renewable energy communities in vulnerable neighbourhoods. The concrete implementation of these measures and their impact on the HTR remains unknown since no ex-ante evaluation was performed. However, most current energy policies for the residential sector have been developed at a strategic level, with instruments, in general, lacking sufficient tailoring to deliver the expected results (Gouveia and Palma, 2021a).

In Portugal, currently implemented policy measures aimed directly at supporting vulnerable households are the automatic social tariffs, reduction of VAT taxes on energy prices and delay of energy disconnections (Gouveia and Palma, 2021b). During the Covid-19 pandemic, disconnections were suspended. A small, extraordinary aid was attributed to residential energy bills, and SMEs were supported at national and municipality levels (*e.g.*, government-backed lay-off schemes, loans and grants; Hesselman *et al.*, 2020).

A few financing schemes have focused on residential energy efficiency improvements, ranging from soft loans (*e.g.*, Casa Eficiente 2020 programme) to grants (*e.g.*, Edifícios Mais Sustentáveis programme). While grants have shown considerably more success than loans, neither is aimed at HTR energy users. Most Portuguese financing schemes to date involve a high degree of bureaucracy and require available own funds and know-how, thus catering to the needs of only easier-to-reach households. On the other hand, HTR energy users benefit from programmes that, while not aiming directly at energy performance, promote interventions in vulnerable households, precarious buildings, disadvantaged communities, and social housing (*e.g.*, 1º Direito and Reabilitar para Arrendar). The PPEC programme (Efficiency Promotion Plan in Electricity Consumers) supports the implementation of energy efficiency measures in end-users through tangible and intangible interventions; a few have focused on HTR energy users, including small businesses and households (DGEG and ERSE, 2016).

Beyond the scarce governmental interventions, a few non-governmental organisations, cooperatives, and research centres have implemented projects affecting HTR energy users. The social organisation Just a Change mobilises volunteers for the rehabilitation of precarious poverty-stricken houses, with a track record of 262 renovated dwellings and 4,600 beneficiaries (Just a Change, 2020). The renewable energy cooperative Coopérnico invests in decentralised photovoltaic projects and, while the cooperative members can be regarded as educated and medium/high-income, it aims to expand its activities towards the vulnerable and the energy-poor through new initiatives (*e.g.*, European project POWERPOOR; (Coopérnico, 2020). Furthermore, CENSE FCT-NOVA, jointly with Coopérnico and Just a Change, co-branded the ENERGY ACTION Project, where energy efficiency tips were disseminated on social media (Gouveia and Palma, 2021b). In 2020, CENSE FCT-NOVA, during a European project co-funded by the EIT Climate-KIC, developed the Green Menu (Menu de Renovação Verde) – a digital one-stop-shop for residential buildings renovation.

Several Portuguese entities working on energy topics (CENSE FCT-NOVA, DECO, RNAE, Lisboa E-Nova, AdePorto, ADENE, ERSE, INESC TEC, DGC, DGEG, and S. Energia) took part in supporting the Energy Efficiency Roadshow initiative from the European Commission held in Lisbon and Porto in 2018. This roadshow featured an interactive exhibition with tips on saving energy, with over 4,000 visitors in Portugal (Gouveia and Palma, 2021b). In 2020, in the scope of the European project STEP, the Portuguese Association for Consumer Protection (DECO) created an office to provide personalised advice on energy management. FCT-NOVA is part of the EPAH – EU Energy Poverty Advisory Hub (2021-2024) coordination team – aiming to provide technical assistance to European municipalities implementing sustainable solutions to alleviate energy poverty. Several Portuguese researchers are also integrated in the activities of the EU COST ACTION – ENGAGER on Energy Poverty (2017-2022).

As the HTR concept, applied to energy users, is relatively novel in Portugal, policies, projects, and measures have not explicitly focused on this topic. Nevertheless, most of the examples synthesised above present relevant experiences to the broader context of Portuguese HTR energy users. The two case studies analysed in the next section, following the methodological approach defined by Karlin *et al.* (2021), were chosen due to their particular focus on targeting and engaging with HTR audiences, their innovative nature in Portugal, and their scope on the residential (Case Study 1) and non-residential (Case Study 2) sectors, as requested by Rotmann *et al.* (2021). The first case study presents an energy poverty vulnerability index, developed by Gouveia *et al.* (2019), which enabled the nationwide mapping of household vulnerabilities. In the LIGAR - Energy Efficiency for All project, the index was used to identify critical regions, and vulnerable energy users were engaged through household interviews (Horta *et al.*, 2019). The second case study Energy Efficiency in Telheiras' Traditional Commerce showcases a neighbourhood-scale project aimed at energy efficiency improvement in traditional commerce and services SMEs, combining energy audits, surveys, and community engagement (Sequeira and Joanaz de Melo, 2020).

4.2.3 Methodology

The overall methodology followed the co-designed CSA methodology and template (Rotmann *et al.*, 2021). Our HTR Task follows a recently-developed research framework by See Change Institute, called 'The ABCDE Building Blocks of Behaviour Change' (BBoBC; Karlin *et al.*, 2021). The ABCDE Building Blocks framework serves as a systemised and data-driven approach to designing, implementing, and evaluating behaviour change interventions, including for those aimed at HTR audiences. These Building Blocks include (see Fig. 1 in Karlin *et al.*, 2021):

- Audience: the pilot or programme's intended participants
- Behaviour: the specific behaviour the programme intends participants to change
- Content: the programme strategy and approach
- Delivery: the mechanism and timing of the intervention (*e.g.* delivery may happen through door-to-door interactions or social media, etc.)
- Evaluation: the way in which programme success is measured or otherwise assessed

Throughout the development of these case studies, it became clear that some of the building blocks applied more readily to these programme examples than others, as discussed in moredetail in the General Discussion section of this document. As will become apparent in each case study, Content and Delivery are often closely linked. Given that certain content lends itself more readily to specific delivery channels, it can be a bit tricky to untangle which was content and which was delivery. The other building blocks, for the most part, proved more straightforward to apply to these concrete programme examples.

4.2.3.1 Methods of data collection for each CSA

The methodology to develop the case studies is simple, and is composed of the following elements (from Mundaca, 2021).

First, the case studies were chosen based on the outcomes of previous activities undertaken by the Users TCP HTR Task. As indicated in the previous section, these activities aimed to identify and characterise HTR audiences in participating countries. To that end, a variety of data sources were used, including an international survey, interviews with experts and practitioners, and a literature review (for details, see Ashby *et al.*, 2020a and b; Rotmann *et al.*, 2020). We then reached out to our funders and other stakeholders to identify the most appropriate CSAs for Portugal.

From an analytical point of view, the approach adopted the BBoBC framework developed (for details see Karlin *et al.*, 2021; and Rotmann *et al.*, 2021). Data gathering was guided by an interview protocol that addressed each building block, and the set of questions can be found in Rotmann *et al.* (2021).

Interviews (~60 minutes) supported data collection and provided a deeper understanding of the chosen cases. These were conducted by the author of this report and the following people were interviewed:

- Dr. Ana Horta, Senior Researcher at ICS
- Prof. João Joanaz de Melo, Environmental Engineering Professor at FCT-NOVA
- Luís Keel Pereira, Coordinator of the Local Partnership of Telheiras

Finally, the case studies were supported by a review of official documentation and related journal publications. This phase also included the analysis of information found on the websites of the four initiatives, and multiple (ex-post) evaluation reports and papers.

4.2.4 Portuguese case study – Residential

4.2.4.1 Background

The project LIGAR - Energy Efficiency for All was promoted by the National Energy Agency of Portugal (ADENE) and counted with the participation of entities with diverse backgrounds: CENSE FCT-NOVA, Institute for Social Sciences of the University of Lisbon (ICS), Sair da Casca (consultancy company in sustainability and social responsibility), and CDI Portugal (non-governmental organisation for inclusion and innovation). LIGAR was funded in the scope of the PPEC Programme and approved by the Portuguese Energy Services Regulator. The project adopted an inclusive approach for implementing consumer engagement actions to increase energy efficiency in vulnerable homes and reduce energy poverty. An interview was conducted with Dr. Ana Horta, senior researcher at ICS and a specialist in social studies on energy poverty, aiming to deepen the configuration and analysis of this case-study.

In the first phase of the project, CENSE developed a multidimensional high-resolution Energy Poverty Vulnerability Index (EPVI) to assess energy poverty vulnerability in all 3,092 Portuguese civil parishes (local administrative units smaller than municipality), aiming to identify and map hotspots of vulnerability in winter and summer (Gouveia *et al.*, 2018b; Gouveia *et al.*, 2019). The index combines the calculation of an energy performance gap (difference between theoretical and actual energy consumption) by Palma *et al.* (2019), using data on construction characteristics of buildings, climate variables, heating and cooling technologies, and official energy consumption statistics for the residential sector; with the adaptive capacity of the population, using socio-economic indicators, into a value of vulnerability ranging from 1 (least vulnerability) to 20 (maximum vulnerability). The average weights of the different indicators for computing the adaptive capacity were selected according to the feedback provided by 13 experts of the consortium. The selected socioeconomic indicators were the following: population with 4 or fewer years of age, population with 65 or more years of age, average monthly income, dwelling owned by the occupant, population with a university degree, unemployment rate, and building state of conservation.

The EPVI results were analysed together with complementary regional indicators such as the share of social housing, informal dwellings, and social tariff recipients typically associated with the concept of HTR energy users. As a result, a shortlist of 168 priority regions was picked. Of this bunch, ten regions from mainland Portugal were selected for the next phase of the project, according to their higher vulnerability levels in summer and winter, territorial typology (rural/urban), size of the population, and easiness in accessibility and communication with local authorities, which were regarded as important intermediaries to engage with the population. The EPVI mapping and the ten selected regions are displayed in Figure 4.6.

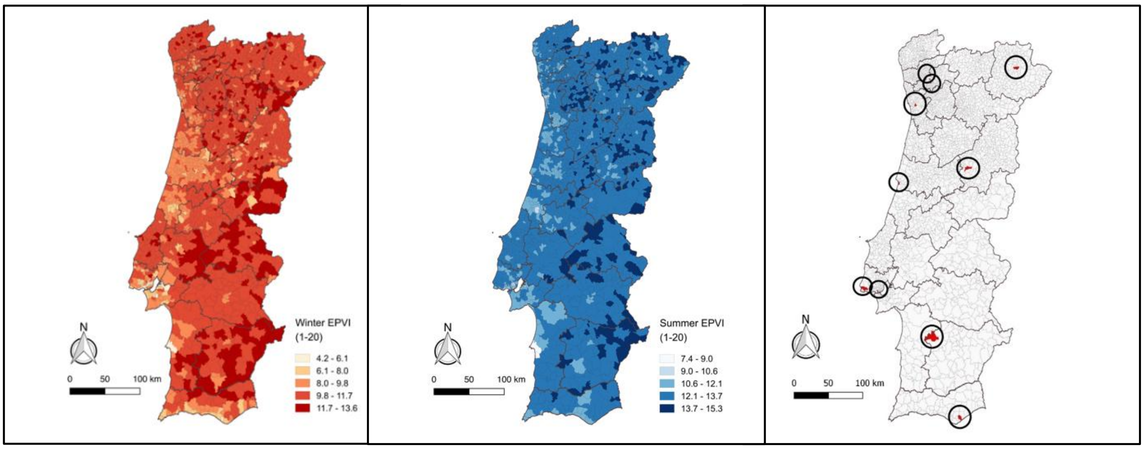


Figure 4.6 - Winter EPVI map (left), Summer EPVI map (centre) and the ten selected regions for intervention (right) (Gouveia *et al.*, 2019; Horta *et al.*, 2019).

4.2.4.2 Audience

In the second phase of the project, ICS devised a methodology to qualitatively study the population, or audience, of the selected regions in what pertains to the circumstances conducive to a situation of energy poverty and its impact on well-being and daily life. The goal was to identify opportunities for interventions and to develop energy poverty alleviation strategies. The method consisted of household interviews – a total of 100 were conducted, distributed by the 10 selected regions from north to south Portugal (10 in each region) to represent the diversity of realities in the national territory.

The interview script integrated common theoretical approaches in sociologic research, like practice theory, to capture the complexity of social dynamics and practices regarding elements such as the use of energy technologies, competencies, and meanings. The interviews touched on the following dimensions: dwelling characterisation, renovation works, conservation state, satisfaction about the dwelling, notion of comfort, evaluation of thermal comfort, practices to cope with the cold and the heat, domestic equipment, energy consumption, energy savings, family budget, impact of the economic crisis, energy supply contracts, access to information, daily habits, and household composition.

> *"It was important not to mention that we were analysing 'energy poverty' but rather studying domestic energy consumption and energy efficiency, as not to put a negative charge on the interviews, which were inevitably a moment of intrusion and tension. The interviewees did not directly benefit from the interview, so it would have been beneficial to provide a compensation for participants, to increase participation rate and motivation. However, this was not possible due to project budget limitations."* Dr. Ana Horta, Senior Researcher at ICS (quote translated by the authors).

With the help of the local authorities, the interviewees were selected according to different profiles of households, dwelling typologies and neighbourhood characteristics to have a diversified sample and capture vulnerable households (Horta and Sousa, 2018). Single-parent families with low income or unemployed, young families with 2+ children (up to 4 years old), big families (with 3+ dependent children), and elderly couples or single persons with low pensions were among the selected in the interviews' sample. Interviewees also included people residing in single-family and multi-family buildings, rented and owned dwellings, rural and urban settings, and different types of neighbourhoods (requalified and non-requalified). The differences in gender, age and income were carefully considered in the sample.

> *"The intermediaries between the project and the vulnerable population were social workers from the local authorities (civil parishes), with whom the population had already a previous connection and an ongoing trusted relationship. This was key to reach and engage these vulnerable groups, who frequently shy away from this kind of interaction."*
> Dr. Ana Horta, Senior Researcher at ICS (quote translated by the authors).

Interviews were primarily conducted in person, with minor exceptions, via computer or telephone. A total of 134 participants were interviewed (as some of the interviews included more than one member of the same family), and their demographic indicators are depicted in Figure 4.7. A literature review process prior to the qualitative analysis highlighted the difficulty of interviewees of these selected profiles in guaranteeing an adequate level of essential energy services in their home due to lack of financial resources, low education levels, and low energy performance of their dwellings, among other reasons.

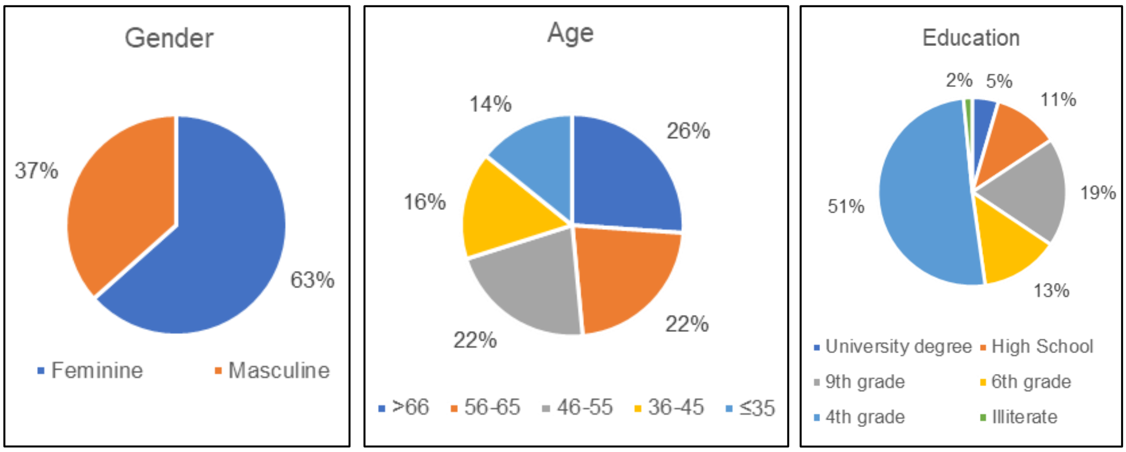


Figure 4.7 - Sociodemographic characterisation of the audience (adapted from Horta and Sousa, 2018).

4.2.4.3 Behaviours

Results show that more than half of households (56%) report living in a home that is either too cold in the winter or too hot in the summer, and only 16% have thermal comfort in both seasons (Horta *et al.*, 2019). The reasons behind these reports are the low quality of dwellings, with frequent air and water leakages and humidity and mould, but more importantly, the high cost of energy when compared with the lower income levels. Several interviewees claim that their dwelling needs renovation, although the lack of financial resources and/or their tenant status makes the process more difficult.

In the winter, these vulnerable households adopt basic daily practices such as using more clothing, blankets and covers and going to sleep earlier instead of using heating appliances (Horta *et al.*, 2019). In the summer, they opt to open the windows and doors to cool their home. Households show a lack of knowledge regarding the energy consumption of domestic appliances and measures to reduce it. Appliances are generally old, and consumers are unaware of the energy label when purchasing them, paying more attention to their price. New appliances can also be problematic, as people have difficult working with them. It can result in misuse, with unnecessary increase in energy consumption or no use at all, potentially creating stress and discomfort. Some people also have personal preferences regarding certain appliances, even if they are not the best option economically and for their comfort. In general, these groups are very resistant to change. There is evidence of a cultural normalisation of feeling cold, especially in regions with a milder climate, translating in habituation and desensitisation to cold temperatures inside homes (Horta *et al.*, 2019).

> *"The essential interventions, such as building renovations and equipment replacement, involve significant investment that people often cannot afford. People instinctively adopt some energy-saving behaviours, except for the frequent use of old freezers and refrigerators, where they store large amounts of food bought on discount in the supermarket, aiming to save money on food but ending up spending more on energy. Stand-by consumptions are often disregarded. There is an opportunity for savings by adjusting energy contracts."* Dr. Ana Horta, Senior Researcher at ICS (quote translated by the authors).

> *"People with low education levels have more difficulty dealing with their vulnerable situation, asking for help, or finding ways to solve their problems. The feeling of shame, which is transversal to all the analysed profiles, is also a major factor behind the condition of hard-to-reach, since it prevents people from speaking out about their problems."* Dr. Ana Horta, Senior Researcher at ICS (quote translated by the authors).

Several opportunities of interventions surfaced at the end of this phase:

i) increasing public awareness for the severity of energy poverty in Portugal,
ii) calling for local and national decision-makers to address regulation and monitoring of domestic energy prices, residential buildings' energy performance, and construction norms,
iii) breaking unhelpful social constructs regarding thermal (dis)comfort,
iv) raising awareness of authorities regarding the state of social housing,
v) providing information to prevent inadequacy between energy supply contracts and consumers' needs, and

vi) increasing awareness and knowledge about the efficient use of appliances and domestic equipment.

"There is a generalised lack of trust when it comes to government support. People are not used to it and do not expect authorities to provide help and promote collective well-being. They are suspicious of bureaucracy. Many have trouble reading and writing and do not know what interventions they need. Often their homes need deep retrofit, which cannot be fully covered by current programmes. There are also significant levels of informal economy and people are afraid to get caught if they apply for support instruments." Dr. Ana Horta, Senior Researcher at ICS (quote translated by the authors).

4.2.4.4 Content

In the third and last phase of the project, drawing on the knowledge obtained in the previous stage, ADENE, Sair da Casca and CDI Portugal developed various initiatives to engage the local community and tackle the identified causes of vulnerability. The first one was the development of an energy efficiency manual (ADENE, 2019) for local agents and the wider population, addressing all the areas about which a lack of information was identified. An ideation contest was also implemented in the selected regions, aiming to promote innovative ideas to stimulate awareness and involvement of local agents for energy efficiency whilst guaranteeing execution and continuity.

Finally, energy brigades were organised, where local groups personally supported vulnerable households to use energy more efficiently. These brigades involved training sessions for local agents at first and then visits of these agents to local households, for diagnosis of housing conditions and equipment, observation of behaviours and understanding of choices, identification of less-efficient practices and appliances, support the interpretation of energy bills and contracts, and advise and educate on better daily practices.

"Support can be most effective when provided by a trained multidisciplinary team, equipped with both technical and interpersonal skills, with frequent visits to vulnerable homes, before, during and after a particular intervention. It would be beneficial to have a local example in each civil parish of a dwelling in which successful interventions were performed, to increase confidence and adhesion to support actions." Dr. Ana Horta, Senior Researcher at ICS (quote translated by the authors).

4.2.4.5 Delivery

In the final phase of the project, delivery was executed through the form of energy efficiency materials provision, event organisation and home visits by the project's partners. Material provision and event communication was mostly done through the website of the project. Home visits were organized with local authorities' intermediaries, so that people would feel more comfortable and trusting of the team visiting their homes. Arguably, the ideation contests had no impact since there were no project proposals from contestants, which denounces problems in the strategy execution. The energy efficiency manual is available to the public and local agents, intending to support energy users. The impact of this strategy is somewhat connected with the willingness of the local authorities and citizens themselves to engage with it. The energy brigades are based on a more proactive form of delivery, as agents contacted the consumers and visited them in their homes, potentially increasing the impact of the intervention.

4.2.4.6 Evaluation

The specific impact of implemented measures was not monitored after the project ended. The real effect of these measures has not been evaluated in the long term, as it is difficult to measure due to its subjective and intangible nature and since they relate to a complex multi-faceted issue as energy poverty. The number of areas targeted (10), number of vulnerable households interviewed (100), and number of interventions (500) were the key indicators to evaluate the performance of the project after its end date.

4.2.4.7 Discussion

This project had a comprehensive approach, from mapping and pinpointing vulnerable regions to identifying and engaging households, and implementing solutions, using different quantitative and qualitative methods in each phase. It involved a wide array of collaborators with diverse backgrounds and expertise, and it targeted different profiles of HTR energy users across the country. While complex, the second and third phases of the project could be replicated in other regions to reach more vulnerable HTR energy users in Portugal. These can be regarded as the main positive takeaways from this project. On the other hand, implemented initiatives had limited impact, as they only focused on information and awareness, leaving out physical and financial interventions, which play a significant part in improving energy performance and reducing energy poverty in HTR energy users. Moreover, the project did not have any follow-up nor were its impacts evaluated at short- or long-term, which makes it difficult to evaluate the effectiveness of the implemented solutions in helping the targeted vulnerable consumers.

4.2.5 Portuguese case study – Non-residential

4.2.5.1 Background

The core tasks of the project Energy Efficiency in Telheiras' Traditional Commerce were conducted in the scope of a master's thesis work in Environmental Engineering at FCT-NOVA (Sequeira, 2016). Two interviews were performed to deepen this case study analysis: João Joanaz de Melo – Environmental Engineering Professor at FCT-NOVA, energy efficiency expert, and academic supervisor of the project –, and Luís Keel Pereira – Coordinator of the Local Partnership of Telheiras and community representative for the project.

The reasoning behind the project was that, despite their acknowledged importance in overall energy consumption and urban sustainability, services and commerce sector SMEs had been little studied and reported in the literature. The lack of policy measures, projects, and actions, as well as scarce and disconnected approaches between researchers, citizens, businesses, and authorities, have undermined the sector's involvement in the energy transition. A literature review conducted before the study revealed the wide-ranging and severe barriers that SMEs face when acting on their energy performance, placing them within the HTR framework.

> *"To achieve the European Green Deal targets and to have a less intensive energy system, we need to reach everybody. We know that SMEs represent something like half of the energy consumption in industry and services in Portugal, but the sector has been absolutely neglected in public policy."* João Joanaz de Melo, Environmental Engineering Professor at FCT-NOVA.

In this context, the project's key goals were to explore the energy-saving potential in the small business service sector and understand the drivers and barriers influencing energy-related behaviours and decisions. Chosen methods took a sequential approach from the mapping and characterisation of target users to the performance of energy audits and surveys and to the provision of direct counselling to project participants and the community (Sequeira and Joanaz de Melo, 2020). The selection of the Telheiras neighbourhood in Lisbon instead of random businesses across the city resulted from:

i) the recognition that a community-based approach would facilitate personal relations with the participants (word-of-mouth playing an essential role in small businesses),
ii) the simpler logistics of conducting fieldwork in a single neighbourhood compared with larger areas, and
iii) the pre-existing solid connections with community associations and other local stakeholders that could support communication and engagement with local businesses and reinforce project outcomes in the long-term.

A shared aim between the project managers and the Local Partnership of Telheiras, which gathers several associations and informal groups active in the neighbourhood, was to go beyond the academic work and generate impact in business and community awareness of energy issues.

> *"As the Local Partnership of Telheiras, we try to involve all groups of our community in everything we do. And local commerce is one of the most difficult groups to engage because they have limited time and are mostly focused on keeping their business running. It made a lot of sense to support this project because we were already trying to develop some ideas on promoting sustainability, and we always try that these initiatives*

also contribute to foster community building." Luís Keel Pereira, Coordinator of the Local Partnership of Telheiras.

4.2.5.2 Audience

The target audience was defined as small businesses of the services and commerce sector that operate mainly at the neighbourhood scale in Telheiras. Six groups of activities were analysed: general retail, refrigerated retail, food services (restaurants, bakeries, coffee shops), health and beauty (hair salons and small medical clinics), associations (sports, arts and social associations), and print shops (Sequeira, 2016). Offices and 'others' were excluded from the scope of the study: offices because they have been the object of other studies and the 'others' group because they were too diverse for a meaningful analysis. At the time, the HTR formulation was not an explicit motivation for selecting the target audience. Nevertheless, the project's participants, and SMEs in general, can be regarded as HTR energy users due to a combination of factors such as lack of awareness, insufficient knowledge, low priority attributed to energy management, split incentives, mistrust, and shortage of funds (Sequeira and Joanaz de Melo, 2020; Rotmann *et al.*, 2020).

> *"We really wanted to match the theoretical framework that we already had on energy efficiency measures with actually speaking to the people that are going to implement them. We are talking about small private businesses, that in business terms are often marginal, and that are highly sensitive to crisis, lack specialised and knowledgeable personnel, and often have a short-term view, so it takes more work or more convincing to have these managers look at something like energy efficiency."* João Joanaz de Melo, Environmental Engineering Professor at FCT-NOVA.

The first step was an inventory and mapping of all commerce and service enterprises in Telheiras (Figure 4.8). A total of 160 service establishments were inventoried in the neighbourhood, of which 148 were small businesses. According to the criteria described above, where large businesses and offices were excluded, 107 establishments became the study universe. Efforts were made to contact the business managers, with success in around 80 cases, and all were offered the opportunity to participate in the project; 47 accepted and thus became the sample. Of these, 13 cases were selected for standard energy audits based on diversity, representativeness, and availability of information, and the other 34 cases were subject to more straightforward walk-through audits (Sequeira and Joanaz de Melo, 2020). Inventoried data focused mainly on businesses' characteristics, and no demographic and psychographic information was collected on the businesses' owners and/or managers.

Figure 4.8 - Location of Telheiras and small businesses in project scope (Sequeira and Joanaz de Melo, 2020).

4.2.5.3 Behaviours

Targeted energy behaviours included optimisation of management practices (*e.g.*, turning off lighting and appliances when not in use, proper maintenance, and efficient use of air conditioning units), upgrade and equipment replacement (*e.g.* LED lighting, efficient refrigerators, and solar thermal systems), and renovation of building components (*e.g.* replacement of windows, and façade insulation). Overall energy-saving potential for each establishment was estimated using case-appropriate measures from this set (Sequeira, 2016).

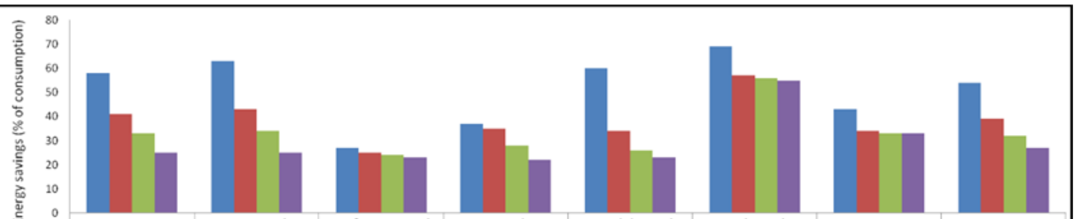
4.2.5.4 Content

In the second phase of the project, a systematic, adaptable, practical, and flexible energy audit program was piloted in Telheiras. Standard energy audits were used to identify energy consumption patterns, applicable measures and costs, and overall saving potential. All energy-consuming equipment was visually inspected and divided into the following end-uses: lighting, cooking, refrigeration, hygiene and cleaning, office equipment, water heating, heating ventilation and air conditioning (HVAC), and activity-specific uses (Sequeira and Joanaz de Melo, 2020). Walk-through energy audits included only the characterisation of the establishment; data from both audit approaches was crossed and compared. Besides the energy audits, participants were also surveyed to better understand their businesses' characteristics (*e.g.*, establishment area, number of employees, working hours, and number of clients), energy behaviours, drivers, and barriers towards energy efficiency. Energy audit reports were produced for each establishment that received a standard audit, with comprehensible detailed information on energy consumption patterns and energy-saving measures (Sequeira, 2016).

Key results from this phase included:

i) most energy-intensive categories were refrigerated retail and food services and the less intensive was general retail,
ii) small business services in the case study were, on average, less energy-intensive than the Portuguese service sector, but more intensive than the residential sector,
iii) HVAC, lighting, and office equipment were relevant end-uses for all businesses, while refrigeration and water heating seemed to be specific to certain activities,
iv) cost-effective energy efficiency measures were most significantly available in refrigeration, lighting, and HVAC, and
v) energy-saving potential is very relevant, but variation between individual cases is considerable (Sequeira and Joanaz de Melo, 2020).

Figure 4.9 showcases the energy-saving potential for the small business activities, according to payback time (*i.e.*, high profitability is under 3 years, medium profitability is under 6 years, economic is under 15 years, and technical has no restrains).



	Retail	General retail	Refrigerated retail	Food services	Health and beauty	Cultural association	Print shop	Average estab.
Technical	58	63	27	37	60	69	43	54
Economic	41	43	25	35	34	57	34	39
Medium profitability	33	34	24	28	26	56	33	32
High profitability	25	25	23	22	23	55	33	27

Figure 4.9 - Energy saving potential in the case-study's services activities (Sequeira and Joanaz de Melo, 2020).

4.2.5.5 Delivery

Small businesses in Telheiras neighbourhood were directly engaged, with a door-to-door, face-to-face individual approach. In this first contact, the project's scope (*i.e.*, not-for-profit and straightforward academic work), goals (*i.e.*, inform on energy use and reduce bills) and tasks (*i.e.*, conduct energy audits and surveys) were explained in detail, aiming to generate trust between auditors and auditees. After the first successful audits, word-of-mouth also played a role in attracting participants since local business managers talk to each other and quickly understood the potential benefits of conducting a free energy audit.

"So, once it was known that this project was underway, it was easier for the next business managers to accept that this was a good thing and not an underhand scheme to get them to pay something. After some initial wariness, because people did not know what this was about, most were conquered by the idea. So, it's both a matter of reaching the people and showing them that we really have something to offer. We are offering an opportunity. We are offering better knowledge. And people react very well to that. And it works better if we treat the issue as a community." João Joanaz de Melo, Environmental Engineering Professor at FCT-NOVA.

The Local Partnership of Telheiras played an important role as a trusted intermediary between the project and the community. This was accomplished in four ways:

i) an initial interview about the project that was widely shared in local media and social networks (Viver Telheiras, 2015),
ii) an explanatory email about the project with an appeal for participation that was sent to all businesses of Telheiras,
iii) three energy-saving workshops for businesses and households organised during local events (in 2016, 2017, and 2019), and
iv) a follow-up interview summarising the project's key outcomes aimed at the local community (Viver Telheiras, 2020).

"I think there are different ways of approaching people that can work. One of them is to provide celebration spaces that bring people together, not only for the celebration itself but also to get people engaged with relevant topics for the community. For example, we can have a music festival in our neighbourhood, where people come for the music and to have a drink, and we take the opportunity to convey information about sustainability issues, in this case energy, and on how they can get involved. The important thing is to build relationships, to build trust, and to build a community." Luís Keel Pereira, Coordinator of the Local Partnership of Telheiras.

In the third and final phase of the project, energy audit reports were provided to the respective small businesses (Sequeira, 2016). These were accompanied by informal counselling sessions, where the main results from the energy audits and the recommended measures were explained in detail, and the auditees feedback was received. Participants often showed surprise when confronted with their energy consumption patterns and the financial costs of inefficient practices. Critical drivers for energy-saving identified in the survey were the desire to cut operational costs and the presence of managers sensitive to energy issues (Sequeira and Joanaz de Melo, 2020). Around one-third of businesses had already taken small steps to reduce their energy consumption – *e.g.*, installing movement sensors for lighting in bathrooms and avoiding the use of heating and cooling equipment, the latter frequently in lieu of thermal comfort. These quick wins were a particular concern for more energy-intensive and/or less financially stable businesses, even though client satisfaction remained the priority.

During the counselling sessions, several barriers surfaced that were faced by small businesses (Sequeira and Joanaz de Melo, 2020). Shortage of funds and lack of access to finance were important obstacles for the non-adoption of expensive measures with longer payback times. However, it became clear that other barriers were responsible for the non-adoption of a significant share of low-cost measures with shorter payback times. The project partially addressed the lack of awareness and insufficient knowledge barriers, but as energy illiteracy is widespread in the Portuguese population, these remain important structural factors that make investment decisions difficult. On the other hand, barriers such as low priority/time for energy management (in micro and small businesses, often only one person makes all decisions), and distrust of profit-oriented energy services providers were not explicitly addressed by the project. Split incentives between building owners and business managers were also uncovered as an important barrier for this type of SMEs since 85% of services activities in the case study take place in rented spaces (usually the ground floor of residential buildings).

4.2.5.6 Evaluation

The core fieldwork of this project was performed for a master's thesis and, thus, within a short, limited timeframe (Sequeira, 2016). Unfortunately, no formal evaluation of the project's real long-term impacts on energy behaviours in Telheiras was conducted. Informal conversations with some business managers and local stakeholders indicated that at least a few of the more accessible and lower-cost measures were adopted and that the project contributed to an increased awareness of energy issues in the community. The repetition of the small businesses inventory, one year after the initial one, revealed a high turnover rate among the 107 establishments of the study universe (9 of these closed while 8 new opened), which could also difficult any monitoring strategy of long-term results. Impacts of the project can be quantitively measured by the number of neighbourhoods (1), and types of SMEs (6) studied, as well as by the number of establishments audited (47), energy audit reports delivered (13), and community energy-saving workshops performed (3).

> *"I think the methodology became quite robust by the end of the fieldwork. What we really need now is to scale up and to understand what kind of tools and organisational setting we need to go to the next level in terms of number of participants and impact. When we scale up things from a pilot, several aspects may work differently."* João Joanaz de Melo, Environmental Engineering Professor at FCT-NOVA.

4.2.5.7 Discussion

Developed at the neighbourhood-scale, the project advanced a comprehensive approach, including an inventory of target users, engagement, performance of energy audits, and provision of energy advice. It gathered useful information on energy consumption patterns and saving opportunities for different profiles of understudied HTR energy users of the SME sector while fine-tuning and piloting methodologies to reach them. The local community was involved in the project from the kick-start, which positively contributed to its execution. From the end of the project to this date, the Local Partnership of Telheiras is continuing to push forward energy issues as a key area for the neighbourhood's long-term social and environmental sustainability. These can be regarded as the main positive takeaways from this project.

> *"The fact that we could support this project opened up some doors because it brought people together that have an interest in the energy area. Currently, we are opening working groups to address different initiatives in sustainability, and one of them will be on energy. The idea is to have a sort of energy community in our neighbourhood that will produce renewable energy locally and improve energy efficiency. We get a lot of inspiration from other projects in Portugal and internationally, and we are really looking forward to establish this energy community."* Luís Keel Pereira, Coordinator of the Local Partnership of Telheiras.

On the other hand, the project was developed in a limited timeframe and geographical scope, while mainly focusing on tailored energy counselling rather than on actual financial support and physical interventions. The project's effectiveness in changing energy behaviours was hindered by these constraints. Although it is labour-intensive and requires context-adapted solutions and communication strategies, the energy audit programme could be replicated in other neighbourhoods and scaled to larger areas to reach more HTR energy users.

4.2.6 General discussion

4.2.6.1 Lessons and recommendations

The ABCDE Building Blocks of Behaviour Change framework by Karlin *et al.* (2021) proved useful for the case studies' analysis as it allowed a fresh, holistic, and critical perspective on the selected projects. This fostered the identification of successes, shortcomings, lessons learned, and recommendations.

Both projects were well-grounded on their motivation and goals, specifically looking at different profiles of HTR energy users. The initial phases involved the mapping of the target audience, either at a national scale through a multidimensional index, or at a local scale through an inventory. Regarding behaviours, the projects strongly focused on improving energy efficiency and increasing awareness around energy poverty. A common positive point was the involvement of trusted intermediaries that facilitated the communication between the project team, the target audience, and the broader community. While the methods were different (one focusing on regional quantitative assessment coupled with qualitative interviews, and the other using quantitative energy audits coupled with qualitative surveys), both examples successfully took advantage of proximity approaches to engage and advise HTR energy users. Although evaluation and monitoring were lacking, which appears to be a frequent flaw in this type of project, the case studies did contribute towards increasing awareness of energy issues in targeted energy users and their respective communities, creating a strong backbone for follow-up activities and further research.

Besides the limited evaluation process, the projects shared other common shortcomings. In the first place, the approach mostly focused on the proactive engagement of HTR energy users and on providing tailored advice on energy behaviours. Notwithstanding the importance of energy literacy, one factor that would improve projects' results would be to offer attractive incentives and continued support, thus, leveraging the actual adoption of measures. In addition, both case studies were limited in geography, time, and number of participants. Even if parts of the work could be replicated and scaled up to reach a larger number of HTR energy users, this would entail more resources, different challenges, and a new level of complexity.

From the Portuguese case studies analysis, the following recommendations can be drawn regarding projects that intend to successfully engage with HTR energy users: a) define and map your target audience early, b) clearly describe the energy behaviours that you would like to be changed, c) build strong ties with trusted intermediaries, such as local authorities and associations, and try to involve the whole community, d) prioritise door-to-door and face-to-face approaches when conducting project activities, and e) establish early-on a quantitative and systematic monitoring and evaluation strategy for your project.

4.2.6.2 Future research

The case study analysis presented allowed a first exploratory look at HTR energy users in the Portuguese context. Although still superficial and requiring further research, it suggests that HTR energy users may represent a significant number of businesses and families in Portugal, whose participation in energy issues is severely constrained by a wide range of vulnerabilities, circumstances and/or characteristics. Nevertheless, effectively engaging this heterogeneous audience is vital to foster a sustainable, inclusive, and just energy transition. Future work on HTR energy users in Portugal should attempt to answer the following research questions:

i) why should we specifically target HTR energy users?
ii) who should be regarded as HTR energy users and why?
iii) what behaviours or interventions we want HTR energy users to change/adopt?
iv) who is targeting the HTR and why?
v) how to successfully engage with HTR energy users and prove that it worked?

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. Pedro Palma: Writing – original draft (only sub-chapter 4.2.4), Visualization, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia: Writing – review & editing, Validation, Supervision, Conceptualisation.

References

Abreu, M. I., de Oliveira, R. A. F., and Lopes, J. (2020). Younger vs. older homeowners in building energy-related renovations: Learning from the Portuguese case. Energy Reports 6, 159-164. 6th International Conference on Energy and Environment Research, ICEER 2019, 22–25 July, University of Aveiro, Portugal. https://doi.org/10.1016/j.egyr.2019.08.036

ADENE (2019). Energia para Poupar, Manual prático sobre eficiência energética ["Energy to Save, Practical Manual about Energy Efficiency"]. Portuguese National Energy Agency. Available at: https://ligar.adene.pt/passar-a-accao/

Ambrose, A., Baker, W., Batty, E., and Hawkins, A. (2019a). Reaching the 'Hardest to Reach' with energy advice: final report. Sheffield Hallam University, Centre for Regional Economic and Social Research. https://doi.org/10.7190/cresr.2019.8286642862

Ambrose, A., Baker, W., Batty, E., and MacNair Hawkins, A. (2019b). Focus Article: "I have a panic attack when I pick up the phone": experiences of energy advice amongst 'hard to reach' energy users. People, Place and Policy, 14(1). https://doi.org/10.3351/ppp.2019.3479427335

Ashby, K., Smith, J., Rotmann, S., Mundaca, L., and Ambrose, A. (2020). HTR Characteristics. HTR Annex by Users TCP by IEA: Wellington. https://doi.org/10.47568/3XR102

AT/MF and PORDATA (2021). Estatísticas de rendimento e despesas familiares ["Income and family expenses statistics"]. Portuguese Tax Authority / Ministry of Finance and Portugal Database. Available at: www.pordata.pt

Backlund, S., Thollander, P., Palm, J., and Ottosson, M. (2012). Extending the energy efficiency gap. Energy Policy, 51, 392-396. http://dx.doi.org/10.1016/j.enpol.2012.08.042

Bouzarovski, S., Burbidge, M., and Stojilovska, A. (2020). Deliverable 2.1a: Report on Energy Poverty in the PRS – Overview & Framework. University of Manchester, United Kingdom: ENPOR Project. Available at: www.enpor.org

Brazão, A., and Melo, J.J. (2012). Barriers to energy efficiency improvement in industrial small- and medium-sized enterprises: the Portuguese case. 1st International Conference on Energy, Environment and Sustainability (EES 2012). Instituto Politécnico do Porto.

Churchill, S. A., and Smyth, R. (2020). Ethnic diversity, energy poverty and the mediating role of trust: Evidence from household panel data for Australia. Energy Economics, 86, 104663. https://doi.org/10.1016/j.eneco.2020.104663

Coopernico. (2020). Quem Somos ["Who We Are"]. Available at: https://www.coopernico.org

DGEG (2020). Balanço energético 2019 provisório ["Preliminary energy balance 2019"]. Portuguese Energy and Geology Directorate. Version of 02/11/2020.

DGEG (2021). Balanço Energético Sintético 2020 ["Summary energy balance 2020"]. Portuguese Energy and Geology Directorate. Version of 29/06/2021.

DGEG and ERSE (2016). Plano de Promoção da Eficiência no Consumo de Energia Elétrica 2017-2018, Anexo I - Proposta de avaliação das candidaturas submetidas no âmbito do PPEC ["Efficiency Promotion Plan in Electricity Consumers 2017-2018, Annex I – Evaluation proposal for the applications submitted in the scope of PPEC"]. Portuguese Energy and Geology Directorate and Portuguese Energy Services Regulator.

DGEG and Portuguese Government (2021). Tarifa Social de Energia ["Energy Social Tariff"]. Portuguese Energy and Geology Directorate. Available at: https://tarifasocial.dgeg.gov.pt/

EEA (2017). Climate Change impacts and vulnerability in Europe 2016 – An indicator-based report. No 1/2017. European Environmental Agency.

Eisermann, M., Maurer, C., and Turner, I. (2019). Boosting energy retrofits in condominiums: Approaches for local authorities to facilitate change. Interreg North-West Europe ACE-Retrofitting and Energy Cities. ISBN: 978-2-490384-11-2.

ERSE (2020). Estudo de literacia dos consumidores na área da energia ["Study on consumers' energy literacy"]. Final report. Portuguese Energy Services Regulator.

European Commission (2020a). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. Brussels, 14.10.2020, COM(2020) 662 final.

European Commission (2020b). User guide to the SME definition. Luxembourg: Publications Office of the European Union. https://doi.org/0.2873/255862

Eurostat (2020). Energy data – 2020 edition. Luxembourg: Publications Office of the European Union. https://doi.org/10.2785/68334

Eurostat (2021a). Inability to keep home adequately warm - EU-SILC survey. Online data code: ILC_MDES01. Last update: 19/05/2021.

Eurostat (2021b). Share of population living in a dwelling not comfortably cool during summer time by income quintile and degree of urbanisation. Online data code: ILC_HCMP03. Last update: 08/02/2021.

Eurostat (2021c). Share of total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames of floor - EU-SILC survey. Online data code: TESSI292. Last update: 19/05/2021.

Eurostat (2021d). Electricity prices for household consumers - bi-annual data (from 2007 onwards). Online data code: NRG_PC_204. Last update: 27/05/2021.

Eurostat (2021e). Gas prices for household consumers - bi-annual data (from 2007 onwards). Online data code: NRG_PC_202. Last update: 20/05/2021.

Eurostat (2021f). Comparative price levels: Comparative price levels of final consumption by private households including indirect taxes (EU27_2020 = 100). Online data code: TEC00120. Last update: 15/02/2021.

Eurostat (2021g). Distribution of population by tenure status, type of household and income group - EU-SILC survey. Online data code: ILC_LVHO02. Last update: 01/07/2021.

Eurostat (2021h). Individuals who have basic or above basic overall digital skills by sex (% of individuals aged 16-74). Online data code: TEPSR_SP410. Last update: 25/05/2021.

Eurostat and PORDATA (2020). Condições de vida e rendimento das famílias ["Living conditions and family income"]. Eurostat and Portugal database. Available at: www.pordata.pt

Feenstra, M., and Clancy, J. (2020). A View from the North: Gender and Energy Poverty in the European Union. In: Clancy J., Özerol G., Mohlakoana N., Feenstra M., Sol Cueva L. (eds) Engendering the Energy Transition. https://doi.org/10.1007/978-3-030-43513-4_8

Figueiredo, R., Nunes, P., Oliveira Panão, M. J. N., and Brito, M. C. (2020). Country residential building stock electricity demand in future climate – Portuguese case study. Energy and Buildings, 209, 109694. https://doi.org/10.1016/j.enbuild.2019.109694

Gouveia J. P. (2017). Residential Sector Energy Consumption at the Spotlight: From Data to Knowledge. PhD thesis on Climate Change and Sustainable Development Policies – Sustainable Energy Systems. Faculty of Sciences and Technology, Nova University of Lisbon. Available at: https://run.unl.pt/handle/10362/23552 . TID: 101577370.

Gouveia, J. P., and Palma, P. (2019). Harvesting big data from residential building energy performance certificates: retrofitting and climate change mitigation insights at a regional scale. Environmental Research Letters, 14, 095007. https://doi.org/10.1088/1748-9326/ab3781

Gouveia, J. P., and Palma, P. (2021a). Perspective on Energy Poverty in the Public Debate and in Research in Portugal. EP-pedia, ENGAGER COST Action. Available at: https://www.eppedia.eu/

Gouveia, J. P., and Palma, P. (2021b). Best practices in Portugal. EP-pedia, ENGAGER COST Action. Available at: https://www.eppedia.eu/

Gouveia, J. P., and Seixas, J. (2016). Unraveling electricity consumption profiles in households through clusters: Combining smart meters and door-to-door surveys. Energy and Buildings, 116, 666-676. https://doi.org/10.1016/j.enbuild.2016.01.043

Gouveia, J. P., Palma, P., and Simões, S. G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187-201. https://doi.org/10.1016/j.egyr.2018.12.004

Gouveia, J. P., Seixas, J., and Long, G. (2018a). Mining households' energy data to disclose fuel poverty: Lessons for Southern Europe. Journal of Cleaner Production 178, 534-550. https://doi.org/10.1016/j.jclepro.2018.01.021

Gouveia, J. P., Seixas, J., Palma, P., Simões, S. G. (2018b). Mapeamento da Pobreza Energética em Portugal [Mapping Energy Poverty in Portugal]. Ligar Energy Efficiency for All!. Available at: https://ligar.adene.pt/wp-content/uploads/2018/07/LIGAR_Mapeamento_FCT_CENSE.pdf

Hall, S., Anable, J., Hardy, J., Workman, M., Mazur, C., and Matthews, Y. (2021). Matching consumer segments to innovative utility business models. Nature Energy, 6, 349-361. https://doi.org/10.1038/s41560-021-00781-1

Hesselman, M., Varo, A., Guyet, R., and Thomson, H. (2020). Global Map of COVID-19 Household Energy Services Relief Measures. Last retrieved in June 2021. Available at: http://www.engager-energy.net/covid19/

Horta, A., and Schmidt, L. (2021). Policy Brief 2021: Energy Poverty in Portugal. Observa – Observatory for environment, territory and society, Institute for Social Sciences of the University of Lisbon. Available at: https://www.ics.ulisboa.pt/flipping/observa2021

Horta, A., and Sousa, J. C. (2018). LIGAR – Eficiência Energética para Todos! Caraterização dos consumidores vulneráveis ["LIGAR – Energy Efficiency for All! Characterization of vulnerable consumers"]. Final report. Institute for Social Sciences of the University of Lisbon. Available at: https://ligar.adene.pt/

Horta, A., Gouveia, J. P., Schmidt, L., Sousa, J. C., Palma, P., and Simões, S. (2019). Energy poverty in Portugal: Combining vulnerability mapping with household interviews. Energy & Buildings, 203, 109423. https://doi.org/10.1016/j.enbuild.2019.109423

II/MTSSS and PORDATA (2021). Proteção Social ["Social security statistics"]. Informatics Institute / Ministry of Employment, Solidarity and Social Security and Portugal Database. Available at: www.pordata.pt

INE (2012). Construção e Habitação ["Construction and housing statistics"]. Portugal Statistics. Available at: www.ine.pt

INE (2016). Construção e Habitação ["Construction and housing statistics"]. Portugal Statistics. Available at: www.ine.pt

INE (2020). Construção e Habitação ["Construction and housing statistics"]. Portugal Statistics. Available at: www.ine.pt

INE (2021). Destaque: Contas Nacionais Trimestrais ["Highlight: Trimestral National Accounting"]. Portugal Statistics. Available at: www.ine.pt

INE and DGEG (2011). Inquérito ao Consumo de Energia no Setor Doméstico 2010 ["Survey of households energy consumption 2010"]. 2011 edition. ISSN 2182-0139. Portugal Statistics and Portuguese Energy and Geology Directorate.

INE and PORDATA (2015). Habitação, conforto e condições de vida ["Housing, comfort and living conditions statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2018). População ["Population statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2020). População ["Population statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2021a). Rendimento e despesas familiares ["Income and family expenses statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2021b). Habitação, conforto e condições de vida ["Housing, comfort and living conditions statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2021c). População ["Population statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2021d). Emprego e mercado de trabalho ["Employment and job market"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2021e). Educação ["Education statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE and PORDATA (2021f). Empresas e Pessoal ["Enterprises and workers statistics"]. Portugal Statistics and Portugal Database. Available at: www.pordata.pt

INE, SEF/MAI, and PORDATA (2020). População ["Population statistics"]. Portugal Statistics, Border and Foreigner Services / Ministry of Internal Administration and Portugal Database. Available at: www.pordata.pt

ISS/MTSSS and PORDATA (2020). Proteção social ["Social security statistics"]. Social Security Institute and Ministry of Employment, Solidarity and Social Security and Portugal Database. Available at: www.pordata.pt

Just a Change. (2020). Sobre Nós ["About Us"]. Available at: https://www.justachange.pt

Karlin B., Forster H., Sheats J., Chapman D., and S. Rotmann (2021). The Building Blocks of Behavior Change: A Scientific Approach to Optimizing Impact. See Change Institute: Venice Beach. 11pp.

Labanca, N., Suerkemper, F., Bertoldi, P., Irrek, W., and Duplessis, B. (2015). Energy efficiency services for residential buildings: market situation and existing potentials in the European Union. Journal of Cleaner Production, 109, 284-295. http://dx.doi.org/10.1016/j.jclepro.2015.02.077

Mahapatra, K., Mainali, B., and Pardalis, G. (2019). Homeowners' attitude towards one-stop-shop business concept for energy renovation of detached houses in Kronoberg, Sweden. Energy Procedia, 158, 3702-3708. 10th International Conference on Applied Energy (ICAE2018), 22-25 August 2018, Hong Kong, China. http://dx.doi.org/10.1016/j.egypro.2019.01.888

Martins, R., Pereira da Silva, P., Antunes, M., and Fortunato, A. (2019). Estudo sobre a aplicação da tarifa social de energia em Portugal ["Study on the application of energy social tariffs in Portugal"]. Portuguese Energy Observatory and CeBER - Centre for Business and Economic Research of Coimbra University.

Melo, J. J., Fernandes, F., Sousa, M. J. F., Galvão, A., Grilo, J., and Pereira, A. M. (2019). Estratégia energética alternativa: princípios e identificação de medidas ["Alternative energy strategy: principles and identification of measures"]. NOVA School of Science and Technology of the NOVA University of Lisbon, June 2019. ISBN 978-972-8893-82-8.

OPENEXP (2019). European Energy Poverty Index (EEPI): Assessing Member States progress in alleviating the domestic and transport energy poverty nexus. ISBN: 978-2-9564721-5-5. Available at: https://www.openexp.eu/european-energy-poverty-index-eepi

Palma, P., Gouveia, J. P., Simoes, S. G. (2019). Mapping the energy performance gap of dwelling stock at high-resolution scale: Implications for thermal comfort in Portuguese households. Energy and Buildings, 190, 246-261. https://doi.org/10.1016/j.enbuild.2019.03.002

Portuguese Energy Observatory (2020). Consumo de Energia Elétrica e consumo de produtos de petróleo – abril 2020 ["Electricity consumption and oil products consumption – April 2020"]. Available at: https://www.observatoriodaenergia.pt

Portuguese Energy Observatory (2021a). Consumo de Energia Elétrica e consumo de produtos de petróleo – abril 2021 ["Electricity consumption and oil products consumption – April 2021"]. Available at: https://www.observatoriodaenergia.pt

Portuguese Energy Observatory (2021b). Certificação Energética de Edifícios - Principais números: habitação ["Energy Certification of Buildings – Key figures: housing"]. Available at: https://www.observatoriodaenergia.pt

Portuguese Energy Observatory (2021c). Certificação Energética de Edifícios - Principais números: comércio e serviços ["Energy Certification of Buildings – Key figures: commerce and services"]. Available at: https://www.observatoriodaenergia.pt

Portuguese Government (2019). Roteiro para a Neutralidade Carbónica 2050 (RNC2050): Estratégia de longo prazo para a neutralidade carbónica da economia portuguesa em 2050 ["Carbon Neutrality Roadmap 2050 (RNC2050): Long-term strategy for a carbon neutral Portuguese economy in 2050"]. R 262/2019.

Portuguese Government (2020). Resolução do Conselho de Ministros n.º 53/2020 - Aprova o Plano Nacional Energia e Clima 2030 (PNEC 2030) ["Resolution of the Council of Ministers no. 53/2020 – Approving the National Energy and Climate Plan 2030 (PNEC 2030)"]. Diário da República, 1.ª série, 133. July 10, 2020.

Portuguese Government (2021a). Resolução do Conselho de Ministros n.º 8-A/2021 – Aprova a Estratégia de Longo Prazo para a Renovação dos Edifícios ["Resolution of the Council of Ministers no. 8-A/2021 – Approving the Long-term Strategy for Building Renovation"]. Diário da República, 1.ª série, 23. February 3, 2021.

Portuguese Government (2021b). Estratégia de Longo Prazo para o Combate à Pobreza Energética 2021-2050 ["Long-term Strategy for Energy Poverty Mitigation 2021-2050"]. Document for public consultation. Ministry of Environment and Climate Action. April 2021.

Reuter, S., Lackner, P., and Brandl, G. (2021). Mapping Small and Medium-sized Enterprises in Europe: focus on economic and energy data. LEAP4SME project. Available at: www.leap4sme.eu

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., Chester, M., Karlin, B., K. Ashby, Butler, D., and J. Chambers (2020). Hard-to-Reach Energy Users: A Literature Review. Prepared for User-Centred Energy Systems TCP – HTR Task. Published by SEA – Sustainable Energy Advice Ltd: Wellington. 252pp. ISBN: 978-0-473-64983-8

Rotmann S., Mundaca L., Ashby K., O'Sullivan K., Karlin B., and H. Forster (2021). Subtask 2: Case Study Analysis Methodology - Template for National and Contributing Experts. Users TCP HTR Annex: Wellington. 16pp.

Schleich, J., and Gruber, E. (2008). Beyond case studies: barriers to energy efficiency in commerce and the services sector. Energy Economics, 30, pp 449-464. https://doi.org/10.1016/j.eneco.2006.08.004

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

Sequeira, M. (2016). Potencial de poupança de eletricidade no pequeno comércio e serviços – caso-estudo Telheiras ["Electricity saving potential in the small business service and commerce sector – case-study Telheiras"]. Master's thesis in Environmental Engineering at the NOVA School of Science and Technology of the NOVA University of Lisbon. Available at: https://run.unl.pt/handle/10362/19555

Sequeira, M., and Joanaz de Melo, J. (2020). Energy saving potential in the small business service sector: case study Telheiras neighborhood, Portugal. Energy Efficiency, 13(4), 551-569. https://doi.org/10.1007/s12053-020-09842-y

Simões, S., Gregório, V., and Seixas, J. (2016). Mapping fuel poverty in Portugal. Energy Procedia, 106, 155-165. 1st Energy Economics Iberian Conference, EEIC | CIEE 2016, February 4-5, Lisbon, Portugal, APEEN and AEEE. https://doi.org/10.1016/j.egypro.2016.12.112

Viver Telheiras (2015). Jovem estudante ajuda comerciantes de Telheiras a reduzir custos energéticos ["Young student helps Telheiras' commerce to reduce energy costs"]. News portal of the Local Partnership of Telheiras. Available at: http://vivertelheiras.pt/jovem-estudante-ajuda-comerciantes-de-telheiras-a-reduzir-custos-energeticos/

Viver Telheiras (2020). Tese de mestrado estudou potencial de poupança energética no comércio de Telheiras ["Master's thesis studied the energy saving potential of Telheiras' commerce"]. News portal of the Local Partnership of Telheiras. Available at: http://vivertelheiras.pt/tese-de-mestrado-estudou-potencial-de-poupanca-energetica-no-comercio-de-telheiras/

Chapter 5.

FOSTERING ENGAGEMENT THROUGH DIGITAL AND COMMUNITY-BASED APPROACHES

5.1 A sequential multi-staged approach for developing digital one-stop shops to support energy renovations of residential buildings

This work is published in: Sequeira, M.M., and Gouveia, J.P. (2022). A Sequential Multi-Staged Approach for Developing Digital One-Stop Shops to Support Energy Renovations of Residential Buildings. Energies, 15, 5389. https://doi.org/10.3390/en15155389.

Abstract

Buildings account for 40% of the European Union's energy consumption. Deep energy renovation of residential buildings is key for decarbonization and energy poverty alleviation. However, renovation is occurring at far below the needed pace and depth. In this context, building renovation one-stop shops, which bring all project phases under one roof and provide advice, support, and finance to households, are highlighted as a promising solution. Nevertheless, this model is still absent or under-developed in most European countries and remains understudied in the scientific literature. Therefore, the present research goals are as follows: (i) to provide a critical review of emerging one-stop shop models; (ii) to streamline the deployment of building renovation digital one-stop shops by piloting a sequential multi-staged approach for Portuguese households and proposing it for replication elsewhere; and (iii) to compare case-study insights with other one-stop shops and discuss the notion in the context of the European Renovation Wave. In total, for the Portuguese case-study, five steps were conducted. The first three - stakeholder mapping, expert interviews, and customer journey - aimed to gather intel on the local energy renovation market. The results from these stages informed the design of the platform (fourth step). Finally, a post-launch market consultation survey gathered user feedback (fifth step). Insights from this study suggest that digital one-stop shops, while providing a helpful tool to close information gaps and activate specific audiences, may be insufficient on their own. As such, a more comprehensive set of instruments supporting households is needed to accelerate building renovation.

Keywords: building retrofitting; energy efficiency; households; home renovation; business model; web portal; online platform; Portugal; Renovation Wave

5.1.1 Introduction

In the European Union (EU), buildings represent 40% of energy consumption and 36% of carbon dioxide emissions (Eurostat, 2020; Roscini *et al.*, 2020). Around 75% of the EU building stock is energy inefficient, and energy poverty affects millions of Europeans (European Commission, 2020). Energy poverty is broadly defined, *e.g.*, in Bouzarovski (2018), as when a household is unable to secure a level and quality of domestic energy services sufficient for its social and material needs. Building renovation can generate multiple social, environmental, and economic benefits, making it a unique opportunity for climate neutrality and COVID-19 recovery (Di Foggia, 2018; Reuter *et al.*, 2020; Shnapp *et al.*, 2020). Bean *et al.* (2019) estimated that 97% of all buildings will need to be upgraded by 2050.

Europeans spend 90% of their time indoors, and the quality of these environments substantially impacts health and well-being. The COVID-19 crisis highlighted the importance and fragilities of the building stock. Some of the effects of the pandemic (*e.g.*, remote working) may continue in the long term with higher occupation schedules and new demands on residential buildings, further reinforcing the need to renovate deeply and on a massive scale (European Commission, 2020; Cheshmehzangi, 2020).

The European Commission has proposed a reduction of at least 55% in net greenhouse gas emissions by 2030 compared to 1990 levels. In this context, the building sector needs to reduce its emissions by 60% and its energy use by 14% from 2015 levels (European Commission, 2020). As the construction of new buildings with higher performance standards happens slowly, it is crucial to target existing buildings. At the same time, around 14.8% of the EU's population lives in dwellings with leaks, damp, or rot, while 15.8% of the housing stock is unoccupied (Eurostat 2021a, 2022a). However, the EU's weighted annual renovation rate is low, at around 1% (with several countries depicting considerably lower rates).

In contrast, deep renovations that reduce energy consumption by at least 60% are carried out in only 0.2% of buildings (European Commission, 2020). The European Renovation Wave sets out a strategy to double the annual renovation rate by 2030. Further, Roscini *et al.* (2020) highlighted that current annual deep renovation rates need to grow to at least 2% and should approach 3% as soon as possible. In this scope, emphasis is given to the worst-performing segments of the building stock, energy poverty alleviation, and public buildings (Economidou *et al.*, 2020; European Commission, 2020).

The main drivers for building energy renovation are cost-saving and improved comfort, though environmental concerns and aesthetics are also factors in homeowners' decisions (Galvin and Sunikka-Blank, 2014; Barbiero and Grillenzoni, 2019; Streimikiene and Balezentis, 2020). The main barriers to energy efficiency have been well-researched and include shortages of finance, split incentives between owners and tenants, insufficient knowledge on current consumption, and a lack of information about renovation measures (Shnapp *et al.*, 2020; Bertoldi *et al.*, 2021; Pillai *et al.*, 2021). In housing, specific barriers include fragmentation of the demand-side mass market, heterogeneity of the building stock, high transaction costs, and mistrust of renovation providers (Labanca *et al.*, 2015; Murto *et al.*, 2019). The complex and fragmented nature of the supply-side renovation market, where multiple and diverse stakeholders coexist, also acts as an obstacle (de Wilde and Spaargaren, 2019; Gonzalez-Caceres *et al.*, 2020). Currently, the renovation market is dominated by siloed approaches and individual solutions, often provided by handicraft-based small companies. Meanwhile, the market for deep renovation is yet to develop (Mlecnik *et al.*, 2018; Mahapatra *et al.*, 2019). Due to their vulnerabilities, circumstances, and characteristics, a significant share of households can be regarded as being hard-to-reach with traditional energy policies, financing schemes, and business models (Ambrose *et al.*, 2019).

Historically, building renovation schemes have often been oversimplified into only technical and economic concerns, leading to low levels of engagement (Gram-Hanssen, 2014; Wise *et al.*, 2021). The lack of easily accessible incentives and financing products is often mentioned as a barrier (Streimikiene and Balezentis, 2020; European Commission, 2021; Pillai *et al.*, 2021). For deep renovations, the absence of long-term energy performance goals may act as a barrier, since homeowners prefer to implement small interventions over time (Gonzalez-Caceres *et al.*, 2020). The management of the energy renovation process can be complex for adopters, as they may need to find, interact, and coordinate multiple actors while simultaneously taking the risk and responsibility for the changes (Mahapatra *et al.*, 2013; Murto *et al.*, 2019). Building owners often do not have the expertise necessary to make decisions, and require professional assistance (Gonzalez-Caceres *et al.*, 2020; Peltomaa *et al.*, 2020). Finally, even if renovation providers can strongly influence homeowners' decisions, these are primarily micro-enterprises that lack knowledge and interest in more holistic renovations (Owen *et al.*, 2014; Maby and Gwilliam, 2021).

Since the incumbent approaches are falling short, particularly among lower-income and hard-to-reach households, several authors have called for additional efforts to overcome the barriers mentioned above (*e.g.*, Boza-Kiss and Bertoldi, 2018; Brown, 2018; Rotmann *et al.*, 2020). One recent and promising solution, backed by the European Commission (2020), is the deployment of one-stop shops (OSS) that deliver tailored technical advice and financing solutions and accompany households throughout their energy-related projects. Although OSSs diffusion in the EU is still in the preliminary stages, the concept seems to be gaining momentum. Bertoldi *et al.* (2021) estimated that around 2/3 of the EU's Member States have at least one OSS on the national market. However, Volt *et al.* (2021) argued that their impacts remain limited and understudied. Research gaps persist both in the Conceptualisation and the practical application of OSSs.

In this context, the goals of this research are three-fold: (i) to undertake a critical review of the OSS concept applied to building energy renovation; (ii) to propose and apply a step-by-step methodological approach for the development of digital OSS for residential building renovation in immature markets; and (iii) to offer insights combining the practical application in the Portuguese case-study with other empirical OSS cases. Whereas most existing OSSs have surfaced in an unstructured way, the novelty of this paper lies in the proposal of a structured and sequential multi-staged process for the development of OSSs that could be replicated elsewhere and further expanded on. Both methodological and result-oriented outputs are presented and discussed, considering the potential role of OSS business models for the implementation of the EU's Renovation Wave strategy, as well as its key strengths and limitations.

The structure of this paper is as follows. Section 5.1.2 critically reviews the current situation regarding OSSs. Building on the literature review, Section 5.1.3 details the methodological framework applied in this research, which comprises the following: (i) a description of Portugal as a case-study; (ii) stakeholder mapping and analysis; (iii) semi-structured expert interviews; (iv) customer journey development; (v) deployment of a digital OSS for residential buildings renovation; and (vi) a market consultation survey. Section 5.1.4 depicts the step-by-step empirical results of the Green Menu digital OSS case-study in Portugal, which are further discussed in Section 5.1.5 and linked to the emerging role of OSSs for large-scale building renovation and energy poverty mitigation. Section 5.1.6 concludes the paper and provides perspectives on the usefulness of OSS business models for the European Renovation Wave.

5.1.2 Literature review: Building renovation one-stop shops

The Energy Performance of Buildings Directive (EPBD 2018/844/EU) requested member states to facilitate access to transparent advisory tools, being the first legislative act calling for OSSs (Bertoldi *et al.*, 2021). OSS can be considered an umbrella term for services offering combined renovation solutions that simplify the homeowner's customer journey (Volt *et al.*, 2021). This approach turns a complex customer journey into a single-entry, customer-friendly one, bridging supply and demand fragmentation (Boza-Kiss and Bertoldi, 2018). By providing trustworthy advice and supporting decision-making, OSSs can address barriers such as a lack of knowledge and information (Mahapatra *et al.*, 2013; Bjørneboe *et al.*, 2017). Several authors have highlighted that OSSs can accelerate and deepen building refurbishments by actively seeking new customers, easing access to finance, and building strong partnerships with local stakeholders (*e.g.*, Boza-Kiss and Bertoldi, 2018; Bertoldi *et al.*, 2020; Mainali *et al.*, 2021). The scientific literature is still scarce on OSSs, with the concept being primarily found in project reports describing empirical case-studies.

An OSS can be a virtual or physical place, present diverse business models, and provide various services, depending on the local context, market maturity, available resources, starting point, and target audience (Boza-Kiss and Bertoldi, 2018; Cicmanova *et al.*, 2020; Kwon *et al.*, 2021). Croci *et al.* (2020) pointed out five main elements that can define an OSS business model: the services offered, the users, the provider, the actors involved, and the revenue streams. In addition, Cicmanova *et al.* (2020) identified four different OSS types, ranging from simpler facilitation models, usually free of charge and focusing on providing advice during the first stages of renovation, to coordination models and complex all-inclusive and ESCO-type models, where the OSS offers complete renovation packages and financing and assumes responsibility for the result. This more integrated approach maximizes long-run benefits while performance gaps and unintended consequences can be minimized (Mahapatra *et al.*, 2013). This contrasts with the highly fragmented supply chains that have characterized most residential renovations (Brown, 2018). Several authors (*e.g.*, Boza-Kiss and Bertoldi, 2018; Volt *et al.*, 2019; Croci *et al.*, 2020; Bertoldi *et al.*, 2021) have also attempted to categorize OSSs according to their governance: local government-supported, public-private partnerships, independent consultants, industry-driven, large store/warehouse based, cooperative-driven, and financial institutions.

Examples of different OSS business models in European countries can be described based on Cicmanova *et al.* (2020), in which the authors detailed 11 OSSs best practices, and Bertoldi *et al.* (2021), in which the authors mapped 63 OSSs located in 22 European countries. In Cyprus, the Aradippou OSS is a municipality-based OSS that benefits from trustful relations to provide free services to its citizens, including recommendations of technical measures, information on financing schemes, and verification of results. In Frederikshavn (Denmark), the preferred OSS approach involved a public-private partnership, targeting condominiums and single-family houses, where energy renovation and financial plans are offered free of charge, and house owners sign a single contract with the OSS that coordinates all works. Initiated by a private company, the Reimarkt OSS has both physical and virtual shops in several Dutch cities, offering an all-inclusive model that accompanies the customer from the first contact until the final evaluation, with a fixed fee of 10% of the total project costs. A significant number OSSs have been created and/or expanded in the context of EU-funded projects (*e.g.*, Volt *et al.*, 2019; Croci *et al.*, 2020; Bertoldi *et al.*, 2021). These selected examples represent innovations that show that OSSs can succeed and surpass difficult circumstances, *e.g.*, budget cuts, competing priorities, and limited powers in local authorities (Tingey *et al.*, 2021).

Although their advantages are widely acknowledged and the business potential is real, OSSs are still rare, since they require extensive knowledge of the local market and may be problematic for small renovation companies (Pardalis *et al.*, 2019a; Maraquin and Eisermann, 2020; Pardalis *et al.*, 2020a). Existing initiatives often remain fragile because the business case is uncertain, and there is a high cost of attracting customers (Gram-Hanssen *et al.*, 2018). Low customer demand can be one of the larger challenges for the start-up and upscaling of OSSs (Brown, 2018). Moreover, the challenges and solutions vary according to building typologies, customer needs, and local settings (Murto *et al.*, 2019; Mainali *et al.*, 2021). Bertoldi *et al.* (2021) found that most existing OSSs in the EU focus on single-family houses, with multi-family buildings and condominiums being less attractive target groups. To accelerate building renovation, innovative business models need to be developed, tested, and replicated through joint efforts in research, business, and policy (Volt *et al.*, 2019; Tingey *et al.*, 2021). Scientific research on OSSs and their role in building energy renovation are still scarce, and the business model is thus largely absent or under-developed in most European countries (Volt *et al.*, 2021).

5.1.3 Materials and methods

5.1.3.1 Methodological approach

Herein, we pragmatically unfold the OSS development, design, and implementation process to directly address critical barriers to energy renovation and contribute to market transformation. The proposed methodology follows a sequential five-step approach for developing digital OSSs for residential buildings renovation, comprising stakeholder mapping and analysis, semi-structured expert interviews, customer journey exercise, digital one-stop shop for building renovation, and market consultation survey, as laid out in Figure 5.1. This approach is applied and explored in the Portuguese context.

Outputs from the stakeholder mapping and analysis are inputs for selecting experts to be interviewed. Outputs from the semi-structured interviews and literature review provide insights into the customer journey exercise. Outputs from these three initial steps feed into the actual development of the digital OSS. Finally, after the launch of the OSS, market consultation surveys serve to gather user feedback, and their outputs are used to fine-tune the online platform.

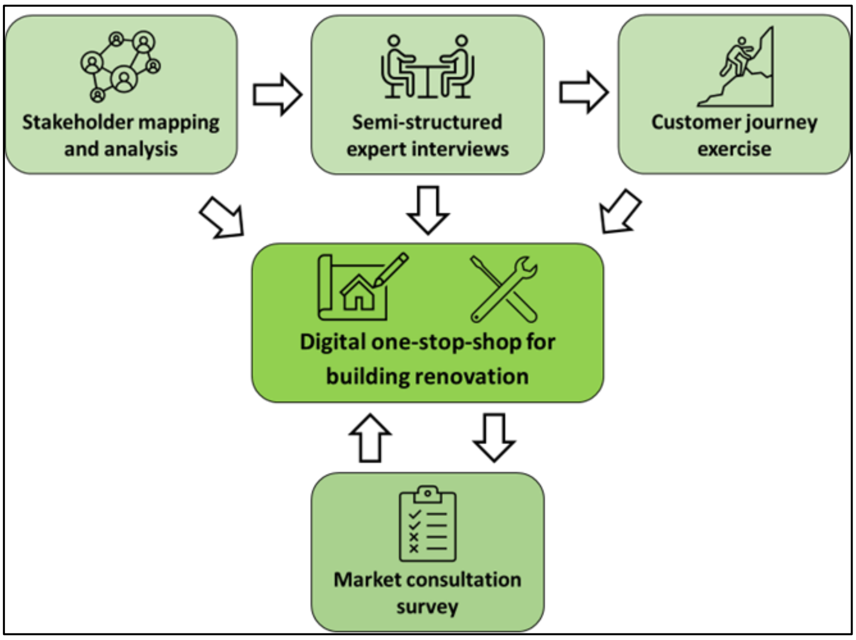


Figure 5.1 - Methodological approach for the development of building renovation digital OSSs.

5.1.3.2 Case-study Portugal

Portugal is committed to climate change mitigation, and key targets for 2030 include a 35% reduction in primary energy use. In 2019, the building sector represented 31% of energy use in Portugal (households represent 17%) (DGEG, 2020). The climate in continental Portugal is mostly temperate, with mild and dry summers in the north and coastal regions and hot and dry summers in the south and centre inland and in part of the northern inland region (Gouveia and Palma, 2019). For the last five-year period (2017–2021), Portugal had an average of 1109 heating degree days - the third lowest value among EU Member States - and an average of 214 cooling degree days - the sixth highest value among EU Member States (Eurostat, 2022b).

Portuguese buildings generally have low energy performance and a high incidence of problems such as lack of thermal comfort, indoor air pollution, leakages, and humidity (Gouveia and Palma, 2019). Available indicators report that 17.5% of households are unable to keep their home adequately warm (fourth highest in the EU and above the average of 7.4% in 2020), 35.7% of the population live in houses that are not comfortably cooled in summer (second highest and above the EU average of 20.9% in 2012), and 25.2% of the population live in dwellings with the presence of leaks, damp, or rot (second highest and above the EU average of 14.8% in 2020) (Eurostat, 2021b, 2022a, 2022c). In addition, based on available energy performance certificates, around 70% of households are inefficient (C class or lower) (Portuguese Energy Observatory, 2021).

Energy use in Portuguese households is the second-lowest per capita in the EU (Eurostat, 2020). Although country-specific factors play a role (*e.g.*, milder climate compared to other EU Member States, cultural normalization of thermal discomfort, and relevant share of unreported energy carriers, such as biomass, in final energy consumption), research has uncovered systemic energy performance gaps and underconsumption (measured as the difference between theoretical energy consumption to attain thermal comfort and actual energy use) in the Portuguese residential sector (Horta *et al.*, 2019; Palma *et al.*, 2019; Antepara *et al.*, 2020). Economic energy-saving potential for Portugal's residential sector has been estimated at approximately 50% of current consumption (Melo *et al.*, 2019). Silva *et al.* (2016) affirmed that applying the nearly zero energy buildings concept in the renovation of Portuguese buildings could lead to a 73% reduction in energy needs while being cost-effective during the buildings' lifetime. Monzón-Chavarrías *et al.* (2020) suggested higher savings of 80–96% in residential buildings.

Energy poverty is a severe societal problem in Portugal that negatively impacts public health, well-being, and the pursuit of overarching social, environmental, and economic goals (Gouveia *et al.*, 2019). According to the index developed by OPENEXP (2019), Portugal is the fourth-worst EU country regarding domestic energy poverty. The recently released national energy poverty mitigation strategy for 2021 to 2050, currently awaiting its final version, defines energy poverty as "the inability to maintain one's dwelling with an adequate level of essential energy services due to a combination of low incomes, low energy performance and energy costs", and estimates that up to 29% of the population may suffer from this condition (Portuguese Government, 2021a).

According to the Portuguese long-term building renovation strategy, virtually 100% of existing buildings will need to be renovated by 2050 (Portuguese Government, 2021b). However, building energy renovation rates remain very low, with deep renovation estimated to occur in fewer than 0.1% of buildings annually (European Commission, 2019; INE, 2020). According to Zangheri *et al.* (2021), from 2012 to 2016, Portugal recorded the lowest values in the EU for specific primary energy savings generated from household renovation. During this period, residential building renovation investment was also substantially below the EU average of 83 €/m^2 at just 37 €/m^2 (European Commission, 2019). In contrast, Palma *et al.* (2022) estimated a minimum investment of 71.7 billion euro for deep energy renovation of Portuguese residential building stock; this value is several orders of magnitude higher than the public funds currently available for building renovation.

The Portuguese residential sector showcases a hard-to-reach profile with many structural socio-economic vulnerabilities, low housing quality, energy illiteracy, and widespread energy poverty (Sequeira *et al.*, 2021). Meanwhile, viable OSS business models are thus far absent in Portugal, and the market for building energy renovation is widely fragmented and immature. Bertoldi *et al.* (2021) identified one OSS example in Portugal as part of the CLEAR European project, but it consists solely of an online discussion group managed by the Portuguese Consumers' Association. Likewise, the few other initiatives in Portugal that have approached the OSS concept have produced few practical results thus far.

5.1.3.3 Stakeholder mapping and analysis

To gather intel on the building renovation market in Portugal and as groundwork for the development of the digital OSS, a stakeholder mapping and analysis exercise was performed. Stakeholders can be considered individuals, groups, organizations, or sectors who may affect, be affected by, or perceive themselves to be affected by the uptake of building renovation (Project Management Institute, 2013). It is vital that stakeholders are identified and characterized and that their views and interests are known (Ginige *et al.*, 2018; Muhr *et al.*, 2020). This exercise followed a snowballing method, whereby expertise from previous projects (*e.g.*, Portuguese Government, 2019; Gouveia *et al.*, 2021) was combined with a literature review to map and analyse key stakeholders for building renovation in Portugal.

The proposed approach divides relevant stakeholders into three groups according to their relative importance from an OSS viewpoint: core, direct, and indirect. In addition to mapping the stakeholders, these can also be analysed regarding their current influence and interest/availability in OSSs, following the power/interest grid as defined by the Project Management Institute (2013). This approach recognizes that different stakeholders have varying levels of responsibility and authority and that a suitable communication strategy should be determined according to their characteristics (Project Management Institute, 2013; Muhr *et al.*, 2020). The communication strategy toward each stakeholder placed on the grid was classified as "monitor", "keep satisfied", "keep informed", and "manage closely", with an increasing level of engagement. The stakeholder mapping and analysis exercise was a useful tool to identify key context-specific players in building renovation who were then contacted for expert interviews. Such analyses could also serve as an initial step to foster deeper engagement and partnerships between the OSS and interested actors.

5.1.3.4 Semi-structured expert interviews

Expert interviews are a widely used qualitative method to gain information about a specific field of action (Galvin and Sunikka-Blank, 2014; Berawi *et al.*, 2019; Döringer, 2021). To understand the different perspectives of the market for building energy renovation in Portugal and map the existing gaps, barriers, and opportunities, exploratory interviews were conducted with 11 experts. The interviews took place in late 2020, were performed individually through an online platform, and were cross-referenced with existing data and research.

The interview script, which can be found in Appendix A, encompassed 32 semi-structured questions organized into six topics: Portuguese buildings characterization, Portuguese renovation market evolution, technical measures, policies and regulations, financing instruments, and citizen engagement and district-scale approaches. Interviewees included four architects, two civil engineers, two researchers, one journalist, one business leader, and one policymaker. Insights from expert interviews provided a better understanding of the current customer journey for household energy renovation and the main gaps and opportunities. Through this Portuguese case study, expert opinions also served as a kick-starter for a deeper discussion on approaches to engage with diverse typologies of households.

5.1.3.5 Customer journey

A customer journey exercise was performed to map the current perception of homeowners regarding building energy renovation and as the basis for decisions about the key features to be included in the online platform. This exercise is proposed as the final preparatory step for developing a building renovation digital OSS. Customer journeys are commonly defined as a series of touchpoints that customers go through before, during, and after building renovation (Volt *et al.*, 2019; Becker *et al.*, 2020). The customer journey involves all activities, encounters, and events linked to delivering a building retrofit service from a customer's perspective (de Wilde and Spaargaren, 2019).

The exercise was performed from the homeowners' perspective, since they are central to the OSS business proposition (Mahapatra *et al.*, 2013). The customer journey was divided into five sequential phases of dwelling renovation linked with the role of OSSs - orientation, advice, finance, implementation, and inspiration (similar to Bjørneboe *et al.*, 2017; de Wilde and Spaargaren, 2019; Kwon *et al.*, 2021). For each phase, four key aspects were mapped: (i) jobs to be done, as the main reason for the customer to consult an OSS; (ii) pains, as the main barriers faced when renovating; (iii) gains, as the main benefits from renovating; and (iv) possible solutions, *i.e.*, the act of the OSS filling in gaps in the customer journey. The customer journey offers a holistic picture of the processes of building renovation, which involves interactions with a range of actors (Becker *et al.*, 2020).

As one of the main challenges for the success of an OSS is to fulfil the homeowner's needs in the local context (Boza-Kiss and Bertoldi, 2018), the customer journey exercise can be used to generate empathy with OSS users. The set of possible solutions identified in the customer journey was a relevant input to better design and target the OSS services.

5.1.3.6 Digital one-stop shop for residential building renovations

Building on the above-described sequential steps, a Portuguese digital OSS for residential building renovations was developed as a case-study that tested the proposed methodological approach. The following subtasks were performed: (i) selecting a representative building typology; (ii) gathering data on appropriate technical measures, financial instruments, and regulations for the selected typology; and (iii) migrating the information to a visually appealing online platform (Green Menu).

Based on previous work (Palma *et al.*, 2019; Gouveia *et al.*, 2021), a uniform and iconic building typology, defined as a "single-family house built before 1919 in Lisbon", was chosen to showcase the process. Examples of real buildings from this typology, which fed the design of the 3D model for the digital OSS, can be found in Figure 5.2.

The prioritization of single-family homes, often owner-occupied, in OSSs is common both in the literature - *e.g.*, Mlecnik *et al.* (2018) - and in empirical case-studies - *e.g.*, 80% of the European OSSs mapped by Bertoldi et al (2021). In addition, the worst-performing buildings were explicitly prioritized in the Renovation Wave; specific skills are needed for the renovation of older buildings to safeguard their heritage value (de Santoli, 2016; European Commission, 2020). Other authors (*e.g.*, Sunikka-Blank and Galvin, 2016; Caro and Sendra, 2019; Mazzola *et al.*, 2019; Wise *et al.*, 2021) further highlighted homeowners' struggle to implement deep renovation measures when faced with a range of heritage and aesthetic concerns while describing health and environmental problems in dwellings in historic Mediterranean cities. In a comprehensive analysis of energy renovations in Portuguese dwellings, Palma *et al.* (2022) found that older building typologies have more potential for cost-effective renovation and that packages of measures lead to higher reductions in energy needs.

Figure 5.2 - Real buildings from Lisbon that served as concrete examples of the building typology selected to pilot the digital OSS (source: Google Maps).

Appropriate renovation measures to this specific building typology were derived from the description and technical analysis of building characteristics, such as age, typology, and construction materials (as suggested in Gonzalez-Caceres *et al.* 2020). Technical measures were selected and detailed based on extensive previously published work (*e.g.*, Sequeira and Melo, 2020; Salvia *et al.*, 2021). Portuguese regulations and ongoing financial schemes, such as soft loans, grants, and tax benefits, were also identified and collected to provide a complete picture of the current financing possibilities and regulatory constraints. The digital OSS, developed in Portugal through the proposed sequential multi-staged approach, followed the customer journey map with detailed information on the five stages of the building renovation process - orientation, advice, finance, implementation, and inspiration.

5.1.3.7 Market consultation survey

Following the launch of the online OSS (December 2020), online tool users were anonymously surveyed for their perception of the platform and of building renovation in general. The market consultation survey is proposed herein as the last stage in this methodological approach for the development of a digital OSS. The survey was conducted in Google forms and included 21 questions and 17 sub-questions (Appendix B). Given the COVID-19 pandemic situation, the online format was the preferred option for conducting the survey. A communication campaign for the platform launch and the market survey was carried out through social networks, institutional websites, and media.

Firstly, the survey addressed demographic aspects of the population (four questions regarding age, qualifications, and municipality) and their living arrangements (four questions about building type, period of construction, and ownership status). Additionally, four questions and nine sub-questions were focused on the drivers and barriers related to home renovation, based on the homeowner's past experiences and future renovation plans. Finally, the survey gathered feedback on the key features of the Green Menu (nine questions and eight sub-questions).

Due to the number of replies and the bias of participant recruitment, the market consultation survey does not intend to have statistical significance and remains an exploratory tool. Nevertheless, user feedback can be valuable for fine-tuning the OSS services and providing relevant insights into finding appropriate ways to engage with households.

5.1.4 Results

5.1.4.1 Overview

This section unfolds the multiplicity of results from the five steps proposed for constructing a digital OSS, exemplified through the Portuguese case-study. It aims to illustrate the operationalization of the proposed process pipeline, contributing toward a framework to mainstream building renovation OSSs in European countries in line with the Renovation Wave strategy. The empirical Portuguese case-study also provides insights for a broader discussion on the role of OSSs in leveraging the building renovation market, aiming for large-scale decarbonization and energy poverty mitigation, and on the current strengths and shortcomings of these emerging business models.

5.1.4.2 Stakeholder mapping and analysis

Figure 5.3 presents a summarized stakeholder map from the perspective of a building energy renovation OSS. Core stakeholders are the OSS's target audience, *i.e.*, homeowners, tenants, building/property owners, and condominium enterprises.

Direct stakeholders include those with an essential role in shaping the renovation market, at a national and local scale, through technical aspects, governance, financing, and citizen engagement. These include companies with business models focused on building renovation, renewable energy and other energy services, municipalities and civil parishes, and energy agencies. Due to the magnitude of the problem (*i.e.*, renovation of a significant proportion of the existing EU building stock), building renovation requires extensive public, private, or innovative mixed investment; thus, financing is a crucial challenge, and banks and organizations that manage existing financing mechanisms were also included in the category of direct stakeholders. Finally, national, regional, and local associations and cooperatives that promote energy literacy can work as trusted intermediaries between OSSs and communities.

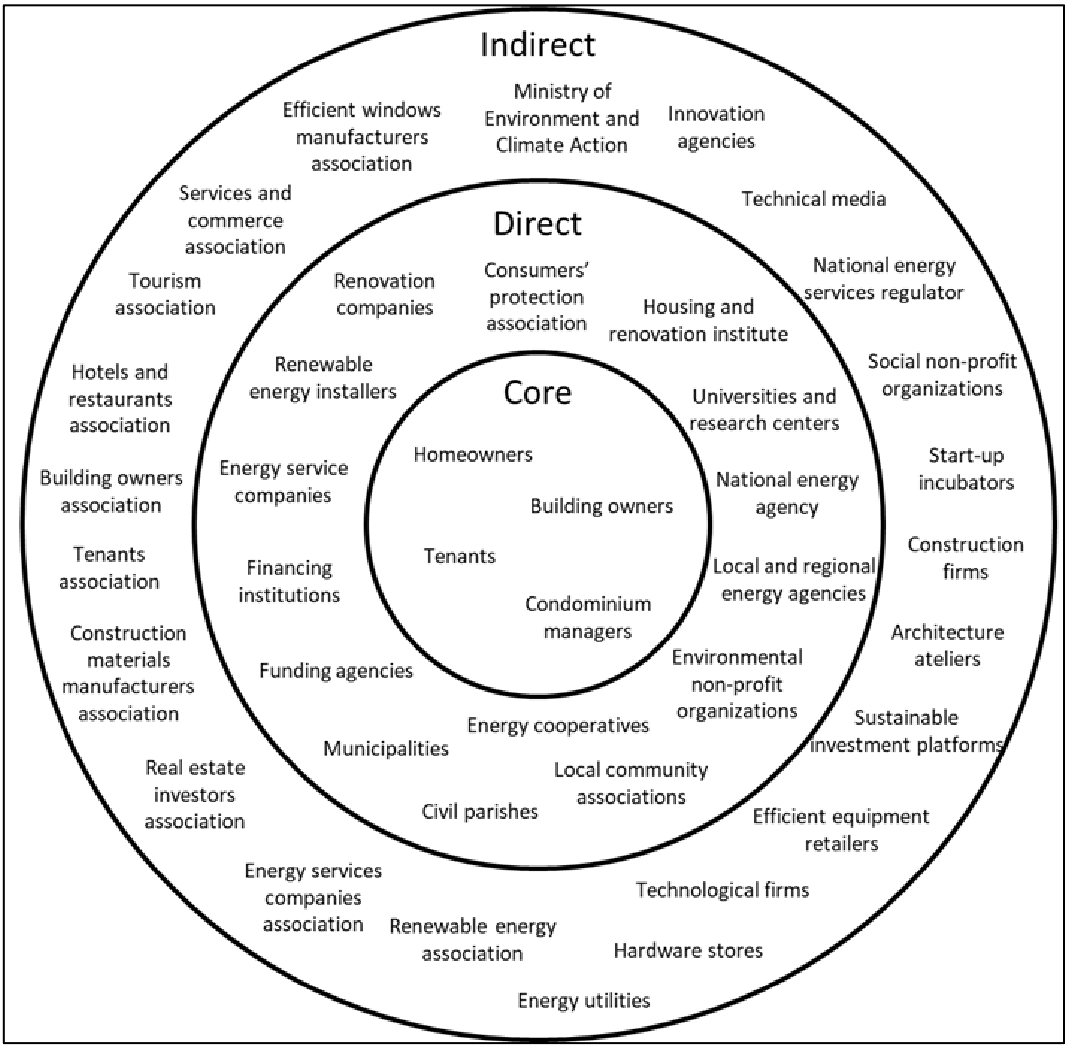


Figure 5.3 - Stakeholder map from the building renovation OSS perspective.

Indirect stakeholders are a heterogeneous group of actors associated with at least one of the multidimensional topics covered by building renovation but that, so far, are not expected to have any direct links to OSSs. The Portuguese Ministry of Environment and Climate Action was included in this group as it is a pivotal agent in energy transition throughout all economic sectors. Public organizations and national-scale associations, such as research laboratories, innovation agencies, entrepreneurship incubators, regulators, environmental and social non-governmental organizations, and others, were also identified as indirect stakeholders. A broad group of associations, private firms, and media was included in indirect stakeholders, ranging in scope, scale, and purpose.

Figure 5.4 presents the stakeholder analysis in the form of an influence and interest/availability grid from the perspective of an OSS. The stakeholders considered with strong influence and high interest/availability for building renovation include those previously identified as core stakeholders and the firms that operate directly with this type of customer. In addition, the Portuguese National Energy Agency, regional and local energy agencies, research centres, energy cooperatives, and the Consumer Protection Association are also relevant stakeholders that are starting to get involved in building renovation and citizen engagement, with some delving into one-off experiences in OSS-type activities, often linked with EU-funded projects. Stakeholders with a low influence but high interest/availability include local-scale associations, environmental non-governmental organizations, technical magazines, and technical associations. This latter group has deep-rooted interests in the services offered by OSSs and should be available for partnerships. However, in this group, each individual organization has a low input in the building renovation value chain.

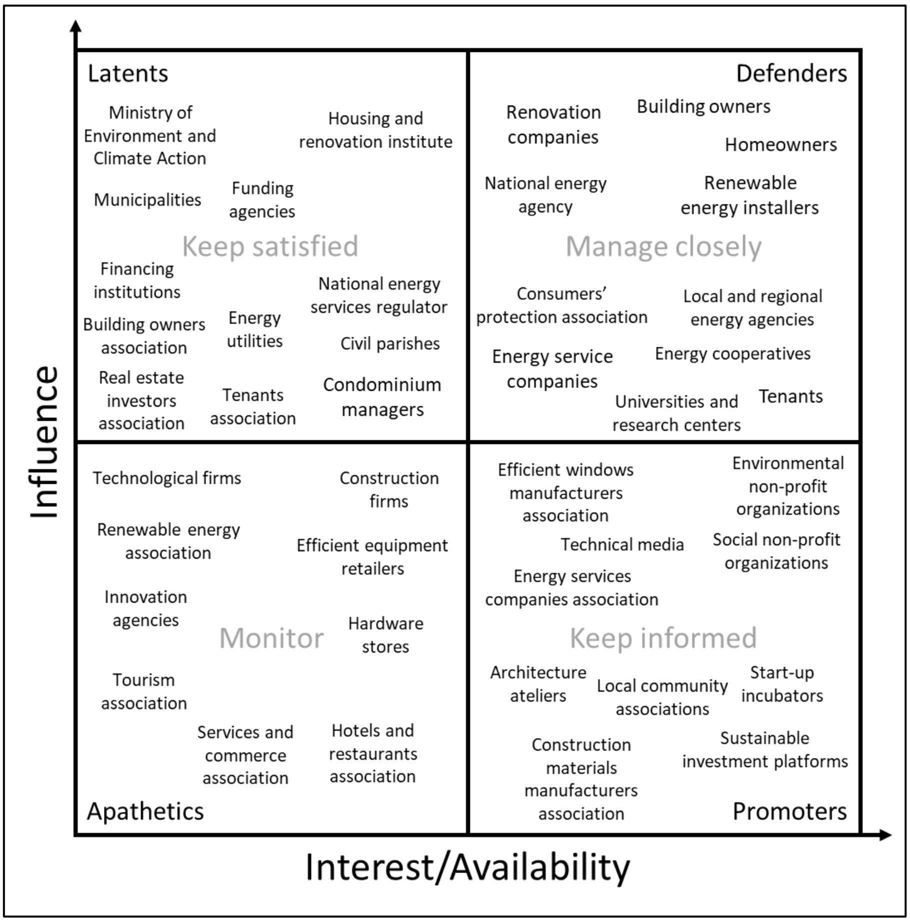


Figure 5.4 - Stakeholder analysis with influence and interest/availability grid.

Stakeholders with a high influence but potential low interest/availability include municipalities, financing institutions, and energy utilities. Although their power is extensive, these agents may not be particularly interested in OSS business models and may lack the motivation to engage in active partnerships. Finally, relevant stakeholders with low influence and low interest/availability include banks, funding agencies, public institutes, and national laboratories.

5.1.4.3 Semi-structured expert interviews

Table 5.1 summarizes the key insights from the expert interviews. While interviewees mostly agreed on the broader benefits of building renovation and the urgent need to increase current renovation rates in Portugal, their answers were less aligned regarding the optimal strategies to attain this goal.

Table 5.1 - Key insights from semi-structured expert interviews.

Topic	Key Insights
Portuguese building stock	- Most Portuguese buildings are of poor construction quality. - The main problems include indoor air pollution, humidity, and low thermal comfort. - Building renovation was highlighted as the future of the construction sector.
Renovation market evolution	- Historically, the urban renovation market in Portugal has been highly residual. - The financial crisis of 2008 was critical for the Portuguese construction sector. - Since 2014, historic centres have seen an impetus in renovation, driven by tourism demand. - However, building renovation did not consistently follow energy performance regulations, mainly focusing on cosmetic renovations, due to an exceptional regime only revoked in 2019. - Interviewees agreed that construction seemed primarily immune to the COVID-19 pandemic and that ongoing trends could return if the pandemic came under control. - Renovation rates remain low and well below the values set by the Renovation Wave. - Financial shortcomings, lack of expertise, insufficient information, slowness of licensing, and small labour forces were mentioned as crucial barriers. - Incoming recovery funds can be a fantastic stimulus for building renovation.
Technical measures	- The priority is to act on the building envelope and ventilation. - Active systems should only be considered later; interviewees were not aligned on the optimal selection of heating, cooling, and water heating technologies. - Be that as it may, three solutions were mentioned as beneficial by most interviewees: solar thermal systems, heat pumps, and biomass-based technologies. - The growing role of renewable energy sources in building renovation was highlighted. - Although technology is evolving, it is not for lack of adequate technical solutions that building renovation rates remain low in Portugal.
Policies and regulations	- The European Union is showing appropriate signs regarding building renovation. - In Portugal, building renovation was transversely facilitated by existing policies; however, practical results may only be visible in the medium-term. - Portugal has a long-term strategy for building renovation, but this plan must be better aligned with short-term visions, practical measures, and effective incentives. - A trade-off persists between heritage protection and large-scale renovation. - Building renovation policies are complex since they confront two essential citizens' rights: the right to adequate housing and the right to private property.

Financing instruments	- In contrast to Northern European countries, a significant share of Portuguese homeowners cannot finance their dwelling renovation and need financial support. - In Portugal, there is a set of financing and tax instruments for building renovation. - Interviewees affirm that their effectiveness has been relatively low due to lack of funds, few projects, poor design, bureaucracy, and insufficient citizen awareness. - Financial support should be assigned according to families' income and investment capabilities; information campaigns and technical support are key to overcome barriers.
Citizen engagement	- Apart from split incentives, condominiums face difficulties in financing, technical limitations, governance inefficiencies, and insufficient information. - Although many benefits were mentioned for taking district-scale approaches to building renovation, there is still a long way to go until full-scale deployment. - OSSs were referred to as an interesting concept, but that is still embryonic in Portugal. - Municipalities and civil parishes were highlighted as key players at local scale. - However, most Portuguese local authorities require additional resources.

5.1.4.4 Customer journey

For the customer journey, the "customer" was defined as homeowners interested in renovating their buildings (Figure 5.5). This exercise allowed us to visualize the critical tasks, barriers, and benefits that a customer must undergo at each stage of the renovation project. Touchpoints to increase an OSS audience were identified and included partner websites, websites of direct and indirect stakeholders, social media, traditional media, and multi-scale dissemination events for all customer journey phases. These touchpoints were later used for the launch of the case-study platform. A deeper understanding of the target audience allowed us to consider possible solutions that meet their needs. The customer journey worked as guidance for the development of the digital OSS.

	Orientation	Advise	Finance	Implementation	Inspiration
Jobs to be done	- Awareness of renovation needs and opportunities - Collect building data - Search for measures - Prioritizing actions - Understand the process	- Find trusted information - Look for expert advise - Select the measures - Search for national and local regulations - Search for providers	- Allocate own funds - Search and apply to public funding opportunities - Negotiate bank loans and/or payment methods - Evaluate budgets & offers	- Apply for a permit - Sign the contractors - Oversee the renovation - Control budget & timeline - Monitor renovation results - Comply with regulation	- Share experience - Recommend measures - Recommend trusted providers and contractors - Share financing options - Warn about problems
Pains	- Lack of awareness & time - Energy illiteracy - Information is spread out over different places - Not knowing which data is accurate and trustworthy	- Understanding complex information & technologies - Not knowing who to contact and who to trust - Selecting the best options - Planning the next steps	- Lack of own funds - Applying to complex funding (bureaucracy) - Unattractive bank loans - Aversion to (more) debt - Perception of low return	- Getting a permit - Renovation noise & waste - Budget & time constraints - Managing contractors - Monitoring the correct adoption of measures	- Lack of time to share experience with others - Lack of interest from those not planning a renovation
Gains	- Gaining awareness and motivation to start - Implementing some quick wins for energy saving - Starting to prioritize and plan the renovation	- Gaining a deeper insight on energy consumption - Detailed data for the home - Understanding renovation options and challenges - Finding trusted advisors	- Taking advantage of funding opportunities - Reducing energy costs - Getting a positive return on investment and raising the building's market value	- Improving thermal and acoustic comfort - Energy savings and healthier living environment - Own electricity generation - Reduced maintenance	- Opportunity to renovate more buildings in the area - Recognizing trusted providers and contractors - Raise awareness and activate other stakeholders
Possible solutions	- Provide free online data - Combine all information in one single trusted platform - Attractive layout & clear user-friendly information - Use building typologies	- Provide simple calculation tools for key measures - Direct users towards trustworthy advisors - Inform on regulations for specific measures	- Provide clear information on funding opportunities - Financing tools are connected to the measures - Direct users towards funding/financing agencies	- Provide information on how to apply for a permit - Advise on how to select a good offer and budget - Advise on how to oversee and monitor the renovation	- Provide a platform to share experiences - Disseminate best practices and success cases

Figure 5.5 - Customer journey map from a homeowner perspective.

5.1.4.5 Digital one-stop shop for residential buildings renovation

The case-study digital OSS for building renovation is showcased in Figure 5.6, with a 3D model of the selected residential building typology and information on measures, financial schemes, and regulations. The overall structure of the platform is shown in Table 5.2 and could serve as a reference for the design of other digital OSSs in European countries. For the Portuguese case-study, around 130 measures, tips, points of attention, and innovations were selected, divided into five overarching themes, and disaggregated into several categories. User-friendly calculation tools are available for 12 key measures, allowing case-specific estimates of energy savings, investment costs, thermal comfort impacts, and CO2 emissions reductions.

Figure 5.6 - Layout of the Green Menu online platform (CENSE NOVA-FCT and De Groene Grachten, 2020).

Table 5.2 - Structure of the Green Menu (* marks categories with calculation tools).

Theme	Category	No. of Measures
Orientation: Quick wins	Energy use	12
	Water use	4
Orientation: Insulation and ventilation	Seams and gaps	6
	Roof insulation	6 *
	Floor insulation	5
	Wall insulation	8 *
	Windows	9
	Ventilation	5
Orientation: Electricity generation and end-use appliances	Electricity generation	10 *
	Monitoring, storage, and electric vehicle charging	4
	Lighting	5 *
	Cooking	4
	Other electrical equipment	6 *
Orientation: Climatization and water heating	Space heating	9 *
	Heat distribution	8
	Water heating	13 *
	Space cooling	6 *
Orientation: Water and greenery	Green roofs and façades	3
	Water use	7
Advise	-	-
Financing	-	12 schemes
Implementation	-	-
Inspiration/News	-	-

The platform also contains up-to-date information on 12 Portuguese financing schemes (*e.g.*, grants and soft loans) and tax benefits available for building renovation in general and for specific measures. Relevant regulations that apply to the implementation of specific interventions are also shown next to the appropriate measure, considering the limitations of heritage protection in older buildings (mainly regarding exterior building alterations). Green Menu users can select the desired measures for their household, run energy-saving simulations, and save them in a tailored energy renovation package. Finally, the Green Menu provides inputs to guide the subsequent phases of a household renovation project, including a set of links where users can seek additional information (*e.g.*, databases on renovation companies).

5.1.4.6 Market consultation survey

A total of 91 responses were obtained on the survey following the online launch of the Green Menu. Although the small number of obtained answers does not provide a statistical basis for the analysis, the outputs serve to gather feedback on the platform and better understand user needs. Firstly, regarding demographics, the survey was completed by all age groups, with a high share (75%) of people with higher education but with no formal training on the topic at hand. The majority resided in the metropolitan area of Lisbon (66%). Around 31% of the inquired live in single-family houses, while 63% state that they live in multi-family buildings. 84% were homeowners or their relatives. Answers on building construction age were heterogeneously spread between 1946 and 2015.

Around 33% of the survey participants stated that they had performed energy-related renovations in the past, while 57% plan to do so in the future. The main drivers included improving comfort (83%), environmental concerns (53%), and reducing energy costs (43%). The main barriers were the unawareness of adequate measures (43%) and other priorities (28%). Around 68% of the survey participants were not aware of any available financing schemes in Portugal.

Regarding feedback on the Green Menu itself, 97% declared their interest in an OSS platform that brings all information under one roof. Around half of the participants found the platform to be well organized, while the other half selected the option "do not know", possibly due to a lack of time to explore it in detail. The visual aspect was considered appealing to more than 75% of the interviewees.

5.1.5 Discussion

The proposed sequential multi-staged approach for developing digital OSSs was successfully tested in the Portuguese case study to create the Green Menu online platform. This methodological toolbox has a high replicability potential, encompassing three initial steps to acquire in-depth knowledge on the status of the local building renovation market, the actual design of the platform, and a market consultation survey to gather feedback and fine-tune the digital OSS. The replicability of OSS approaches is deemed crucial by Volt *et al.* (2021) for the rapid deployment of the model across the EU. In this section, results from the five steps are integrated and discussed in the context of the Portuguese case study, including possible future pathways for the digital OSS. Insights from the application of our methodology in Portugal, as well as the key case-study findings, contribute to the broader discussion on the potential role of renovation OSSs for a sustainable and inclusive energy transition.

The barriers mentioned during our interviews and survey overlap with those found in the literature (Shnapp *et al.*, 2020), with lack of knowledge, competing priorities, and insufficient funds seeming particularly severe. The customer journey exercise further highlighted the multiple barriers that appear at each phase of a renovation project. The main trigger for renovations in our case study appears to be the increase in thermal and acoustic comfort (83% of participants), both for past and future renovations, as also found by other authors (*e.g.*, Barbiero and Grillenzoni, 2019; Ebrahimigharehbaghi *et al.*, 2019). Aesthetic improvements and maintenance are also high on the agenda for these households, which correlates with other research that noted that energy-related renovation has a lower priority (Mahapatra *et al.*, 2019; Pardalis *et al.*, 2021). Survey results from this study suggest that over half of homeowners are interested in renovating their dwellings, a slightly lower value than that stated in Causse *et al.* (2021); in that report, the authors conducted a survey of property owners and found that around 70% of Portuguese respondents said that they planned to carry out renovation works. Even though a policy framework is in place and a few financing mechanisms are available in Portugal, expert opinions indicate that their effectiveness has been relatively low. This was further suggested in our survey by the low share of people aware of financing schemes, which is particularly noteworthy, since most of the surveyed individuals were highly educated. The fragmented and complex nature of the mapped customer journey denotes the insurmountable barriers for homeowners that wish to renovate.

Interviewees mentioned OSSs as a promising solution that is still embryonic in Portugal and most other European countries. In addition, our market survey suggests that the concept is attractive to homeowners, even if the surveyed population was small and is not intended to represent the Portuguese context. The Green Menu offers information on specific building typologies and suitable technical solutions, as well as calculation tools and comparisons, which can help to manage the complex process of renovating real buildings, as also suggested by Murto *et al.* (2019). In the online OSS platform, besides energy savings, non-energy benefits, such as improving comfort, health, safety, and aesthetics, were also emphasized as an important component of the value proposition of deep energy renovation (as suggested by Brown, 2018; Mahapatra *et al.*, 2019; Abreu *et al.*, 2020). Together with environmental concerns, as mentioned by Mlecnik *et al.* (2018), the importance of these drivers was exposed during our market consultation survey. While the focus of the OSS is on deep renovation, low-cost and self-renovation measures were also included in the platform since these can be particularly relevant for households that are not able to make large investments in home renovation (Senior *et al.*, 2021). Portuguese financing schemes are showcased in the OSS since the availability of financing incentives can create customer interest in energy renovations (as found by Mahapatra *et al.*, 2013).

The Green Menu currently follows the facilitation OSS model, where trustworthy information for the first stages of renovation is provided for free (Cicmanova *et al.*, 2020). As a more straightforward service with low costs, it is the preferred model to gauge the reception of this innovation in an immature market and pave the way for more integrated solutions, as recommended by Cicmanova *et al.* (2020). An online portal is considered by the same authors as an efficient method to engage with customers while reducing costs and increasing conversion rates, thus creating a scalable and more viable process. Kwon *et al.* (2021) similarly argue for modular web portals that follow the home renovation customer journey for specific building typologies and provide context-appropriate information and advice at every stage. Online tools also respect COVID-19 restrictions and may be particularly helpful in these uncertain times; privacy and security are growing concerns (Kwon *et al.*, 2021). However, there is an inherent tension between giving independent energy advice and paying for it (as asserted by Mlecnik *et al.*, 2018). These costs are usually covered by the projects obtained following the free advice, but a digital OSS, such as the one developed in this case-study, may not be able to provide advanced services that can generate revenues, at least during the start-up phase.

Even if the digital OSS seems to address some of the barriers to building renovation, such as lack of information and energy illiteracy, our experience also indicates that it may be insufficient on its own to activate a significant share of hard-to-reach energy users (Boza-Kiss and Bertoldi, 2018). As in other OSS services and studies (*e.g.*, Mahapatra *et al.*, 2013; Mlecnik *et al.*, 2018; Croci *et al.*, 2020; Hall *et al.*, 2021), the target group for the Green Menu was single-family houses and surveyed customers can be defined as homeowners that are educated, innovative, open-minded, interested in environmental issues, and likely to have above-average income. Pardalis *et al.* (2021) further narrow homeowners younger than 45 years old, with dwellings built from 1960 onward, and with environmental awareness, as potential early adopters of OSS concepts. Since the OSS renovation market is immature and full renovations are expensive, only customers with these specific characteristics are expected to show interest in complex building renovation processes (as also found by Mahapatra *et al.*, 2013; Pardalis *et al.*, 2019b; Abreu *et al.*, 2020). While the Green Menu's online presence is a positive feature, it can also turn off customers who prefer a face-to-face approach, hard-to-reach users with limited access and knowledge of online systems, and users who cannot find the needed information for their building typology on the platform (as suggested by Maraquin and Eisermann, 2020). This risk was uncovered by our market survey, where only half of the survey participants confirmed that they found the information clear and well organized, suggesting that detailed but comprehensible descriptions of measures should be prioritized.

By combining all information in one platform, the digital OSS reduces complexity in the first phases of a project. Nevertheless, since the facilitator model does not imply a follow-up on implementation, the homeowner still needs to deal with the complexity during this critical phase. Besides, as mentioned by Bjørneboe *et al.* (2017), the OSS only reaches those already motivated, often with available funds, and just needing guidance. However, the number of homeowners with deep renovation plans for their house is suspected to be minimal, especially when budget limitations are factored in, as reported by Mahapatra *et al.* (2019) and Pardalis *et al.* (2019b). For this small share of homeowners, digital OSSs may provide valuable information, simplify the process, and increase the effectiveness and depth of renovation. Even so, other barriers, such as competing priorities and lack of time, can still constrain homeowners, as exposed in our market survey. It should also be noted that Mahapatra *et al.* (2019) found that as high as 50% of homeowners may be less interested in the OSS concept because they perceive it as a more expensive option. Pardalis *et al.* (2019b) stated that 20% of surveyed homeowners in Sweden have a favourable view of OSSs.

In contrast, the OSS will not contribute significantly toward engaging citizens that remain inert regarding renovation for many reasons (*e.g.*, energy and digital illiteracy, and others reviewed by Rotmann *et al.*, 2020). This is problematic because it seems that the current customer journey only addresses one type of homeowner - a small share of higher-income and educated population - excluding all others from more sustainable housing (de Wilde and Spaargaren, 2019). Indeed, our case-study's digital OSS services may not match the needs of many Portuguese households. These cannot be activated by online information alone and are the ones that, most likely, will require greater assistance to mitigate energy poverty and keep up with the energy transition; as recognized in the Portuguese energy poverty mitigation strategy (draft version) and the Portuguese long-term building renovation strategy (Portuguese Government, 2021a, 2021b).

Without targeted intervention, innovative business models, such as OSS, may exacerbate social inequalities (Bartiaux *et al.*, 2016; Hall *et al.*, 2021). Looking beyond single-family houses, OSSs need to be able to support large-scale energy renovation in multi-family buildings, condominiums, social housing, and vulnerable and energy-poor households (as also stated by Boza-Kiss and Bertoldi, 2018; Murto *et al.*, 2019; Volt *et al.*, 2019; Domínguez-Amarillo *et al.*, 2020) Bertoldi *et al.*, 2021). These audiences present additional challenges for OSSs, such as the inability to make collective decisions due to lack of cooperation between homeowners, tenants, and condominium associations (Streimikiene and Balezentis, 2020). Further research is needed to discover which groups of households are motivated and satisfied by what type of services and customer journeys.

Some of the aforementioned shortcomings of the OSS case-study in Portugal can be mitigated by providing additional services and moving up the ladder toward more complex, all-inclusive models (as described in Cicmanova *et al.*, 2020). Actively seeking new customers, offering complete packages, and easing access to finance may improve the value proposition and attract larger audiences in the residential sector. While digital platforms are a good place to start an OSS business, Cicmanova *et al.* (2020] recommend creating a physical shop with qualified personal if sufficient financial resources are available. Trust is one of the decisive factors in selecting renovation services, and credibility must be maintained through quality assurance, monitoring, and follow-up (Pardalis *et al.*, 2019b; Maraquin and Eisermann, 2020; Hall *et al.*, 2021). It might be relevant to partner with intermediary organizations, building on existing trusted relationships that can simplify the customer journey, lower transaction costs, facilitate project implementation, and help raise awareness on retrofit opportunities (Kivimaa and Martiskainen, 2018; Peltomaa *et al.*, 2020). Synergies for energy renovation are clear when scaled up to the neighbourhood level, creating new business opportunities for OSSs to cluster several houses with similar needs (European Commission, 2020; Mainali *et al.*, 2021).

Key stakeholders identified for the Green Menu, apart from homeowners, broadly fall under the four categories described by Mlecnik *et al.* (2018): (i) renovation providers; (ii) trusted intermediaries (*e.g.*, community organizations, hardware stores); (iii) local, regional, and national authorities; and (iv) financial supporters. While small renovation providers may be interested in participating in OSSs, Pardalis *et al.* (2020a) suggested that they prefer to leave the coordination role to an external party. Ebrahimigharehbaghi *et al.* (2019) highlighted homeowners' associations, governmental authorities, and environmental agencies as the most reliable sources of information among surveyed Dutch homeowners. By involving some of these key partners, the case-study OSS can build customer trust and better target specific users, for instance, by providing a single customer interface (as recommended by Pardo-Bosch *et al.*, 2019). Collaborative business models for energy renovations and alliances with local authorities, micro-enterprises, and large companies, can speed up the OSS market (Owen *et al.*, 2014; Mlecnik *et al.*, 2018). Several authors (*e.g.*, Mahapatra *et al.*, 2013; Bertoldi *et al.*, 2021) have suggested a specific focus on local communication channels as an important way to motivate homeowners. Satisfied customers can be ambassadors for energy renovation in their community (as noted by Gram-Hanssen, 2014; Mlecnik et al, 2018), as planned for the 'inspiration' section of the Green Menu to showcase success stories.

An OSS can be the first piece of a more comprehensive local strategy to support citizens in various aspects of the energy transition, as suggested by the European Commission (2020). Local authorities have in-depth knowledge about the building stock and can take the initiative of combining support, guidance, and group purchasing of energy renovation services, therefore accelerating the building renovation market in their region (Pardo-Bosch *et al.*, 2019; Kwon *et al.*, 2021; Tingey *et al.*, 2021). OSSs, local authorities, and other stakeholders can also collaborate to train renovation providers and equipment installers/sellers to better inform and act on energy-efficient solutions (Mahapatra *et al.*, 2013; Bertoldi *et al.*, 2021). This research adds to several authors' statements that public funding should be provided to OSS projects that aim to test different cost-effective business models, develop reference sites, and bring together relevant stakeholders (*e.g.*, Murto *et al.*, 2019; Kerr and Winskel, 2020). This public finance flow is particularly crucial for emerging OSSs, as they may need 5 to 8 years to close market gaps and make the business model financially viable (according to Cicmanova *et al.*, 2020).

Public finance can make-or-break OSSs in immature markets, as is the Portuguese case, where buildings energy renovation services may not be profitable enough for private companies (due to under consumption situations and energy performance gaps) and may instead need to be regarded as a public service (as also stated by Cicmanova *et al.*, 2020; Domínguez-Amarillo *et al.*, 2020). Likewise, Bertoldi *et al.* (2021) see OSSs as an essential tool to alleviate energy poverty, bridging financial and power gaps and mediate split incentives, and Pardalis *et al.* (2020b) explore OSS as a sustainability-oriented business model innovation. Since the challenges to deep building renovation are multifaceted, an effective OSS business model needs to be framed by favourable overarching policy instruments and financial conditions, from the European to the local scale (Brown, 2018; Di Foggia, 2018; Kerr and Winskel, 2020). For instance, Pillai *et al.* (2021) describe an Irish building renovation scheme tailored to low-income households that combines 100% grant funding with the OSSs approach to achieve significant energy efficiency improvements. In the context of the Portuguese case-study, viable OSSs can play a pivotal role in meeting the country's energy and climate targets and implementing the long-term building renovation and energy poverty mitigation strategies (Portuguese Government, 2021a, 2021b).

5.1.6 Conclusions

This research critically reviewed the one-stop shop concept, as an emerging approach that can help to leverage energy renovations of residential buildings by specifically addressing key market barriers. It proposes a sequential multi-staged approach for the development of digital OSSs for building energy renovation, which may be particularly relevant for European countries where the business model is still absent or niche, including (i) stakeholder mapping and analysis, (ii) semi-structured expert interviews, (iii) customer journey, (iv) design of a digital platform, and (v) market consultation survey. The methodological approach was successfully tested for a Portuguese case study, and the authors encourage its replication and further expansion in countries with immature building energy renovation markets.

The case-study digital OSS represented a practical attempt to close information gaps, activate citizens, and leverage Portugal's still immature building renovation market. The online platform combined information on technical measures, financing, and regulations, making the customer journey simpler and more attractive. Based on the facilitation model where only information is provided, it caters mainly to the needs of homeowners who are already motivated regarding building renovation. However, while the digital OSS can address several barriers to citizen engagement, the current scope of services is insufficient for most Portuguese households.

These simply do not have the resources, knowledge, and motivation required to kick-start a renovation process in their houses and are also the ones at risk of being left behind in the energy transition. Therefore, a broader range of both virtual and physical OSSs services, including tailored local-scale support, dedicated funding streams, and coordination of the works, may be necessary to engage larger audiences in energy renovations of residential buildings. These should be accompanied by an enabling national and local policy environment with a comprehensive set of instruments and overarching financing for building renovation.

To fulfil the potential of OSSs to increase building renovation rates in Portugal and elsewhere, and based on our case study, the following key points should be focused on: (i) complement digital OSSs with physical (local or regional) OSSs; (ii) develop partnerships with relevant stakeholders as local and regional authorities, energy agencies, renovation providers, and community actors; (iii) provide trustworthy services that link all project phases; (iv) streamline access to finance and public funds; and (vi) explore neighbourhood-scale approaches for building renovation. Building upon the proposed multi-staged approach, innovative OSS business models can flourish, enabling a larger number of households to engage in building renovation and enjoy its multiple benefits.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia: Visualization, Methodology, Investigation, Validation, Conceptualisation, Project administration, Funding acquisition.

Appendix A. Interview script for the semi-structured expert interviews

Portuguese buildings characterization:

1. What are the most pressing pathologies and needs of residential buildings in Portugal?
2. What kind of construction and materials are more common in old residential buildings in Lisbon (constructed before 1919/1945)? What pathologies are typically present and require intervention? Other common characteristics (area, number, divisions, owner/tenant, among others)?
3. What type of energy consumption is typically found in old residential buildings in Lisbon (*e.g.*, electricity, natural gas, biomass)? What type of energy-consuming equipment exists?

Portuguese renovation market evolution:

4. How has the building renovation market evolved in Portugal over the last few decades?
5. What are the main drivers and barriers from the perspective of the various players involved in the different stages of the energy renovation process of a residential building?
6. What is the average quality of renovation works of buildings in Portugal, taking into account energy performance improvement?
7. Why is the rate of building renovation in Portugal so low compared with the European average and the figures predicted in the European Green Deal and the European Renovation Wave?
8. How has the market for the renovation of historic areas of Lisbon/Portugal been evolving? What are the main drivers? What needs to be addressed to increase the number and quality of projects, without requiring the residents to leave?
9. How to leverage the residential building renovation market in Portugal taking into consideration the decarbonization of the sector by 2050?

Technical measures for the energy renovation of residential buildings:

10. Which energy efficiency and comfort measures must be prioritized in Portuguese buildings? Which of them are most frequently applied? Which could be applied, but are not? Why?
11. What type of measures provide an improvement in thermic performance of buildings in both winter and summer?
12. What type of energy efficiency and comfort solutions are most appropriate for old buildings? Which of them are most frequently applied? Which of them could bring benefits, but are not applied? Why?
13. How is the integration of renewables (mainly solar photovoltaic) evolving in the renovation of residential buildings? And in old residential buildings with historic value?
14. What type of innovative, technical solutions are being developed to improve the energetic and thermic comfort performance, with short/medium term impact on the market?
15. How much importance do you give to local knowledge and techniques in the renovation of buildings? And to the existence of qualified entities in a context of proximity to the community?
16. How important is it to use locally sourced materials, from the perspective of sustainability, circular economy, and thermic performance improvement?

Policies and regulations for the renovation of residential buildings:

17. What is your perspective on the evolution of policies and regulations, in Lisbon and Portugal, which establish the norms for the renovation of buildings? What are their pros and cons when considering a continued and sustainable energy renovation?
18. What policies and regulations, in Lisbon and Portugal, are specific to the renovation of old and historic residential buildings?
19. What are the main barriers to the renovation of historic buildings?
20. Which regulations/measures/processes could be adopted to streamline and expedite the renovation process of a building?

Financing instruments for the renovation of residential buildings:

21. Do you think that financial support instruments for the renovation of buildings in Portugal have been effective? If not, why not?
22. What are the factors that determine the success of this kind of support? What importance do you give to personal and personalized contact for the adoption of financial support?
23. How important are digital platforms to involve people in building renovation and to increasing the rate of adoption of financial instruments by the population. What information do you consider should be on these sites?
24. What financial (or other) barriers are still present in renovation projects for the various participants?
25. What financial (or other) mechanisms could be implemented in order to accelerate the renovation and regeneration of historic areas? And what about the renovation of residential buildings in general to increase the current rate (from 1% to 3.5%)?
26. How should the renovation of buildings, where people on low wages live and who have no ability to invest, be promoted? How could a financial instrument be specifically directed to these people?
27. How could traditional commerce and services, often situated on the ground floor of residential buildings, be involved in the rehabilitation process? What instruments should be directed to these small and medium sized companies?

Citizen engagement and district-scale approaches:

28. Which stakeholders should be involved in the renovation of buildings in Portugal?
29. What type of approach is necessary to involve citizens, companies, and authorities in the renovation of buildings?
30. What possible advantages and disadvantages are there in the adoption of an approach to renovation on a neighbourhood or district scale, compared with the traditional approach at the single building scale? What role should the different stakeholders take on in both situations?
31. What examples are there in Portugal (and other countries) that might be relevant to the boosting of the renovation of residential buildings?
32. Can you recommend another entity or person to interview with respect to this matter?

Appendix B. Structure of the market consultation survey

1. Age
   - 18–24
   - 25–39
   - 40–59
   - 60–70
   - >70
   - Does not answer
2. Education level
   - 4-years
   - 9-years
   - 12-years
   - Bachelor's
   - Master's
   - Ph.D.
   - Does not answer
   - Other
3. Do you work in the energy, construction, or housing sector?
   - Yes
   - No
   - Does not answer
4. Municipality
5. Year of construction of the building
   - before 1919
   - 1919–1945
   - 1946–1960
   - 1961–1980
   - 1981–1990
   - 1991–2004
   - 2005–2015
   - after 2015
   - Does not answer
6. Building typology
   - Single-family house (isolated)
   - Single-family house (in band/geminated)
   - Apartment in a multi-family building with 2 floors or less
   - Apartment in a multi-family building with 3 or 4 floors
   - Apartment in a multi-family building with 5 floors or more
   - Does not answer
   - Other
7. Do you own or rent your dwelling?
   - Owner
   - Family member of the owner (no rent or symbolic rent)
   - Long-term tenant
   - Short-term tenant
   - Does not answer

Other

8. Are you a landlord?
Yes
No
Does not answer

8.1. If "yes" on question 8, do you worry about the energy performance of the houses you rent?
Yes
No
Does not answer

8.1.1. If "yes" on question 8.1, why do you worry about the energy performance of the houses you rent (select all options that apply)?
To increase the value of the rent
To make renting easier
To reduce energy costs
To increase thermal and acoustic comfort
To address worries about sustainability
To fulfill legal concerns
Other

8.1.2. If "no" on question 8.1, why do you not worry about the energy performance of the houses you rent (select all options that apply)?
It is not possible to improve energy performance of the house
I do not know if the measures will bring benefits
I have other priorities
It is not possible to conduct renovation works
I do not pay the energy bill
Other

9. Have you conducted renovation works in your home with the goal to improve energy performance?
Yes
I conducted renovation works but not acted on energy performance
No
Does not answer

9.1. If "yes" on question 9, what drivers led to the renovation works with the goal to im-prove the energy performance of your house (select all options that apply)?
I had to renovate the house anyway
To increase the house's market value
To reduce energy costs
To improve thermal and acoustic comfort
To improve the environmental sustainability of the house
To fulfill legal requirements
To produce my own renewable energy
Other

9.2. If the answer on question 9 was "I conducted renovation works but not acted on ener-gy performance", what were the barriers to improve the energy performance of your house during the renovation works?
I do not know what measures are appropriate to my house
It is not possible to improve the energy performance of the house
I do not know if the measures will bring benefits

I had other priorities
I had a limited budget
I cannot implement measures in my house
I do not pay the energy bills
Other

10. Are you planning to perform renovation works (even if simple) at some point in the next 10 years?
Yes
No
Does not answer

10.1. If "yes" on question 10, are energy efficiency measures and renewable energy sys-tems among your priorities for renovation works?
Yes
No
Does not answer

10.1.1. If "yes" on question 10.1, what are the drivers to implement these solutions?
To increase the house's market value
To reduce energy costs
To improve thermal and acoustic comfort
To improve the environmental sustainability of the house
To fulfill legal requirements
To produce my own renewable energy
Other

10.1.2. If "no" on question 10.1, what are the barriers to implementing these solutions?
I do not know what measures are appropriate to my house
It is not possible to improve the energy performance of the house
I do not know if the measures will bring benefits
I have other priorities
I have a limited budget
I cannot implement measures in my house
Other

11. Do you know any financing schemes that support the improvement of energy perfor-mance in the residential sector?
Yes
No
Does not answer

11.1. If "yes" on question 11, which one?

12. If a digital platform with all the needed information—such as technical measures, fi-nancing schemes and regulations—to improve energy performance was available would you be interested in using it?
Yes
No
Does not answer

13. How would you like to receive information about this platform (select all options that apply)?
E-mail
Social networks (Facebook, Instagram, Twitter, LinkedIN)
Written press
Radio

Television
With your energy bill

14. What would be the preferential way of using the platform?
Computer
Tablet
Smartphone

15. Do you consider the visual aspects of the Green Menu (3D model, animations, and pictures) attractive when compared with other platforms?
Yes, but I do not know others
Yes, even when compared with others
No
Does not answer

15.1. Can you suggest any improvements?

16. The Green Menu combines in the same platform technical information, financing, and regulations. Do you think that this is a useful feature that can facilitate the process of ren-ovation your dwelling?
Yes
No
Does not answer

16.1. Can you suggest any improvements?

17. Is the information on the technical measures well organized, clear, and accessible?
Yes
No
Does not answer

17.1. Can you suggest any improvements?

18. Is the information on the financing schemes well organized, clear, and accessible?
Yes
No
Does not answer

18.1. Can you suggest any improvements?

19. Do you consider useful for the financing schemes to be directly linked to the corre-sponding technical measures?
Yes
No
Does not answer

19.1. Can you suggest any improvements?

20. Is the information on the regulations and licensing processes well organized, clear, and accessible?
Yes
No
Does not answer

20.1. Do you consider useful for the regulations and licensing processes to be directly linked to the corresponding technical measures?
Yes
No
Does not answer

20.2. Can you suggest any improvements?

21. The Green Menu already includes a short list of key stakeholders to contact to perform energy renovation of the house. Do you consider this information useful?

- Yes
- Yes, but more information is needed
- No
- Does not answer

21.1. Can you suggest any improvements?

References

Abreu, M.I., de Oliveira, R.A., and Lopes, J. (2020). Younger vs. older homeowners in building energy-related renovations: Learning from the Portuguese case. Energy Rep., 6, 159–164. https://doi.org/10.1016/j.egyr.2019.08.036.

Ambrose, A., Baker, W., Batty, E., and Hawkins, A. (2019). Reaching the 'Hardest to Reach' with Energy Advice: Final Report, Sheffield Hallam University: Sheffield, UK. https://doi.org/10.7190/cresr.2019.8286642862.

Antepara, I., Papada, L., Gouveia, J.P., Katsoulakos, N., and Kaliampakos, D. (2020). Improving Energy Poverty Measurement in Southern European Regions through Equivalization of Modeled Energy Costs. Sustainability, 12, 5721. https://doi.org/10.3390/su12145721.

Barbiero, T., and Grillenzoni, C. (2019). A statistical analysis of the energy effectiveness of building refurbishment. Renew. Sustain. Energy Rev., 114, 109297. https://doi.org/10.1016/j.rser.2019.109297.

Bartiaux, F., Schmidt, L., Horta, A., and Correia, A. (2016). Social diffusion of energy-related practices and representations: Patterns and policies in Portugal and Belgium. Energy Policy, 88, 413–421. https://doi.org/10.1016/j.enpol.2015.10.046.

Bean, F., Volt, J., Dorizas, V., Bourdakis, E., Staniaszek, D., Roscetti, A., and Pagliano, L. (2019). Future-Proof Buildings for all Europeans: A guide to Implement the Energy Performance of Buildings Directive (2018/844), Buildings Performance Institute Europe (BPIE): Brussels, Belgium.

Becker, L., Jaakkola, E., and Halinen (2020), A. Toward a goal-oriented view of customer journeys. J. Serv. Manag., 31, 767–790. https://doi.org/10.1108/JOSM-11-2019-0329.

Berawi, M.A., Miraj, P., Windrayani, R., and Berawi, A.R.B. (2019). Stakeholders' perspectives on green building rating: A case study in Indonesia. Heliyon, 5, e01328. https://doi.org/10.1016/j.heliyon.2019.e01328.

Bertoldi, P., Boza-Kiss, B., Della Valle, N., and Economidou, M. (2021). The role of one-stop shops in energy renovation—A comparative analysis of OSSs cases in Europe. Energy Build., 250, 111273. https://doi.org/10.1016/j.enbuild.2021.111273.

Bertoldi, P., Economidou, M., Palermo, V., Boza-Kiss, B., and Todeschi, V. (2020). How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU. Wiley Interdiscip. Rev. Energy Environ., 10, e384. https://doi.org/10.1002/wene.384.

Bjørneboe, M.G., Svendsen, S., and Heller, A. (2017). Using a One-Stop-Shop Concept to Guide Decisions When Single-Family Houses Are Renovated. J. Arch. Eng., 23, 05017001. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000238.

Bouzarovski, S. (2018). Energy Poverty: (Dis)Assembling Europe's Infrastructural Divide, Palgrave Macmillan: Cham, Switzerland, ISBN 978-3-319-69298-2. https://doi.org/10.1007/978-3-319-69299-9.

Boza-Kiss, B., and Bertoldi, P. (2018). One-Stop-Shops for Energy Renovations of Buildings, Joint Research Centre Science for Policy Report (JRC113301), European Commission: Ispra, Italy.

Brown, D. (2018). Business models for residential retrofit in the UK: A critical assessment of five key archetypes. Energy Effic., 11, 1497–1517. https://doi.org/10.1007/s12053-018-9629-5.

Caro, R., and Sendra, J.J. (2020). Are the dwellings of historic Mediterranean cities cold in winter? A field assessment on their indoor environment and energy performance. Energy Build., 230, 110567. https://doi.org/10.1016/j.enbuild.2020.110567.

Causse, E., Figueira, M., Gutiérrez, B., and Panagiotopoulou, I. (2021). UIPI Survey Final Report: European Property Owners' Readiness and Capacity to Renovate, International Union of Property Owners: Brussels, Belgium.

CENSE NOVA-FCT and De Groene Grachten (2020). Menu Renovação Verde. December 2020. CENSE - Center for Environmental and Sustainability Research, NOVA-FCT - NOVA School of Science and Technology, NOVA University of Lisbon, De Groene Grachten. Available online: https://www.menurenovacaoverde.pt (accessed on 27 December 2021).

Cheshmehzangi, A. (2020). COVID-19 and Household Energy Implications: What are the Main Impacts on Energy Use? Heliyon, 6, e05202. https://doi.org/10.1016/j.heliyon.2020.e05202.

Cicmanova, J., Eisermann, M., and Maraquin, T. (2020). How to Set Up a One-Stop-Shop for Integrated Home Energy Renovation? A Step-by-Step Guide for Local Authorities and Other Actors, INNOVATE Project, Energy Cities: Besancon, France.

Croci, E., Molteni, T., and Penati, T. (2020). Mapping of Existing One-Stop-Shop Initiatives in EU and Beyond and Underlying Business Models for Integrated Home Energy Renovation Services, Bocconi University (UB), Padova FIT Expanded Project, European Commission: Brussels, Belgium.

de Santoli, L. (2016). Guidelines on energy efficiency of cultural heritage. Energy Build., 86, 534–540. https://doi.org/10.1016/j.enbuild.2014.10.050.

de Wilde, M., and Spaargaren, G. (2019). Designing trust: How strategic intermediaries choreograph homeowners' low-carbon retrofit experience. Build. Res. Inf., 47, 362–374. https://doi.org/10.1080/09613218.2018.1443256.

DGEG (2020). Balanço Energético 2019 Provisório ["Preliminary Energy Balance 2019"], Version of 02/11/2020, Portuguese Energy and Geology Directorate: Lisbon, Portugal.

Di Foggia, G. (2018). Energy efficiency measures in buildings for achieving sustainable development goals. Heliyon, 4, e00953. https://doi.org/10.1016/j.heliyon.2018.e00953.

Domínguez-Amarillo, S., Fernández-Agüera, J., Peacock, A., and Acosta, I. (2020). Energy related practices in Mediterranean low-income housing. Build. Res. Inf., 48, 34–52. https://doi.org/10.1080/09613218.2019.1661764.

Döringer, S. (2021). 'The problem-centred expert interview'. Combining qualitative interviewing approaches for investigating implicit expert knowledge. Int. J. Soc. Res. Methodol., 24, 265–278. https://doi.org/10.1080/13645579.2020.1766777.

Ebrahimigharehbaghi, S., Qian, Q.K., Meijer, F.M., and Visscher, H.J. (2019). Unravelling Dutch homeowners' behaviour towards energy efficiency renovations: What drives and hinders their decision-making? Energy Policy, 129, 546–561. https://doi.org/10.1016/j.enpol.2019.02.046.

Economidou, M., Todeschi, V., Bertoldi, P., D'Agostino, D., Zangheri, P., and Castellazzi, L. (2020). Review of 50 years of EU energy efficiency policies for buildings. Energy Build., 225, 110322. https://doi.org/10.1016/j.enbuild.2020.110322.

European Commission (2019). Comprehensive Study of Building Energy Renovation Activities and the Uptake of Nearly Zero-Energy Buildings in the EU, European Commission: Brussels, Belgium.

European Commission (2020). A Renovation Wave for Europe - Greening our Buildings, Creating Jobs, Improving Lives, 14.10.2020, COM(2020) 662 Final, European Commission: Brussels, Belgium.

European Commission (2021). Commission Staff Working Document: Preliminary Analysis of the Long-Term Renovation Strategies of 13 Member States, 25.3.2021. SWD(2021) 69 Final, European Commission: Brussels, Belgium.

Eurostat (2020). Energy Data—2020 Edition, Publications Office of the European Union: Luxembourg. https://doi.org/10.2785/68334.

Eurostat (2021a). Conventional Dwellings by Occupancy Status, Type of Building and NUTS 3 Region, Publications Office of the European Union: Luxembourg.

Eurostat (2021b). Share of Population Living in a Dwelling Not Comfortably Cool during Summer Time by Income Quintile and Degree of Urbanisation, Publications Office of the European Union: Luxembourg.

Eurostat (2022a). Share of Total Population Living in a Dwelling with a Leaking Roof, Damp Walls, Floors or Foundation, or rot in Window Frames of Floor—EU-SILC Survey, Publications Office of the European Union: Luxembourg.

Eurostat (2022b). Cooling and Heating Degree Days by Country—Annual Data, Publications Office of the European Union: Luxembourg.

Eurostat (2022c). Inability to Keep Home Adequately Warm—EU-SILC Survey, Publications Office of the European Union: Luxembourg.

Galvin, R., and Sunikka-Blank, M. (2014). The UK homeowner-retrofitter as an innovator in a socio-technical system. Energy Policy, 74, 655–662. https://doi.org/10.1016/j.enpol.2014.08.013.

Ginige, K., Amaratunga, D., and Haigh, R. (2018). Mapping stakeholders associated with societal challenges: A Methodological Framework. Procedia Eng., 212, 1195–1202. https://doi.org/10.1016/j.proeng.2018.01.154.

Gonzalez-Caceres, A., Lassen, A.K., and Nielsen, T.R. (2020). Barriers and challenges of the recommendation list of measures under the EPBD scheme: A critical review. Energy Build., 223, 110065. https://doi.org/10.1016/j.enbuild.2020.110065.

Gouveia, J.P., and Palma, P. (2019). Harvesting big data from residential building energy performance certificates: Retrofitting and climate change mitigation insights at a regional scale. Environ. Res. Lett., 14, 095007. https://doi.org/10.1088/1748-9326/ab3781.

Gouveia, J.P., Palma, P., and Simoes, S.G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Rep., 5, 187–201. https://doi.org/10.1016/j.egyr.2018.12.004.

Gouveia, J.P., Seixas, J., Palma, P., Duarte, H., Luz, H., and Cavadini, G.B. (2021). Positive Energy District: A Model for Historic Districts to Address Energy Poverty. Front. Sustain. Cities, 3, 648473. https://doi.org/10.3389/frsc.2021.648473.

Gram-Hanssen, K. (2014). Retrofitting owner-occupied housing: Remember the people. Build. Res. Inf., 42, 393–397. https://doi.org/10.1080/09613218.2014.911572.

Gram-Hanssen, K., Jensen, J.O., and Friis, F. (2018). Local strategies to promote energy retrofitting of single-family houses. Energy Effic., 11, 1955–1970. https://doi.org/10.1007/s12053-018-9653-5.

Hall, S., Anable, J., Hardy, J., Workman, M., Mazur, C., and Matthews, Y. (2021), Matching consumer segments to innovative utility business models. Nat. Energy, 6, 349–361. https://doi.org/10.1038/s41560-021-00781-1.

Horta, A., Gouveia, J.P., Schmidt, L., Sousa, J.C., Palma, P., and Simões, S. (2019). Energy poverty in Portugal: Combining vulnerability mapping with household interviews. Energy Build., 203, 109423. https://doi.org/10.1016/j.enbuild.2019.109423.

INE (2020). Construção e Habitação ["Construction and Housing Statistics"]. Portugal Statistics. Available online: www.ine.pt (accessed on 15 August 2021).

Kerr, N., and Winskel, M. (2020). Household investment in home energy retrofit: A review of the evidence on effective public policy design for privately owned homes. Renew. Sustain. Energy Rev., 123, 109778. https://doi.org/10.1016/j.rser.2020.109778.

Kivimaa, P., and Martiskainen, M. (2018). Innovation, low energy buildings and intermediaries in Europe: Systematic case study review. Energy Effic., 11, 31–51. https://doi.org/10.1007/s12053-017-9547-y.

Kwon, M., and Mlecnik, E. (2021). Modular Web Portal Approach for Stimulating Home Renovation: Lessons from Local Authority Developments. Energies, 14, 1270. https://doi.org/10.3390/en14051270.

Labanca, N., Suerkemper, F., Bertoldi, P., and Irrek, W., Duplessis, B. (2015). Energy efficiency services for residential buildings: Market situation and existing potentials in the European Union. J. Clean. Prod., 109, 284–295. https://doi.org/10.1016/j.jclepro.2015.02.077.

Maby, C., and Gwilliam, J. (2021). Integrating energy efficiency into private home repair, maintenance and improvement practice in England and Wales. Build. Res. Inf., 50, 424–437. https://doi.org/10.1080/09613218.2021.1963652.

Mahapatra, K., Gustavsson, L., Haavik, T., Aabrekk, S., Svendsen, S., Vanhoutteghem, L., Paiho, S., and Ala-Juusela, M. (2013). Business models for full service energy renovation of single-family houses in Nordic countries. Appl. Energy, 112, 1558–1565. https://doi.org/10.1016/j.apenergy.2013.01.010.

Mahapatra, K., Mainali, B., and Pardalis, G. (2019) Homeowners' attitude towards one-stop-shop business concept for energy renovation of detached houses in Kronoberg, Sweden. Energy Procedia, 158, 3702–3708. https://doi.org/10.1016/j.egypro.2019.01.888.

Mainali, B., Mahapatra, K., and Pardalis, G. (2021). Strategies for deep renovation market of detached houses. Renew. Sustain. Energy Rev., 138, 110659. https://doi.org/10.1016/j.rser.2020.110659.

Maraquin, T., and Eisermann, M. (2020). The Accelerator for Renovation One-Stop-Shops: Final Publishable Report about the Why, How and What of This European Experimentation, INNOVATE Project, European Commission: Brussels, Belgium.

Mazzola, E., Mora, T.D., Peron, F., and Romagnoni, P. (2019). An Integrated Energy and Environmental Audit Process for Historic Buildings. Energies, 12, 3940. https://doi.org/10.3390/en12203940.

Melo, J.J., Fernandes, F., Sousa, M.J.F., Galvão, A., Grilo, J., and Pereira, A.M. (2019). Estratégia Energética Alternativa: Princípios e Identificação de Medidas ["Alternative Energy Strategy: Principles and Identification of Measures"], NOVA School of Science and Technology of the NOVA University of Lisbon: Lisbon, Portugal, ISBN 978-972-8893-82-8.

Mlecnik, E., Straub, A., and Haavik, T. (2018) Collaborative business model development for home energy renovations. Energy Effic., 12, 123–138. https://doi.org/10.1007/s12053-018-9663-3.

Monzón-Chavarrías, M., López-Mesa, B., Resende, J., and Corvacho, H. (2020). The nZEB concept and its requirements for residential buildings renovation in Southern Europe: The case of multi-family buildings from 1961 to 1980 in Portugal and Spain. J. Build. Eng., 34, 101918. https://doi.org/10.1016/j.jobe.2020.101918.

Muhr, L., Clanzett, S., and Hildebrand, J. (2020). Stakeholder Analysis Report: General and Country Specific Stakeholder Maps, Version 1, IZES gGmbH—Institut für Zukunftsenergie und Stoffstromsysteme. ePanacea Project, ePanacea: Sarriguren, Spain, September 2020.

Murto, P., Jalas, M., Juntunen, J., and Hyysalo, S. (2019). Devices and strategies: An analysis of managing complexity in energy retrofit projects. Renew. Sustain. Energy Rev., 114, 109294. https://doi.org/10.1016/j.rser.2019.109294.

OPENEXP (2019). European Energy Poverty Index (EEPI): Assessing Member States Progress in Alleviating the Domestic and Transport Energy Poverty Nexus. Available online: https://www.openexp.eu/european-energy-poverty-index-eepi (accessed on 28 May 2021).

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, 169–179. https://doi.org/10.1016/j.enpol.2014.06.013.

Palma, P., Gouveia, J.P., and Barbosa, R. (2022). How much will it cost? An Energy Renovation Analysis for the Portuguese Dwelling Stock. Sustain. Cities Soc., 78, 103607. https://doi.org/10.1016/j.scs.2021.103607.

Palma, P., Gouveia, J.P., and Simoes, S.G. (2019). Mapping the energy performance gap of dwelling stock at high-resolution scale: Implications for thermal comfort in Portuguese households. Energy Build., 190, 246–261. https://doi.org/10.1016/j.enbuild.2019.03.002.

Pardalis, G., Mainali, B., and Mahapatra, K. (2019a), One-stop-shops as an innovation, and construction SMEs: A Swedish perspective. Energy Procedia, 158, 2737–2743. https://doi.org/10.1016/j.egypro.2019.02.031.

Pardalis, G., Mahapatra, K., Bravo, G., and Mainali, B. (2019b). Swedish House Owners' Intentions towards Renovations: Is there a Market for One-Stop-Shop? Buildings, 9, 164. https://doi.org/10.3390/buildings9070164.

Pardalis, G., Mahapatra, K., and Mainali, B. (2020a). Swedish construction MSEs: Simply renovators or renovation service innovators? Build. Res. Inf., 48, 67–83. https://doi.org/10.1080/09613218.2019.1662713.

Pardalis, G., Mahapatra, K., and Mainali, B. (2020b). A triple-layered one-stop-shop business model canvas for sustainable house renovations. IOP Conf. Ser. Earth Environ. Sci., 588, 022060. https://doi.org/10.1088/1755-1315/588/2/022060.

Pardalis, G., Mahapatra, K., Mainali, B., and Bravo, G. (2021). Future Energy-Related House Renovations in Sweden: One-Stop-Shop as a Shortcut to the Decision-Making Journey. In Emerging Research in Sustainable Energy and Buildings for a Low-Carbon Future, Howlett, R.J., Littlewood, J.R., Jain, L.C., Eds., Advances in Sustainability Science and Technology, Springer: Singapore. https://doi.org/10.1007/978-981-15-8775-7_4.

Pardo-Bosch, F., Cervera, C., and Ysa, T. (2019). Key aspects of building retrofitting: Strategizing sustainable cities. J. Environ. Manag., 248, 109247. https://doi.org/10.1016/j.jenvman.2019.07.018.

Peltomaa, J., Mela, H., and Hildén, M. (2020). Housing managers as middle actors implementing sustainable housing policies in Finland. Build. Res. Inf., 48, 53–66. https://doi.org/10.1080/09613218.2019.1655629.

Pillai, A., Reaños, M.T., and Curtis, J. (2021). An examination of energy efficiency retrofit scheme applications by low-income households in Ireland. Heliyon, 7, e08205. https://doi.org/10.1016/j.heliyon.2021.e08205.

Portuguese Energy Observatory (2021). Certificação Energética de Edifícios—Principais Números: Habitação ["Energy Certification of Buildings—Key Figures: Housing"]. Available online: https://www.observatoriodaenergia.pt (accessed on 16 February 2021).

Portuguese Government (2019). Roteiro para a Neutralidade Carbónica 2050 (RNC2050): Estratégia de Longo Prazo para a Neutralidade Carbónica da Economia Portuguesa Em 2050 ["Carbon Neutrality Roadmap 2050 (RNC2050): Long-Term Strategy for a Carbon Neutral Portuguese Economy in 2050"]. R262/2019. Available online: https://descarbonizar2050.apambiente.pt/ (accessed on 19 May 2021).

Portuguese Government (2021a). Estratégia de Longo Prazo para o Combate à Pobreza Energética 2021–2050 ["Long-Term Strategy for Energy Poverty Mitigation 2021–2050"], Document for Public Consultation, Ministry of Environment and Climate Action: Lisbon, Portugal.

Portuguese Government (2021b). Resolução do Conselho de Ministros n.º 8-A/2021 - Aprova a Estratégia de Longo Prazo para a Renovação dos Edifícios ["Resolution of the Council of Ministers no. 8-A/2021 - Approving the Long-Term Strategy for Building Renovation"], Diário da República, 1.ª Série, 23, Ministry of Environment and Climate Action: Lisbon, Portugal.

Project Management Institute (2013). A Guide to the Project Management Body of Knowledge (PMBOK® Guide), 5th ed., Project Management Institute, Inc.: Newtown Square, PA, USA, ISBN 978-1-935589-67-9.

Reuter, M., Patel, M.K., Eichhammer, W., Lapillonne, B., and Pollier, K. (2020). A comprehensive indicator set for measuring multiple benefits of energy efficiency. Energy Policy, 139, 111284. https://doi.org/10.1016/j.enpol.2020.111284.

Roscini, A.V., Rapf, O., and Kockat, J. (2020). On the Way to a Climate-Neutral Europe: Contributions from the Building Sector to a Strengthened 2030 Climate Target, Buildings Performance Institute Europe (BPIE): Brussels, Belgium,

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., Chester, M., Karlin, B., K. Ashby, Butler, D., and J. Chambers (2020). Hard-to-Reach Energy Users: A Literature Review. Prepared for User-Centred Energy Systems TCP – HTR Task. Published by SEA – Sustainable Energy Advice Ltd: Wellington. 252pp. ISBN: 978-0-473-64983-8.

Salvia, M., Simoes, S.G., Herrando, M., Čavar, M., Cosmi, C., Pietrapertosa, F., *et al.* (2021). Improving policy making and strategic planning competencies of public authorities in the energy management of municipal public buildings: The PrioritEE toolbox and its application in five mediterranean areas. Renew. Sustain. Energy Rev., 135, 110106. https://doi.org/10.1016/j.rser.2020.110106.

Senior, C., Salaj, A., Vukmirovic, M., Jowkar, M., and Kristl, Ž. (2021). The Spirit of Time—The Art of Self-Renovation to Improve Indoor Environment in Cultural Heritage Buildings. Energies, 14, 4056. https://doi.org/10.3390/en14134056.

Sequeira, M., and Joanaz de Melo, J. (2020). Energy saving potential in the small business service sector: Case study Telheiras neighborhood, Portugal. Energy Effic., 13, 551–569. https://doi.org/10.1007/s12053-020-09842-y.

Sequeira, M.M., Gouveia, J.P., and Palma, P. (2021). Case Study Analysis—Portugal, HTR Task Users TCP: Lisbon, Portugal, 38p. https://doi.org/10.47568/3XR115.

Shnapp, S., Paci, D., and Bertoldi, P. (2020). Untapping Multiple Benefits: Hidden Values in Environmental and Building Policies, Joint Research Centre Technical Report (JRC120683). EUR 30280 EN, Publications Office of the European Union: Luxembourg. https://doi.org/10.2760/314081.

Silva, S.M., Mateus, R., Marques, L., Ramos, M., and Almeida, M. (2016). Contribution of the solar systems to the nZEB and ZEB design concept in Portugal - Energy, economics and environmental life cycle analysis. Sol. Energy Mater. Sol. Cells, 156, 59–74. https://doi.org/10.1016/j.solmat.2016.04.053.

Streimikiene, D., and Balezentis, T. (2020). Willingness to Pay for Renovation of Multi-Flat Buildings and to Share the Costs of Renovation. Energies, 13, 2721. https://doi.org/10.3390/en13112721.

Sunikka-Blank, M., and Galvin, R. (2016). Irrational homeowners? How aesthetics and heritage values influence thermal retrofit decisions in the United Kingdom. Energy Res. Soc. Sci., 11, 97–108. https://doi.org/10.1016/j.erss.2015.09.004.

Tingey, M., Webb, J., and Van der Horst, D. (2021). Housing retrofit: Six types of local authority energy service models. Build. Cities, 2, 518–532. http://doi.org/10.5334/bc.104.

Volt, J., McGinley, O., Moran, P., Fabbri, M., and Steuwer, S. (2021). Underpinning the Role of One-Stop Shops in the EU Renovation Wave: First Lessons Learned from the Turnkey Retrofit Replication, TURNKEY Solution for Home RETROFITting Project, European Commission: Brussels, Belgium.

Volt, J., Zuhaib, S., and Steuwer, S. (2019). Benchmarking of Promising Experiences of Integrated Renovation Services in Europe, TURNKEY Solution for Home RETROFITting Project.

Wise, F., Jones, D., and Moncaster, A. (2021). Reducing carbon from heritage buildings: The importance of residents' views, values and behaviours. J. Arch. Conserv., 27, 117–146. https://doi.org/10.1080/13556207.2021.1933342.

Zangheri, P., Castellazzi, L., D'Agostino, D., Economidou, M., Ruggieri, G., Tsemekidi-Tzeiranaki, S., Maduta, C., and Bertoldi, P. (2021). Progress of the Member States in Implementing the Energy Performance of Building Directive, Joint Research Centre Science for Policy Report (JRC122347). EUR30469 EN, Publications Office of the European Union: Luxembourg. https://doi.org/10.2760/914310.

5.2 From the bottom-up: The development process and participants of the Telheiras Renewable Energy Community, Portugal

This work is published in: Sequeira, M.M., Ferreira, E., and Gouveia, J.P. (2024). From the bottom-up: the development process and participants of the Telheiras Renewable Energy Community, Portugal. In Vañó, M.J.V., *et al.* (Eds), POWERCOOP - Comunidades Energéticas de Autoconsumo: Análisis Organizacional Desde una Perspectiva Jurídica, de Gestión y Tecnológica (pp. 137-158). Instituto Universitario de Economía Social, Cooperativismo y Emprendimiento (IUDESCOOP). ISBN 978-84-127263-9-8. Available at: https://www.powercoop.es/

Abstract

Renewable energy communities have been proposed as a key piece of the European energy transition. While these can boost citizen participation and deliver multiple benefits to their members, scarce research has managed to report on empiric case studies and their drivers, barriers, and success factors. Furthermore, there is also limited evidence on the ability of energy communities to engage with energy-poor households. In this context, we first map the ten steps in creating the Telheiras Renewable Energy Community in Portugal as an innovative energy-sharing approach developed by citizens, associations, and local government. Following, we analyse the results of two surveys to characterise the volunteers involved in the energy community working group that built the project from the ground up and the households that signed up to join the energy community's pilot project. In line with previous studies, we find that volunteers and energy community members tend to be male, highly educated (prominently, engineers), and with higher incomes, and that environmental and social drivers are the main motivations. Nevertheless, the positive return on investment is an important pre-condition to joining the energy community, highlighting the importance of having a solid economic case. In this context, we argue that energy poverty mitigation is not a naturally occurring feature for energy communities and that the participation of vulnerable and hard-to-reach households must be fostered through particular approaches and conditions. Creating a local-scale technical and financial support system could enable more citizens, associations, and local governments to develop their own energy communities

5.2.1 Introduction

The European Commission's (2019) Clean Energy for All Europeans policy package positioned citizens as the centrepiece of the energy transition. Furthermore, the Renewable Energy Directive (RED II, 2018/2001/EU) defined renewable energy communities as a legal entity based on open and voluntary participation, autonomous, and effectively controlled by its members that are in the proximity of the renewable energy projects. The main goals should be to deliver environmental, social, and economic benefits to its members or location rather than financial profits.

Energy communities are also identified as a relevant mechanism for energy poverty mitigation and for just energy transitions (Koukoufikis *et al.*, 2023). Energy poverty is defined by the European Union's (EU) Energy Efficiency Directive (2023) as the "lack of access to essential energy services [...] caused by a combination of factors, including at least non-affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes" where energy communities can directly provide affordable energy and reduce energy expenditure. Nevertheless, community energy is still an emerging concept and there is limited evidence of its multiple benefits unfolding in real-world case-studies (Caramizaru and Uihlein, 2020; Hanke *et al.*, 2021).

Portugal has transposed the European law to its national context through Decree-Law no. 162/2019 and Decree-Law no. 15/2022. These documents define the concepts of collective self-consumption – the sharing of renewable energy between at least two consumers – and of renewable energy communities – a legal entity which can share renewable energy with its members and/or perform other energy market activities and that follow the general principles established by the European Commission. However, only a few renewable energy-sharing projects are currently operational in Portugal, and most do not fulfil the conditions set to be considered as renewable energy communities (Expresso, 2023).

The Portuguese Long-Term Energy Poverty Combat Strategy 2023-2050 estimates that around three million people are in energy poverty and identifies renewable energy communities as one of the mechanisms to alleviate this situation (Portuguese Government, 2024). Nevertheless, more research is still needed to understand the drivers and barriers to energy community development and participation, particularly the participation of energy-poor households, and to map the processes through which energy communities may successfully establish themselves in Portugal.

In this context, we map the bottom-up development process of the Telheiras Renewable Energy Community in Lisbon – promoted by a network of non-profit organizations and by the local government – based on over three years accompanying the project and on available internal and external documents (Ferreira, 2023; Sequeira *et al.*, 2024). Furthermore, we present novel results from two surveys conducted during this process – first, with the volunteers leading the initiative and, second, with the energy community members. These allow insights into the specific conditions that fostered the emergence of the energy community and challenge the preconceived notion of a prominent role for energy communities in just energy transitions. Policy implications include the need to provide technical and financial support for local stakeholders to kick-start and develop energy communities, with specific provisions to foster the inclusion of energy-poor families.

5.2.2 Methods

5.2.2.1 Case-study: Telheiras Renewable Energy Community, Portugal

The Telheiras neighbourhood is located in the Lumiar Parish Council in the North part of Lisbon Municipality. It has a population of around 17,000 inhabitants, who are mostly middle-class to high-middle class. Most buildings date from the 1980s and 90s. Since 2013, the Local Partnership of Telheiras has brought together over 20 associations and groups from the neighbourhood to organise events, share resources, and engage the population.

In 2018, the Local Partnership established sustainability in its environmental, social, and economic dimensions as a key focus for all organisations to work collaboratively through a specific working group named Sustainable Telheiras. This group launched the Network of Ideas process in 2020 – a collection of ideas from residents of the neighbourhood – which provided the seed for the energy community with the motto "Let's produce our own renewable energy and share it among neighbours" (Sequeira and Mameri, 2022). Stemming from this process, a renewable energy community working group kick-started in November 2021 with volunteers from the neighbourhood.

In this context, the Telheiras Renewable Energy Community is a community-led project that aims to contribute to a sustainable, fair, accessible, and democratic energy transition (Figure 5.7). Its pilot project is being promoted by the Local Partnership of Telheiras and the Lumiar Parish Council with joint investment in a solar photovoltaic system and sharing of the renewable energy generated amongst members (Viver Telheiras, 2024). This initiative was selected in the first call for technical assistance of the European Union's Energy Poverty Advisory Hub (EPAH, 2024), receiving support from the renewable energy cooperative Coopérnico and the Center for Environmental and Sustainability Research of the NOVA School of Science and Technology of NOVA University of Lisbon (CENSE NOVA-FCT).

Figure 5.7 - The Telheiras Renewable Energy Community (source: Viver Telheiras).

5.2.2.2 Mapping of the process

The process that led to the creation of the Telheiras Renewable Energy Community can be described in 10 steps (Sequeira *et al.*, 2024):

1) launching the idea and building momentum including through the emergence of a core group of volunteers that met regularly,
2) searching for reliable partners with complementary roles, including by fostering collaboration with the local government and gaining technical support from external parties,

3) building capacity in the community by assessing in detail and gaining knowledge of Portuguese energy-sharing regulations,
4) selecting buildings and sizing solar photovoltaic systems for a pilot project in a public building with 7.0 kWp and 17 members – the Parish Council itself, 13 local families, and three energy-poor families – and for future installations (Ferreira *et al.*, 2024),
5) finding a legal structure to house the project through an already existing local non-profit association which adapted its internal regulations and membership conditions,
6) designing internal regulations to manage the entrance and exit of members, equitable sharing of electricity, and one-member-one-vote decision-making (an existing template from the national energy agency was tailored to the energy community's needs and approved in the first general assembly),
7) developing an inclusive financing and operational model by securing the initial investment from the members, by covering operational costs with an annual fee, and by providing special conditions for energy-poor members,
8) communicating with the local community and recruiting members through informative articles, social media, flyers and posters, local events, public sessions, and word-of-mouth – these were intensified during the period of member recruitment to collect the necessary data to kick-start the licensing process,
9) identifying and integrating energy-poor families by collaborating with social services of the Parish Council which already support vulnerable families to invite them to join on special conditions but with full membership and voting rights,
10) completing the licensing process with the national authority, electricity grid distribution system operator, and municipality and installing the solar photovoltaic panels (a lengthy process that started in early 2023 and finished in mid-2024).

While these steps follow a logical order and there are some interconnections between them (*e.g.*, it is necessary to have information on all energy community members before the licensing process), they are primarily non-sequential, and several tasks were conducted in parallel. In the following chapters, we focus on step 1, namely by exploring the results of a survey conducted with the volunteers that built the energy community from the ground up, and on step 8, namely by exploring the results of a survey conducted with the energy community members that signed up for the pilot project.

5.2.2.3 Characterisation of the working group volunteers

In the context of the Network of Ideas process previously described (Sequeira and Mameri, 2022), a survey was conducted from May to June 2022 with the volunteers engaged in several neighbourhood-scale working groups. The survey was sent to all volunteers by email. Its main goals were to characterise the volunteers, understand motivations and barriers for involvement, and evaluate specific aspects of the coordination of the working groups. Here, we focus only on results from the volunteers engaged with the energy community working group (in total, the survey was sent to 12 volunteers, of which 9 answered it).

The first part of the survey included nine questions, focusing on socio-economic and demographic aspects (*e.g.*, gender, age, professional background, nationality), the volunteer's relationship with the neighbourhood (resident or not), and their knowledge of ongoing community dynamics (volunteers were asked to self-evaluate their knowledge of local organisations, projects, and events according to a Likert scale). Following, volunteers were asked to select a maximum of five drivers that led to joining this working group and of five barriers hindering their full-on participation from a predetermined set. The drivers and barriers showcased as options were inspired by other studies (*e.g.*., Koirala *et al.*, 2018). Finally, in the last part of the survey, the volunteers evaluated 21 aspects related to the working group's coordination, organisation, and goals, following a Likert scale.

5.2.2.4 Characterisation of the energy community members

Roughly one year after the first survey was conducted with the volunteers, the energy community had matured enough to be able to recruit its first members and start the licensing process. In this context, an online registration form was launched in May 2023 for interested households to sign up for the energy community. This also served as an opportunity to collect data for research. The survey was meant to be filled in by the household member appointed as the energy community point-of-contact (usually the head of the household and the person responsible for managing energy bills). It was opened for only two weeks with 22 valid answers (for the pilot project, only 13 energy community membership spots were available).

Besides collecting the needed data for licensing (*e.g.*, full name, contacts, address), the survey also collected socio-economic and demographic data following the same questions as the previous survey. Potential energy community members were asked how they learned about the project, with several options available for selection. A pre-established list of environmental, social, and economic drivers was presented inspired on other studies (*e.g.*, Radtke, 2014), and energy community members were asked to evaluate the importance of each one through a Likert scale. Finally, the energy poverty vulnerability of the energy community members was assessed through proxy indicators asking about thermal comfort, inability to pay bills, and behavioural measures (similar to Gouveia *et al.*, 2024).

5.2.3 Results and discussion

5.2.3.1 Characterisation of the working group volunteers

The survey was sent to 12 volunteers who signed up to join the energy community working group and who participated in at least one meeting. It was conducted from May to June 2022, which roughly incorporates step 1 mentioned beforehand. When the survey was closed, the working group had met 11 times (the first meeting was in November 2021), with an average of six persons participating in meetings. One public session was organised to present the project to the neighbourhood (in February 2022). Collaboration with the Parish Council and other external partners was just kick-starting; EPAH's technical assistance only began in October 2022. Of this initial group of 12 volunteers, seven signed up to join as members of the energy community pilot project in May 2023.

Nine volunteers answered the survey, three identified as females and six as males (Figure 5.8). Volunteers came from various age groups, from 25 to 74 years old. All volunteers were of Portuguese nationality and had a university education. Six of the volunteers were engineers, and two worked in management. Five were employed full-time, three were retired, and one was unemployed. Self-reported gross monthly income levels were above the national average for at least five volunteers (some preferred not to answer this question). This aligns with other research that finds a predominance of highly educated, above-average-income males (and engineers) in renewable energy community projects (Radkte and Bohn, 2023).

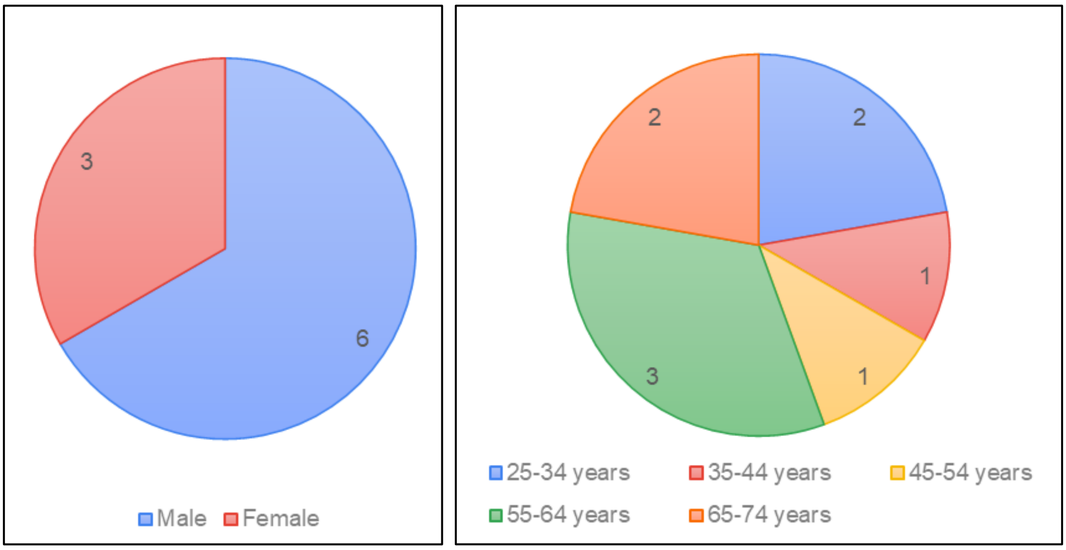


Figure 5.8 - Volunteers of the energy community working group by gender (left) and age (right).

Six persons were already volunteers or associates of at least one local association, while three were not previously connected to the Local Partnership. While all volunteers resided in the Telheiras neighbourhood, the survey uncovered different levels of involvement and knowledge of local dynamics (Figure 5.9).

The local festival was the best-known initiative, showcasing the importance of cultural and festive activities for community cohesion (Sequeira *et al.*, 2021). Volunteers were primarily aware of the Local Partnership's role in the neighbourhood and the online communication platforms used (the group's open call was performed through this platform). Still, three of the volunteers had poor knowledge of the previous processes that led to the creation of the energy community working group in which they actively participated. Three participants only joined in 2022 when some of the earlier steps were finished, and the working group was already meeting regularly. Finally, most volunteers had little knowledge about another sustainability-oriented project implemented by the Local Partnership three years before the survey was conducted. Other research has shown how community-based initiatives can be ephemeral and fail to provide significant long-term impacts (Grandin and Sareen, 2020).

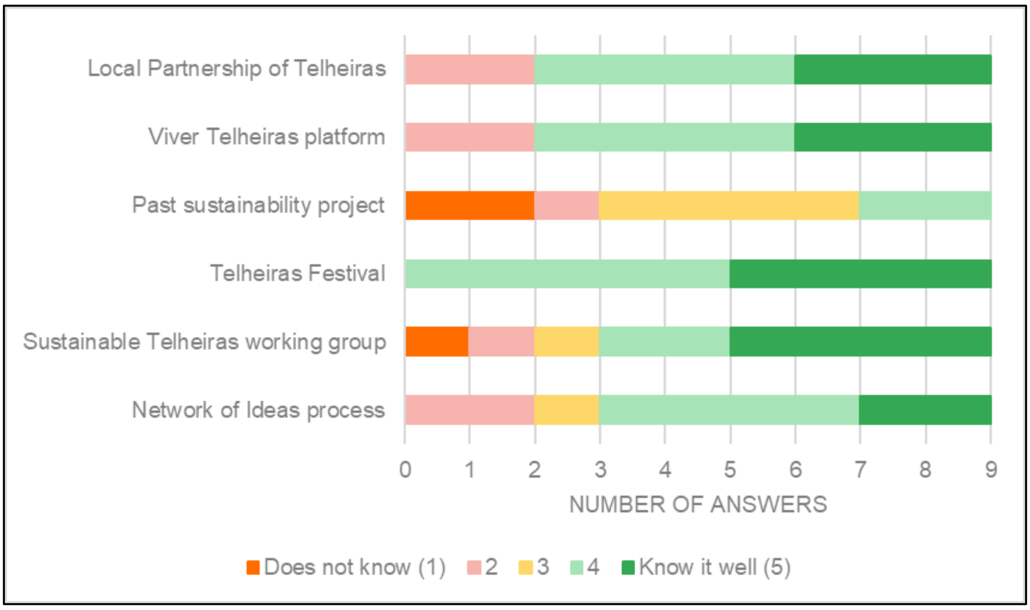


Figure 5.9 - Volunteers' knowledge of neighbourhood-scale organisations and dynamics.

Volunteers were asked about their motivations to join the energy community working group (Figure 5.10). In line with other research (Koirala *et al.*, 2018), sustainability improvement and environmental concerns were the most prominent drivers of engagement. Social and governance aspects were also seen as important, particularly regarding participation in the community, influence in local decision-making processes, and provision of social support and inclusion to vulnerable families. A significant number of volunteers also reported both personal and professional interest in the topic at hand, which is in line with their academic background. Finally, it is noteworthy that none of the working group volunteers joined out of dissatisfaction with the current situation in the neighbourhood or due to economic drivers such as financial and business opportunities.

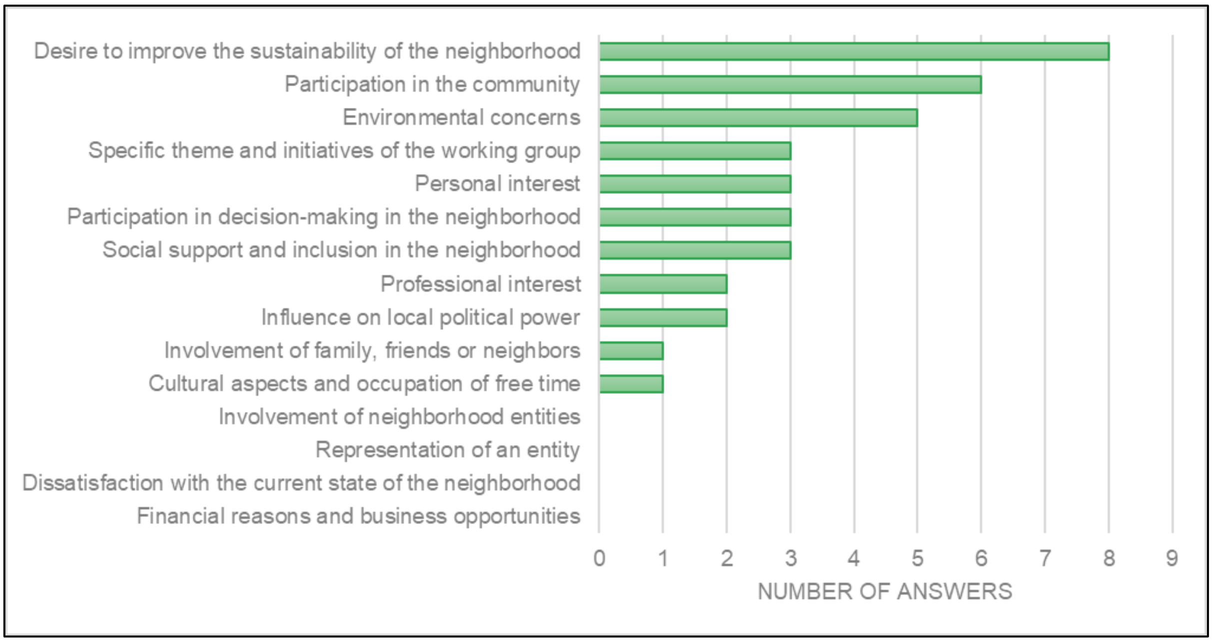


Figure 5.10 - Volunteers' drivers to join the energy community working group.

Furthermore, volunteers were also asked about the barriers limiting their participation (Figure 5.11). First, volunteers pinpointed more drivers than barriers; this can also be due to the lack of answers from three volunteers who eventually left the working group. The key barriers identified were a lack of time, other priorities, and difficulties matching schedules, which aligns with other research showcasing the inherent weakness of voluntary-led processes in local communities (Grandin and Sareen, 2020).

Lack of knowledge was identified as a limitation by three volunteers. Renewable energy communities were a novel concept in Portugal at the time with many uncertainties about their real-world application; furthermore, the energy system is often seen as hermetic and energy literacy levels are low amongst the population. Two volunteers were also poorly informed about the possibilities of involvement, perhaps due to having joined at a later stage. Finally, it is noteworthy that none of the volunteers identified a lack of trust, reluctance to participate, objections to the processes or objectives, or doubts about the potential impacts of activities as barriers to participation in the working group.

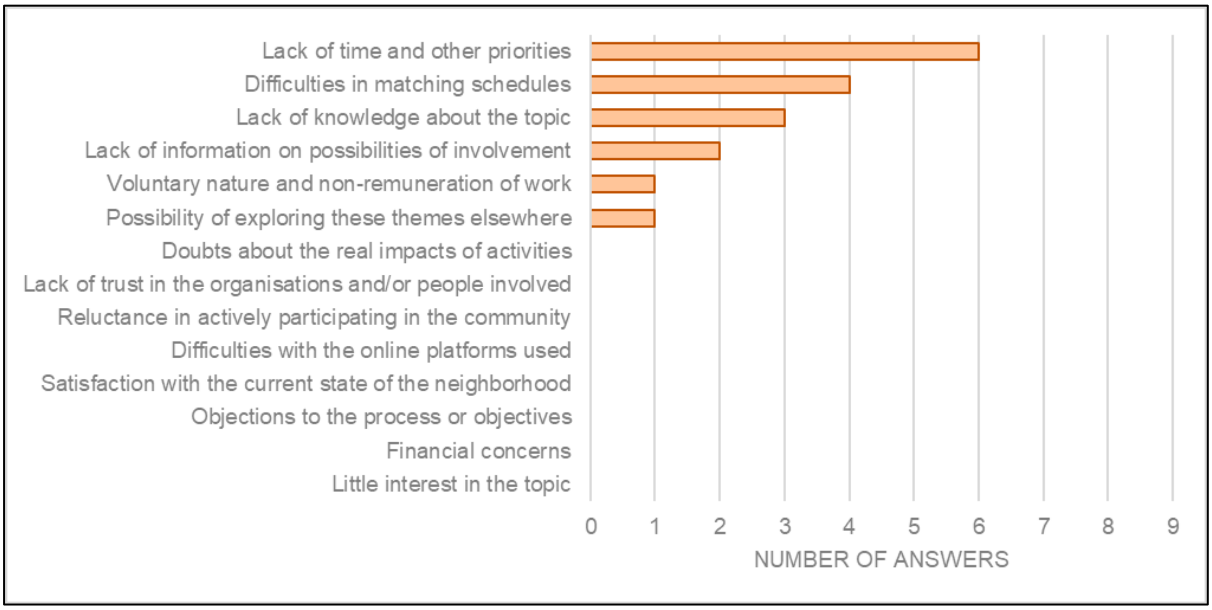


Figure 5.11 - Volunteers' barriers to participation in the energy community working group.

To identify opportunities for improvement, volunteers were asked to evaluate critical aspects of the functioning of the working group (Figure 5.12). Since the working group managed to keep the momentum and eventually accomplish most of its objectives, these can also be seen as success factors of a community-led initiative. Most volunteers evaluated positively the internal communication strategy of the working group (through regular emails), the scheduling of meetings (through a participatory and democratic selection of the most convenient date and time for each meeting), the transparency of the process (through the publication of collaborative meeting notes), the participation in decision-making, freedom of opinion, and openness to criticism, and the definition, organisation, execution and impact of activities.

Nonetheless, there were also aspects to be improved, such as fostering interactions between the volunteers, enhancing external communication and communication with other working groups active in the neighbourhood, and establishing collaboration with relevant stakeholders (*e.g.*, especially with the local governments at the level of the parish council and municipality – a key aspect mentioned in the literature (Koukoufikis *et al.*, 2023) – and with organisations having technical knowledge on the topic). Arguably, these factors were acted upon by the working group by organising a few in-person meetings and by continuously creating online and physical communication materials as the project progressed and in response to current events (*e.g.* writing informative materials on new energy efficiency funding schemes, distributing flyers in local festivals, and sharing relevant event participations and media appearances of the project). Most importantly, collaboration with the local government at the parish council level and with technical and scientific partners was unlocked through EPAH's technical assistance in October 2022 (step 2 mentioned above), which aided the planning and development of the next eight steps of the energy community pilot project.

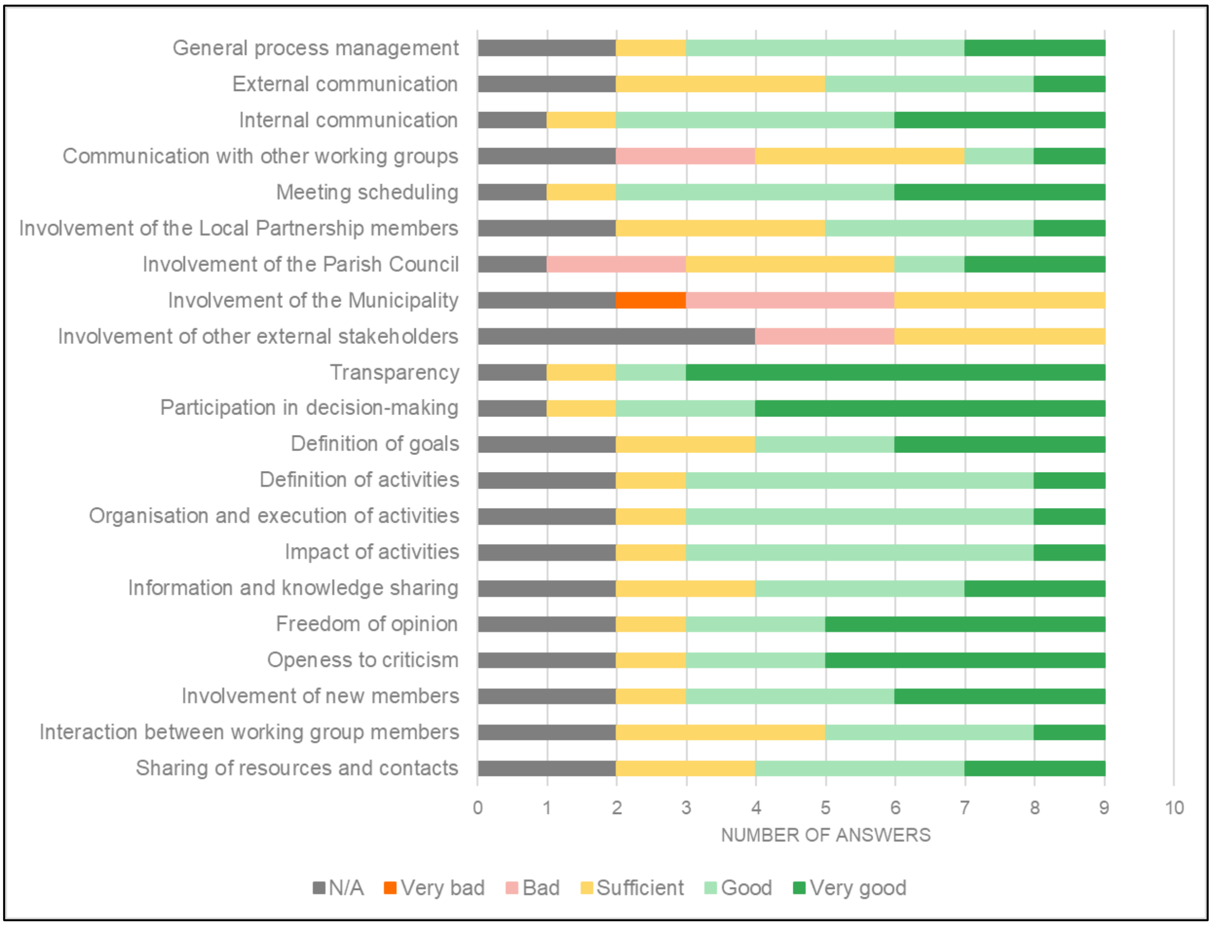


Figure 5.12 - Evaluation of critical aspects of the energy community working group functioning.

5.2.3.2 Characterisation of the energy community members

In the scope of step 8 mentioned above (communication and participant recruitment), a registration form was created for local households to sign up as members of the energy community's pilot project while also providing research data voluntarily. The survey was open for two weeks in May 2023, preceded by a strong local-scale communication campaign, including two public sessions organised by the Local Partnership, the Parish Council, and the other project partners. Potential members were provided detailed and transparent information on the project's goals, internal regulations, financing and operational aspects, and enrolment conditions. The survey was filled by the point of contact of 22 local households, with 13 being selected as energy community members for the pilot project on a first-come, first-served basis and the remaining households staying on a waiting list for future expansions of the initiative.

Some of the trends previously identified for the volunteers are also present regarding the households willing to join the energy community. In more than half of households, the decision to sign up for the energy community was made by a male (Figure 5.13). The age of the household's head varied across the sample. The average size of the household was 2.7 persons, with 9 out of 22 reporting the presence of dependent minors.

All potential energy community members were of Portuguese nationality, and only 1 out of 22 did not have higher education. Once again, the engineers dominate the sample, with 10 out of 22 members having studied different branches of engineering. Other members also primarily work in highly qualified professions such as architecture, medicine, management, and science. Most were employed full-time (17 out of 22) or retired (4 out of 22). The household's self-reported gross monthly income levels were above the national average for at least half of those interested in joining the energy community (a significant share of the surveyed preferred not to answer this question). These findings contribute to the existing literature identifying energy communities as an approach which caters mainly to the needs and preferences of highly educated and higher-income households (Dudka, 2024).

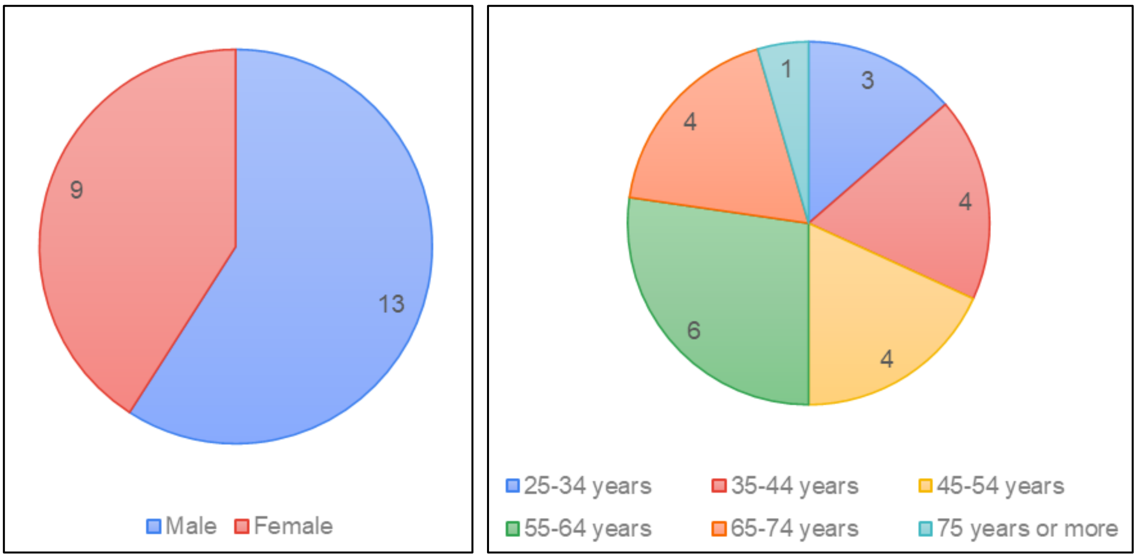


Figure 5.13 - Potential energy community members by gender (left) and age (right).

Figure 5.14 showcases how people became aware of the opportunity to join the energy community's pilot project. As mentioned, seven people had already volunteered in the working group for more than one year and thus were deeply interested in joining as energy community members. For the remainder, the Local Partnership was the main point of contact. There was an important role of well-established online communication channels and word-of-mouth between family members, friends, and neighbours; other authors also see trust as a key lever (Grossmann *et al.*, 2021). The local events organised before the recruitment campaign and the physical materials distributed to the members seem to have positively affected some of them.

Furthermore, some families learned about the project through the project partners, but only one identified the local government as the source of information. Notably, none of the respondents selected other local associations and articles in the media as their gateway to the energy community; the former represents an improvement opportunity for the energy community to further collaborate with local stakeholders, while the latter might not be strictly relevant at a neighbourhood scale. Other research has also suggested that, while local middle actors can have a role in facilitating participation in energy projects, these collaborations need to be actively fostered and equipped with adequate resources (McMaster *et al.*, 2024).

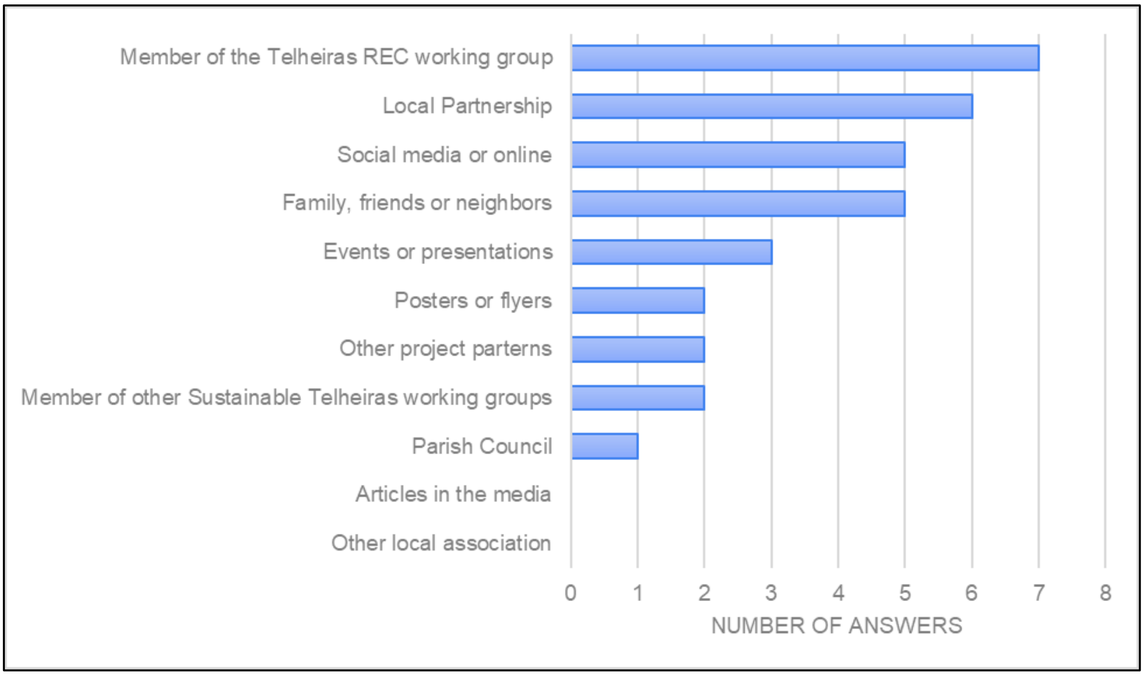


Figure 5.14 - Way through which people became aware of the energy community project.

Households were also asked about their motivations for joining the energy community (Figure 5.15). Like the original volunteers' answers, environmental drivers featured prominently, namely the local generation of renewable energy, increased energy independence, and reduced carbon footprint. In our case, social drivers such as community empowerment and active participation were seen as necessary, followed by social support to local vulnerable families.

Regarding economic motivations, the foundational one was that entering the energy community was seen as a local investment with a positive return in the medium to long term; this driver scored higher than all social drivers. The actual reductions in energy bills and the increased resilience to volatile energy prices seemed to be the least important (but still influential) motivations. These results may reconcile contrasting results of other studies which find both environmental (*e.g.*, Koirala *et al.*, 2018) and economic (*e.g.*, Caramizaru and Uihlein, 2020) aspects as the main reason for people to join energy communities; in our case, it seems that the possibility to have a positive return on investment was a foundational and rational requirement to sign up but that environmental concerns topple economic returns as the actual motivation.

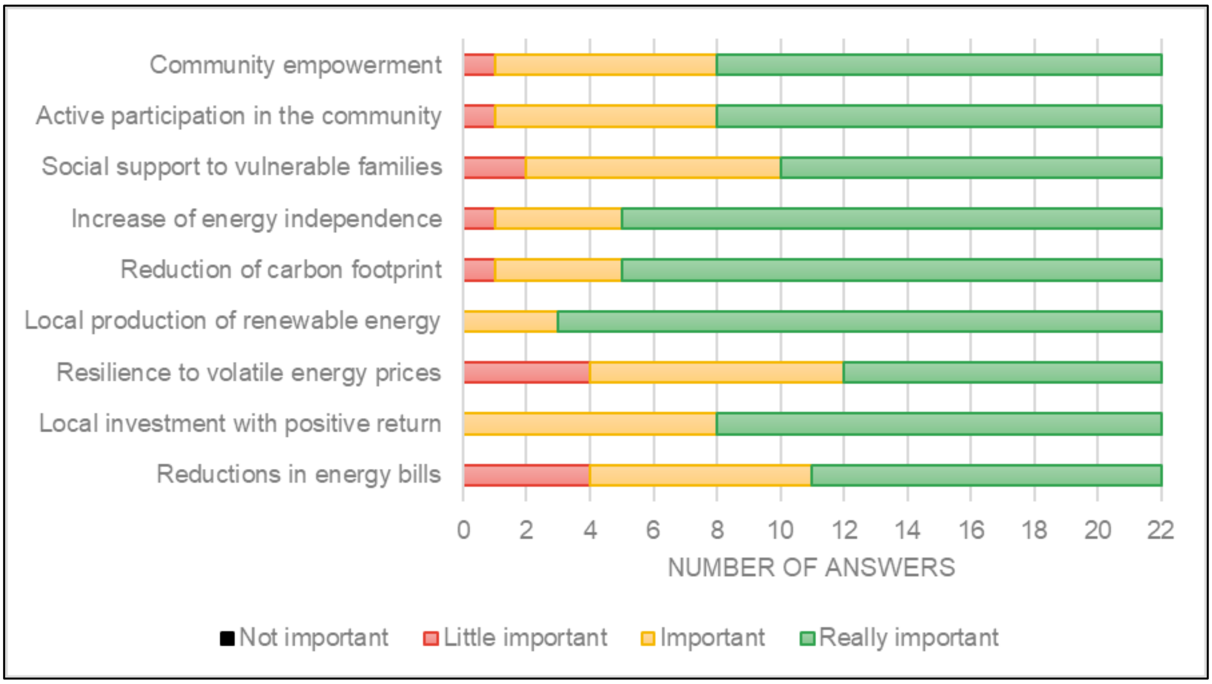


Figure 5.15 - Potential members' drivers to join the energy community.

Renewable energy communities are often described as one of the key approaches to mitigate energy poverty in European countries, including by providing locally produced and affordable energy to vulnerable households (European Commission, 2023). Our results challenge this preconceived notion by highlighting the inherent participation bias and conditions that exclude vulnerable households from energy community membership. Vulnerable households can be hard-to-reach by energy policies and interventions due to a range of characteristics and circumstances, such as low income, low education, advanced age, ill-health and disabilities, migrant background, among others, which hinder engagement (Rotmann *et al.*, 2020). Energy communities are often quite complex and innovative endeavours that require significant energy literacy and upfront investment from the members, thus excluding a substantial share of families.

In the case-study, the energy poverty vulnerability index developed by Gouveia *et al.* (2019) was used for an initial evaluation of the energy poverty baseline in the Lisbon Municipality and the Lumiar Parish, revealing relatively low energy poverty vulnerability levels when compared with the national average. Nevertheless, this analysis based on socio-economic, buildings, climate, and energy consumption indicators can hide significant heterogeneity within the territory in which energy poverty pockets may exist.

To assess the vulnerability to energy poverty in the energy community, a simple questionnaire was included in the registration form, and five questions mimicked European and national scale proxy energy poverty indicators (Figure 5.16). Although the sample is relatively small, results suggest that energy community members face lower vulnerability compared to national-scale indicators and to the results of an equivalent survey conducted in a separate project. The latter refers to a pilot one-stop shop which provided energy efficiency support to more than 500 families, including vulnerable households in three municipalities of the Lisbon Metropolitan Area (described by Gouveia *et al.*, 2024). National-scale indicators are collected through binary (yes/no) questions; to allow comparison with our survey, the answers "always" and "frequently" considered positive.

Around 14% of energy community members reported always or frequently getting cold at home in the winter, which contrasts with 42% at national scale (21% were due to financial constraints and 22% for other motives) (INE, 2024) and with 58% in the one-stop-shop project (Gouveia *et al.*, 2024). In the summer, 18% of energy community members reported feeling hot at home, compared with 38% nationally (INE, 2024) and 33% in the other project (Gouveia *et al.*, 2024).

While energy community members do not appear to suffer from economic difficulties, still 27% stated that they avoid switching on heating and/or cooling equipment so as not to increase the bills compared with 71% in the other project (Gouveia *et al.*, 2024); this point towards the existence of cultural normalization of thermal discomfort in the Portuguese population. Only 9% of energy community members reported having mold, damp of leaks in their homes which contrasts with 29% at national scale (INE, 2024). Energy community members do not report having frequent difficulties in paying energy bills. In the other project, 21% mention difficulties (Gouveia *et al.*, 2024); at the national level, 5% have arrears on utility bills (Eurostat, 2024).

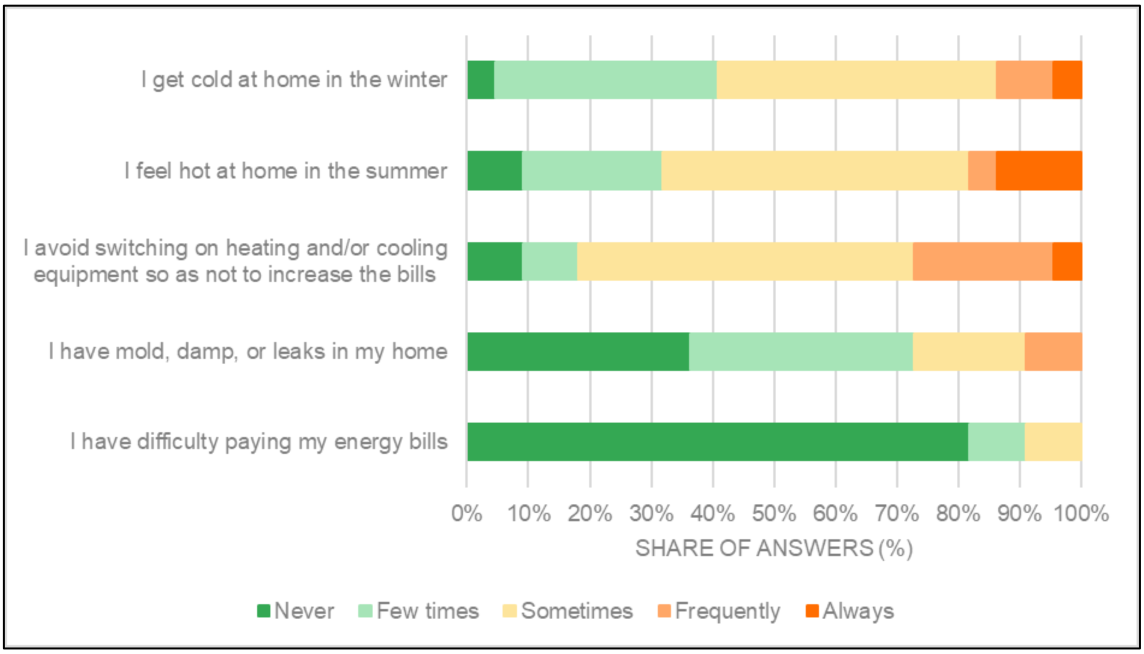


Figure 5.16 - Assessment of vulnerability to energy poverty among energy community members.

5.2.4 Conclusions

In this research, we mapped the bottom-up process of establishing a renewable energy community in the Portuguese context, based on the Telheiras Renewable Energy Community case study. This in-depth analysis of an on-the-ground energy community experience provides valuable data and insights on the constraints and solutions to constructing citizen-led energy communities, which can be useful for replication elsewhere. Furthermore, through two separate surveys, we characterised the volunteers who built up the energy community and the persons who signed up to join the pilot project as members.

While the sample is small and based on a single case study, results seem to confirm previous studies that found pioneers in energy communities tending to be male, with higher education (prominently, engineers), and with higher incomes. Environmental drivers, such as renewable energy installation, are the most mentioned, followed by social drivers, such as community participation. While economic drivers were the least selected set by the volunteers and the energy community members, it seems that the possibility of having a positive return on the investment made by the members is seen as an essential pre-condition to join and to enable environmental and social motivations to kick in. Barriers to participation mainly relate to lack of time, other priorities, difficulties in matching schedules, and lack of knowledge on the topic.

Volunteers evaluated the functioning of the working group mostly positively, identifying potential success factors (*e.g.*, clear internal communication, participation in decision-making, common definition of goals and tasks, transparency, freedom of opinion, and openness to criticism). Poorly evaluated aspects were acted upon, including fostering collaboration with the local government and with expert organisations and creating the opportunity for informal interactions between volunteers to develop personal relations. These community-based approaches were also fundamental for recruiting energy community members, with most coming from within the working group or the network of local organisations and with a strong role in local communication channels and word-of-mouth.

Our characterisation of the energy community volunteers and members leads to the insight that energy poverty mitigation most likely does not emerge naturally as a feature of energy communities. Members of the energy community showcase lower levels of energy poverty vulnerability in the proxy indicators compared to the national average and other similar surveys conducted. Thus, specific conditions must be in place to ensure the participation of vulnerable and hard-to-reach households in energy communities. In the case study, this was planned by reserving a few energy community spots for energy-poor households to join without the need for initial investment and with a reduced annual fee. The local governments' social services were responsible for identifying and engaging these households, leveraging on relationships of trust.

Renewable energy communities have the potential to provide multiple social, environmental, and economic benefits while contributing to the transformation towards a decarbonized, just, and democratic energy system; however, this paradigm change remains far from being realized, and more action is urgently needed. The authors propose creating a technical and financial support system working at a local scale to enable citizens, associations, and local governments to develop their energy communities.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation, Project administration, Funding acquisition. Evandro Ferreira: Writing – review & editing. João Pedro Gouveia: Writing – review & editing, Validation, Supervision.

References

Caramizaru, A., and Uihlein, A. (2020). Energy communities: an overview of energy and social innovation. EUR 30083 EN. JRC119433. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-10713-2. https://doi.org/10.2760/180576

Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast).

Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast).

Dudka, A. (2024). Women in Energy Communities: An Intersectional Analysis of Their Participation. In: Rocha Lawton, N., Forson, C. (eds) Women and the Energy Sector. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-43091-6_10

EPAH (2024). Energy Poverty Advisory Hub – Technical Assistance. Available at: https://energy-poverty.ec.europa.eu/get-support/technical-assistance_en

European Commission (2019). Clean Energy for all Europeans. https://doi.org/10.2833/9937

European Commission (2023). Commission Recommendation (EU) 2023/2407 of 20 October 2023 on energy poverty. Official Journal of the European Union, L series. Available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302407

Eurostat (2024). Arrears on utility bills - EU-SILC survey. Last updated on 03/05/2024. Retrieved on 14/05/2024. https://doi.org/10.2908/ILC_MDES07

Ferreira, E. (2023). Renewable Energy Communities: Concepts, Approaches and the Case Study of Telheiras Neighborhood in Lisbon. Masters' thesis, FCT-NOVA, Portugal.

Ferreira, E, Sequeira, M.M., and Gouveia, J.P. (2024). Sharing Is Caring: Exploring Distributed Solar Photovoltaics and Local Electricity Consumption through a Renewable Energy Community. Sustainability, 16, 2777. https://doi.org/10.3390/su16072777

Gouveia, J.P., Mendes, M., Sequeira, M.M., and Palma, P. (2024). A new way to mitigate energy poverty: Lessons from the Transition Point 'One-Stop Shop' Pilot. Calouste Gulbenkian Foundation.

Gouveia, J.P., Palma, P., and Simões, S.G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187-201. https://doi.org/10.1016/j.egyr.2018.12.004

Grandin, J., and Sareen, S. (2020). What sticks? Ephemerality, permanence and local transition pathways. Environmental Innovation and Societal Transitions, 36, 72–82. https://doi.org/10.1016/j.eist.2020.04.008

Grossmann, K., Jiglau, G., Dubois, U., Sinea, A., Martín-Consuegra, F., Dereniowska, M., Franke, R., Guyet, R., Horta, A., Katman, F., Papamikrouli, L., Castano-Rosa, R., Sandmann, L., Stojilovska, A., and Varo, A. (2021). The critical role of trust in experiencing and coping with energy poverty: Evidence from across Europe. Energy Research & Social Science, 76, 102064. https://doi.org/10.1016/j.erss.2021.102064

Hanke, F., Guyet, R., and Feenstra, M. (2021). Do renewable energy communities deliver energy justice? Exploring insights from 71 European cases. Energy Research & Social Science, 80, 102244. https://doi.org/10.1016/j.erss.2021.102244

INE (2024). Rendimento e condições de vida, habitação, dificuldades habitacionais e eficiência energética dos alojamentos - 2023 ["Income and life conditions, housing, housing difficulties, and energy efficiency of dwellings - 2023"]. Portugal Statistics. Available at: www.ine.pt

Koirala, B. P., Araghi, Y., Kroesen, M., Ghorbani, A., Hakvoort, R. A., and Herder, P. M. (2018). Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems. Energy Research & Social Science, 38, 33-40. https://doi.org/10.1016/j.erss.2018.01.009

Koukoufikis, G., Schockaert, H., Paci, D., Filippidou, F., Caramizaru, A., Della Valle, N., Candelise, C., Murauskaite-Bull, I. and Uihlein, A. (2023). Energy Communities and Energy Poverty, Publications Office of the European Union, Luxembourg. DOI 10.2760/389514, JRC134832.

McMaster, R., Noble, B., and Poelzer, G. (2024). Assessing local capacity for community appropriate sustainable energy transitions in northern and remote Indigenous communities. Renewable and Sustainable Energy Reviews, 191, 114232. https://doi.org/10.1016/j.rser.2023.114232

Portuguese Government (2024). Resolução do Conselho de Ministros n.º 11/2024 de 8 de Janeiro – Estratégia Nacional de Longo Prazo para o Combate à Pobreza Energética 2023-2050 ["National Long-term Strategy for Energy Poverty Mitigation 2023-2050"]. Diário da República, 1.ª série, 5. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/11-2024-836222486

Sequeira, M.M., Ferreira, E., Pereira, L.K., Cachinho, L., Martins, H., Gouveia, J.P., Antunes, A.R., and Boucinha, A. (2024). Practical guide: Development of renewable energy communities by citizens, associations, and local governments – The example of the Telheiras Renewable Energy Community. Available at: https://vivertelheiras.pt/certelheiras/en

Sequeira, M.M, Gouveia, J.P., and Palma, P. (2021). Case study analysis – Portugal. IEA UsersTCP Hard-To-Reach Energy Users Task. https://doi.org/10.47568/3XR115.

Sequeira, M.M., and Mameri, D. (2022). Can communities lead the way for socio-ecological urban transformations? The empiric experience of the "network of ideas" process in the Telheiras neighborhood, Portugal. Proceedings of the ISDRS Conference 2022.

Radtke, J. (2014). A closer look inside collaborative action: civic engagement and participation in community energy initiatives. People, Place and Policy, 8(3), 235-248. https://doi.org/10.3351/ppp.0008.0003.0008

Radtke, J., and Bohn, N.S. (2023). Mind the gap: Community member perceptions of shortcomings in diversity and inclusivity of local energy projects in Germany. Utilities Policy, 85, 101686. https://doi.org/10.1016/j.jup.2023.101686

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., Chester, M., Karlin, B., Ashby, K., Butler, D., & Chambers, J. (2020). Hard-to-Reach Energy Users: A Literature Review. UsersTCP - HTR Task. Available at: https://userstcp.org/hard-to-reach-energy-users-task/

Viver Telheiras (2024). Telheiras Renewable Energy Community. Available at: http://vivertelheiras.pt/certelheiras/en

Chapter 6.

EXPLORING THE ROLES OF LOCAL ORGANISATIONS IN ENERGY TRANSITIONS

6.1 Can local organizations act as middle actors in energy support? Exploring their functions, motivations, challenges, and needs

This work is published in: Sequeira, M.M., Gouveia, J.P. and Melo, J.J. (2024). Can local organizations act as middle actors in energy support? Exploring their functions, motivations, challenges, and needs. Energy Efficiency 17, 81. https://doi.org/10.1007/s12053-024-10262-5

Abstract

Energy efficiency is vital for energy transitions, and energy-poor, vulnerable, and hard-to-reach groups are at risk of being left behind. In this context, local middle actors have been suggested as partners in deploying targeted energy support. Nevertheless, scarce research has engaged with them to assess if they are willing and capable of contributing, if they can reach households, and if they have unmet needs. In this research, we draw on the mapping of 198 local organizations and 34 semi-structured interviews conducted after deploying a pilot energy support service in Setúbal, Portugal. Interviews characterized the organizations and target audiences, assessed energy literacy, explored potential collaborative roles, and recognized drivers, barriers, and solutions. Results show that most organizations are willing to disseminate activities, forward citizens, facilitate contacts, co-organize events, and participate in training. Half can identify vulnerable families for proactive support. Drivers include environmental concerns, community participation, and social support. However, few seem able to conduct energy support, hire/redirect staff, or participate in coordination. Scarce human resources, lack of time, other priorities, and financing concerns severely constrain local organizations. This case study finds some potential for local organizations to act as intermediaries in energy support, building on their communication channels and trusted relationships to fulfil specific roles. However, they are often hard-to-reach themselves and burdened with demanding activities. Thus, we suggest that fostering collaborations with local organizations is challenging but possible. It requires dedicated funding, time, and resources to empower, capacitate, and reward middle actors for their contributions in delivering energy support.

Keywords: Energy efficiency, One-stop shop, Vulnerable households, Energy poverty, Intermediaries, Portugal

6.1.1 Introduction

Energy transitions are urgently needed to mitigate the worst effects of climate change. One critical factor for their success is the involvement of all citizens, who are needed to unleash the two major pillars of energy systems' transformation: energy efficiency and renewable energy (IEA, 2023).

Buildings currently use 42% of the European Union's (EU) final energy (Eurostat, 2023a). Thus, the sector is a crucial arena for action, including through the Renovation Wave strategy published by the European Commission (2020). This proposed deep renovation of the EU building stock is framed by the European Green Deal's principles of fairness and inclusivity, putting people first and ensuring no one is left behind (European Commission, 2019).

In this context, the concept of hard-to-reach energy users is receiving growing attention, being defined as those that are "either hard-to-reach physically, underserved, or hard to engage or motivate in behaviour change, energy efficiency, and demand response interventions" (Rotmann *et al.*, 2020; Mundaca *et al.*, 2023). Sequeira *et al.* (2024) described in detail several profiles of residential hard-to-reach energy users and ascertained that these groups represent a significant share of the population in the EU and its Member States. These authors argue for targeted and tailored interventions to identify and engage hard-to-reach energy users.

Hard-to-reach energy users include vulnerable households, representing a significant share of the population whose engagement requires greater attention (Ashby *et al.*, 2020). Vulnerable households are also more susceptible to energy poverty, defined by the EU's Energy Efficiency Directive (Directive (EU) 2023/1791) as the "lack of access to essential energy services [...] caused by a combination of factors, including at least non-affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes". Research in the Global North suggests that demographic and socio-economic variables – such as age, income, gender, education, employment, household composition, health and disabilities, migratory status, and ethnicity – can aggravate the risk of energy poverty and may signal a hard-to-reach profile (Simcock *et al.*, 2021; Middlemiss, 2022; Sequeira *et al.*, 2024).

Vulnerable households should be prioritized for the uptake of energy efficiency measures that can address the root causes of energy poverty. In its latest recommendation on energy poverty, the European Commission (2023) urges Member States to "ensure an enhanced governance with a holistic approach to tackle energy poverty, including cross-departmental and vertical collaboration across national, regional, and local governance structures, involving closer engagement with vulnerable households and relevant energy and social partners and stakeholders". Furthermore, this document proposes to "step up energy efficiency information campaigns targeting households affected by energy poverty, to ensure that those population groups receive tailor-made information and advice while using all the potential of energy advisory networks and one-stop shops". In addition, the EU's Energy Poverty Advisory Hub (2024) provides technical assistance for local governments to diagnose energy poverty in their territories and to implement mitigation actions in collaboration with other local stakeholders.

In contrast to one-size-fits-all approaches, local solutions can recognize unique realities and address communities' needs (Middlemiss and Parrish, 2010; Elmallah *et al.*, 2022). Examples of local energy support activities include the setup of energy cafes, collective assemblies, and one-stop shops to inform households about energy savings, funding opportunities, renewable energy sharing, and possibilities to switch providers (Martiskainen *et al.*, 2018; Hanke *et al.*, 2021; Ortiz *et al.*, 2021). While some of these models are still underdeveloped (*e.g.*, energy sharing), others, such as physical and digital one-stop shops, have been the object of recent research and empirical projects which could pave the way for their mainstreaming across EU countries (Bertoldi *et al.*, 2021; Kwon *et al.*, 2021; Kwon and Mlecnik, 2021).

A key question is how to provide on-the-ground, well-targeted interventions that meet vulnerable groups' needs, encourage wider social integration, and enact the multiple benefits of energy transitions (Gillard *et al.*, 2017). Recent studies have suggested that local-scale approaches coupled with the active enrolment of middle actors and intermediaries can successfully fulfil this aim (*e.g.*, Frick *et al.*, 2017; Horta *et al.*, 2019; Kivimaa and Martiskainen, 2018). Any organization between two or more actors can be considered an intermediary, while middle actors can be broadly defined as those with their own activities that may include but always go beyond the intermediation role (Parag and Janda, 2014). The European Commission (2023) highlights the role of these middle actors, stating that "when designing measures and actions that tackle energy poverty, [Member States] pay particular attention to targeted and tailored communication that builds trust among beneficiaries of relevant schemes and avoids stigmatizing vulnerable groups" and that "Member States should make use of qualified front line workers [...] to help identify and advise households in energy poverty."

However, comprehensive research on the role of middle actors in energy transitions is still lacking, as reported for the United Kingdom by Bouzarovski *et al.* (2022) and Australia by Willand *et al.* (2023). Furthermore, scarce scientific research has directly engaged with local stakeholders to critically assess their willingness to enrol in energy support, the contributions they can realistically provide, and their needs to potentially unlock deeper collaboration. Most previous research has considered middle actors homogeneous or focused on pre-established typologies (*e.g.*, Ramsden, 2020, focuses on charities; McMaster *et al.*, 2024, research remote Indigenous communities). Thus, the perspectives of local organizations, including non-profit and community-based organizations, have not been fully integrated into energy policies and interventions (Elmallah *et al.*, 2022; Willand *et al.*, 2023).

In this research, we address this gap by drawing from a case study analysis, including a stakeholder mapping exercise and semi-structured exploratory interviews, conducted after deploying an energy efficiency one-stop shop pilot project in the Setúbal Municipality in Portugal. We ask the following research questions: i) are local organizations willing, capable, and impactful enough to act as middle actors in energy support?, ii) what are the roles that local organizations might assign to themselves?, and iii) if a collaboration is to be enabled, what are the unmet needs of local organizations?. It should be clearly stated that this research does not intend to assess the effectiveness of collaborating with local middle actors in energy support. Instead, the novelty of this work lies in the empiric exploration of potential collaborative roles of diverse typologies of local organizations in delivering energy support to vulnerable audiences while recognizing the major challenges obstructing this approach and the pressing needs that this endeavour entails. Although the results are case-specific, the applied methodology and critical insights are relevant for local-scale energy support interventions elsewhere.

This work is structured as follows: section 6.1.2 provides a literature review on middle actors in energy transitions, section 6.1.3 details the methods used to accomplish the research goals, section 6.1.4 outlines and discusses the results obtained, and section 6.1.5 concludes with insights and recommendations for future research and practitioners.

6.1.2 Literature review

6.1.2.1 Middle actors in energy transitions

Researchers in Global North countries have started looking at "middle-out" mechanisms – whereby middle actors exercise their agency and capacity to influence other bottom, middle, or top actors – as a relevant tool to accelerate energy transitions (Parag and Janda, 2014). Middle actors and intermediaries have been suggested as relevant stakeholders for the deployment of community energy in Ireland (Boyle *et al.*, 2021), heat pumps in Belgium (Decuypere *et al.*, 2022), battery storage in Australia (Page and Fuller, 2021), electric vehicles in Israel and Sweden (Zohar *et al.*, 2021; Eriksson and Olsson, 2022), solar photovoltaic systems in Israel (Zohar *et al.*, 2021), and energy efficiency in the United States (Reames, 2016), among others. The definition of middle actors is broad, and these studies include a myriad of public and private organizations, such as local governments and other public authorities, industry and market players, non-governmental organizations and grassroots initiatives, energy advisors, building professionals, and technical experts, among others.

Local middle actors have been considered of interest to facilitate, mediate, and accelerate technology adoption and behaviour change in the energy sector (Mundaca *et al.*, 2023). They may be able to overcome barriers to participation by creating institutional capabilities for increased recognition of specific needs in their communities and by facilitating alternative solutions (Reames, 2016; Frick *et al.*, 2017; Kivimaa and Martiskainen, 2018). One of such solutions are one-stop shops, which have emerged as a relevant approach to facilitate the uptake of building renovation and energy efficiency and overcome persistent barriers (European Commission, 2020). These can consolidate information mechanisms and advisory services under one single roof, providing full-value-chain technical, financial, and legal support to households (Bertoldi *et al.*, 2021).

Several business models are being tested across Europe, including from private and public initiatives, through digital platforms and physical spaces, and with varying levels of support delivered to the end users (Kwon *et al.*, 2021; Pardalis *et al.*, 2022; Sequeira and Gouveia, 2022). Success factors of one-stop shops include their local nature and connection with stakeholders in the building renovation ecosystem (Bertoldi *et al.*, 2020). One-stop shops are already reaching vulnerable households, providing support, bridging financial and capacity gaps, and collaborating with intermediaries to combat energy poverty (Bertoldi *et al.*, 2021).

Besides fostering participation among the general population, some middle actors may indeed be strategically placed to facilitate engagement with hard-to-reach groups, such as vulnerable households, benefiting from a pre-existing relationship of trust that may be transposed to the energy field (Lacey-Barnacle and Bird, 2018; Ramsden, 2020). For instance, Mundaca *et al.* (2023) analysed 19 case studies across eight Global North countries that entailed energy efficiency and climate mitigation interventions focused on hard-to-reach energy users, finding that the engagement of stakeholders and, particularly of local middle actors was a relevant feature in a significant number of cases. Rotmann (2024) also highlighted middle-out solutions with the involvement of community representatives and frontline workers as a way to reach vulnerable groups and indigenous populations in New Zealand.

Trust and impartiality have been highlighted by the European Commission (2023) as key elements to successfully identify, reach out, and engage energy-poor households. This is critical in disadvantaged communities who often lack access to information about support programs and where barriers are severe, including competing priorities, and pervasive distrust and fear of authorities and market actors (Reames, 2016; Lacey-Barnacle and Bird, 2018; Willand *et al.*, 2023). In addition, peer effects may be unlocked, where individuals and organizations influence each other by observation and communication, driving participation and uptake of sustainable energy solutions (Palm, 2016; Balta-Ozkan *et al.*, 2021). These can be enhanced over time, as households may reinforce behaviours through continuous and deeper engagement (Donnelly, 2014).

Large companies have traditionally dominated the energy sector, but civil society organizations seem to be increasingly entering this sphere (Martiskainen *et al.*, 2018; Lacey-Barnacle and Bird, 2018). However, while some middle actors can support the energy transition, others may act against it to pursue their own goals (Parag and Janda, 2014; Zohar *et al.*, 2021). Furthermore, some authors alert against overly optimistic interpretations of the role of middle actors in energy transitions and signal a positivity bias, which can lead to false expectations (Shaw *et al.*, 2018; Boyle *et al.*, 2021). More research is still needed to comprehend the range of roles different middle actors can play in energy transitions and leverage their potential contributions toward a decarbonized energy system.

6.1.2.2 Portuguese energy policy context

Portugal is in Southern Europe and is an EU Member State. The country has a National Climate Law (Portuguese Government, 2019), a Roadmap for Climate Neutrality by 2050 (Portuguese Government, 2021a), and is currently reviewing its National Energy and Climate Plan 2030 (Portuguese Government, 2023). Buildings account for 32% of final energy consumption, with the domestic sector representing 19% (DGEG, 2023). Buildings are inefficient compared with current standards, with existing energy performance certificates suggesting that around two-thirds are C-class or below (ADENE, 2024). Portugal has a National Long-Term Building Renovation Strategy that recognizes the structural problems in the building stock. It foresees that most buildings will need major renovations by 2050 (Portuguese Government, 2021b). This endeavour's costs are tremendous, estimated at a minimum of 40 to 72 thousand million euro to bring the current building stock up to regulation standards (Melo *et al.*, 2021; Palma *et al.*, 2022).

Energy poverty is a key concern, with Portugal performing amongst the worst EU Member States in several proxy indicators – *e.g.*, 17.5% of the population reports an inability to keep their home adequately warm, and 25.2% of the population lives in dwellings with leaks, damp, or rot (Gouveia *et al.*, 2022; Eurostat, 2023b; Eurostat, 2023c). In 2024, the Portuguese Government published the National Long-Term Energy Poverty Combat Strategy 2023-2025, mimicking the European Commission's definition and identifying that up to 29% of the population – around three million people – may suffer from different facets of energy poverty (Portuguese Government, 2024). This strategy highlights the need to reinforce local citizen support networks, including by establishing advisory and support services for sustainable energy practices: "citizen support spaces are structures usually of local initiative, which correspond to a physical and/or virtual location, anchored in municipal spaces or other nearby local structures and organizations which are close to citizens, which offer a range of energy services to residents". Local governments, energy and environmental agencies, and non-governmental organizations from the social economy are referenced as relevant stakeholders for energy support. Still, there are few practical examples of successful implementation in the country (Portuguese Government, 2024).

6.1.3 Methods

6.1.3.1 Case-study: Transition Point one-stop-shop in Setúbal, Portugal

The Transition Point mobile one-stop shop pilot project was launched in the beginning of 2022 in Setúbal, Portugal, to develop and test an integrated approach of providing energy support at a local scale (Figure 6.1) (CGF, 2024). The Setúbal municipality is in the southern part of the Lisbon Metropolitan Area. For administrative purposes, it is divided into five civil parishes. Data from the Portuguese Census of 2021 paint a picture of the demographic, socioeconomic, and buildings factors that may affect energy poverty vulnerability at the local scale (INE, 2023). Mainly urban, Setúbal hosts a population of 123 000 people, 53% women. Buildings are energy inefficient, as 49% were built before 1980 when thermal regulations were non-existent (country average: 38%). 25% of households rent their dwelling (country average: 22%). 51% of the population has a high school diploma (country average: 46%), and the unemployment rate is

9% (country average: 8%). 7% have foreign citizenship (country average: 5%). 23% are over 65 years old (country average: 23%).

Figure 6.1 – Transition Point mobile one-stop shop in Setúbal.

In the energy poverty vulnerability index developed by Gouveia *et al.* (2019) (which brings together buildings' energy performance, climate characteristics, heating and cooling technologies with an evaluation of the adaptative capacity of the population based on socio-economic indicators at the municipal and sub-municipal scale in Portugal), the Setúbal municipality ranks 296 and 257 out of 308 municipalities for winter and summer, respectively, showcasing a relatively low vulnerability in the national scenario. While useful for a national-scale analysis, this index is not suitable to detect the presence of energy poverty hotspots within the municipalities.

In this context, Transition Point was innovatively located in a mobile container, providing the following free in-person services: i) energy efficiency advice, ii) energy tariffs optimization, iii) support on application to national energy efficiency funding schemes, and iv) free home energy audits. These types of energy support services are commonly mentioned in the literature (Simcock and Bouzarovski, 2023). The regional energy agency carried out the project's on-the-ground activities. In its pilot phase, it operated for one year and three months, served four locations and three municipalities, and supported over 500 people (Gouveia *et al.*, 2024). From

February 2022 to September 2022, the container was in the Setúbal municipality, half the time in a vulnerable neighbourhood and half the time downtown.

The one-stop shop attempted to foster direct collaboration with local organizations, seeking to increase engagement from the general population and vulnerable families. Overall, the results of this effort were mixed. The energy agency contacted local governments in the territory, disseminated the project in local media, and provided training to 17 local youth. However, only around 5% of energy support beneficiaries reported being forwarded by community-level organizations or by their local government, with the remaining being attracted by the physical container itself, by flyers and online dissemination, and by word-of-mouth (Gouveia *et al.*, 2024).

In this context, the research adheres to the methodological approach shown in Figure 6.2, which is explained in detail in the following subsections.

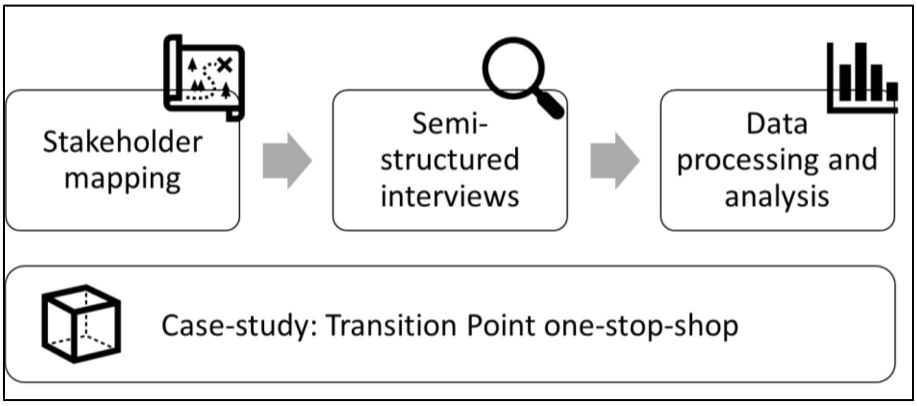


Figure 6.2 - Methodological approach followed by the research.

6.1.3.2 Stakeholder mapping

After the Transition Point pilot phase in Setúbal, a deeper analysis and engagement of local organizations was performed to assess challenges and collaboration opportunities seeking to increase the project's impact and better reach vulnerable families. The relevance of mapping stakeholders for improved project management is well-established in the literature; in this work, we followed the guidelines of the Project Management Institute (2013). Likewise, some authors have used stakeholder mapping and consultation in the context of energy efficiency and energy poverty research (*e.g.*, Papantonis *et al.*, 2022; Mahoney *et al.*, 2024). Kivimaa and Martiskainen (2018) consider that middle actors for building renovation can be public or private organizations, including local governments. In our study, local organizations are explored as middle actors that have their own raison d'être which can include but is not limited to bridging the gap between citizens and energy companies, funding agencies, and policymakers (a similar definition was used by Parag and Janda, 2014, and Frick *et al.*, 2017).

In September 2022, following three data collection approaches, a systematic stakeholder mapping exercise focused on local organizations was performed for the Setúbal municipality. First, these were collected from the publicly available list of organizations participating in the Local Social Action Council of Setúbal, a network of around 80 organizations managed by the Setúbal City Council. Second, from the publicly available lists of organizations participating in the Civil Parish Social Committees, a mechanism like the social action council but operating at the civil parish scale (only available for two civil parishes in Setúbal). Third, from the websites of local governments, namely from the pages listing local associations.

Data on the organization's name, e-mail, website, and social media were collected. Based on the publicly available information, mapped organizations were classified according to their primary type of activity: local government (*i.e.* official administrative units managing the territory across various sectors), energy and environmental agency (*i.e.* non-profit organization conducting activities from awareness raising to direct consumer support), community and education (*i.e.* mainly non-profit associations organizing local events, fostering sustainability-oriented projects, providing training to different groups, and occasionally integrating social support and inclusion of vulnerable groups), social support and health (*i.e.* mainly non-profit associations or institutions focusing almost exclusively on providing essential support services, mentoring, and advice to vulnerable and marginalized groups through domiciliary care, a network of infrastructures, and preventive action with awareness-raising campaigns), arts and sports (*i.e.* mainly non-profit associations or clubs dedicated to specific activities related to artistic expression, for instance, theatre and dance, and to sports practice, for example, canoeing and basketball), religion (*i.e.* mostly churches), and others. Frick *et al.* (2017) follow a similar classification. The "others" category encompasses local organizations that were too diverse to be grouped. The original list of mapped stakeholders was refined by erasing duplicates and those without an active e-mail, resulting in 198 local organizations as the study universe.

6.1.3.3 Semi-structured exploratory interviews with local stakeholders

All 198 mapped stakeholders were contacted by e-mail with a general presentation of the Transition Point one-stop shop and an invitation to participate in a research activity consisting of a single one-on-one interview. This invite was sent to all organizations on three separate occasions: September 2022, November 2022, and April 2023. In total, it was possible to obtain an answer from 47 stakeholders, of which 34 were available to participate in semi-structured exploratory interviews (representing 17% of the study universe). All interviews were conducted from October 2022 to May 2023. Stakeholder interviews are a well-established research approach in the energy field, being able to provide detailed case-specific information on the relationship between the energy system, the organizations on the ground, the vulnerable consumers, and the population at large (*e.g.*, Hargreaves *et al.*, 2013; Magnani and Osti, 2016; Willand *et al.*, 2023).

The interviews were performed online (26 out of 34) or by telephone (8 out of 34) when the interviewee lacked digital skills, following a four-section script. The full interview script can be found in Appendix A.

The first section characterized current goals, activities, legal structure, resources, geographical scope, and target audiences (12 open-answer questions). The second assessed the knowledge base on energy topics (four open-answer questions). The third explored potential roles as intermediaries in energy-related support (one closed question with 16 options where interviewees answered yes/no/maybe to each option and were invited to comment on their answers; options for "prefer not to answer" and "other" were also provided); the design of these options was inspired by several studies and empiric case studies that describe or suggest different roles for stakeholders in energy support (*e.g.*, Parag and Janda, 2014; Kivimaa and Martiskainen, 2018; Sequeira and Gouveia, 2022). Finally, the fourth section identified drivers, barriers, and solutions for collaboration (three closed questions with seven options each, where interviewees chose a maximum of two options and were invited to comment on their choices; options for "prefer not to answer" and "other" were also provided). These options were designed based on existing literature analysing participation in local-scale energy initiatives (*e.g.*, Ornetzeder and Rohracher, 2013; Kivimaa and Martiskainen, 2018; Koch and Christ, 2018; Koirala *et al.*, 2018).

6.1.3.4 Data processing and analysis

The transcripts of the interviews were manually processed, including quantitative and qualitative outputs. The former includes data analysis on the organization's human resources, their potential collaborative roles in energy support, and their choice of drivers, barriers, and solutions to collaboration. The latter includes a thematic analysis with the extraction of direct citations from the interviewees to illustrate their perspectives (translated from Portuguese to English by the authors). These results are shown for each type of organization defined before.

Furthermore, an attempt is made to pinpoint key local organizations ("overachievers") based on three dimensions, namely i) capability (defined as having several full-time employees or volunteers 50% above the median of the interviewed sample), ii) willingness (defined as being willing to perform a number of tasks 50% above the median), and iii) reach (broadly defined as reporting to be able to reach "hundreds" of persons per year, as quantitative responses were scarce on this topic). This is an exploratory exercise, and the limits considered for each component are essentially arbitrary. Parag and Janda (2014) also assess the behaviour of middle actors based on agency – as the willingness of actors to make their own choices – and capability – as the ability of actors to perform these choices – with change being more likely to happen when both are high for a specific action.

The interviewed sample does not intend to be representative of the study universe, nor do the results seek to be statistically meaningful (although theoretical saturation appears to have been reached, at least for some types of organizations). Instead, it aims to critically explore the potential to integrate local organizations in energy support by testing a collaborative methodology and analysing results in a real-world case study. Galvin (2015) describes the limitations of interview-based approaches in the energy field and advises caution when using small samples to make inferences and transfer these to broader populations. It should be noted that interviews were conducted with the organizations that agreed to participate, which may reveal a preexisting willingness to collaborate. Thus, the results are likely to be inherently biased towards positive answers compared to the universe of stakeholders. A similar bias is reported by Schneider *et al.* (2023) regarding households' recruitment.

6.1.4 Results and discussion

6.1.4.1 Characterization – Goals and activities

The 198 mapped local organizations in the Setúbal Municipality are shown in Table 6.1 by their primary type of activity. The territory encompasses one municipality and five civil parishes. A single energy agency is active in the Setúbal municipality and two adjacent municipalities. Many other local stakeholders are active in Setúbal, providing various activities and services. In our interviewed sample, social support and health institutions are overrepresented compared with the universe of mapped organizations. At the same time, arts and sports clubs are underrepresented, suggesting that the former may have more interest in the topic than the latter. It was not possible to interview religious organizations (congregations are mentioned as relevant middle actors by Parag and Janda, 2014, due to their moral authority over their members) while "others" were too diverse for a meaningful analysis.

Table 6.1 - Local organizations mapped and interviewed in Setúbal according to their type of activity.

Type of organization	No. mapped	No. answered	No. interviewed
Local government	6	3	2
Energy agency	1	1	1
Community and education	39	8	8
Social support and health	52	20	15
Arts and sports	86	14	8
Religion	7	1	0
Other	7	0	0
Total	**198**	**47**	**34**

The first step in the interviews was to identify self-reported goals and activities. The complete coded list of interviewed organizations is presented in Appendix B, including their self-reported goals and activities. These goals offer insights into the organizations' core values that may be articulated with the long-term benefits of local energy transitions (McMaster *et al.*, 2024). The wide array of activities reflects the dynamics of the territory and the services available to the population. A promising avenue could be to find synergistic goals between an energy support service and the interviewed organizations, looking for common ground that can foster collaborations.

For instance, local governments focus on managing the territory across various sectors, including housing and health, closely matching energy efficiency improvement and energy poverty mitigation. The energy agency seeks to raise awareness and directly support consumers on energy topics which is one of the core goals of a one-stop shop. Community and education organizations have the role of building, dynamizing and improving their local community's sustainability and well-being, including through events, training, and projects, which seems well-aligned with purpose of the energy support services.

Social support and health institutions focus almost exclusively on aiding vulnerable and marginalized groups, including poor households, elderly people, disabled and chronically ill, migrants, disadvantaged youth, persons in homeless situation, persons with HIV/AIDS, persons with substance abuse problems, sex workers, and ex-convicts, among others. They provide essential support services, mentoring, and advice mostly through domiciliary care, a network of infrastructures, and preventive action with awareness-raising campaigns. This overall ambition of improving health and well-being in the most vulnerable groups may be synergetic with the one-stop shop's goal of reducing energy poverty and its well-researched impacts on public health (Pan *et al.*, 2021). Arts and sports clubs are dedicated to specific goals activities related to artistic expression and to sports practice; these may indicate that this type of organization has less common ground with energy support services.

Most interviewed organizations are legally established as non-profit associations (17 out of 34) or private institutions for social solidarity (11 out of 34). Other legal structures, *e.g.*, cooperatives, mutualist associations, and non-governmental humanitarian institutions, are less common in our sample. Only six stakeholders stated that they were a local delegation of a larger national or regional organization, with the remaining (28 out of 34) being fully autonomous. The median year of foundation is 2003, but the range is vast, with the oldest dating back to 1860 and the newest from 2021; Parag and Janda (2014) also report on a wide range of lifespans for local organizations. Regarding their geographical scope, most report operating at the regional (13 out of 34) or municipal (14 out of 34) level, while fewer are focused only on the civil parish (5 out of 34) or neighbourhood (2 out of 34) scale. In their study, Hargreaves *et al.* (2013) also reported a prevalent heterogeneity in grassroots movements, including in their organizational forms, goals, and activities.

The relatively low rate of responses from the mapped stakeholders shows the inherent difficulty in engaging with local organizations unfamiliar with energy topics. In addition, it might also be a lingering effect of the COVID-19 pandemic as a challenging time that tested the resilience of many local organizations. Virtually all interviewees mentioned relevant changes to their activities due to lockdowns, with around half stating that it caused long-term halts in their activities, for instance:

> *"We stopped completely. Stagnated. But then we were able to start again."* [Com1]

Still, the other half carried on in some way, including to provide essential aid to vulnerable populations, as illustrated by a social support and health organization:

> *"[COVID-19] was very bad. Some of our beneficiaries suffered deeply from isolation and mental health. Some lost income. We saw an increase in demand for our social canteen and food baskets. We never stopped working."* [Soc6]

Most interviewees state that they were able to restart their activities after the COVID-19 pandemic; however, it is possible that some of the mapped organizations did not pass this stress test. This is exemplified by an organization's struggles:

> *"We closed the door. We were afraid. We did not want to put people's lives at risk. After, we reopened, but we lost one-third of our members [...] it is still a challenge."* [Com8]

6.1.4.2 Capability – Resources and knowledge

Regarding human resources, a significant share of the interviewed organizations (10 out of 34) entirely depends on volunteers, while an additional 15 have between one and ten persons employed full-time. Except for the municipality, all organizations (8 out of 34) have less than 100 full-time employees. This dependence on a handful of key members accentuates vulnerabilities to external and internal shocks, such as diminishing funds, loss of employees or volunteers, and changing priorities (Hargreaves *et al.*, 2013). Figure 6.3 shows the number of full-time employees per main type of organization.

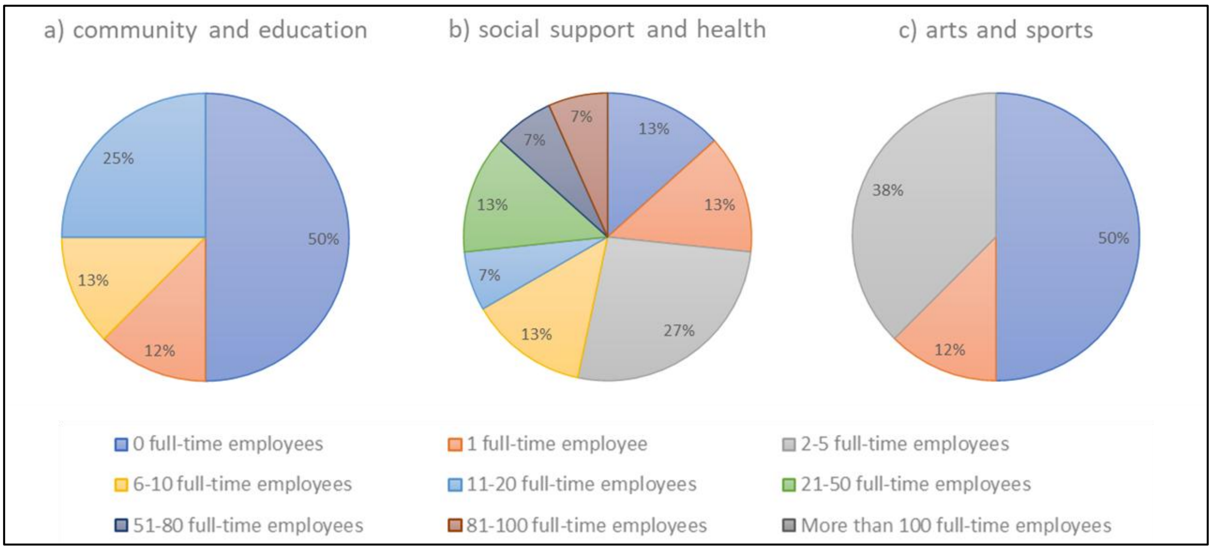


Figure 6.3 - Self-reported number of full-time employees by type of organization: a) community and education, b) social support and health, and c) arts and sports.

A wide gap in available resources exists between the municipality and civil parish levels of government. The former reports over 1700 employees, and the latter between 81 and 100 employees. The energy agency has seven full-time employees. Notably, half of community and education organizations and half of arts and sports clubs rely only on volunteer work, with the maximum self-reported number of full-time employees being 15 for the former and five for the latter. For instance, one arts and sports club reports:

> *"The only ones that have contracts are the four coaches. All others are volunteers. Around seven since two do not have the availability they once had."* [Art7]

Social support and health institutions seem better equipped with full-time human resources; one-third of the interviewed sample has over ten employees. A prominent example is an organization with several infrastructures and social responses:

> *"We have around 80 people full-time. Our nursery and kindergarten employ the most resources, and we also have a canteen and storage. We only work with volunteers to distribute food baskets and for other occasional activities."* [Soc2]

In our interviewed sample, most organizations (23 out of 34) rely on volunteers to perform at least some tasks. Figure 6.4 shows the self-reported number of volunteers by type of organization, with no significant differences. Between two-thirds and three-quarters rely on up to ten volunteers, and the remaining rely on more than ten. The two local governments and the energy agency do not use volunteer work.

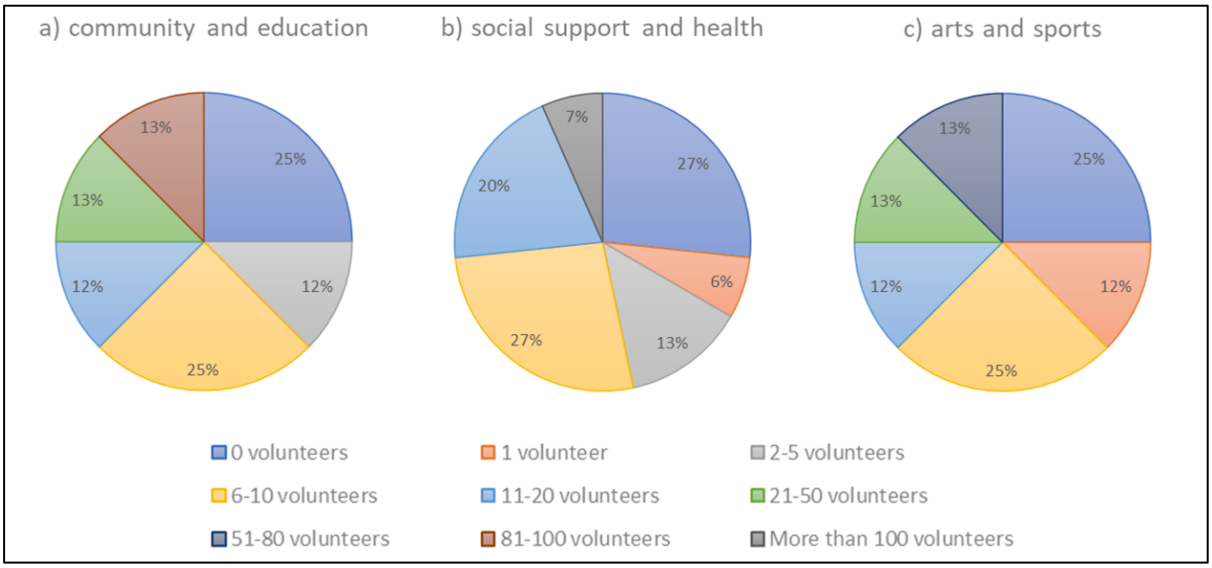


Figure 6.4 - Self-reported number of volunteers by type of organization: a) community and education, b) social support and health, and c) arts and sports.

The number of volunteers varies from just a few to several hundreds of citizens, with around one-third of the organizations being able to recruit more than 20 volunteers on a regular basis.

This capability to mobilize many volunteers is reported by a community and education organization with a citizenship centre:

> *"[Volunteering] is a way for people to reinforce their self-esteem, develop skills, and socialize. We have had hundreds of volunteers that we know we can mobilize."* [Com6]

However, volunteer work can present specific challenges that hinder the capabilities of local organizations, including hostility from local people, funding difficulties, and burnout (Middlemiss and Parrish, 2010). This was a recurring theme during the interviews, for instance, with volunteers' age also being reported as a significant factor by two organizations:

> *"We have around 20 volunteers, but it is hard to keep their commitment. They are young, and these activities are very time-consuming."* [Com1]

> *"We are only 13 people, all volunteers, and we are all already old, all 70 years old or close to that…"* [Soc12]

Only six out of 34 interviewed claimed to have a person specifically dedicated to environmental and/or energy issues, namely four community and education organizations, the local energy agency, and the municipality. Notably, neither the social support and health institutions nor the arts and sports clubs seem to have resources allocated to these topics while reporting a prevalent lack of knowledge on energy issues. This may hinder the capabilities of these organizations to act as middle actors in energy support. Similar results were obtained by Willand *et al.* (2023) when interviewing frontline support staff. This is also in line with the perspective of the energy agency:

> *"There is a widespread lack of energy literacy. Energy is hard to understand; we do not see or touch it, and we often lose track of it."* [Ene1]

Nevertheless, when asked if their beneficiaries suffer from energy poverty – framed as thermal discomfort or difficulty in paying energy bills – most interviewees emphatically acknowledged the problem by mentioning their lived experiences of interacting with vulnerable households. It is possible that by conducting this research the interviewees became more alert to energy poverty in their communities, as also acknowledged by Martiskainen *et al.* (2018) and Willand *et al.* (2023). This empirical knowledge is aligned with scientific research on energy poverty in Portugal (Gouveia *et al.*, 2017; Horta *et al.*, 2019). It is exemplified by two organizations:

> *"Yes, our houses are not in good condition; they were not built in a proper manner. We hear everything our neighbour says. We feel cold at home. Horrible heat. The windows and blinds are degraded. The paint has fallen off the walls."* [Com4]

> *"In winter, we visited the house of one of our beneficiaries. He did not have heating; it was like walking into a freezer. There were children and elderly there. Even if we gave them equipment, they would not use it; they cannot afford their bills."* [Soc9]

6.1.4.3 Reach – Target audiences

The target audiences of the interviewed organizations were assessed in qualitative and quantitative terms. First, their self-reported target audiences are shown in Figure 6.5, according to the type of organization. The target audiences were coded based on the profiling of residential hard-to-reach energy users performed by Rotmann *et al.* (2020), Ashby *et al.* (2020), and Sequeira *et al.* (2024).

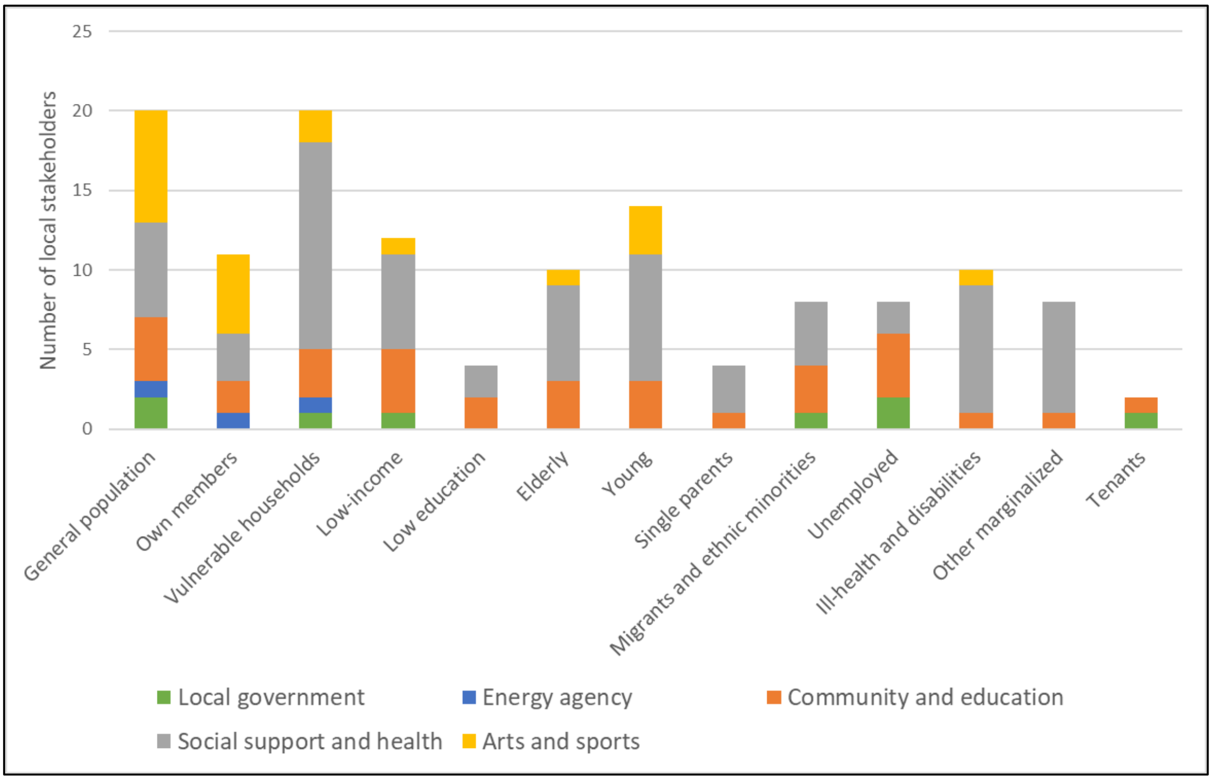


Figure 6.5 - Self-reported target audiences according to the type of stakeholder.

While some types of organizations focus primarily on the general population and on their own members, *e.g.*, those performing artistic and sports activities, there is still overlap in many target audiences. Local governments participate in support activities for a few vulnerable groups, but often only in a supportive role to other local stakeholders. Community and education organizations take a whole-community approach, but some also dedicate special attention to specific vulnerable groups.

Notably, there is significant coverage across profiles pointing towards the possibility of building a complete and coherent energy support structure that manages to identify and engage even those that are harder-to-reach (Warbroek *et al.*, 2018). Mainly, social support and health organizations provide essential aid to the most marginalized groups, such as homeless persons, persons with substance abuse problems, persons infected with HIV/AIDS, sex workers, and people living in inadequate housing conditions. Following Chard and Walker's (2016) argument for a "making every contact count" approach, these organizations can also be alert and active on energy topics. This is particularly important since Darby (2017) found that households resorting to energy advice services needed not only information but also interpretation, advocacy, and confidence-building, which can better be provided by trusted middle actors. It is fundamental that energy advisors act in the interest of their beneficiaries, including by being able to assist people with disabilities, ill-health, or other impairments (Forster *et al.*, 2019).

The quantitative assessment of audiences was complex since most interviewees could only mention rounded numbers and often grouped different profiles. Local governments see the entire population in their territory as their target audience. The energy agency has 13 collective members but also targets the general population and vulnerable households through its multiple projects. Table 6.2 shows examples of local organizations' self-reported quantitative assessment of target audiences. Some contacts seem to occur regularly, for instance, through continued support to a specific family. In contrast, others are sporadic and time-limited, for example, through awareness-raising campaigns. Double counting is also present, even within the same organization, as some persons receive several types of support. From these results, local organizations seem able to engage and mobilize a significant number of persons in their territory, including groups usually referred to as being hard-to-reach, which might hold some potential for synergies in delivering targeted and tailored energy support

Table 6.2 - Self-reported quantitative descriptions of target audiences of the interviewed organizations.

Type of organization	Examples of self-reported quantitative descriptions of target audiences
Community and education	20-50 youths per activity; hundreds of migrants and hundreds of unemployed persons per year; 120 unemployed persons per year; 60 teachers per year and 16 unemployed persons per year; 1000 people per year in their activities; 40 members on a regular basis; 105 elderly persons on a regular basis.
Social support and health	80 partners on a regular basis; almost 1000 vulnerable families per year; 770 people per year in their activities; 200-250 persons with VIH/AIDS per year; 40 elderly or disabled persons on a regular basis; 400 families with a disabled person per year; 150-200 people per month (illegal migrants, sex workers, homeless, substance abuse problems, VIH/AIDS); 650 vulnerable persons per year; 450 vulnerable persons on a regular basis; 350-400 unstable families per year and 24 youth on a regular basis; 1300 associates, 85 elderly, 70 people with chronic ill-health, and 10 unemployed or homeless persons on a regular basis; 90 families with children at risk per year; 3000-3500 people per year in their activities and 15-20 beneficiaries per week (sex workers, ex-convicts, VIH/AIDS, disabled); 3000 hospitalized children per year; 27 vulnerable households on a regular basis.
Arts and sports	15-30 persons per show and 180 children per year; 60-120 persons per show and 20 youth on a regular basis; 600 people per annual festival and 300-500 youth per year; 60 associates on a regular basis; 200 athletes on a regular basis; 5000 people per year in their activities and 180 associates on a regular basis; 20-30 athletes on a regular basis; 30-35 members on a regular basis.

Finally, it is also relevant to understand these organizations' approaches to making first contact and maintaining a relationship with their target audience. These include an active presence on social media, use of emails and direct messaging, forwarding from partner organizations, participation in local events and local media, dissemination of materials such as flyers and posters, domiciliary visits, services in own facilities, and word-of-mouth. The relative importance conferred to attracting new members and the preferred communication channels varies according to organization and target audience, as demonstrated through two examples:

> *"We have an online communication strategy through our social media, website, and mailing list. We promote our activities in the local media and municipality. We have direct protocols with schools and other organizations. There is a large community of participants, and word-of-mouth is one of our strongest communication tools."* [Art3]

> *"We are very bad at marketing; it is not a concern. Our 'product' sells by itself. Most people come to us through word-of-mouth, from community networks and family members. Some are forwarded from social security and health centres."* [Soc6]

Frick *et al.* (2017) found that local governments communicate through mail, advertising, newspapers, and events; however, these mainly attract individuals who are already engaged in the topic at hand. The same authors assert that middle actors have more personal and frequent contact with the population than authorities, using diverse means and relying on face-to-face and word-of-mouth. In the United States, Donnelly (2014) also highlighted a crucial role of word-of mouth in driving residential energy efficiency uptake. The importance of these communication methods is exemplified by a social support and health organization that provides aid to marginalized groups:

> *"Our mobile team [providing essential aid to the homeless, drug addicts, and sex workers] already exists for a long time. It has a well-established audience that grows on word-of-mouth among 'the guys', as they say it."* [Soc13]

6.1.4.4 Willingness – Functions in energy support

Results from the interviews show areas where collaboration between local organizations and energy support projects seems possible. These are shown for specific types of organizations in Figure 6.6.

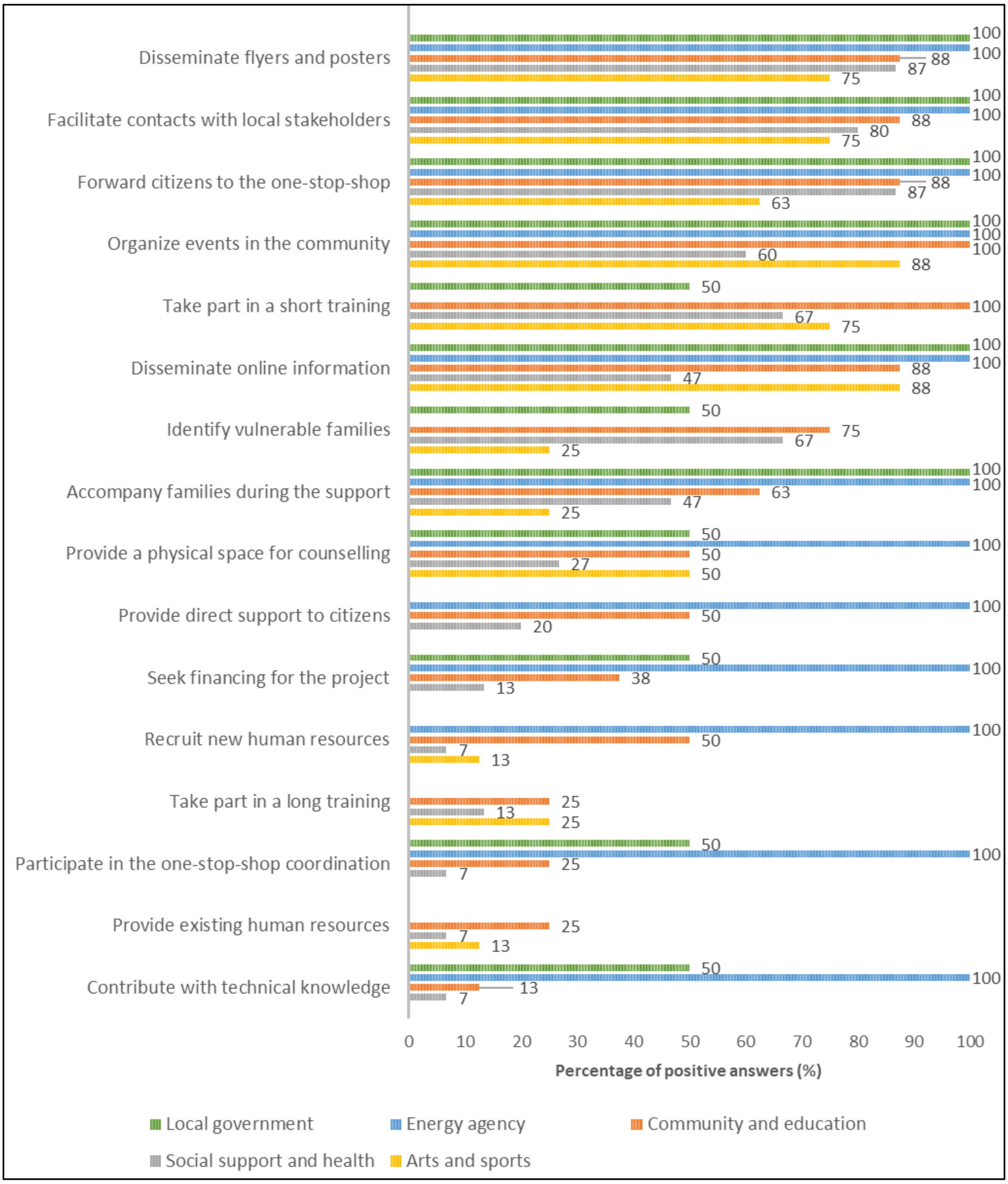


Figure 6.6 - Positive answers to potential collaborative roles from the interviewed organizations.

A large share of the organizations provided positive answers for the roles of physical and online project dissemination, forwarding citizens to energy-related support, facilitating contacts with other local partners, organize community events, and participating in short training sessions. Local organizations seem able to aid in the setup of communication campaigns, which are considered by the European Commission (2023) as a critical aspect of energy poverty mitigation, aiming to build trust in the energy support services while avoiding stigmatization of vulnerable groups. Arts and sports clubs may collaborate in short-term dissemination activities but seem to struggle in more specialized functions:

> *"Yes, we can inform people of the energy support service, for example, during our shows. We can also have the flyers in our stall or the ticket office."* [Art1]

Organizations focused on community and education seem particularly well-placed for communication tasks and citizen mobilization through local events. These findings concur with Sequeira and Melo (2020), who conducted energy audits in small businesses through a community-based approach in Portugal, and Balta-Ozkan *et al.* (2021), who analysed the role of charities in fostering solar photovoltaic uptake in the United Kingdom. This willingness to organize local events or to add energy support to existing events is stated by a community and education association:

> *"Yes, we can collaborate in organizing local events; we already organize community events with a strong ecological component."* [Com7]

All types of organizations are willing to act as intermediaries with other local organizations, exploring their existing network of partners, as also reported by Parag and Janda (2014). This is exemplified by a social support and health institution which mentioned having over 80 partners in the territory:

> *"We have a network of partners built over the years. So yes, we can share the energy support with our contacts. To strengthen the network and share resources."* [Soc1]

Community and education associations and social support and health institutions seem able to forward their beneficiaries to energy support, for instance, by communicating face-to-face the advantages of these services while conducting their usual activities. According to a few other studies (*e.g.*, Mould and Baker, 2017), the referral of vulnerable households via local organizations can be a key recruitment mechanism. This type of collaboration can be particularly crucial in marginalized populations, where Forster *et al.* (2019) recommend obtaining previous permission and being introduced by local leaders before conducting interventions.

Around half of the interviewees can identify vulnerable families and pass on that information to the coordinators of the energy support for their proactive contact, with an emphasis on community and education associations and social support and health institutions, where this percentage rises to around 70%. These results suggest collaboration with these middle actors can provide synergies in addressing intersecting vulnerabilities and enable better access to vulnerable families, as Ramsden (2020) also suggests based on a charity-led energy project in the United Kingdom. This should be a bi-directional flow whereby energy advisors can also provide information and reference beneficiaries to other organizations if needed (Willand *et al.*, 2023; Simcock and Bouzarovski, 2023).

The European Commission (2023) recognizes this potential role of social, health, and other frontline workers who are in regular contact with vulnerable groups, ascertaining that these should have the skills to identify energy poverty and provide advice: "front-line workers addressed in those programmes should include health and social care workers or other professionals who can help identify households affected by energy poverty and provide them directly with advice and information on solutions to reduce energy consumption and access more affordable and innovative sources of energy.". This is also considered necessary by one of the social support and health institutions interviewed:

> *"Yes, we think it's important to have a training on this. Our response to problems with energy is not well-structured, and our personnel could be more alert. The energy technician could also accompany our social workers during domiciliary support since we have beneficiaries who are not able to leave their homes."* [Soc3]

Willand *et al.* (2023) state that middle actors can help identify and remedy hidden energy poverty situations that are not captured by traditional indicators or do not request help. Nevertheless, in marginalized groups (*e.g.*, persons with HIV/AIDS, homeless, unstable families, and persons living in informal housing), the urgency of basic health, social, or housing support may be so dire that energy is far from being a primary concern. In some cases, providing energy support might even be seen as a distraction to dealing with the broader challenges affecting vulnerable groups (Willand, 2022). Willand *et al.* (2023) and Simcock and Bouzarovski (2023) report a feeling of powerlessness from energy advisors when supporting highly vulnerable groups; these already ration their energy use and are often not eligible for energy efficiency funding. Furthermore, our research also finds that confidentiality and fear of breaking trust can be impediments since local organizations have worked hard to build long-term relationships, as reported by one organization:

> *"If our beneficiaries are interested, yes, we can flag situations of vulnerability. But they may not want to be identified, it aggravates stigma and may have other unintended consequences."* [Soc10]

If a logic of decentralized energy support were to be employed, as suggested by Gouveia *et al.* (2024), a relevant share of organizations state that they can provide a physical space for the services. Community and education organizations and arts and sports clubs seem more adept to offer their space, probably due to lower occupation rates, than social and health institutions for whom their physical infrastructure is entirely devoted to aid vulnerable groups.

Notably, few local organizations seem able to provide direct energy support to citizens, redirect existing staff, hire new personnel, contribute with technical knowledge, provide or seek financing, or take part in the coordination of the support (*i.e.*, less than 25% of positive answers from the total sample). However, collaboration in these areas may be possible with a few community and education associations whose goals are aligned with the engagement of citizens in environmental and social issues. Social support and health institutions and arts and sports clubs seem even less willing to provide these functions.

Finally, the interviews suggest that energy agencies and local governments may be uniquely positioned to take up leadership roles in energy support and fill the previously mentioned void in human resources, technical knowledge, coordination, and funding. Other authors (*e.g.*, Kivimaa and Martiskainen, 2018; Rose *et al.*, 2021; Eriksson and Olsson, 2022; Economidou *et al.*, 2023) also see a key role for local authorities, including through local energy plans, financing schemes for energy-poor households, communication amongst stakeholders, and influencing political decisions at a national level. In parallel, the energy agency can also provide several of these tasks:

> *"We can provide planning and tools and share knowledge. For instance, we can act directly on the ground by developing pilots showing that energy support works and then bringing on board other organizations."* [Ene1]

However, they may not be able to do this alone: technical and institutional capability is not necessarily coupled with the intimate acquaintance of the community and the trust required to engage vulnerable families. Frick *et al.* (2017) show this through an empirical case where households' willingness to participate in energy conservation campaigns was increased when messages came from formal social groups (*e.g.*, sports clubs and neighbourhood associations) than when they came from city governments; this suggests an enhanced feeling of legitimacy and ownership when multiple local organizations are involved. Furthermore, energy agencies and local governments may not be able to identify vulnerable families, having to rely on other organizations to fulfil this role – this is mentioned by the civil parish level of government in our case study:

> *"In our civil parish, we do not provide social support directly to the vulnerable population; the local associations play that role."* [Gov2]

6.1.4.5 Overachievers – Pinpointing key local organizations

Based on the previous results, we conducted an exploratory exercise to pinpoint local organizations for which involvement in energy support seems possible – the "overachievers". McMaster *et al.* (2024) also highlight the need for "local champions" that can enable innovation. We attempted to identify these stakeholders based on three dimensions – capability, willingness, and reach – adding the latter to the framework defined by Parag and Janda (2014). The results of this exercise are shown in Figure 6.7 as a Venn diagram; these findings are highly exploratory, and the reality on the ground may differ with organizations scoring lower potentially being able to provide meaningful collaboration, and vice versa.

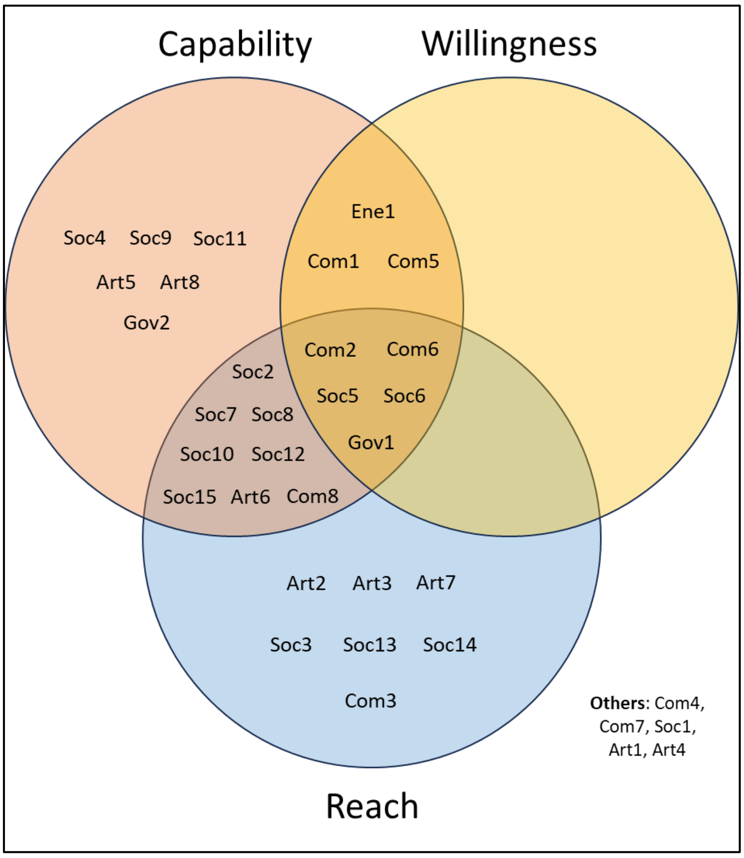


Figure 6.7 - Interviewed organizations according to capability, willingness, and reach.

Some organizations may already have enough capabilities based on their employees or volunteers (22 out of 34) and already reach hundreds of persons in their target audiences (20 out of 34). Still, the willingness for more extensive collaboration seems lower (8 out of 34). Only five organizations score high on all three dimensions, namely two community and education associations (which organize events and activities and provide training and support to several population segments), two social support and health institutions (which support vulnerable groups in social, health, food, and other areas), and the local municipality. This mismatch between capabilities, willingness, and reach decreases the likelihood of local organizations providing impactful contributions to energy support (as also suggested by Parag and Janda, 2014).

Three organizations have the capabilities and willingness to engage but lack the necessary reach to wider audiences, namely the energy agency and two community and education associations. Eight organizations have the capabilities and the reach potential but may lack the willingness to participate, namely six social support and health institutions, one arts and sports club, and one community and education association; this might be due to the barriers of lack of time, other priorities, and low receptivity in their target audiences. Only five organizations seem to fall short in all the dimensions and are probably wholly unsuitable to contribute in local efforts to deliver energy support.

These results are not static in time, and these organizations may increase or reduce their capabilities, reach broader or smaller audiences, and be more or less willing to actively engage in the future (Parag and Janda, 2014; Warbroek *et al.*, 2018). Finally, a few authors argue that stakeholders should be involved throughout the entire energy support chain – from the services' design to implementation – to leverage their extensive expertise in the target audiences and territory (Gillard *et al.*, 2017; Cattino and Reckien, 2021; Mundaca *et al.*, 2023).

6.1.4.6 Motivations – Drivers for collaboration

During the interviews, the organizations were asked about their motivations to collaborate in local-scale energy support by selecting a maximum of two options from a defined set of drivers and then commenting on their choice (Figure 6.8).

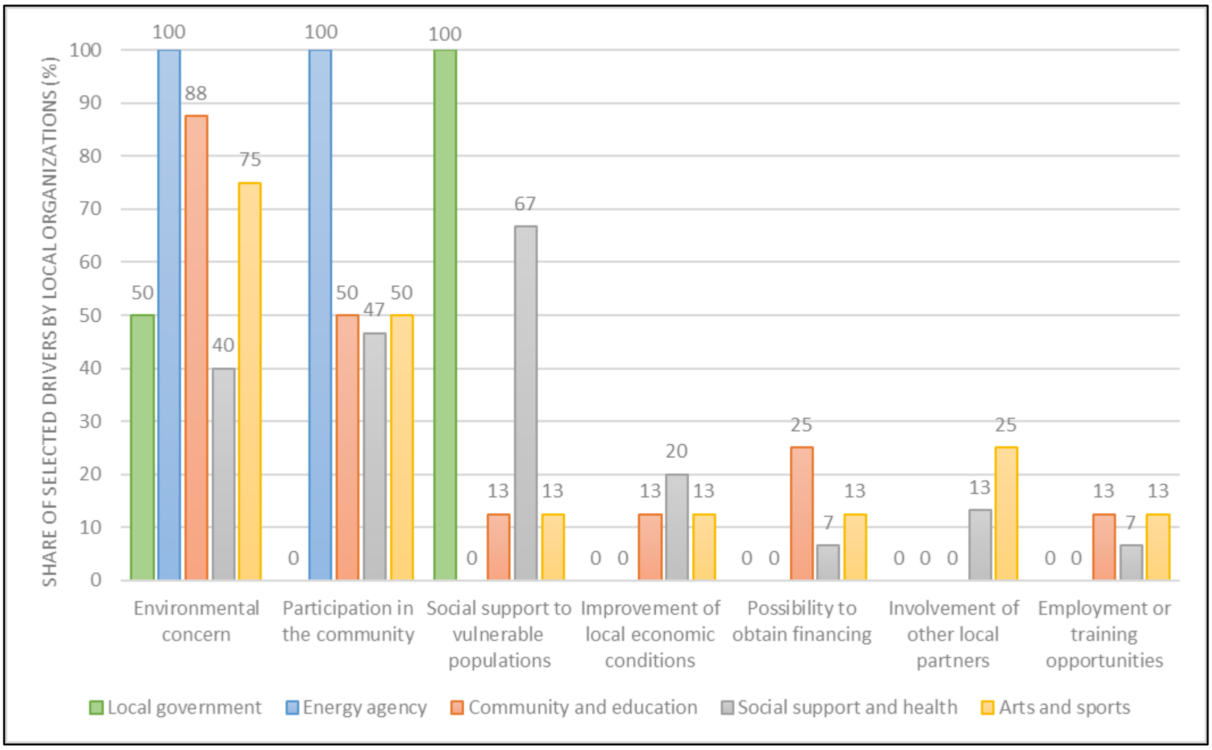


Figure 6.8 - Drivers for local stakeholders' collaboration in energy projects.

While energy issues are not a core activity for all organizations interviewed, except for the energy agency, most still expressed interest in becoming more involved as a component of their goals to improve their communities' environmental, social, and economic sustainability. In the United States, Elmallah *et al.* (2022) also highlighted the need to consider organizations' perspectives that, while not having an explicit energy focus, hold knowledge of their communities' needs and may already engage in energy topics indirectly.

When asked about the critical drivers of collaboration, interviewed stakeholders most frequently mentioned environmental concerns, participation in the community, and social support to vulnerable populations. Factors such as the improvement of local economic conditions, the possibility of obtaining financing, involvement of other local partners, and employment or training opportunities generally seem less important to the interviewees. Other authors (*e.g.*, Ornetzeder and Rohracher, 2013; Kivimaa and Martiskainen, 2018; Koch and Christ, 2018) also identify environmental sustainability, participation in local actions, and social equality as key motivations for engagement; financial reasons seem more relevant in some cases than in others. This combination of critical drivers is exemplified by three of the interviewees:

> *"We work with children, so environmental topics are a must. We try to empower our community; we give them tools, and then good things can happen."* [Com7]

> *"We always try to be present in our community. We meet with citizens' groups and with the local government. We strive for proximity."* [Soc5]

> *"Energy poverty is very severe in our population. We should ensure that the ecological transition is just and that the most vulnerable do not shoulder the burden."* [Soc1]

A few differences between types of local organizations are noteworthy. Environmental concerns are the predominant driver in community and education organizations but are less relevant for social support and health institutions. On the other hand, support for vulnerable populations is the primary driver for social support and health institutions but is less relevant for community and education organizations and arts and sports clubs. This difference between priority drivers may derive from the recognition of the lived experience of energy poverty and its health and well-being impacts, which naturally occurs through the day-to-day work of the former type of organization, as also mentioned by Willand *et al.* (2023). Furthermore, community and education organizations seem particularly keen on the possibility of obtaining financing. At the same time, arts and sports clubs would be more persuaded to participate if other local partners were already involved. The energy agency sees environmental concerns and participation in the community as their main drivers, while local governments mentioned environmental concerns and the provision of support to vulnerable citizens.

6.1.4.7 Challenges – Barriers hindering collaboration

Most interviewed local organizations seem willing and motivated to collaborate in energy support – a topic they see as relevant. However, this potential collaboration is hindered by several challenges that may jeopardize their involvement and limit the effectiveness of their collaboration. These were discussed in the interviews through predefined options where organizations selected a maximum of two barriers and commented on their choice (Figure 6.9).

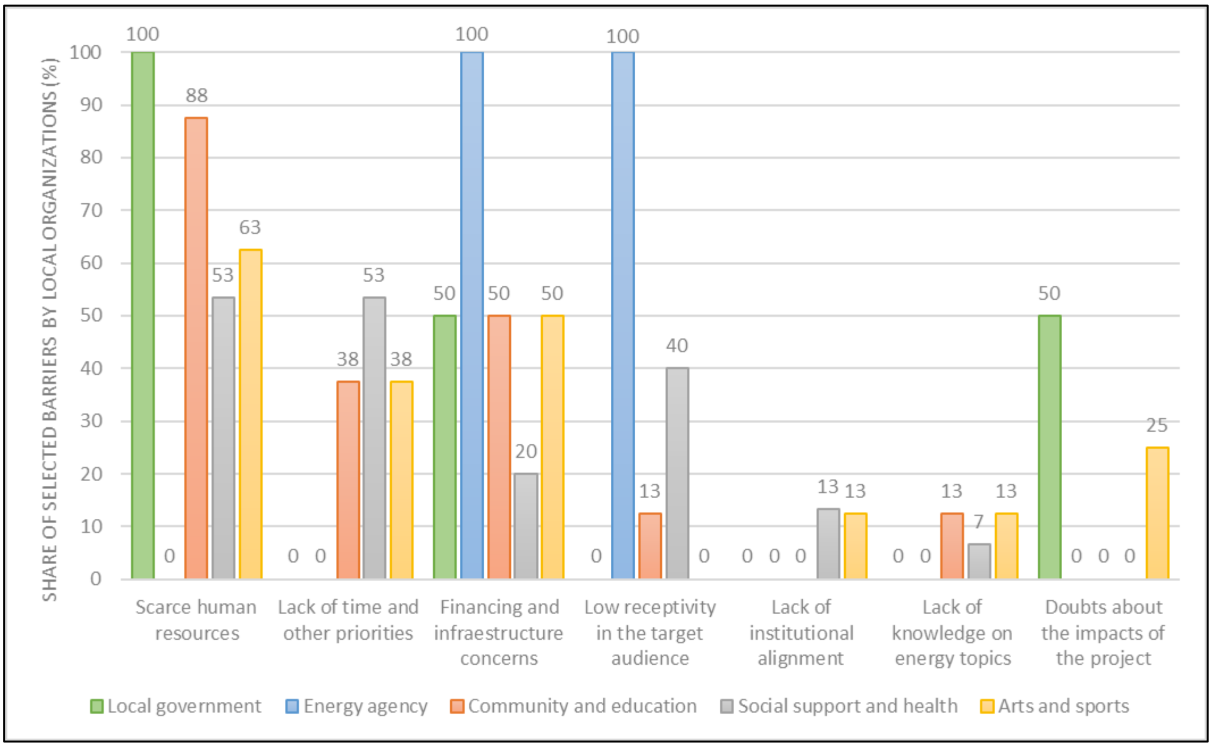


Figure 6.9 - Barriers to local stakeholders' collaboration in energy projects.

Most notably, interviewed organizations mentioned scarce human resources, lack of time and other priorities, concerns about financing and infrastructure, and low receptivity to energy-related issues in their target audiences. Two organizations exemplify these pressing barriers:

> *"We have between 350 and 400 beneficiaries. Our services are unique in Setúbal. We have a waiting list. We are already working above our capacity."* [Soc8]

> *"We work in a social housing neighbourhood; most people have low education levels, work many hours, and have other concerns. We struggle to find volunteers".* [Com7]

These findings align with Magnani and Osti (2016), who recognize the importance of civil society in transforming the Italian energy system but underline that it requires time and specialized knowledge that cannot be provided on a frail foundation of voluntary work. Other research has also highlighted that local organizations have limited power, resources, and capabilities, which may hinder more comprehensive collaboration (Middlemiss and Parrish, 2010; Lacey-Barnacle and Bird, 2018). Most local organizations did not identify a lack of institutional alignment, lack of energy knowledge, and doubts about impacts as significant barriers.

Community and education associations struggle with human resources, being highly dependent on low-reliability volunteer work, and with financing and infrastructure, often relying on ad-hoc funding and rented spaces. Social support and health institutions perform better on these dimensions, likely due to long-term partnerships with public authorities who depend on them to guarantee essential social services. However, social support institutions argue that lack of time, other priorities, and low receptivity in their target audience to energy issues can be significant barriers. This was also recognized by Willand (2022) who explored stakeholders' perception on the integration of energy assistance with health services in Australian in-home aged care services. This is better explained through the lived experience of one social support and health organization:

> *"We understand the importance of these topics. But it is not easy; we must be creative. When you talk about raising awareness, that is quite pretty, but there are other concerns. Our families need support that goes way above the energy area. Some live in houses that do not have the minimum conditions; some are illegal. Some have illegal connections; they do not pay for electricity. When a family comes to us asking for support on energy bills, it is an extreme situation and too late for proper responses."* [Soc2]

Arts and sports clubs also mention the same obstacles of scarce human resources, financing and infrastructure concerns, and lack of time and other priorities; notably, doubts about the practical impacts of this type of energy support also emerge for one-quarter of the interviewed. The former might point to what Parag and Janda (2014) see as the risk of middle actors promoting values and norms contradicting the ones encouraged by energy policies. Other research has identified similar difficulties, with Hargreaves *et al.* (2013) bluntly stating that grassroots movements struggle to survive and are far from being effective at substantially influencing wider systems.

Both levels of local government agreed on scarce human resources as a key barrier. The municipality also stressed the difficulty in allocating financial resources, and the civil parish expressed doubts about the practical impacts of energy support. Eriksson and Olsson (2022) and Economidou *et al.* (2023) also found resource limitations to be a challenge at this level of governance, particularly for smaller municipalities. The energy agency mentioned financing and infrastructure concerns and low receptivity in their target audience as the main barriers to deliver energy support, stating that:

> *"It is difficult to put things on the ground. To unlock financing. There are other priorities seen as more important. We make plans, but only a few come to be."* [Ene1]

6.1.4.8 Needs – Solutions to foster collaboration

Finally, interviewed organizations were asked about their needs if deeper collaboration in the provision of energy support were to be deemed feasible, by selecting a maximum of two solutions to overcome the mentioned barriers from a predefined set and commenting on their choice (Figure 6.10).

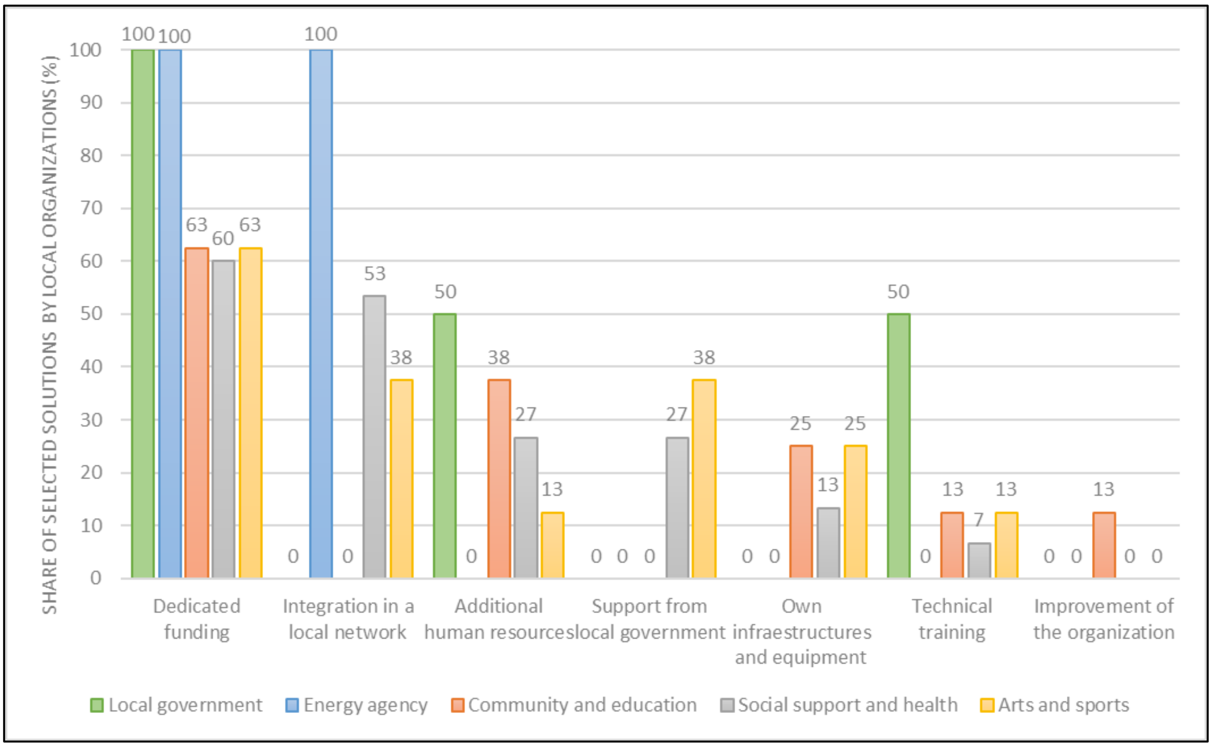


Figure 6.10 - Proposed solutions for local stakeholders' collaboration in energy projects.

The most frequently proposed solution across the board was dedicated funding (as a basic need to solve most other barriers). The prerequisite for more funding recognizes that energy-poor households have specific needs and limited capabilities to engage in energy issues, for instance, not being able to afford upfront costs and having restricted access to information, demanding more extensive technical, social, and financial support (European Commission, 2023).

Dedicated funding was followed by integration into a comprehensive local network, additional human resources, and support from local governments. The acquisition of own infrastructure and equipment, the completion of technical training, and the internal improvement of the organization were seen as less relevant. Other authors (*e.g.*, Reames, 2016; Lacey-Barnacle and Bird, 2018; Stewart, 2022) also mention the need to allocate funding, empower and build capacity, and dynamize partnerships and networks fostering collaborative work between stakeholders. For instance, Boyle *et al.* (2021) suggest that local organizations may play a networking function in the scaling up of community energy initiatives.

Regarding human resources, Gouveia *et al.* (2024) argue for the recruitment of peers from the target community to facilitate access and conduct locally based interventions. In the United Kingdom, Lacey-Barnacle and Bird (2018) report on using funding to create a permanent job position as fundamental to reaching out to marginalized groups. In another example, Schneider *et al.* (2023) assess that local volunteers trained as energy coaches can help to reduce energy consumption in Dutch households. While most stakeholders showed interest in participating in a small training to raise energy literacy and better understand the support services offered, only 12% see it as a priority. Nevertheless, this improvement of skills is considered vital by McMaster *et al.*, 2024, who highlight youth engagement as future leaders in their communities. The need for training was justified by one of the interviewees:

> *"It is not only about having the energy support available, but the connection to local organizations is also important. To communicate with a series of agents, provide training, and pass on the information to the social assistants on the ground."* [Soc8]

Social support and health institutions and arts and sports clubs seem particularly keen on working integrated into a local network with support from local governments; this may reflect their acknowledgment that they can only contribute to specific functions of the energy support. The involvement of governmental authorities and agencies is also considered relevant by Decuypere *et al.* (2022), who assessed the role of intermediaries in the adoption of heat pumps in Belgian households. Two of these organizations highlighted the importance of working in partnerships:

> *"To work as a strong network is very important for us. It has always been a need for us since we do not have our own space to organize activities."* [Art3]

> *"We must work together with the municipality and the civil parishes. The organizations that are on the ground must work in unison. It is a bidirectional relationship."* [Soc3]

Community and education associations already have their work well-grounded on local networks and may be more confident in their capabilities, particularly if better equipped with funding, human resources, and own infrastructure and equipment. Frick *et al.* (2017) suggest that local governments should engage more often with these middle actors since they seem able to successfully convey information to citizens. The energy agency mentioned dedicated funding and integration in a local network as the key solutions to leverage energy support. The interviewee emphasized these needs:

> *"We need to be able to provide examples and show that it can be done. If we want to work with the population, we must work with local governments. If we want to reach specific groups, we need to work with partners. Working in partnerships is in our DNA."* [Ene1]

Both levels of local government see dedicated funding as a key requirement. The municipality also seeks additional human resources, while the civil parish states the need for technical training; similar needs were mentioned by Economidou *et al.* (2023). This is illustrated by the local municipality statement:

> *"We had vibrant experiences with community workshops delivered with associations and civil parishes. But to implement the outcomes, we need funding."* [Gov1]

6.1.5 Conclusions

6.1.5.1 Insights to enact local-scale energy support

This case-study research contributes to an emerging literature that showcases some untapped potential for local organizations to act as middle actors in energy support. In the context of an energy efficiency one-stop shop pilot project we mapped almost 200 local stakeholders in the Setúbal municipality, Portugal, including local governments, energy agency, community and education associations, social support and health institutions, and arts and sports clubs, of which 34 agreed to participate in interviews.

Through this approach, we captured multiple dimensions across organizations, namely their goals and activities, resources and knowledge, target audiences, potential functions in energy support, and drivers, barriers and needs to unlock collaboration. It is time to bring it all together and reckon on how energy support initiatives can or cannot collaborate with local organizations. These insights are of interest to policymakers, practitioners, and researchers seeking to foster citizens' engagement in energy transitions while avoiding a positivity bias towards middle actors' capacity and agency.

First, we argue that an energy support scheme seeking to increase its impact on the population could attempt to bring together local organizations that, while working in different areas, share likeminded goals. These already provide distinct and complementary services that guarantee essential functions of the territory and dynamize local communities. Through this research, we suggest that fostering synergies can potentially improve both the effectiveness of energy support and the comprehensiveness of other existing services.

Second, it should be recognized that not all local organizations will show interest or capability to participate in energy-related activities, which may burden their day-to-day. From the mapped universe, around 25% answered the request sent by email, and 17% agreed to participate in interviews. The aftermath of the COVID-19 pandemic was advanced as one potential explanation for this low response rate, while the short timeframe of the research activity and the engagement method itself may also have limited participation; however, it is likely that a relevant share of the organizations simply did not have the interest or availability to collaborate. Among those that showed interest, some have scarce resources, and most lack knowledge, hindering their effectiveness as partners.

Third, attracting organizations that already deal with the desired target audiences, including the general population, energy-poor households, specific hard-to-reach household profiles, or even the most marginalized groups, can be highly relevant. They may be able to reference their beneficiaries to the energy support, serve as intermediaries in the actual delivery of the services, and even provide themselves basic aid on energy issues. The interviews show that local organizations have already identified and reached out to vulnerable groups. Nevertheless, trust is hard to win and easily lost; thus, care should be given to confidentiality, stigma, and careful and empathetic messaging.

Fourth, there is a wide range of functions that local organizations may be able to fulfil, and different organizations can match different and complementary roles. In general, they can build on their well-established communication channels, existing local dynamics, and trusted relationships to foster engagement and better identify and target hard-to-reach groups. For instance, in our case study, community and education associations seem suited to raise awareness, launch communication campaigns, and forward citizens to energy support. Social support and health organizations can identify vulnerable households and act as intermediaries during in-person support. Arts and sports clubs can contribute to project dissemination but struggle to take part in other functions. The energy agency can provide technical knowledge, and local governments can be the centrepiece, including finding funding and coordinating the energy support and the network of partners. The organizations that perform each function may naturally change according to the local context.

Fifth, the motivations expressed by the interviewees reinforce their willingness to participate in energy support, including to further pursue their own goals of environmental action, community participation, and social support. These are the drivers that should be explored when seeking to build partnerships. However, even interested, motivated, and willing organizations are susceptible to challenges hindering their participation, including scarce human resources, other priorities, lack of time, financing and infrastructure concerns, and low receptivity in their target audience. These barriers are severe and need to be recognized. Importantly, the interviews allowed an open conversation about the needs of local organizations. As a priority, energy support projects could provide dedicated funding to reward partners for their collaborative roles. This may solve other needs, such as additional human resources, infrastructure and equipment. In addition, time and resources could be allocated to embedding the energy support in already existing (or new) local networks where the participation of local governments is seen as relevant.

Sixth, through the combined approach of stakeholder mapping and one-on-one interviews, it seems possible to pinpoint "over-achievers" across all described dimensions as the key organizations to be involved in energy support. Their active participation in the whole process of designing and delivering energy support can be beneficial to ensure that the community's needs are met.

Finally, local middle actors may be able not only to tailor interventions to downstream needs but also to reason with upstream decision-makers for more systemic change. This is crucial because even if energy support can partially improve energy efficiency and ameliorate energy poverty, its impacts are limited by structural factors. Thus, it is only one piece of a holistic energy transition strategy where the perspectives of local organizations can reduce the risks of exacerbating energy injustices.

6.1.5.2 Recommendations for future work

The applied methods of mapping and interviewing local stakeholders to explore opportunities for collaboration in delivering energy support can be replicated elsewhere. These organizations are widespread across the territory, and each location will have its own dynamics, networks, and characteristics. Our research has limitations. Namely, it draws on a single case study, a small sample of interviewed organizations, and a breath of self-reported data. Future research can continue exploring the approaches, benefits, and drawbacks of working with middle actors in energy interventions, for instance, focusing on different organizations and activities beyond energy support and providing ex-post assessments of the effectiveness of these collaborations.

From our case study, key recommendations for energy support services seeking to collaborate with local middle actors include i) map and reach out to the stakeholder universe, ii) proceed swiftly with those that show interest and availability, iii) find likeminded organizations that recognize the relevance of energy support, iv) connect with organizations that already engage with and have the trust of the desired target audiences, v) allocate the energy support roles according to the organizations' individualities, vi) leverage on drivers related to environmental concern, community participation, and social support, health and well-being, vii) recognize the tremendous challenges that can make these middle actors hard-to-reach as they are burdened with demanding tasks performed with few resources, viii) meet the needs of local organizations so that they can be empowered to collaborate in energy support, namely by providing funding and resources, building capacity, and strengthening local networks, ix) pinpoint "overachievers" as local leaders whose engagement is crucial for the success of the energy support, and x) translate the experience and findings to policymakers to trigger systemic change.

Current energy policies and interventions are failing to engage with hard-to-reach and energy-poor households; if these are to be reached in just energy transitions, alternative approaches must be tested. We believe our work contributes to the literature on the role of middle actors in sustainable transitions. In this context, we emphasize that this potential can be fragile and will only materialize if local organizations are allowed to participate and are empowered with adequate means.

Authors' contributions

Miguel Macias Sequeira: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. João Pedro Gouveia: Writing – review & editing, Validation, Supervision, Conceptualisation, Project administration, Funding acquisition. João Joanaz de Melo: Writing – review & editing, Validation, Supervision.

Appendix A. Interview script

1. Characterization of the organization's goals, activities, structure, human resources, geographical scope, target audiences, and COVID-19 impacts.

   1.1. What is the full name of the organization?
   1.2. What is the organization's legal structure?
   1.3. Is it autonomous or a local delegation of a larger organization?
   1.4. When was the organization founded?
   1.5. What would you say is your main goal?
   1.6. Can you describe in detail your current activities and services?
   1.7. How many collaborators do you have? Follow-up: are they full-time employees or volunteers?
   1.8. What were the impacts of the COVID-19 pandemic?
   1.9. What is the geographical scope of your organization?
   1.10. Who are your main target audiences? Follow-up: can you describe them in detail? How many people do you currently engage?
   1.11. What are your strategies to reach out and engage with your target audiences?
   1.12. Do you regularly work with your local government and with other organizations?

2. Assessment of the organization's current knowledge on energy topics.

   2.1. Do you have specific person(s) working in environmental or energy-related themes?
   2.2. What activities have you done or are doing in relation to these topics?
   2.3. How does the theme of sustainability link to your own goals?
   2.4. Do you identify the need for energy support in your target audience?

3. Exploration of potential collaborative roles in delivering energy support

   3.1. In the scope of an energy support program in your territory (one-stop shop), which delivers free in-person advice on improving efficiency, optimizing energy bills, applying to governmental funds, and conducting energy audits to the general population and vulnerable groups, what types of collaborative roles are you willing to perform? Please answer with "yes", "maybe", or "no" and justify your choice.

      a) Identify vulnerable families.
      b) Forward citizens to the one-stop shop.
      c) Accompany families during the support.
      d) Disseminate flyers and posters.
      e) Disseminate online information.
      f) Take part in a short training.
      g) Take part in a long training.
      h) Provide existing human resources.
      i) Recruit new human resources.
      j) Organise events in the community.
      k) Provide direct support to citizens.
      l) Provide a physical space for counselling.
      m) Facilitate contacts with local stakeholders.
      n) Contribute with technical knowledge.
      o) Seek financing for the project.
      p) Participate in the one-stop shop coordination.
      q) Other.
      r) Prefer not to answer.

4. Identification of drivers, barriers, and solutions for collaboration

4.1. What would motivate you to collaborate in the provision of energy support? If possible, please select two options and justify them.

a) Environmental concern.
b) Participation in the community.
c) Possibility to obtain financing.
d) Employment or training opportunities.
e) Improvement of local economic conditions.
f) Social support to vulnerable populations.
g) Involvement of other local partners.
h) Other.
i) Prefer not to answer.

4.2. What would hinder you from collaborating in the provision of energy support? If possible, please select two options and justify them.

a) Lack of institutional agreement.
b) Low receptivity in the target audience.
c) Financing and infrastructure concerns.
d) Lack of knowledge on energy topics.
e) Lack of time and other priorities.
f) Scarce human resources.
g) Doubts about the impacts of the project.
h) Other.
i) Prefer not to answer.

4.3. What solutions would suit your needs and enable deeper collaboration in the provision of energy support? If possible, please select two options and justify them.

a) Dedicated funding.
b) Additional human resources.
c) Technical training.
d) Improvement of the organization.
e) Integration in a local network.
f) Support from local government.
g) Own infrastructures and equipment.
h) Other.
i) Prefer not to answer.

Appendix B. List of interviewed organisations

Type of organization	Code	Self-reported goals	Self-reported activities
Local government	Gov1	To define policies to in the interest of the population in all areas of life.	Broad range of activities in Environment, Culture, Citizenship, Sports, Economy, Education, Finance, Housing, International, Youth, Works, Health, Security, Social, Tourism, Urban Planning.
	Gov2	To manage heritage, tradition, customs, school network, and associations.	Hygiene and urban cleaning, maintenance of green spaces, civil construction works, cemetery services, job insertion, legal consultancy, dissemination of information.
Energy agency	Ene1	To promote energy efficiency, renewable energy, and sustainability.	Awareness raising, information dissemination, training, energy audits and certification, local energy-climate strategies, other energy-related support.
Community and education	Com1	To help the youth build their future and the elderly feel safe.	Training for young adults, organization of cultural events, gardening in a social housing neighborhood, intergenerational activities.
	Com2	To support local businesses, independent workers, and entrepreneurs.	Support and training to the local commerce and to the unemployed, job integration, legal support for migrants.
	Com3	To promote the integrated development of rural, coastal, and urban areas.	Support for enterprises in agriculture, tourism, and coastal sectors, support for local associations in the social economy, training for the unemployed.
	Com4	To help those in need, particularly the elderly and families with children.	Organization of local events, organization of neighborhood walks, dissemination of information to the residents.
	Com5	To foster communities as agents of change for sustainable behaviors.	Raising awareness for sustainability (schools, communities, enterprises, unemployed), training of teachers, community workshops, agro-ecology, organization of events
	Com6	To support active citizenship, and associative and cooperative spirit.	Events, community workshops, gardening, language classes, training for vulnerable women, support for victims of domestic abuse, social and psychological support for vulnerable persons, integration of migrants, training for the unemployed, training for social assistants.
	Com7	To prepare young people for the future in criminalized neighborhoods.	Weekly meetings, nature activities for children and young adults, local events, social support for youth in difficult economic situations (basic good baskets, clothes).
	Com8	To encourage active retirement and establish bonds of friendship.	Classes for the elderly on various topics, arts and cultural activities, music group, field trips, gymnastics.
Social support and health	Soc1	To contribute to a fairer society, dignified and participatory citizenship.	Provision of information and training to local social support institutions and networking, organization of citizen councils on poverty.
	Soc2	To support the vulnerable population of Setúbal.	Domiciliary support for the elderly (hygiene, food, psychological support), daycare/kindergarten, social canteen, food aid, support for people with low pensions and social insertion income.
	Soc3	To support persons with HIV/AIDS and prevent infections.	HIV/AIDS screenings, clothing bank, social support, food donations, occasional financial support, psychological support, support to children of persons with HIV/AIDS, nursery.
	Soc4	To provide humanitarian and social assistance to the most vulnerable.	Domiciliary support services (hygiene, food), transport of urgent and non-urgent patients, events, first aid and nursing courses, transportation of disabled school children.

	Soc5	To support those in need in coordination with the local churches.	Community center, elderly daycare and transport, afterschool activities for children, organization of cultural events, social and psychological support, food baskets, social store, and canteen.
	Soc6	To promote social justice, equality, inclusion, and opportunities for all.	Afterschool activities for children, kindergarten, nursery, therapeutics for persons with substance abuse problems, support for recipients of social insertion income, canteen, community activities.
	Soc7	To be a reference for people with autism and their families.	Support center for disabilities, diagnosis and follow-up for children with autism, support in legal, social security and education, rehabilitation, therapeutics, training for teachers, raising awareness.
	Soc8	To educate children and young people and insert them into society.	Social support for children and young adults, children and young adults' institutional homes, mediation for unstable and vulnerable families.
	Soc9	To defend the rights of children, especially the most vulnerable.	Family support center and parental advising services, social, legal and court support for unstable and vulnerable families with children or youth at risk.
	Soc10	To support to those infected by HIV/AIDS, provide training and informing.	Training and raising awareness with a particular focus on youth, scientific research, intervention theatre, psychosocial support for those infected by HIV/AIDS, diagnosis and forwarding for medical appointments.
	Soc11	To manage a social support facility for the residents and locally employed.	Social support facility with a community center, daycare, domiciliary services, nursery, kindergarten, retirement home, activities for youth and children, social shop, ateliers, events.
	Soc12	To raise awareness among the population about blood donation.	Organization of monthly blood donations in rotative locations, raise awareness among the population and the youth.
	Soc13	To reduce risks associated with the use of psychoactive substances.	Diagnosis, medical appointments, support for people with substance abuse problems and/or infections, forwarding to other types of support, mobile team to improve consumption and sexual safety and identify those in need, food and clothes donations, education for health.
	Soc14	To provide social protection and health through mutual assistance.	Doctor appointments, physiotherapy, musical choirs, dance classes, daycare center, laundry, domiciliary services (food, medication, cleaning, hygiene), transport, social store, and canteen.
	Soc15	To de-dramatize the hospital context for hospitalized children.	Clowns that visit children admitted in hospitals, training for nurses and medical staff.
Arts and sports	Art1	To contribute to culture democratization and socio-cultural dynamization.	Development of cultural shows, organization of cultural events, theatre and artistic expression classes, organization of activities for children.
	Art2	To bring theatre to the local community and beyond.	Theatre, organization of cultural events, artistic residences, theatre classes and workshops, outdoor talks, national tours.
	Art3	To promote active youth engagement through art and culture.	Organization of cultural events and workshops, training for youth, international exchange programs for youth.
	Art4	To maintain and show the local traditions across the country and abroad.	Dance classes and performances, event organization, national and international exchanges.
	Art5	To bring together fans and support the local football club.	Organization of events and travels for sports fans, collection of goods for vulnerable families, entertainment in elderly institutions.

	Art6	To provide young people with sports activities.	Male and female basketball teams for all ages, practice for disabled persons, promotion of social inclusion for disadvantaged athletes, extracurricular activities for children.
	Art7	To promote water sports and especially canoeing in its various forms.	Practice of canoeing for children and adults, competition, nautical tourism and leisure canoeing, organization of canoeing events.
	Art8	To encourage the population to practice sports outdoors.	Practice of canoeing and triathlon for children and adults, summer activities for children.

References

ADENE (2024). Statistics of the System for Energy Certification of Buildings. Portuguese Energy Agency. Retrieved in January 2024. Available on: https://www.sce.pt/estatisticas/

Ashby, K., Smith, J., Rotmann, S., Mundaca, L., and Ambrose, A. (2020). HTR Characteristics. HTR Annex by Users TCP by IEA: Wellington. https://doi.org/10.47568/3XR102

Balta-Ozkan, Yildirim, J., Connor, P. M., Truckell, I., and Hart, P. (2021). Energy transition at local level: Analyzing the role of peer effects and socio-economic factors on UK solar photovoltaic deployment. Energy Policy, 148, 112004. https://doi.org/10.1016/j.enpol.2020.112004

Bertoldi, P., Boza-Kiss, B., Della Valle, N., and Economidou, M. (2021). The role of one-stop shops in energy renovation - A comparative analysis of OSSs cases in Europe. Energy and Buildings, 250, 111273. https://doi.org/10.1016/j.enbuild.2021.111273

Bertoldi, P., Economidou, M., Palermo, V., Boza-Kiss, B., and Todeschi, V. (2020). How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU. WIREs Energy and Environment, 10, 1, e384. https://doi.org/10.1002/wene.384

Boyle, E., Watson, C., Mullally, G., and Gallachóir, B.O. (2021). Regime-based transition intermediaries at the grassroots for community energy initiatives. Energy Research & Social Science, 74, 101950. https://doi.org/10.1016/j.erss.2021.101950

Bouzarovski, S., Burbidge, M., Sarpotdar, A., and Martiskainen, M. (2022). The diversity penalty: Domestic energy injustice and ethnic minorities in the United Kingdom. Energy Research & Social Science, 91, 102716. https://doi.org/10.1016/j.erss.2022.102716

Cattino, M., and Reckien, D. (2021). Does public participation lead to more ambitious and transformative local climate change planning? Current Opinion in Environmental Sustainability, 52, 100-110. https://doi.org/10.1016/j.cosust.2021.08.004

CGF (2024). Transition Point: Pilot projet to combat energy poverty in Portugal. Calouste Gulbenkian Foundation. Accessed in January 2024. Available on: https://gulbenkian.pt/en/initiatives/sustainable-development-programme/climate-action/transition-point

Chard, R., and Walker, G. (2016). Living with fuel poverty in older age: Coping strategies and their problematic implications. Energy Research & Social Science, 18, 62-70. http://dx.doi.org/10.1016/j.erss.2016.03.004

Darby, S. J. (2017). Coal fires, steel houses and the man in the moon: Local experiences of energy transition. Energy Research & Social Science, 31, 120-127. http://dx.doi.org/10.1016/j.erss.2017.05.025

Decuypere, R., Robaeyst, B., Hudders, L., Baccarne, B., and Van de Sompel, D. (2022). Transitioning to energy efficient housing: Drivers and barriers of intermediaries in heat pump technology. Energy Policy, 161, 112709. https://doi.org/10.1016/j.enpol.2021.112709

DGEG (2023). Energy statistics: Main energy indicators (1995-2021p). Portuguese Directorate-General of Energy and Geology. Retrieved in January 2024. Available on: https://www.dgeg.gov.pt/pt/estatistica/energia/indicadores-energeticos/

Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast). Official Journal of the European Union, L 231, 1-111. Available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

Donnelly, K.A. (2014). Energy Efficiency and Conservation Block Grant (EECBG): Better Buildings Neighborhood Program Final Report. United States. https://doi.org/10.2172/1114148

Economidou, M., Della Valle, N., Melica, G., and Bertoldi, P. (2023). The role of European municipalities and regions in financing energy upgrades in buildings. Environmental Economics and Policy Studies. https://doi.org/10.1007/s10018-023-00363-3

Elmallah, S., G. Reames, T. G., and Spurlock, A. (2022). Frontlining energy justice: Visioning principles for energy transitions from community-based organizations in the United States. Energy Research & Social Science, 94, 102855. https://doi.org/10.1016/j.erss.2022.102855

Energy Poverty Advisory Hub (2024). Energy Poverty Advisory Hub. Available on: https://energy-poverty.ec.europa.eu/

Eriksson, L., and Olsson, L. (2022). The role of middle actors in electrification of transport in Swedish rural areas. Case Studies on Transport Policy, 10, 3, 1706-1714. https://doi.org/10.1016/j.cstp.2022.06.009

European Commission (2019). The European Green Deal. COM(2019) 640 final. Brussels, Belgium. Available on: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640&from=EN

European Commission (2020). A Renovation Wave for Europe - Greening our Buildings, Creating Jobs, Improving Lives. COM(2020) 662 Final. Brussels, Belgium. Available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

European Commission (2023). Commission Recommendation (EU) 2023/2407 of 20 October 2023 on energy poverty. Official Journal of the European Union, L series. Available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302407

Eurostat (2023a). Shedding light on energy in the EU - 2023 interactive publication. https://doi.org/10.2785/405482

Eurostat (2023b). Inability to Keep Home Adequately Warm - EU-SILC Survey. Data last updated on 15/12/2023. Retrieved in January 2024. Available on: https://ec.europa.eu/eurostat/databrowser/view/ilc_mdes01/default/table?lang=en

Eurostat (2023c). Share of Total Population Living in a Dwelling with a Leaking Roof, Damp Walls, Floors or Foundation, or rot in Window Frames of Floor - EU-SILC Survey. Data last updated on 16/11/2023. Retrieved in January 2024. Available on: https://ec.europa.eu/eurostat/databrowser/view/ilc_mdho01/default/table?lang=en

Forster, N., Hodgson, P., and Bailey, C. (2019). Energy advice for Traveller Communities in the context of ethnic and spatial premiums: 'paying the price' for other people's choices. Journal of Poverty and Social Justice, 27 (1), 61-78. https://doi.org/10.1332/175982718x15451316707778

Frick, V., Seidl, R., Stauffacher, M., and Moser, C. (2017). Promoting energy-saving behaviour: formal social groups as promising middle actors for municipal interventions. Energy Efficiency, 10, 1539-1551. https://doi.org/10.1007/s12053-017-9543-2

Galvin, R. (2015). How many interviews are enough? Do qualitative interviews in building energy consumption research produce reliable knowledge? Journal of Building Engineering, 1, 2-12. http://dx.doi.org/10.1016/j.jobe.2014.12.001

Gillard, R., Snell, C., Bevan, M. (2017). Advancing an energy justice perspective of fuel poverty: Household vulnerability and domestic retrofit policy in the United Kingdom. Energy Research & Social Science, 29, 53–61. http://dx.doi.org/10.1016/j.erss.2017.05.012

Gouveia, J. P., Mendes, M., Sequeira, M. M., and Palma, P. (2024). A New Way to Mitigate Energy Poverty: Lessons from the Transition Point 'One-Stop Shop' Pilot. Transition Point: Full Report. Published by the Calouste Gulbenkian Foundation (1st edition). Available on: https://gulbenkian.pt/en/publications/a-new-way-to-mitigate-energy-poverty-lessons-from-the-transition-point-one-stop-shop-pilot/

Gouveia, J. P., Palma, P., and Simões, S. G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187-201. https://doi.org/10.1016/j.egyr.2018.12.004

Gouveia, J. P., Palma, P., Bessa, S., Mahoney, K., and Sequeira, M. (2022). Energy Poverty National Indicators: Insights for a more effective measuring. EU Energy Poverty Advisory Hub. Directorate General for Energy. European Commission. Available on: https://energy-poverty.ec.europa.eu/discover/publications/publications/energy-poverty-national-indicators-insights-more-effective-measuring_en

Gouveia, J. P., Seixas, J., and Mestre, A. (2017). Daily Electricity Profiles from Smart Meters - Proxies of Active Behaviour for Space Heating and Cooling. Energy, 141, 108-122. https://doi.org/10.1016/j.energy.2017.09.049

Hanke, F., Guyet, R., and Feenstra, M. (2021). Do renewable energy communities deliver energy justice? Exploring insights from 71 European cases. Energy Research & Social Science, 80, 102244. https://doi.org/10.1016/j.erss.2021.102244

Hargreaves, T., Hielscher, S., Seyfang, G., and Smith, A. (2013). Grassroots innovations in community energy: The role of intermediaries in niche development. Global Environmental Change, 23, 868–880. http://dx.doi.org/10.1016/j.gloenvcha.2013.02.008

Horta, A., Gouveia, J. P., Schmidt, L., Sousa, J. C., Palma, P., and Simões, S. (2019). Energy poverty in Portugal: Combining vulnerability mapping with household interviews. Energy and Buildings, 203, 109423. https://doi.org/10.1016/j.enbuild.2019.109423

IEA (2023). Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach (2023 update). International Energy Agency. Available on: https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

INE (2023). Census 2021 data. Portugal Statistics. Retrieved in June 2023. Available on: www.ine.pt

Kivimaa, P., and Martiskainen, M. (2018). Innovation, low energy buildings and intermediaries in Europe: systematic case study review. Energy Efficiency, 11, 31–51. https://doi.org/10.1007/s12053-017-9547-y

Koch, J., and Christ, O. (2018). Household participation in an urban photovoltaic project in Switzerland: Exploration of triggers and barriers. Sustainable Cities and Society, 37, 420-426. https://doi.org/10.1016/j.scs.2017.10.028

Koirala, B. P., Araghi, Y., Kroesen, M., Ghorbani, A., Hakvoort, R. A., and Herder, P. M. (2018). Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems. Energy Research & Social Science, 38, 33-40. https://doi.org/10.1016/j.erss.2018.01.009

Kwon, M., and Mlecnik, E. (2021). Modular Web Portal Approach for Stimulating Home Renovation: Lessons from Local Authority Developments. Energies, 14, 1270. https://doi.org/10.3390/en14051270

Kwon, M., Mlecnik, E., and Gruis, V. (2021). Business Model Development for Temporary Home Renovation Consultancy Centres: Experiences from European Pop-Ups. Sustainability, 13, 8450. https://doi.org/10.3390/su13158450

Lacey-Barnacle, M., and Bird, C. M. (2018). Intermediating energy justice? The role of intermediaries in the civic energy sector in a time of austerity. Applied Energy, 226, 71-81. https://doi.org/10.1016/j.apenergy.2018.05.088

Magnani, N., and Osti, G. (2016). Does civil society matter? Challenges and strategies of grassroots initiatives in Italy's energy transition. Energy Research & Social Science, 13, 148–157. http://dx.doi.org/10.1016/j.erss.2015.12.012

Mahoney, K., Lopes, R., Sareen, S., and Gouveia, J.P. (2024). Perceptions of competing agendas in carbon neutrality policies in Portugal: Adverse impacts on vulnerable population groups. Energy Research & Social Science, 112, 103509. https://doi.org/10.1016/j.erss.2024.103509

Martiskainen, M., Heiskanen, E., and Speciale, G. (2018) Community energy initiatives to alleviate fuel poverty: the material politics of Energy Cafés. Local Environment, 23:1, 20-35. https://doi.org/10.1080/13549839.2017.1382459

McMaster, R., Noble, B., and Poelzer, G. (2024). Assessing local capacity for community appropriate sustainable energy transitions in northern and remote Indigenous communities. Renewable and Sustainable Energy Reviews, 191, 114232. https://doi.org/10.1016/j.rser.2023.114232

Melo, J. J., Sousa, M. J. F., Pereira, A. M., Fernandes, F., Galvão, A. and Grilo, J. (2021). Strategy for a sustainable decarbonization of the energy sector in Portugal: identification of priority policy measures. In: Mauerhof, V. (Ed), The Role of Law in Governing Sustainability, 81-99. Routledge. ISBN: 978-0-367-74632-2

Middlemiss, L. (2022). Who is vulnerable to energy poverty in the Global North, and what is their experience? WIREs Energy Environ., 11, e455. https://doi.org/10.1002/wene.455

Middlemiss, L., and Parrish, B. D. (2010). Building capacity for low-carbon communities: The role of grassroots initiatives. Energy Policy, 38, 7559–7566. https://doi.org/10.1016/j.enpol.2009.07.003

Mould, R., and Baker, K. J. (2017). Documenting fuel poverty from the householders' perspective. Energy Research & Social Science, 31, 21–31. http://dx.doi.org/10.1016/j.erss.2017.06.004

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M. M., Gouveia, J. P., Palma, P., Realini, A., Maggiore, S., and Feenstra, M. (2023). Hard-to-Reach Energy Users: An ex-post cross-country assessment of behavioural-oriented interventions. Energy Research & Social Science, 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Ornetzeder, M., and Rohracher, H. (2013). Of solar collectors, wind power, and car sharing: Comparing and understanding successful cases of grassroots innovations. Global Environmental Change, 23, 856–867. http://dx.doi.org/10.1016/j.gloenvcha.2012.12.007

Ortiz, J., Jiménez Martínez, M., Alegría-Sala, A., Tirado-Herrero, S., González Pijuan, I., Guiteras Blaya, M., and Canals Casals, L. (2021). Tackling Energy Poverty through Collective Advisory Assemblies and Electricity and Comfort Monitoring Campaigns. Sustainability, 13, 9671. https://doi.org/10.3390/su13179671

Page, M., and Fuller, S. (2021). Governing energy transitions in Australia: Low carbon innovation and the role for intermediary actors. Energy Research & Social Science, 73, 101896. https://doi.org/10.1016/j.erss.2020.101896

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. http://dx.doi.org/10.1016/j.erss.2015.12.027

Palma, P., Gouveia, J. P., and Barbosa, R. (2022). How much will it cost? An Energy Renovation Analysis for the Portuguese Dwelling Stock. Sustainable Cities and Society, 78, 103607. https://doi.org/10.1016/j.scs.2021.103607

Pan, L., Biru, A., and Lettu, S. (2021). Energy poverty and public health: Global evidence. Energy Economics, 101, 105423. https://doi.org/10.1016/j.eneco.2021.105423

Papantonis, D., Tzani, D., Burbidge, M., Stavrakas, V., Bouzarovski, S., and Flamos, A. (2022). How to improve energy efficiency policies to address energy poverty? Literature and stakeholder insights for private rented housing in Europe. Energy Research & Social Science, 93, 102832. https://doi.org/10.1016/j.erss.2022.102832

Parag, Y., and Janda, K. B. (2014). More than filler: Middle actors and socio-technical change in the energy system from the "middle-out". Energy Research & Social Science, 3, 102–112. http://dx.doi.org/10.1016/j.erss.2014.07.011

Pardalis, G., Mahapatra, K., and Mainali, B. (2022). Comparing public- and private-driven one-stop-shops for energy renovations of residential buildings in Europe. Journal of Cleaner Production, 365, 10, 132683. https://doi.org/10.1016/j.jclepro.2022.132683

Portuguese Government (2019). Roteiro para a Neutralidade Carbónica 2050 (RNC2050): Estratégia de longo prazo para a neutralidade carbónica da economia portuguesa em 2050 ["Carbon Neutrality Roadmap 2050 (RNC2050): Long-term strategy for a carbon neutral Portuguese economy in 2050"]. R 262/2019. Available on: https://descarbonizar2050.apambiente.pt/

Portuguese Government (2021a). Lei n.º 98/2021 de 31 de dezembro – Lei de Bases do Clima ["Law no. 98/2021 of December 31 – Climate Law"]. Diário da República, 1.ª série, 253. Available on: https://diariodarepublica.pt/dr/detalhe/lei/98-2021-176907481

Portuguese Government (2021b). Resolução do Conselho de Ministros n.º 8-A/2021 – Aprova a Estratégia de Longo Prazo para a Renovação dos Edifícios ["Resolution of the Council of Ministers no. 8-A/2021 – Approving the Long-term Strategy for Building Renovation"]. Diário da República, 1.ª série, 23. Available on: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/8-a-2021-156295372

Portuguese Government (2023). Plano Nacional de Energia e Clima (PNEC 2030) – Atualização/Revisão ["National Energy and Climate Plan (NECP 2030) – Uptade/Revision"]. Draft version of June 2023. Available on: https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en

Portuguese Government (2024). Resolução do Conselho de Ministros n.º 11/2024 de 8 de Janeiro – Estratégia Nacional de Longo Prazo para o Combate à Pobreza Energética 2023-2050 ["Resolution of the Council of Ministers no. 11/2024 of January 8 – National Long-term Strategy for Energy Poverty Mitigation 2023-2050"]. Diário da República, 1.ª série, 5. Available on: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/11-2024-836222486

Project Management Institute (2013). A Guide to the Project Management Body of Knowledge (PMBOK®Guide), 5th Edition. Project Management Institute, Inc, Newtown Square, PA, USA. ISBN 978-1-935589-67-9.

Ramsden, S. (2020). Tackling fuel poverty through household advice and support: Exploring the impacts of a charity-led project in a disadvantaged city in the United Kingdom. Energy Research & Social Science, 70, 101786. https://doi.org/10.1016/j.erss.2020.101786

Reames, T. G. (2016). A community-based approach to low-income residential energy efficiency participation barriers. Local Environment, 21, 12, 1449-1466. https://doi.org/10.1080/13549839.2016.1166567

Rose, J., Thomsen, K. E., Domingo-Irigoyen, S., Bolliger, R., Venus, D., Konstantinou, T., Mlecnik, E., Almeida, M., Barbosa, R., Terés-Zubiaga, J., Johansson, E., Davidsson, H., Conci, M., Mora, T. D., Ferrari, S., Zagarella, F., Ostiz, A. S., Miguel-Bellod, J. S., Monge-Barrio, A., and Hidalgo-Betanzos, J. M. (2021). Building renovation at district level – Lessons learned from international case studies. Sustainable Cities and Society, 72, 103037. https://doi.org/10.1016/j.scs.2021.103037

Rotmann, S. (2024). Research into hard-to-reach customers living in hidden hardship. Available at: https://indd.adobe.com/view/f395a924-0ad3-4bd3-a542-df8a49a664ec

Rotmann, S., Mundaca, L., Castaño-Rosa, R., O'Sullivan, K., Ambrose, A., Marchand, R., Chester, M., Karlin, B., Ashby, K., Butler, D., & Chambers, J. (2020). Hard-to-Reach Energy Users: A Literature Review.

UsersTCP - HTR Task. ISBN: 978-0-473-64983-8. Available on: https://userstcp.org/hard-to-reach-energy-users-task/

Schneider, P. T., van de Rijt, A., Boele, C., and Buskens, V. (2023). Are visits of Dutch energy coach volunteers associated with a reduction in gas and electricity consumption? Energy Efficiency, 16, 42. https://doi.org/10.1007/s12053-023-10116-6

Sequeira, M., and Melo, J. J. (2020). Energy saving potential in the small business service sector: Case study Telheiras neighborhood, Portugal. Energy Efficiency, 13, 551-569. https://doi.org/10.1007/s12053-020-09842-y

Sequeira, M. M., and Gouveia, J. P. (2022). A Sequential Multi-Staged Approach for Developing Digital One-Stop Shops to Support Energy Renovations of Residential Buildings. Energies, 15, 5389. https://doi.org/10.3390/en15155389

Sequeira, M. M., Gouveia, J. P., and Melo, J. J. (2024). (Dis)comfortably numb in energy transitions: Profiling residential hard-to-reach energy users in the European Union. Energy Research & Social Science, 115, 103612. https://doi.org/10.1016/j.erss.2024.103612

Shaw, C., Hurth, V., Capstick, S., and Cox, E. (2018). Intermediaries' perspectives on the public's role in the energy transitions needed to deliver UK climate change policy goals. Energy Policy, 116, 267-276. https://doi.org/10.1016/j.enpol.2018.02.002

Simcock, N., and Bouzarovski, S. (2023). A cure-all for energy poverty? Thinking critically about energy advice. Critical Social Policy, 1-23. https://doi.org/10.1177/02610183231219185

Simcock, N., Jenkins, E. H. K., Lacey-Barnacle, M., Martiskainen, M., Mattioli, G., and Hopkins, D. (2021). Identifying double energy vulnerability: A systematic and narrative review of groups at-risk of energy and transport poverty in the global north. Energy Research & Social Science, 82, 102351. https://doi.org/10.1016/j.erss.2021.102351

Stewart, F. (2022). Friends with benefits: How income and peer diffusion combine to create an inequality "trap" in the uptake of low-carbon technologies. Energy Policy, 163, 112832. https://doi.org/10.1016/j.enpol.2022.112832

Warbroek, B., Hoppe, T., Coenen, F., and Bressers, H. (2018). The Role of Intermediaries in Supporting Local Low-Carbon Energy Initiatives. Sustainability, 10, 2450. https://doi.org/10.3390/su10072450

Willand, N. (2022). Opportunity, ideal or distraction? Exploring stakeholder perceptions of tackling energy poverty and vulnerability among older Australians. Energy Research & Social Science, 94, 102852. https://doi.org/10.1016/j.erss.2022.102852

Willand, N., Torabi, N., and Horne, R. (2023). Recognition justice in Australia: Hidden energy vulnerability through the experiences of intermediaries. Energy Research & Social Science, 98, 103013. https://doi.org/10.1016/j.erss.2023.103013

Zohar, T., Parag, Y., and Ayalon, O. (2021). Of agency, action, and influence: The middle-out mechanism for promoting a low-carbon energy transition. Energy Research & Social Science, 72, 101900. https://doi.org/10.1016/j.erss.2020.101900

Chapter 7.

DISCUSSION AND CONCLUSIONS

7.1 Answering the research questions

RQ1: Who might be classified as a hard-to-reach energy user in the European Union and what is the significance of these groups at multiple scales?

HTR terminologies were recently transferred to energy research. While paving the way for a future research agenda, early works have been criticised for being too broad in their definition, identification and characterisation of HTR users, for not properly assessing the significance of these groups in real-world settings, and for putting the onus on consumers instead of tackling more systemic injustices. Moreover, other terms have also been proposed (*e.g.*, hard-to-heat, complex-to-decarbonise, hardly reached). Arguably, more time has been spent discussing the semantic advantages and shortcomings of alternative terms than in operationalising the concept as a useful tool for just energy transitions. Still, in a context of accelerating energy transitions where consumers' engagement is often seen as a pre-requisite, HTR terms are useful to fill a gap in energy research being distinct from other concepts such as vulnerability and EP.

In this scope, this research contributed to theory development on HTR energy users. It identified, systematised, and characterised residential and non-residential profiles that may be classified as HTR in the Global North and EU background. This process was informed by an extensive and interdisciplinary literature review (chapters 3.1 and 3.2), leading to the selection of typologies and culminating in the development of a theoretical framework on HTR energy users. Its current version is shown in chapter 3.1 for the residential sector and in chapter 3.2 for the non-residential sector; an aggregated version is shown in chapter 3.3.

To answer directly to RQ1, Table 7.1 shortly lists the profiles that were classified as potentially being HTR for energy transitions. On the one hand, this analysis showcases the vagueness of the term, including different and contrasting profiles from the residential and non-residential sectors. On the other hand, it also evidences its usefulness in pinpointing very specific groups that may remain "(dis)comfortably numb" in energy transitions. This is a novelty of this research which goes beyond previous scientific literature. Furthermore, the research critically discussed the issues of heterogeneity within and intersectionality among HTR profiles.

It is acknowledged that the theoretical framework on HTR energy users is not set in stone and that, in line with critical theory as a scientific paradigm, it is subject to researchers' bias. For instance, gender was admittedly insufficiently explored during the research. This is justified primarily by the inherent complexity of the topic which intersects virtually all the defined typologies and merits a comprehensive research agenda on its own. Furthermore, in general terms, some of the systematised profiles can potentially be considered as being much harder-to-reach than others, *e.g.*, homeless and informal settlements versus young or elderly, and micro-enterprises versus SMEs. The classification is also highly dependent on context, *e.g.*, rural households may be HTR in certain socioeconomic settings but not in others, and installation of collective solutions such as solar PV in multi-family buildings can be more challenging due to national or local regulations. Future research is welcome to modify, criticise, and challenge the proposed theoretical framework on HTR energy users, including in relation to different geographical settings and to evolving political, technological, cultural, and social factors.

Table 7.1 - Hard-to-reach energy users theoretical framework.

Hard-to-reach energy users theoretical framework				
Vulnerable households	**High-income households**	**Tenants and landlords**	**Small and medium enterprises**	**Commercial subsectors**
• Low-income • Low education • Rural • Multi-family • Elderly • Young • Single parents • Migrants • Unemployed • Ill-health and disabilities • Ethnic minorities and Indigenous groups • Homeless and informal settlements • Travellers and Nomadic Communities	• High-income • Sumptuous spenders	• Tenants • Landlords	• SMEs • Micro-enterprises	• Wholesale trade • Retail trade • Accommodation • Food services • Offices • Other activities

Following, this research used the theoretical framework to bridge the gap on the quantification of HTR energy users at multiple scales. First, for the EU and its 27 Member States, this was performed based on secondary statistical data from Eurostat's open-access database for the residential sector (chapter 3.1) and non-residential sector (chapter 3.2). For the residential sector, an additional step was conducted through the quantification of one-on-one combinations of HTR profiles to assess intersectionality and pinpoint potential priority groups. Second, aligning with the subsequent case-study-based research work, residential and non-residential HTR profiles were quantified at the national, municipal, and sub-municipal levels in Portugal using secondary data from INE (chapter 3.3).

To complete the answer to RQ1, Figures 7.1 and 7.2 summarise the results of gauging HTR energy users at multiple scales, namely for the EU and Portugal (based on Eurostat data from 2020, for non-residential groups, and from 2022, for residential) and for Portugal, Setúbal and Lisbon Municipalities, and Lumiar Civil Parish (based on INE data from 2021 and 2022, for residential groups, and from 2023, for non-residential). In the figures, data for residential profiles are shown as a share of the total population (except for the low-income and high-income profiles based on INE data which are shown as a share of the total number of fiscal households) and as a share of the total number of enterprises for non-residential profiles. Eurostat and INE data are not directly comparable for most profiles due to differences in data availability and to distinct data collection methods, samples, and time periods.

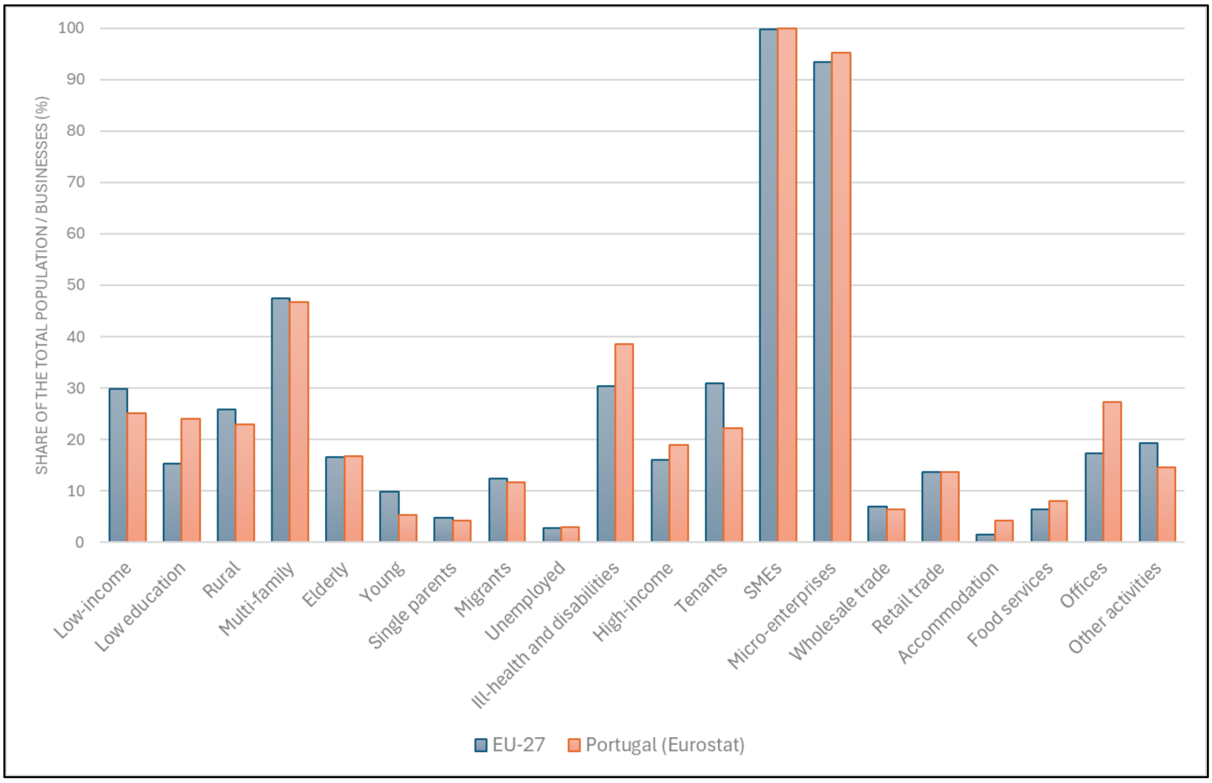


Figure 7.1 - Summary of results from gauging HTR profiles for the EU-27 and Portugal (data from Eurostat).

Transversally, some of the major HTR groups in terms of size include low-income households, multi-family buildings, people with ill-health and disabilities, tenants, and micro-enterprises. Still, relevant differences are found between the various scales of analysis. For instance, compared to the EU average, Portugal presents higher share of people with low education levels, lower share of young people living on their own, higher share of people with ill-health and disabilities, lower share of people living as tenants, higher share of micro-enterprises, and higher share of accommodation and food services enterprises.

Looking at the intersectionality of residential HTR profiles presented in chapter 3.1, at EU-level, a few priority groups can be proposed, namely low-incomes in both rural settings and multi-family buildings, tenants with low-incomes and/or migrant status, and people with ill-health and disabilities and with low education levels, rural locations, and/or advanced age. For Portugal, it is particularly noteworthy how low-incomes, low education levels, advanced age, ill-health and disabilities, and rural settings compound to aggravate vulnerabilities while also requiring additional effort to overcome these HTR markers.

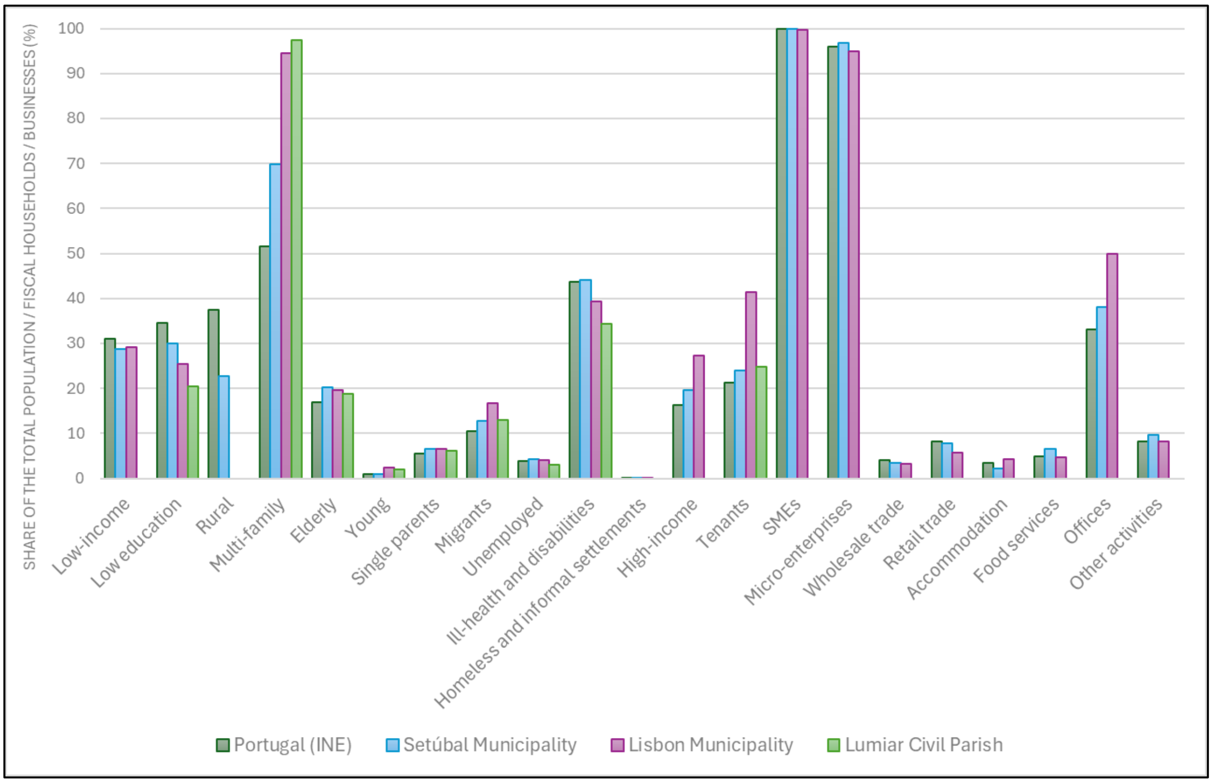


Figure 7.2 - Summary of results from gauging HTR profiles for Portugal, Setúbal and Lisbon Municipalities, and Lumiar Civil Parish (data from INE).

The deep dive on two municipalities and one sub-municipal area in Portugal showcases the heterogeneity of the country. For instance, education levels are higher in these territories compared to the national average, particularly in Lisbon and Lumiar. While all territories are located within Lisbon's Metropolitan Area, it is noteworthy that Setúbal still includes areas that can be classified as rural while Lisbon and Lumiar are fully urban with more than 90% of the population living in multi-family buildings. The Lisbon Municipality presents higher shares of migrants and tenants, compared with the national average and with the Setúbal Municipality. On the other hand, Lisbon has a larger share of high-income households. Being the capital, Lisbon has a slightly smaller share of SMEs and micro-enterprises, and a higher share of offices compared with the other territories of analysis. Data gaps are particularly severe at the lower resolution of civil parish and regarding income levels and the non-residential sector.

In short, the deep dive into multi-scalar data to quantify the previously defined HTR profiles proved useful for pinpointing particularly significant target groups for energy policies and interventions. Still, data gaps prevail for some of the most vulnerable and marginalised groups (*i.e.*, ethnic minorities and Indigenous groups, homeless and informal settlements, travellers and Nomadic communities) and for some of the most wealthy and powerful groups (*i.e.*, sumptuous spenders and landlords). Moreover, there are inconsistences in the collection of data by the statistical bodies. The results are not definitive, since they report on single points in time, and other authors may select different data sources and data treatment approaches.

In the process of answering RQ1, this research produced a theoretical framework on HTR energy users identifying and quantifying specific profiles to evidence their significance, heterogeneity, and intersectionality at multiple scales. These outcomes proved useful for the next steps of the work, including to assess existing energy and climate policies and local-scale interventions and to conduct action and participatory research in the selected case-studies, while also contributing to scientific knowledge. Nevertheless, the HTR framework is not all-inclusive, *i.e.* some groups may have still fallen through the cracks, and the quantification of HTR profiles and identification of major groups should not outshine the lived experience of families and businesses. Complete, fast, and just energy transitions imply that all HTR groups are included, even if they represent only a minor share of the total number of energy users.

RQ2: How do national energy and climate policies and local-scale interventions integrate the specific challenges and needs of hard-to-reach energy users?

Often, systemic issues lie at the heart of a HTR profile with little responsibility from the energy users themselves. Thus, more importantly than describing and quantifying HTR profiles, it is to evaluate how these are currently being (or not being) involved in energy transitions and to identify potential solutions to foster their engagement. In this context, this research assessed if and how selected national policies and local interventions are integrating HTR groups.

First, the theoretical framework on HTR energy users and the quantification of HTR profiles were operationalised for an *ex-ante* assessment of the revised NECPs for 2030 of EU Member States Belgium and Portugal (chapter 4.1). These countries were selected as a testbed for the application of the methodology before its expansion to the remaining Member States. Portugal and Belgium were, in March 2024, among the few countries fulfilling the European Commission's NECP revision deadlines. Furthermore, these countries have similar population levels but contrasting climate, socio-economic, and energy contexts.

NECPs are the key policy instruments guiding energy transitions in EU Member States until 2030. Still, as shown with the examples of Belgium and Portugal, the recognition of HTR groups and the design of targeted and tailored measures are lacking. Vulnerable households are mentioned in Belgium's and Portugal's NECPs, prominently in the context of EP mitigation through specialised on-the-ground support and dedicated financing. However, specific HTR profiles are overlooked, such as people with low education levels, rural households, migrants, people with ill health and disabilities, and other marginalised groups. The Portuguese NECP does not sufficiently mention other groups which are significant in the national context, such as elderly people, multi-family buildings, single parents, and unemployed persons. In contrast, excessive energy use and luxury consumption are mostly neglected; a single mention was found in Belgium's NECP arguing for restrictive measures to encourage building renovation in high-income households.

The rented building stock is considered one of the hardest-to-reach segments, due to split incentives and other barriers, being, however, quite significant in both countries. The Belgian NECP recognises this issue and proposes measures to facilitate renewable energy sharing, promote energy renovation, and protect tenants from rent increases. On the other hand, the Portuguese NECP scarcely mentions tenants and landlords, except social housing renovation.

Regarding the non-residential sector, both countries' NECPs recognise the need to protect SMEs from high energy prices and detail measures to support them in the implementation of EE and RES solutions (*e.g.*, energy audits with or without support, mandatory implementation of measures with short payback, and capacity building). While some measures are conditional on the size of the enterprises, micro-enterprises which comprise over 90% of businesses are not sufficiently mentioned. On the other hand, several activities of the commercial/services sector are recognised in the NECPs, except for food services enterprises, and targeted and tailored measures are proposed.

Second, in the scope of the IEA UsersTCP Task on Hard-To-Reach Energy Users, an *ex-post* evaluation of two previous on-the-ground projects aimed at HTR groups was conducted for Portugal (chapter 4.2). This international collaboration included, in total, 19 case-studies from eight Global North countries. A comprehensive cross-country comparison effort was led by Mundaca *et al.* (2023), including the authors of chapter 4.2, and pinpointed common best practices and challenges in engaging HTR energy users (Figure 7.3).

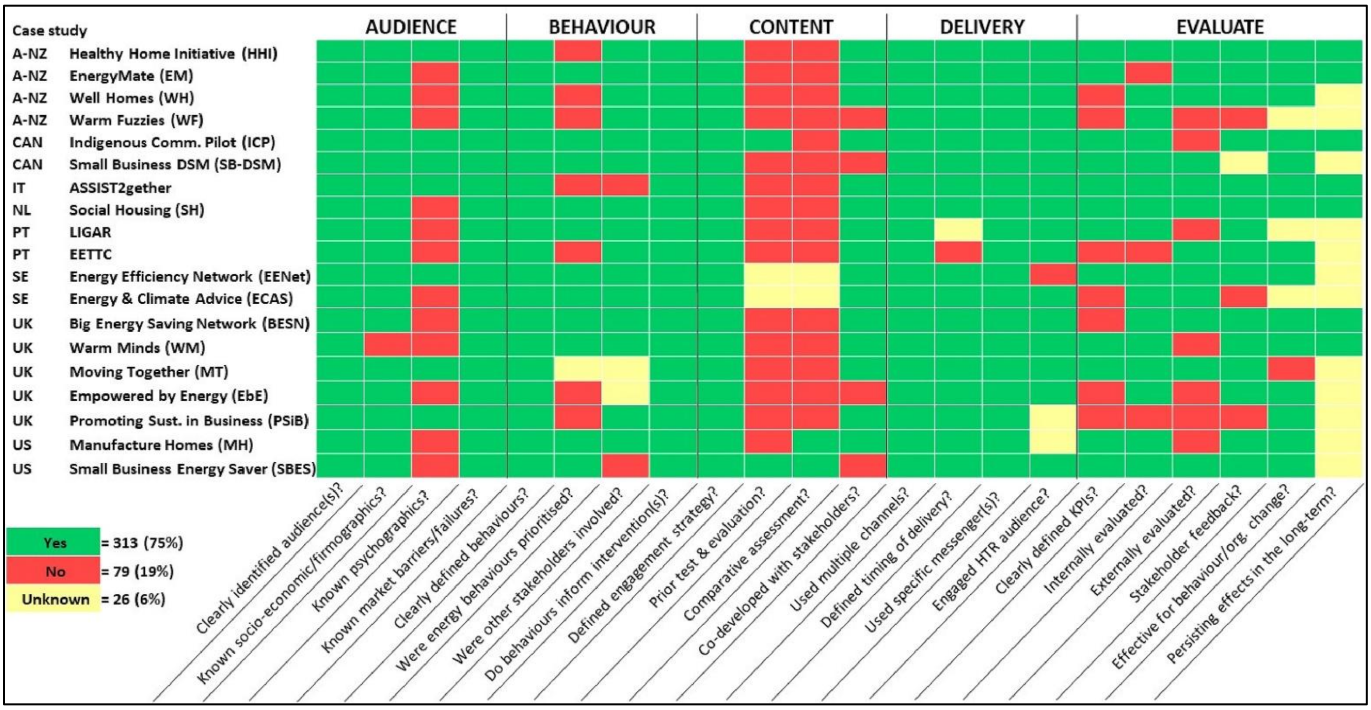


Figure 7.3 - Cross-country assessment of case-studies aimed at HTR groups (Mundaca *et al.*, 2023).

Most projects were able to clearly identify and characterise their audiences, collecting socio-economic, demographic, and firmographic data and, to a lesser extent, psychographic data.

Furthermore, the intent of the projects (*e.g.*, raise energy literacy, improve energy performance, improve thermal comfort) was well established from the start, although not always adequately prioritised. Engagement strategies were co-designed with stakeholders, but most case-studies failed to properly test and compare different methods before deployment and instead adopted "learn as you go" iterations. To successfully engage their HTR audiences, the projects used diverse communication channels and resorted to specific messengers and times of delivery. Finally, while some degree of evaluation was included, most did not assess long-term impacts.

In Portugal, the focus was on the LIGAR Energy Efficiency for All project and on the Energy Efficiency in Telheiras' Traditional Commerce project. These were evaluated within the Portuguese background of regularly poorly designed energy policies (with the automatic energy social tariff being seen as a rare good practice), insufficiently targeted funding and financing schemes (*e.g.*, EE grants that require upfront investment and/or that have complex processes which exclude a wide range of HTR profiles), and well-meaning but scattered and sometimes inconsequential actions by a handful of organisations (on one hand, with some being able to renovate houses and install renewables at relatively small scales, on the other hand, with others overemphasising energy-saving advice for households that already under-consume). The selected case-studies were no exception to these national trends as well as to international patterns uncovered by Mundaca *et al.* (2023).

On a positive note, both projects were able to properly identify and characterise their target audiences (*i.e.*, vulnerable households and micro-enterprises) and scope of action (*i.e.*, promoting energy literacy and improving energy efficiency). Furthermore, collaboration with local stakeholders was ensured, seeking to leverage on trusted messengers. On a more negative note, both projects were deployed for a limited time and in strictly defined geographical settings (*i.e.*, ten regions in mainland Portugal and one neighbourhood in Lisbon), including relatively few participants (*i.e.*, around 100 vulnerable households and 50 micro-enterprises). Support was delivered mostly through information on EE measures and feedback on energy use since more extensive technical and financial support was not included. Finally, there was no formal evaluation of the long-term tangible and intangible impacts.

Answering directly to RQ2, the assessed national energy and climate policies still fail to recognise the challenges of engaging specific HTR profiles for energy transitions while mostly neglecting to propose tailored and targeted measures to address their needs. Vulnerable households are often seen as homogenous, without accounting for the diversity of HTR profiles, and as victims of high energy prices and recipients of general information and financial instruments aimed at mitigating EP through the improvement of EE and access to RES. High-income households are mostly forgotten with curbing excess and luxury energy consumption being taboo. The recognition of the HTR nature of the rented sector, privately or publicly owned, may depend on its significance in each national setting. Maintaining economic competitiveness of SMEs in the face of rising energy prices is seen as essential, including through EE and RES measures, but the more stringent challenges of micro-enterprises are not properly recognised. The HTR energy users concept is shown to be useful to evaluate energy policies and to potentially support their design under the banner of just energy transitions.

In contrast, actions grounded at a local scale hold significant potential for better recognition of the needs of HTR groups and for effective targeting and tailoring of energy interventions. These can precisely map target audiences, focus on desired interventions, build connections with local communities and trusted actors, and deploy proximity face-to-face and door-to-door approaches. Still, local-scale actions have limitations related with lack of persistence, scalability, and replicability, high burden of human resources, and strenuous coordination needs among several on-the-ground organisations. In answering RQ2, this work provided insights for the design of local-scale interventions which were immediately useful for the action research conducted in three case-studies in Portugal.

Evidently, this research focused only on two out of 27 EU Member States thus far and expanding it to other countries would most likely offer evidence of recognition of additional HTR groups and of targeted and tailored measures appropriate to each national context. Although it reviewed the Portuguese background, it detailed only two on-the-ground projects aimed at HTR groups. Considering the international collaboration, it still only assessed 19 case-studies in eight countries. In contrast, for instance, the EPAH (2025) Atlas of local-scale EP actions has mapped over 300 projects across the globe. If the analysis was to be repeated with other case-studies, *e.g.*, aimed at other HTR profiles beyond vulnerable households and micro-enterprises, different results would be obtained, and additional best practices and shortcomings might be found. Nevertheless, even if a few examples of inclusion of HTR groups can be found, policymakers and practitioners can do much more to ensure their inclusion.

RQ3: How can digital tools and local-scale actions engage the hard-to-reach in energy initiatives and mitigate energy poverty?

This question was explored through action research and participatory methods deployed longitudinally in three case-studies in Portugal which produced a harvest of scientific and empirical outputs. To recapitulate, these were i) the Green Menu digital OSS (chapter 5.1), ii) the Telheiras/Lumiar REC (chapter 5.2), and iii) the Transition Point mobile OSS (chapter 6.1). These represent paradigmatic cases which illustrate emerging approaches proposed by the EU's Directives and by Portuguese energy policies to engage citizens in energy transitions.

First, the Green Menu digital OSS provides behavioural tips, technical EE and RES measures, energy-saving and investment costs calculation tools, funding schemes, and regulatory provisions under one single virtual platform. In line with the revised Energy Efficiency Directive (Directive (EU) 2023/1791), it tackles persistent information and knowledge gaps, aiming to increase building renovation rates in the residential sector.

While fulfilling its outspoken objectives, this case-study can be considered to present negative evidence on engagement of HTR groups and mitigation of EP within the Portuguese context. Being a digital tool, it does not cater to the needs of a wide range of HTR profiles, prominently vulnerable households such as those with low education levels or advanced age and tenants which lack power over decisions to renovate their dwellings, and is only findable to those already interested and actively searching online for the topic of home renovation. It aims at residential buildings and non-residential consumers were out of its scope by design. On the other hand, virtual platforms are found by a few researchers to potentially be suitable instruments to engage younger audiences and tech-savvy higher-income households.

While raising energy literacy is fundamental, simple informational measures are often seen as one of the least effective approaches for triggering action. Thereby, the outcomes of the Green Menu regarding EE improvement and RES adoption are intangible and hard to estimate. Some issues can be ameliorated through the evolution of the digital platform, *e.g.*, by including other building typologies, improving communication, collaborating with stakeholders, linking up to renovation companies and equipment installers, standardising contracts and other legal procedures, and highlighting positive user feedback. Still, this will most likely not be enough for vulnerable and energy-poor households. These require more extensive support which is not possible to deliver solely through an online platform. A learning from this case-study is that digital OSSs can play a relevant role in energy transitions, but effectively reaching wider audiences, including HTR groups, frequently requires boots on the ground.

Second, the Telheiras/Lumiar REC embodies a new model of decentralised RES generation and sharing in line with the revised Renewable Energy Directive (Directive (EU) 2023/2413). With a long germination period dating from 2021, the project has three main pillars of action, namely raising awareness, providing free counselling, and investing, producing, and sharing solar power. It is co-promoted by the Local Partnership of Telheiras (a network of local NGOs) and the Lumiar Civil Parish (the local authority in the territory) and the on-the-ground coordination is ensured by a small group of volunteers and one technician from the local government.

The Telheiras/Lumiar REC charted a 10-step pathway which is extensively described in the Practical Guide written by Sequeira *et al.* (2024a). The project adopts a highly localised communication strategy. Successful approaches include carrying out multiple public sessions and workshops, participating in community events, distributing flyers and posters, using social media accounts from local organisations, launching open calls for volunteers and for energy community members, sending direct messages and e-mails, and encouraging word-of-mouth. By integrating itself in local networks, by fostering transparency and open participation, and by being non-profit and volunteer-led, it subtly branded itself as a project promoted "by and for the community" likely drawing more interest compared to externally imposed projects.

Still, a targeted approach was deemed necessary to include vulnerable households in the Telheiras/Lumiar REC. To this aim, the non-profit business model is tailored with bonified conditions, namely with a few membership spots set aside for energy-poor households which benefit from an exemption on the entrance fee and a reduction on the annual fee. These costs are covered by the other members through a solidarity mechanism. Specific eligibility criteria for vulnerable households include the social energy tariff and a referral by a social support organisation. An open call is broadcasted to eligible households, but it is reinforced through face-to-face contact by frontline social workers. While benefiting from specific conditions, energy-poor households are full members of with equal voting rights.

Currently, the Telheiras/Lumiar REC has one pilot solar PV system, with 7.15 kWp installed in a public building and 16 energy community members. Plans are underway to expand the REC to a nearby public building with already 65 households, small businesses, and condominiums signed up. Moreover, a handful of other local organisations have expressed interest in joining REC Telheiras/Lumiar as producers-consumers that can share their surplus with REC members.

While having potential for spurring collective citizen investment in RES and even for improving EE and mitigating EP, RECs have yet to substantially materialise their benefits. In Portugal, but also in other countries, the process of establishing RECs is riddled with overwhelming barriers. There is energy illiteracy, insufficient knowledge, lack of information, organisational constraints, dependence on volunteers, and technical limitations. In the case-study, these initial obstacles were surpassed by having a capable coordination team from early-on and pragmatically allocating roles to the different organisations (as discussed in Sequeira *et al.*, 2024b).

Recruitment of REC members and financing can also be challenges for starting initiatives. In the case-study, these were surpassed by capitalising on local dynamics, repeatedly raising awareness, producing easy-to-grasp communication materials, and collecting funds both from the local government and from REC members. Nonetheless, it needs to be recognised that the project was deployed in a setting with a predominantly privileged socio-economic background. This is exemplified by the surveys conducted with volunteers and members which showcase high incomes and high education levels. Key drivers for participation include environmental concerns, social cohesion, and community involvement. Arguably, the REC Telheiras/Lumiar provides positive evidence on the engagement of some HTR profiles, including high-income households (with disposable income to invest in solar PV), multi-family apartments (simplifying their access RES), and micro-enterprises (small investment with an attractive payback time).

Communicating with energy-poor households presents a new set of challenges, even when the financial part can be handled. For instance, households with social tariffs already pay lower electricity prices and often use less energy which reduces the benefits of joining energy communities. In this context, the Telheiras/Lumiar case might come to show positive evidence on EP mitigation through a solidarity mechanism leveraging public and private funds to provide access to RES and reduce energy bills. Although this model functions in the case-study, it might be difficult to translate to more deprived areas (where public funds may need to be more significative). Moreover, in practice, the process of identifying and engaging energy-poor households was very challenging - not due to a lack of vulnerable families in Lumiar - and only succeeded due to the persistent effort of a few trusted frontline workers that reached out to low-income families, elderly people, and unemployed persons.

Beyond contextual and internal barriers, other macro issues further hinder the creation of RECs. Regulatory uncertainty still poses challenges, information is scarce and poorly organised, and few practical examples are operational. Another growing challenge is the availability of grid capacity which can delay, make more expensive, or even block the installation of larger solar PV systems. In Portugal, licensing is a major problem, being an opaque, complex, bureaucratic, and lengthy process even for small projects. The sum of many months and years waiting for licenses has practical implications, some of them being the demobilisation of the community and the loss of trust from REC members with higher expectations and/or more pressing needs.

As a final concern, a trend of corporate capture of energy communities is ongoing in many EU Member States, including Portugal as a particularly severe case. Taking advantage of regulatory grey zones, of the lack of oversight by licensing authorities and regulators, and of improper use of concepts by energy sector actors and journalists alike, a handful of energy utilities and technology companies have moved to develop, finance, own, sell, and manage collective-self consumption projects that are marketed as RECs. While these projects advance RES, in most cases, consumers remain passive clients at the end of the wire while buzzwords of energy citizenship, democracy, and EP mitigation are thrown around meaninglessness in an exercise of "community-washing" (Ferreira *et al.*, 2024). A palpable consequence is the corruption of the collective imaginary on community energy, from a radically new governance model to businesses-as-usual by an emergent oligopoly, and the perpetuation of a narrative that blames Portuguese citizens for a supposed cultural indifference regarding energy transitions.

Third, the Transition Point mobile OSS piloted a face-to-face energy support service in the Setúbal, Palmela, and Sesimbra municipalities (phase one) which was later duplicated in the Barreiro, Moita, Alcochete, and Montijo municipalities (phase two). In line with the revised Energy Performance of Buildings Directive (Directive (EU) 2024/1275), the support focuses on EE advice, energy tariffs optimisation, support on application to national EE funding, and home energy audits. While being a free and independent service available for everyone, it openly aims to engage energy-poor households. The non-residential sector was out of scope.

Transition Point was deployed as a refurbished maritime container and the on-the-ground operationalisation was ensured by regional energy and environment agencies. The selection of locations to set up the container was performed in collaboration with local authorities. Aiming for proximity to vulnerable households, the first location was within a deprived neighbourhood. However, this produced negative evidence on engagement with energy-poor households. The sudden appearance of the container was not well-perceived by the local community which did not trust its well-meaning services. Furthermore, the few households that sought support often did not see relevant benefits. For instance, EE advice, energy bills optimisation, or energy audits can be ineffective when energy use is already very low while public EE funds at the time demanded upfront investment and were not available for social housing. Perhaps unexpectedly, the container's location on the city's periphery also inhibited other citizens from seeking support. Learning from this lesson, the next locations were highly frequented and public accessible areas which were able to attract more visitors seeking support. The opening hours were also expanded to reach out to people with different work and family schedules.

The Transition Point visual identity was seen as a distinctive feature of the project with its key positive messages of reducing energy bills and increasing thermal comfort. EP was not mentioned to avoid generating stigma. Moreover, local communication channels (*e.g.*, local newspapers and websites of local partners) were explored, and the project strongly wagered on flyers, posters, and billboards to get its message across. Small gifts, such as LED lightbulbs, were distributed seeking to attract more people. Albeit modestly, the project reached out to other local stakeholders to foster synergies for identifying energy-poor households.

A technician was responsible for delivering face-to-face energy support which requires both technical and communicational skills; arguably, proactiveness would also be desired aiming to directly invite people to the service and to ensure follow-up after the first contact. In some locations, door-to-door approaches were conducted with social workers. Furthermore, Transition Point recruited and trained young adults not in employment or education who conducted home energy audits as a paid task. In a way, this enabled Transition Point to include this potentially HTR profile while planting the seeds for capacitation of the local communities.

The results from phase one of Transition Point were summarised by Gouveia *et al.* (2024). Based on a survey conducted with 216 visitors of the container, these authors show that Transition Point presents moderately positive evidence of engaging energy-poor households and HTR groups. Almost 30% of the surveyed reported incomes below the national median, 27% were older than 65 years, 26% had an education level below the current mandatory minimum, 14% were unemployed, and 5% lived as tenants. Furthermore, around 58% reported always or frequently feeling cold at home during winter, 33% reported feeling hot at home during summer, and 21% mentioned difficulties in paying energy bills. Still, even if these households were reached, the effectiveness of the support is difficult to ascertain. For instance, financial support for measures proposed during energy audits was not included, there was no follow-up on energy tariffs optimisation, and applications to public EE funding can take months or even years to be processed.

This case-study shows that physical OSSs hold potential to support households throughout their participation in a complex energy system undergoing large transformations. The mobile approach was field-tested in seven municipalities and by different organisations which further solidifies the concept against varying socio-economic settings. Being mobile has advantages, such as the ability to be close to different communities sequentially, but also drawbacks, such as the limited period in each location. Still some challenges remain, including reinforcing collaboration with local community-level organisations, deepening support to vulnerable households, bridging funding gaps, and ensuring policy integration. In this context, a fundamental issue is to maintain the sustainability of an OSS in the long run.

To directly answer RQ3, digital platforms, such as virtual OSS, can be useful in the energy transitions' toolbox but are largely insufficient to activate citizens, particularly those that are harder-to-reach; simultaneously, they are not adequate solutions to address EP. In contrast, local-scale actions may hold greater promise. RECs and physical OSS can translate policies into concrete solutions implemented near citizens and businesses. These can more effectively recognise the needs of local communities, target and tailor their communication approaches to HTR groups, collaborate with multi-sectoral partners, and develop context-adapted social innovation models. Still, it must be recognised that it takes considerable time and effort by multiple dedicated and competent people and organisations to set up and maintain these initiatives. In turn, this formula is difficult to repeat when scaling up or when replicating to other locations aiming for national level mainstreaming.

As recognised in chapters 2.1 and 2.2, this analysis has limitations, due to the small number of case-studies, and may contain a degree of bias due to the researcher's extensive involvement. While the local action case-studies strived for inclusiveness, some HTR profiles were still excluded by their engagement approaches. For example, communication in Transition Point was mostly in Portuguese, data on ethnicity was not collected in surveys, tenants with utility bills in the landlord's name cannot join the Telheiras/Lumiar REC, and some of the most marginalised groups are unable to benefit from these initiatives since they require support that goes way beyond the energy sector. Furthermore, misalignment with national-level conditions hinders the deployment of these approaches, *e.g.*, due to inadequate funding mechanisms and long licensing processes. In the end, neither digital OSSs, physical OSSs, or RECs are silver bullets, and to accelerate just energy transitions and foster engagement of HTR groups a comprehensive combination of approaches deployed at multiple scales is needed.

In answering RQ3, this collaborative work contributed to scientific knowledge on OSSs and RECs with ramifications for their practical implementation in Portugal and beyond. For instance, the Green Menu digital OSS is being revamped with new partners and functionalities and is being expanded to additional countries. The Transition Point mobile OSS was an inspiration for the concept of "Energy Spaces" from the National Long-Term Strategy to Combat Energy Poverty 2023-2050 with at least 50 OSSs expected to be launched by the end of 2025. The Telheiras/Lumiar REC has been considered as a best practice in the EU and Portugal, and it has published a practical guide to inspire other projects. Furthermore, it informed the definition of comprehensive policy recommendations to accelerate self-consumption and RECs in Portugal (Calado *et al.*, 2025). Finally, this research work crossed paths with multiple other likeminded initiatives, enabling knowledge cross-fertilisation and integrating networks of organisations and individuals working towards just and democratic energy transitions.

RQ4: What roles can local organisations play in energy transitions and what conditions must be met to foster effective collaborations?

A cross-cutting topic from the research is the ubiquitous mentioning of local organisations as gatekeepers of HTR groups and as facilitators of local action. A few authors have proposed relevant roles for middle actors and intermediaries in energy transitions, while others have warned against a positivity bias that may swell up this potential beyond sound evidence. Still, scarce scientific research has engaged with local stakeholders to critically assess their willingness, capabilities, and unmet needs to meet these high expectations.

The two local-scale case-studies explored during this research - Telheiras/Lumiar REC in chapter 5.2 and Transition Point mobile OSS in chapter 6.1 - provide mixed evidence on collaborating with local stakeholders. The former was promoted by a network of local organisations; still, most of the work was performed by a small group of volunteers integrated in a single local association, by the small team of the local government, and by the external technical partners. Other local organisations played smaller roles, if any, related with general dissemination and with identification of energy-poor households with some also expressing interest in obtaining advice and/or participating in energy sharing. The latter was financed by a wealthy foundation and deployed on-the-ground by a regional energy agency with the support of external technical partners. Local authorities were involved in site selection and associated logistics, as well as, in some cases, dissemination of the support services and engagement of energy-poor households, while other local organisations had mostly negligible communication roles, if any.

In this context, this work provided a deeper analysis of middle actors' roles in energy transitions, based on participatory approaches conducted with local stakeholders of Setúbal in association with case-study 3 (Transition Point mobile OSS). It should be acknowledged that the research was limited to a single case-study and to a relatively small sample of stakeholders that agreed to participate in the study, and that other case-studies and organisations could provide different insights. In general, local organisations are responsible for a myriad of activities and services in their communities and already routinely engage with large numbers of citizens and businesses across a wide range of HTR profiles. Some organisations present goals that are aligned with energy transitions, for instance, showcasing drivers related to improving sustainability, participating in the community, and supporting vulnerable families.

According to the local context, different organisations can suit diverse functions in energy support which, preferably, should be compatible with their day-to-day work. In general, community, education, health, and social organisations can build on their communication channels to raise awareness and forward citizens to the energy initiative and on trusted relationships to foster participation and to better identify and engage HTR groups. In addition, energy agencies and local experts can provide technical knowledge while local governments are seen as a natural leader in these initiatives. However, not all organisations are equipped or willing to engage on energy issues, and it is not farfetched for some of them to act in detriment of this agenda (*e.g.*, to protect the confidentiality of their beneficiaries). Even willing organisations suffer from severe barriers, including scarce human resources, other priorities, lack of time, financing and infrastructure concerns, and low receptivity in their target audience.

Similar results were described by Sequeira *et al.* (2024c), who reported on a short spin-off project conducted in conjunction with phase two of the Transition Point OSS. In the Union of the Civil Parishes of Baixa da Banheira and Vale da Amoreira, a pragmatic partnership was established between the local government, the regional energy agency, a family health centre, and a few social support organisations. On the one hand, this combination of trusted local partners from the health and social sectors managed to successfully identify some of the most vulnerable and harder-to-reach families in this territory and reference them to the energy support service delivered by the energy agency. This is show, for instance, by the high share of people reporting feeling cold at home in winter and hot in summer (70% and 66%, respectively) and experiencing difficulties in paying energy bills (55%). Moreover, several HTR profiles were engaged by the partners, *e.g.*, 64% had low education levels, 52% were unemployed, and 44% were born in a foreign country. On the other hand, coordination between organisations proved challenging in the project's short timeframe, all participants struggled with competing priorities and lack of resources, mistrust was still an issue, and proactive follow-up support was lacking.

To directly answer RQ4, there is a wide range of roles that local organisations can play in energy transitions - including as middle actors for local-scale action. They can perform from low-intensity functions, such as dissemination to their audiences, direct referencing to energy support, or making rooftops available for RES installation, to more complex and time-consuming tasks, such as identification and engagement of vulnerable households, intermediation with HTR groups, and overall coordination of energy support, energy sharing or other initiatives. A matrix of engagement levels and potential roles of local organisations in the scope of energy-related initiatives is shown in Figure 7.4.

The most suitable organisations for each role will depend on the national and local context and pinpointing them to kick-start collaborations requires a deep understanding of local dynamics, a degree of proactivity, and significant time and human resources allocated to building partnerships. Furthermore, it needs to be recognised that many of these organisations are HTR themselves, due to the mentioned barriers, and that getting them on board requires a careful approach that answers their pressing needs. As a priority, energy projects should be able to provide dedicated funding to pay local partners for their collaborative work which, in turn, may help address other challenges such as lack of human resources, infrastructure, and equipment.

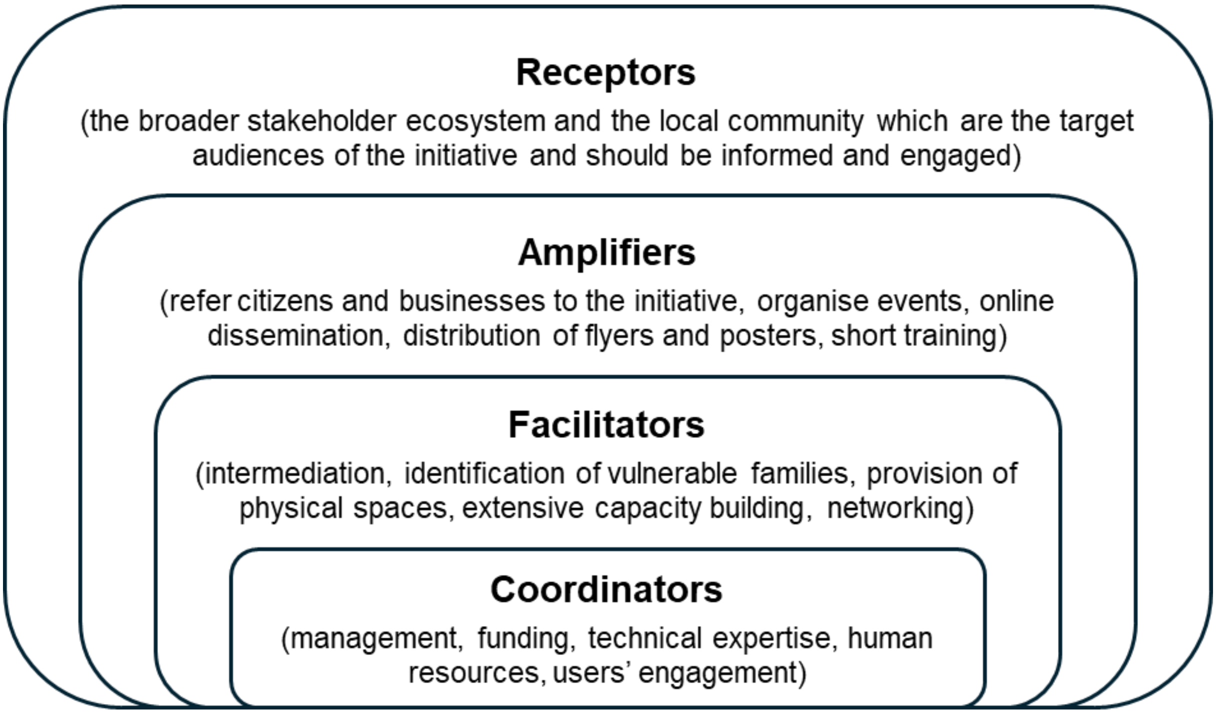


Figure 7.4 - Matrix of engagement for local organisations in energy interventions.

In addressing RQ4, this research provided a pathway for deploying more effective and fairer local-scale collaborations with local organisations aimed at enhancing citizen engagement in energy transitions and ensuring participation of harder-to-reach groups. However, if this is to be enabled, local stakeholders need to be empowered to fulfil expected tasks and should be adequately rewarded for their successful completion. In turn, working on energy topics can help establish and reinforce partnerships in local communities and contribute to address other pressing environmental, social, and economic concerns. Finally, bottom-up action can provide invaluable policy insights which could be leveraged to trigger more systemic change.

7.2 Final considerations and future research

This research produced a panoply of outputs under the thematic umbrella of HTR energy users in energy transitions, enhancing scientific knowledge and informing policymakers and practitioners. Two main contributions of the PhD work are highlighted: i) the development, quantification, and operationalisation of a HTR energy users theoretical framework to inform policymakers, researchers, and practitioners at multiple scales, and ii) the provision of direct support for the creation of a digital OSS, a mobile OSS, and a REC, informing their engagement of HTR groups and paving the way for upscaling and replication. Limitations are acknowledged throughout the research, including data unavailability and inconsistencies, potential researcher's bias, small number of analysed policies and case-studies, and relatively small number of experts, organisations, and citizens engaged through participatory approaches.

The HTR energy users theoretical framework can be linked to the growing scientific literature on energy justice which usually revolves around three main tenets, namely recognition, procedural, and distributional, but can also include additional ones (*e.g.*, restorative justice). The HTR concept argues for recognising the different needs and responsibilities of contrasting groups, such as vulnerable households and high-income households, in the context of their engagement in energy transitions. It opens the possibility for equal participation in energy decisions, including by pinpointing groups that are marginalised, while, simultaneously, warning against the excessive influence and power of wealthy groups.

The systematised HTR profiles also provide a case for the fair distribution of positive and negative consequences of current and future energy systems; for instance, it is argued that vulnerable households, tenants, and micro-enterprises should be able to benefit from energy transitions and that high-income households, sumptuous spenders, and larger corporations ought to pitch in their fair share of the effort. By highlighting historically marginalised groups, such as ethnic minorities, Indigenous people, and Nomadic communities, the HTR concept may also contribute to the discussion on restorative justice. Still, more importantly than describing HTR profiles and quantifying them, is to ensure that science has real-world impact through policies and actions that acknowledge energy access as a public good and a basic human right rather than as a commodity in the hands of profit-driven corporations.

The deployment of digital tools and local-scale actions can be explored in relation to a growing energy democracy movement which proposes popular sovereignty, participatory governance, and civic ownership as its fundamental pillars. The assessed OSS case-studies do not align particularly well against energy democracy criteria since decision-making processes and infrastructure management are still in the hands of a few private organisations. Still, it can be argued that, by providing information and especially by enabling face-to-face EE support, these initiatives contribute to raise energy literacy and build capacity which is vital for increasing citizens' authority and power over energy decisions. In contrast, the described REC case-study might be better aligned with energy democracy, as also described by other authors for energy cooperatives. It respects the principle that people should have authority over decisions by establishing a one-member-one-vote mechanism, defining general assemblies as participatory decision-making processes, and ensuring infrastructures are collectively owned by the REC members. Evidently, it is not a perfect embodiment of energy democracy, including since participation in decision-making processes tends to be low, but the pre-requisites are there.

It should be noted that this lens was applied to three specific case-studies and that, depending on the organisations and on the governance models, OSSs, RECs, and other approaches may align better or worse with energy democracy standards. These local-scale actions, performed independently from major energy companies, still face unsurmountable challenges for their implementation, growth, and long-term viability. In many ways, the energy sector remains a rigged game where incumbents block and capture novel technologies, concepts, and narratives to perpetuate their business-as-usual market activities. Although collective actions at local scale cannot replace this hardened capitalist paradigm, they may be able to provide an alternative, but only if given a fair opportunity and if their unvalued contributions in addressing environmental, social, economic, and technical energy system challenges are recognised.

This research paves the way for future research on multiple interlinked topics. Many of the proposed HTR profiles should be further investigated, including by integrating the lived experience of families and businesses, critically exploring engagement approaches, and solidifying the connection to energy justice. Marginalised groups (*e.g.*, ethnic minorities, Indigenous groups, homeless, informal settlements, travellers, and Nomadic communities), high-income households, sumptuous spenders, landlords, and micro-enterprises seem particularly worthy of research due to the still scarce literature and the unavailability of data. Following, multiple other data sources and data collection and processing methods can be tested, including to provide information on HTR profiles at other scales of analysis. Admittedly, gender was not sufficiently explored during this work and could be the focus of future research including by assessing its interaction with the systematised HTR profiles.

While briefly assessed, heterogeneity and intersectionality are also topics that merit a deep dive to more precisely characterise HTR groups. Furthermore, the operationalisation of the theoretical framework for a growing number of *ex-ante* and *ex-post* evaluations of policies and interventions seems relevant, especially if it guides their design towards greater inclusiveness and fairer processes. As this work focused on the Global North, particularly on the EU, its Member States, and Portugal, attempting the translation of the HTR concept to the Global South should also be of interest to international researchers.

Digital tools and local-scale actions also present a rich scope for future applied research. For instance, researchers can continue to assess how digital tools impact different audiences while critically evaluating their effectiveness in motivating behaviour change, EE improvement, RES integration, and EP mitigation. In the local-scale arena, it is highly relevant for authors to report on and contrast empiric case-studies, as well as their development processes, challenges, and opportunities, across a range of geographical, social, cultural, and political backgrounds. In turn, this accumulated scientific knowledge can guide the pragmatic and constructive deployment of more effective local-scale actions. This is particularly important for emerging initiatives, such as OSSs and RECs, which are high on the EU's energy and climate agenda but still lack proper scientific analysis and impact reporting. Research topics can include EP diagnosis and mitigation, HTR engagement, technical EE and RES analysis, behavioural change tactics, and emerging governance, business, and social innovation models.

Furthermore, the role of middle actors could be further investigated by expanding the analysis to other locations, organisation types, and scopes of action. Researchers can evaluate these stakeholders' success in fulfilling the expected roles, including through cost-effectiveness assessments which consider the human and financial resources spent in building local partnerships and the tangible and intangible outcomes of the resulting collaboration. Finally, scientists, practitioners, and policymakers are encouraged to explore combinations of digital, national, regional, and local approaches that may results into an integrated, comprehensive, and participatory strategy to foster multi-scalar just and democratic energy transitions.

Against the backdrop of escalating environmental, social, political, health, and military crisis - knitted together and spiralling out of control as a polycrisis - a profound transformation is urgently needed if untold human and non-human suffering is to be lessened. Energy lies at the heart of modern societies and, albeit at an insufficient rhythm, a systems' overhaul is underway with decarbonisation, security, and poverty eradication as stated objectives. Framed by this macro-context, this research produced scientific and empirical knowledge useful to recognise the needs and responsibilities of energy users, particularly the citizens and businesses that are potentially harder-to-reach, and to more effectively engage them through policies, digital tools, and on-the-ground interventions. Acknowledging prevailing systemic inequalities, it pragmatically showed how local-scale actions can, and already are, blossoming across the territory promoted by well-meaning, collaborative, but often powerless actors. Pessimism and resignation may arise given the ominous challenges ahead but are not useful, just as false hope and utopian visions are laughable and unhelpful. Instead, this work concludes by stating that alternative models for more sustainable, just, and democratic energy systems are achievable.

References

Calado, B., Garcia, D., Sequeira, M.M., and Sereno, P. (2025). Observar, Informar, Facilitar e Apoiar - Medidas para democratizar e acelerar o autoconsumo e as comunidades de energia renovável ["Observing, Informing, Facilitating, and Supporting - Measures to democratise and accelerate self-consumption and renewable energy communities"]. Citizens' Commission on Environment and Energy. Os 230 project. Available at: https://www.os230.pt/comissao-dos-cidadaos/

EPAH (2025). EPAH ATLAS. Energy Poverty Advisory Hub. European Commission. DG Energy. Available at: https://energy-poverty.ec.europa.eu/discover-community/epah-atlas

Ferreira, E., Sequeira, M.M., and Gouveia, J.P. (2024). Energy poverty mitigation through the deployment of renewable energy communities: The case of Portugal. Proceedings of the International Conference on Sustainable Development (ICSD 2024). Available at: https://ic-sd.org/2024/11/17/icsd-2024-proceedings/

Gouveia, J. P., Mendes, M., Sequeira, M. M., and Palma, P. (2024). A New Way to Mitigate Energy Poverty: Lessons from the Transition Point 'One-Stop Shop' Pilot. Transition Point: Full Report. Published by the Calouste Gulbenkian Foundation (1st edition). Available at: https://gulbenkian.pt/en/publications/a-new-way-to-mitigate-energy-poverty-lessons-from-the-transition-point-one-stop-shop-pilot/

Mundaca, L., Rotmann, S., Ashby, K., Karlin, B., Butler, D., Sequeira, M.M., *et al.* (2023). Hard-to-reach energy users: An ex-post cross-country assessment of behavioural-oriented interventions. Energy Research & Social Science 104, 103205. https://doi.org/10.1016/j.erss.2023.103205

Sequeira, M.M., Ferreira, E., Pereira, L.K., Cachinho, L., Martins, H., Gouveia, J.P., *et al.* (2024a). Practical guide: Development of renewable energy communities by citizens, associations, and local governments – The example of the Telheiras/Lumiar Renewable Energy Community. Portuguese and English versions. Available at: https://fireflyenergylab.com/research/publications/107

Sequeira, M.M., Ferreira, E., and Gouveia, J.P. (2024b). Promovendo a produção e partilha local de eletricidade: Uma análise detalhada da experiência da Comuni-dade de Energia Renovável de Telheiras em Portugal ["Promoting local electricity generation and sharing: A detailed analysis of the experience of the Telheiras Renewable Energy Community in Portugal"]. In Oliveira, F.P., and Chediek, J. (Eds), Comunidades de Energia ["Energy Communities"]. Almedina. ISBN 9789894021162. Available at: https://www.almedina.net/comunidades-de-energia-1719320486.html

Sequeira, M.M., Sapatinha, M., Gouveia, J.P., Henriques, I.R., Camacho, S., Figueiredo, J., and Barroso, J. (2024c). Prescribing a comfortable home: Health, social support, and energy poverty at Baixa Banheira e Vale da Amoreira. Conference poster at the Portuguese Science Summit 2024. Porto, Portugal, July 2024. Available at: https://app.encontrociencia.pt/exhibitor/23372

2025

Miguel Macias Marques Sequeira

HARD-TO-REACH ENERGY USERS IN JUST ENERGY TRANSITIONS:
IDENTIFYING TARGET GROUPS AND PILOTING LOCAL ACTION