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Socioeconomic effects of EU Renovation Wave expenditure on low-income groups in the EU27

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EU	European Union
GHG	Greenhouse Gas
ETS2	Emissions Trading System for buildings and transport
SCF	Social Climate Fund
EC	European Commission
EPBD	Energy Performance of Buildings Directive
EED	Energy Efficiency Directive
NECP	National Energy and Climate Plans
RED	Renewable Energy Directive
NRRP	National Recovery and Resilience Plan
LTRS	Long-term renovation strategy
TJ	terajoule
kWh	kilowatt hour
EPOV	EU Energy Poverty Observatory
POEU	Publications Office of the European Union
SMEs	Small and medium-sized enterprises
IEECP	Institute for European Energy and Climate Policy
Eceee	European Council for an energy-efficient economy
FEANTSA	European Federation of National Organizations Working with the Homeless
EU-SILC	European Union Statistics on Income and Living Conditions
ECHP	European Community Household Panel
SFH	Single-family housing
MFH	Multi-family housing

Abstract

Buildings are responsible for more than 30% of the EU's greenhouse gas emissions from energy. To increase energy and resource efficiency, the EU Renovation Wave sets the target of doubling renovation rates in the next ten years. The EU also presents the Renovation Wave as a countermeasure against energy poverty, which currently impacts around 34 million EU residents. However, EU-level analyses which connect the technical aspects of the plan with socioeconomic criteria related to energy poverty remain scarce. This paper addresses that gap by investigating the distributional effects of reaching the Renovation Wave's 2030 goals in the EU27 countries, based on data from Invert/EE-Lab and Eurostat. It assesses changes in heating expenditure as well as renovation investment needs relative to the total expenditure of private households. The analysis relies on four price scenarios and two renovation scenarios. Quantitative findings are further contextualized with three examples: Austria, Spain, and Romania. The results indicate that for the lowest income quintile, the heating cost burdens are disproportionately high compared to higher-income groups. However, these burdens can be alleviated if final energy demand is reduced through renovation measures targeting energy efficiency improvements and deployment of renewables. This study thus both underscores the importance of considering distributional effects when designing and evaluating renovation policies, before concluding with an overview of data gaps and further research recommendations.

Key words: Renovation Wave, energy efficiency, energy poverty, heating, distributional effects

1. Introduction

“We want everyone in Europe to have a home they can light, heat, or cool without breaking the bank or breaking the planet“ (EC, 2020c, p. (paragraph) 1), said Frans Timmermans, Executive Vice-President for the European Green Deal, while introducing the European Union (EU) Renovation Wave for the EU Commission (EC). Launched in 2020 as part of the European Green Deal, the Renovation Wave is the EU’s response to the twin challenges of decarbonizing the building stock and alleviating energy poverty (EC, 2020c).

Because the building sector is responsible for 40% of energy consumption and 36% of greenhouse gas emissions (GHG), it needs to be decarbonized for the EU to reach its goal of climate neutrality by 2050 (EC, 2020b). However, despite the fact that the EU’s overall energy consumption overshoots its natural resources, an estimated 34-to-50 million EU residents are unable to cover their basic energy needs and live in energy poverty (Chlechowitz & Reuter, 2020; EC, n.d.-f). Renovations which make buildings more energy-efficient and reliant on renewable rather than fossil-based energy have the potential to both decrease greenhouse gas emissions and energy costs (Schneller et al., 2021) and “act as a buffer against people falling into energy poverty if energy prices rise” (Schneller et al., 2021, p. 26, 2021). Yet, few publications project the socioeconomic effects of the EU Renovation Wave on low-income households in the years leading up to 2030 or explore the design and implementation of a socially just EU Renovation Wave. Moreover, EU-level analyses that link technical characteristics with socioeconomic criteria related to energy poverty remain scarce.

In response, this paper contributes to the existing body of literature by investigating the distributional effects of reaching the 2030 goals in the EU27 countries based on data by Invert/EE-Lab and Eurostat. Accordingly, the analysis answers the following research question: *What are the socioeconomic effects of decarbonization-related household expenditure on low-income households in the EU-27?*

The analysis assesses changes in heating expenditure as well as renovation investment needs relative to the total expenditure of private households. The calculations are based on four price scenarios and two renovation scenarios. The study puts forward two hypotheses: first, in 2030, low-income private households in all EU Member States will spend a larger share of their income on heating than high-income households; and second, if EU Renovation Wave measures are implemented in dwellings inhabited by low-income households by 2030, then low-income households will spend a lower share of their income on heating. To highlight the diverse challenges EU countries face regarding energy poverty, the quantitative findings are further contextualized with three country examples: Austria, Spain, and Romania. The three countries were selected because they represent different EU regions, have different energy mixes in heating, and experience energy poverty to different degrees. Overall, this research emphasizes the importance of considering distributional effects when designing and evaluating renovation policies and highlights examples of such policies.

Against the background of the Russian invasion of Ukraine in early 2022, the EU Renovation Wave has arguably become even more important. Europe now faces three interconnected crises: the climate crisis, a social crisis and an energy security crisis (Oikonomou et al., 2022). All three have strong implications for the building sector.

The **climate crisis,** and the devastating consequences should global warming not be limited to 1.5 degrees Celsius, pose a serious threat to the world population (Oikonomou et al., 2022). The EU has set a legally binding target to achieve climate neutrality by 2050 (EC, n.d.-a). The EU Renovation Wave is presented as one of the cornerstones of this effort (EC, 2020c).

The **social crisis** is a crisis of persistent energy poverty in the EU (Oikonomou et al., 2022). More than 34 million EU residents cannot afford to keep their homes adequately warm (EC, n.d.-f). As a consequence of the Russian invasion in Ukraine, the prices of most energy carriers have increased drastically (→ *3.3 Price Scenarios)* and annual inflation in the EU hit 8.9%[1] last August (Gill, 2022). It can be assumed that energy poverty has risen since February 2022. For instance, every fifth person in the UK, France and Poland says they rely on savings to cover bills; every tenth person says they skip meals to cope with rising costs (Fox, 2022). Headlines like "*Heat or eat?*" (Gill, 2022) address rising energy poverty in Europe and protests around the topic of energy poverty are taking place across the continent. For example, the campaign Don't Pay UK calls on people to boycott payment of their energy bills (Gill, 2022). In Spain, France and Belgium workers have gone on strike in the health, public transport and aviation sectors, demanding an increase in wages to better cope with the high inflation (Gill, 2022). Energy poverty is also expected to affect more households overall and more middle-class households (Wehrmann, 2022). Low-income households are likely to be disproportionately affected by the current developments due to budgetary constraints. Furthermore, because housing conditions are a determinant of an individual's health, social inequalities linked to energy poverty can trigger and aggravate a range of other health-related problems (Oikonomou et al., 2022).

The third crisis facing the EU is an **energy security** crisis (Oikonomou et al., 2022). To become politically independent from Russia, EU heads of state aim at cutting the EU's reliance on Russian fossil fuels (Oikonomou et al., 2022). This also includes the fuels that heat the dwellings of private households (Oikonomou et al., 2022). While the energy security crisis is a challenge for EU leaders, it also opens a window of opportunity to shift away from a fossil fuel based infrastructure and instead invest more in renewable energies and energy efficiency (Oikonomou et al., 2022). A recent survey conducted by YouGov suggests strong public support: the majority of respondents in France, Germany and the UK believe that deferring climate change commitments will increase energy bills in the long and medium term (Fox, 2022). However, if this window of opportunity is missed, the EU risks exacerbating the climate crisis (Oikonomou et al., 2022).

This thesis follows a six-step structure. First, the topic and research aim are introduced. Second, the literature review provides an overview of the EU Renovation Wave and renovation policies targeting vulnerable households. The former part goes into detail on Renovation Wave targets,

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[1] About half of the increase in inflation can be attributed to more expensive energy (Gill, 2022).

policy and governance context, building stock renovation, energy mixes in heating, investment and funding, and socioeconomic implications. More specifically, the section on socioeconomic implications covers the topics of energy poverty, the socio-ecological benefits of renovation and gives an overview of literature on a socially just Renovation Wave. For each subsection, the literature review maps out the information for both the EU27[2] overall and the three country examples. Following the literature review, the thesis proceeds with the methods section, which describes the research question, data sources, price scenarios, and analysis approach. The fourth section presents the results for the EU27 and the country examples. The discussion section then elaborates on unexpected results, compares the findings to those of a similar publication, details the limitations of this analysis, and provides future research recommendations. The conclusion sums up the results.

2. Literature Review

2.1 The EU Renovation Wave targets

As part of the European Green Deal, the EU presented the 'Renovation Wave' strategy in October 2020 (EC, n.d.-a, 2020b). The strategy aims to achieve a 60% reduction in the buildings sector's GHG emissions by 2030 compared to 2015 levels and to double annual renovation rates over the course of the next ten years (EC, n.d.-f; Staniaszek et al., 2021). It provides guidelines and regulations to reach these goals (von Platten et al., 2021). Three areas of action make up its building blocks: first, decarbonizing heating and cooling in buildings; second, alleviating energy poverty; and, third, renovating public buildings and promoting deep renovations (von Platten et al., 2021). Deep renovations are more comprehensive renovations that tend to be more costly but also lead to higher energy savings (Staniaszek et al., 2021; von Platten et al., 2021). With the Renovation Wave, the EU intends to trigger a transformation of the European building stock to improve its resource and energy efficiency (Staniaszek et al., 2021). Although the renovation wave does increase existing renovation targets, the Buildings Performance Institute Europe (BPIE) argues that the renovation rate needs to go up to 3% from the current 1% per year over the course of the next ten years to achieve the EU's goal of climate neutrality by 2050 (Staniaszek et al., 2021).

2.2 Policy and governance

Policy and governance in the EU

The EC prioritizes energy retrofitting of energy poor households in many of its official documents such as the EU Green Deal, the Renovation Wave, and a number of

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[2] The EU27 refers to all 27 EU Member States

recommendations and directives (Schneller et al., 2021). In July 2021, the Fit-for-55 package, a legislative instrument to reach the 2030 and 2050 decarbonization milestones, was adopted; it increased the EU's GHG emissions reduction target from a 40% to an at least 55% reduction by 2030, compared to 1990 levels (EC, 2021b, 2022c; European Climate Foundation, 2022). Responding to energy security challenges following the Russian invasion in Ukraine, the REPowerEU Plan proposed that the EU's 2030 goal for renewably generated energy should increase from 40% to 45% (EC, 2022b). One key EU Green Deal initiative which both carries strong socioeconomic implications and impacts the building sector is the introduction of a second Emissions Trading System (ETS2); as of 2026, the ETS2 will put a uniform price on GHG emissions from the building and road transport sector which will disproportionately affect low-income households compared to other households if no cushioning elements are included (Braungardt et al., 2022; EC, 2021b). Therefore, to cushion adverse effects of the ETS2, the EU has proposed the creation of a Social Climate Fund (SCF) that will support citizens through both direct compensation payments and financial support for climate-related investments (WWF European Policy Office, 2021). It is valued at 72.2 billion € for a duration of eight years (2025-2032) (WWF European Policy Office, 2021). Out of the 72.2 billion €, the maximum financial allocation for Austria is about 644,000,000 €, for Spain is about 7,600,000,000 €, and for Romania is about 6,683,000,000 € (EC, 2021a). The fund will enter into force one year before the ETS2 starts operating (EC, 2021b; WWF European Policy Office, 2021). The funding objectives are (i) renewable energy projects, (ii) tackling transport poverty, and (iii) supporting businesses and (iv) supporting vulnerable households[3] (Oikonomou et al., 2022). However, neither the revenues of the ETS2 nor the SCF have thus far been earmarked for renovating the dwellings of low-income households, which is why some stakeholders have doubt the sufficiency of the SCF to cover the financial needs of low-income households (Lorek et al., 2022; Oikonomou et al., 2022). Yet, other scholars argue that the SCF is sufficient to cover investment needs and support vulnerable households but has to be well-targeted to provide these households with the necessary financial means (Braungardt et al., 2022) (→ *2.8*).

To foster building renovations and increase energy performance, the EU has developed a comprehensive legislative framework (EC, n.d.-a). Alongside the EU Renovation Wave, two key directives are the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) (EC, n.d.-a). In combination, these directives guide policies to help achieve the following objectives: (i) creating an energy efficient and decarbonized building stock by 2050, (ii) producing a reliable environment for investment decision-making, and (iii) helping consumers and businesses make better-informed choices so that they can save financial resources and energy (EC, n.d.-a).[4] The EPBD requires EU member states to adopt a national long-term renovation strategy (LTRS) for the building sector (EC, n.d.-b).[5] The long-term strategies are integrated with member states' National Energy and Climate Plans (NECPs) (EC,

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[3] This group can encompass more than households in the first income quintile (Oikonomou et al., 2022)

[4] However, increased climate policy targets as part of the Fit-for-55 package require an updated regulatory framework which is why the European Commission proposed a revision of the EPBD in December 2021 (EC, n.d.-a).

[5] In quantitative terms, the LTRS of Spain mentions energy poverty significantly more often than the LTRS of Austria and Romania. A table with the number of mentions of both 'energy poverty' and 'low-income household(s)/families' is included in *Appendix 5*.

n.d.-c), and the strategies have to achieve the energy efficiency targets set out in the NECPs (EC, n.d.-b, n.d.-a). For example, because of the EPBD, whenever a building is rented or sold, inspection schemes for heating systems as well as energy performance certificates have to be issued (EC, n.d.-a). Finally, another important governance document is the Recovery and Resilience Facility, that was put in place to reduce the economic and social impact of the Covid-19 pandemic and make Europe more resilient; it requires the EU27 to submit National Recovery and Resilience Plans (NRRPs) (EC, n.d.-e).

Policy and governance in Austria, Spain, and Romania

The EU Energy Poverty Observatory published a report in 2020 which explored how the NECPs address energy poverty (Bouzarovski & Thomson, 2020). While the Spanish NECP is largely based on the "very comprehensive" (Bouzarovski & Thomson, 2020, p. 30) 2019 National Energy Poverty Strategy, which distinguishes between palliative measures (short-term) and structural measures (long-term), the Austrian NECP relies mainly on social policies, information campaigns, and both targeted and non-targeted energy efficiency measures to tackle energy poverty (Bouzarovski & Thomson, 2020). The Romanian NECP focuses on just transition aspects related to high-carbon industries and monitoring (Bouzarovski & Thomson, 2020). Also, the Romanian NECP (2021-2030) proposes a target of 30.7% of renewable energy by 2030 (Miu & Prantner, 2021), while Spain sets a high energy efficiency target, namely to increase energy efficiency by 39.5% by 2030 (Gumbau, 2022). Regarding the NRRPs, the Green Recovery Tracker provides assessments as to how far the recovery measures aid green transition objectives. In the case of Austria, the Tracker concludes that 34% of recovery measures contribute to the green transition, slightly below the EU benchmark of 37% (Neier & Stagl, 2021). However, the NRRP does not include any conditionalities or targets regarding GHG emission reductions (Neier & Stagl, 2021) and rarely connects NRRP objectives with the LTRS (Renovate Europe, 2021a). The Austrian Plan includes several measures related to Renovation Wave goals; all of which were rated 'positive' by the Green Recovery Tracker (Neier & Stagl, 2021). In Spain's case, the Tracker gives a 'positive' rating regarding the green transition, even though the overall green spending share is at 31%, which is 6% below the EU benchmark (Heilmann et al., 2021). Spain's NRRP lays out ambitious objectives for building renovation, mostly for residential and public buildings (Renovate Europe, 2021c), which is evaluated as 'very positive' (Heilmann et al., 2021). In comparison, the Austrian NRRP allocates 3% to the Renovation Wave, and the Romanian 8.9% (Renovate Europe, 2021b, 2021a). Regarding the Romanian NRRP, the Green Recovery Tracker concludes that Romania's recovery measures positively contribute to the green transition, but points out that some recovery measures cannot be addressed due to lack of detail (Miu & Prantner, 2021). On the whole, the draft corresponds to a green spending share of 24%, which is significantly below the EU benchmark (Miu & Prantner, 2021). The Green Recovery Tracker assesses the NRRP's Renovation Wave measures as 'positive' because of its joint financing and regulatory approach to building renovation investment, as well as upskilling of the supply chain (Miu & Prantner, 2021). Despite the Plan not meeting the EU recommendation, the approach toward renewable energy and energy efficiency was assessed as 'very positive' due to increased targets for renewable energy capacity and better industrial energy efficiency (Miu & Prantner, 2021).

2.3 Building stock renovation

Building stock renovation in the EU

The EU building stock is in urgent need of renovation. 85% of the EU building stock was built earlier than 2001 and the majority of it is heated with fossil fuels (Vandenbussche, 2021). Across the EU, deep renovations have only been performed in 0.2-0.3% of the total floor area (de Arriba Segurado, 2021). The EU building stock is responsible for 40% of energy consumed and 36% of energy-related GHG emissions (EC, 2022c). In 2020, space heating accounts for 62.8% of energy consumption in residential households, followed by domestic hot water at 15.1% and lighting and appliances at 14.5% (Eurostat, 2022l). Cooking (6.1%), space cooling (0.4%) and other end uses (1%) are responsible for the remaining energy consumption (Eurostat, 2022l). Importantly, some buildings still do not meet the EU standards on the minimum conditions for provision of public utilities, such as access to drinking water from public infrastructure and sewage connection (Government of Romania, 2020).

Building stock renovation in Austria, Spain, and Romania

About 75% of Austrian buildings were built before 1990 and about 60% of them need energy retrofitting (City of Tomorrow, 2022). In Spain, the building stock is oversized due to the property expansion starting in the 1990s (de Arriba Segurado, 2021). As a result, new buildings with better energy efficiency labels are projected to only make up about 10% of the 2050 building stock and 84% of the building stock is not energy efficient (de Arriba Segurado, 2021; Gumbau, 2022). A positive development in the Spanish building stock is the evolution of renovation activity; since 2015, turnover in retrofitting of residential housing surpasses that of new construction projects (de Arriba Segurado, 2021). However, most of these renovations are not deep renovations; therefore, retrofitting targets must be more ambitious to attain energy savings goals (de Arriba Segurado, 2021). In Romania, 90% of the floor area in residential buildings was constructed before 1989 (Schneller et al., 2021). As of 2020, 77% of the building stock floor area will require renovation before 2050, of which 91% belongs to the residential sector (Government of Romania, 2020). By 2030, the Romanian government aims to renovate 6% of the existing buildings in Romania (Schneller et al., 2021). It is important to mention that Romania is experiencing significant depopulation; the decline in population is projected to surpass 15% by 2050 (Government of Romania, 2020). As a consequence, the number of dwellings (about 8 million) is higher than that of families (7.2 million) (Government of Romania, 2020), making well-designed renovation policies even more crucial. Furthermore, renovation of the Romanian building stock faces similar challenges to other former communist EU countries: lower average incomes, many inefficient buildings, and similar states of their heating and electricity markets (Schneller et al., 2021). A partial explanation for these challenges lies in the financial constraints during the most active construction period (1961-1980), which dictated that buildings needed to be as cheap as possible (Schneller et al., 2021). In turn, the state heavily subsidized energy costs to keep living costs to a manageable level (Schneller et al., 2021). Today, with energy costs no longer as highly subsidized, households in Eastern European countries often save money by reducing their thermal comfort (Schneller et al.). Consequently, many homes still suffer from similar low levels of thermal insulation and lack investments in maintenance and energy efficiency improvements from both state and private actors (Schneller et al., 2021). Other barriers surrounding Romanian building renovations include missing incentives, labor market constraints, financial product access and too few private financial products, and a lack of energy efficient technologies (Renovate Europe, 2021b).

The Austrian residential sector consumed 280,125 terajoule (TJ) in 2020, which corresponded to 26.6% of total final energy consumption (Statistics Austria, 2021). With a slightly higher share, the final energy consumption in the Spanish building sector amounted to 29.5%, landing below the EU average due to the warmer climate and lower heating costs (de Arriba Segurado, 2021). Even higher, the Romanian building sector consumed 42% of Romania's total final energy consumption in 2019, 34% of which stemmed from the residential sector (Government of Romania, 2020). Further, Romania is exposed to relatively cold temperatures and thus has a high heating energy demand (POEU, 2020)[6]. Energy consumption in heating amounts to 55% of final energy use in apartment buildings and up to 80% in single buildings (Schneller et al., 2021). Residential buildings consume 308 kilowatt hour per square meter (kWh/m$^{2)}$ on average, which is roughly twice as much as a Label A building uses (150 kWh/m^2) (Schneller et al., 2021). This illustrates the enormous potential for energy and cost savings in the Romanian building stock (Schneller et al., 2021).

2.4 Energy mix

Exemplifying the diversity in heating energy mixes among the EU27 countries, the final energy consumption of the residential space heating sector differs between Austria, Spain, and Romania.

The two figures below illustrate the share of energy carriers in the energy mixes of the three countries and the EU27 average for space and water heating, respectively. In the EU27, the most important fuel in the final energy consumption of the residential space heating sector in 2020 was natural gas (38%), followed by renewables and biofuels (27%) and oil and petroleum products (16%) (Eurostat, 2022j). It is important to note that the largest share (85%) of renewable heating was generated through biomass and biogas; the remaining 15% from heat pumps (12%), solar thermal (2.4%) and geothermal (0.8%)[7] (Graf, 2021). As *figure 1* illustrates, the main energy carriers in the Austrian residential space heating sector in 2020 were renewables and biofuels (35.4%) and natural gas (26.8%), whereas Spain heavily relied on renewables and biofuels (32.8%), oil and petroleum products (31.3%), and natural gas (27.4%) and Romanian households mainly used renewables and biofuels (52.8%), followed by natural gas (32%) (Eurostat, 2022j).

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[6] POEU refers to the Publications Office of the EU.

[7] In 2018

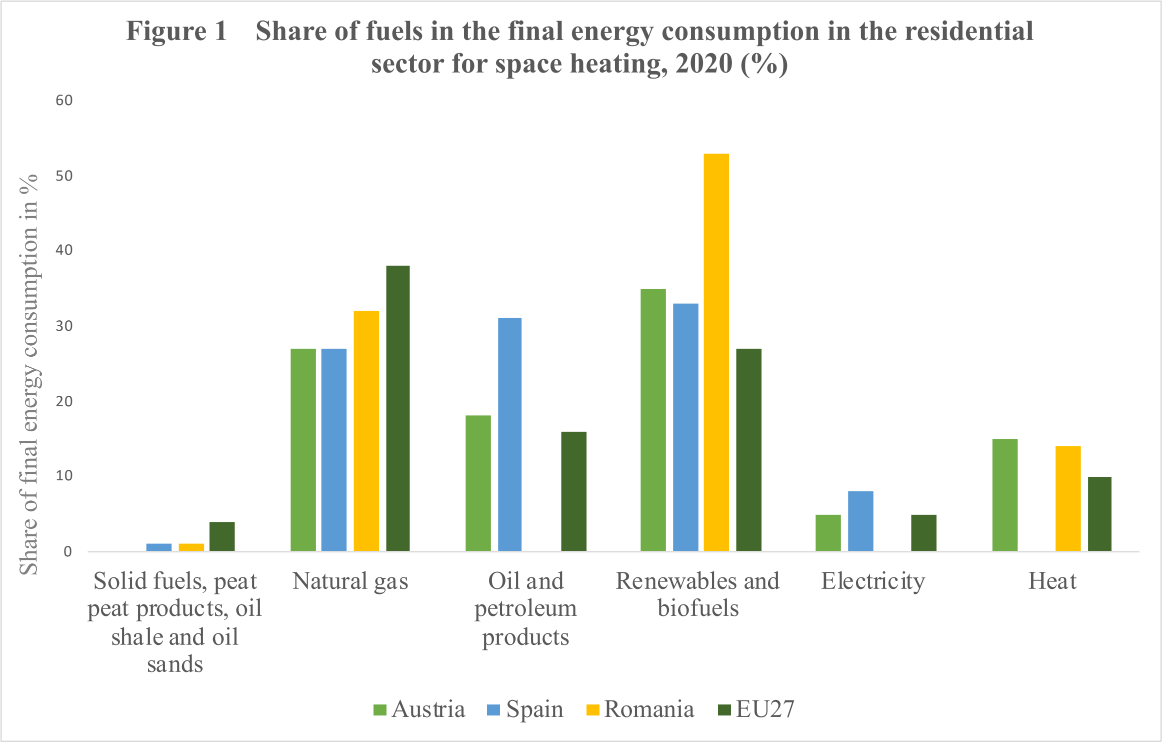

Fig.1: Own image based on (Eurostat, 2022j)

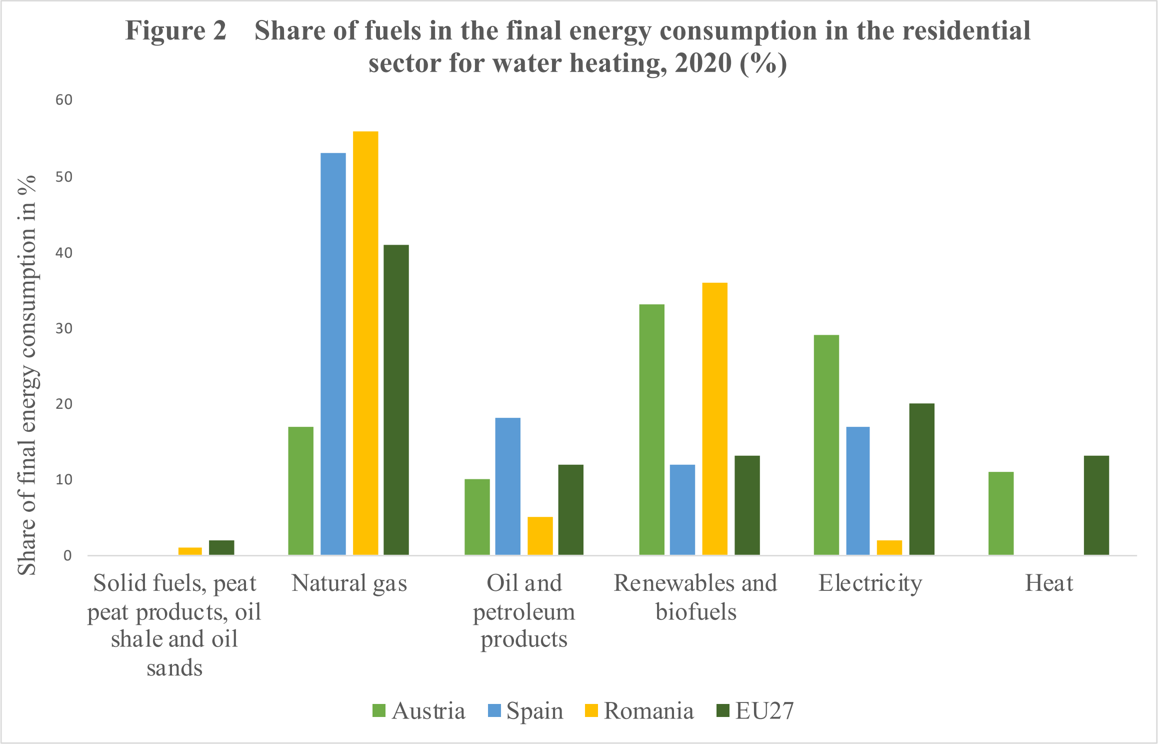

Fig.2: Own image based on (Eurostat, 2022k)

Similarly, in the residential water heating sector, the most important fuel in the final energy consumption in 2020 was natural gas (41%), followed by electricity (20%) (Eurostat, 2022k). In a similarity with Romania, whose main energy carriers in water heating were natural gas (56.1%) and renewables and biofuels (35.5%), the main energy carriers for Austria were renewables and biofuels (32.9%) and electricity (29.3%), while the main energy carrier for Spain was natural gas by a large share (53.2%) (Eurostat, 2022k).

Notably, Austria relies on a comparatively large share of district heating (TU Vienna & e-think, 2015). Equally noteworthy is Romanian's high reliance on biomass; for example, about 80% of rural households in Romania heat with biomass, while just 10% of households in urban areas heat with biomass (Schneller et al., 2021). District heating, on the other hand, hardly exists in the Romanian context: the Romanian district heating grid is particularly expensive, inefficient and lacking in maintenance resources because, after 1989, many Romanian households disconnected from the grid (Schneller et al., 2021).

2.5 Investment and funding

Investment and funding in the EU

The building sector is one of the sectors confronted with large investment gaps (EC, 2020a), with investment needs expected to peak between 2030 and 2040 (Oikonomou et al., 2022). The estimated investment needs for building renovation to reach a 55% cut in emissions by 2030 amount to an additional 275 billion € per year (EC, 2020a). Various financial instruments, such as the Recovery and Resilience Facility and public guarantees assured under InvestEU, address market barriers to help with attracting private investment (EC, 2020a). Investment barriers on the household level include the inability to cover high upfront investment costs for renovation as well as split incentives in the rental market and barriers to using financial services (Oikonomou et al., 2022).

Investment and funding in Austria, Spain, and Romania

The investment landscape in the three countries is difficult to map out due to overlapping initiatives on multiple governance levels and the lack of information on investment activities. Thus, this literature review gives an overview of investment needs in renovation and the funding objectives included in the NRRPs. It can be assumed that large parts of the remaining investment gaps will be covered through national funding channels.

In Austria, the estimated investment needed to uphold the current renovation rate of 1.5% is 5.3 billion € per year (Austrian Institute of Construction Engineering (OIB), 2020). The Austrian NRRP distributes a budget of 4.5 billion € (Neier & Stagl, 2021). One of the measures included is promoting the exchange of gas and oil heating systems, for which 158.9 million € were set aside (Neier & Stagl, 2021). The plan also allocates 50 million € to tackling energy poverty in low-income households through thermal renovations in buildings (Neier & Stagl, 2021), which are anticipated to aid 2,250 households by 2025 (Renovate Europe, 2021a). Another 50 million € are earmarked for renovating village centers, including building refurbishments and greening facades (Neier & Stagl, 2021). Nonetheless, Renovate2Recover states that "Austria's existing renovation funding landscape is complex, with overlapping regional and national-level initiatives, but remains insufficient to reach government goals" (Renovate Europe, 2021a, p. 1).

The Spanish LTRS estimates that the renovation investment needed between 2020 and 2030 is about 41.5 billion €; private investment is supposed to provide 15.5 billion of the overall amount, while public funding will cover 2.6 billion (Renovate Europe, 2021c). Spain's NRRP lays out ambitious objectives for building renovation and allocates 11% (7.8 billion €) of its total NRRP budget (69.5 billion €) to renovations; specifically, it aims to fund 71,000 home renovations annually, surpassing the NECP goal of 50,000 dwellings between 2021 and 2026 (Renovate Europe, 2021c). Some programs determine the funding level of grants by household income and renovation depth and, for example, pay for 70-100% of the investment costs for energy-poor households (Renovate Europe, 2021c).

According to Romania's LTRS, the country needs 12.8 billion € to carry out the necessary renovations between 2020 and 2030; an additional 1 billion € will be required to pay for technical assistance costs (Renovate Europe, 2021b). Of the 12.8 billion €, the LTRS allocates 7.7 billion € to the residential building sector for multifamily dwellings and 3.2 billion € to single-family dwellings (Renovate Europe, 2021b). The Romanian NRRP has a total volume of 29.2 billion € and allocates almost 7.5% (2.2 billion €) to the 'Fund for the Renovation Wave', 1.1 billion € each to energy renovation measures in multifamily residential properties and public buildings (Renovate Europe, 2021b). There are no specifically-targeted measures to tackle energy poverty, but 20% of funding for multifamily house renovation is supposed to address houses occupied by vulnerable households (Renovate Europe, 2021b). Renovate Europe concludes that, despite earmarking significant amounts of funding to the Renovation Wave Fund, "a longer-term funding plan and further resources would be required to accelerate delivery at the necessary scale" (Renovate Europe, 2021b, p. 1). Furthermore, Romania receives funds from programs of the 2021-2027 Multiannual Financial Framework, including 26.8 billion € from the EU Cohesion Policy, and 1.9 billion € from the Just Transition Fund (Miu & Prantner, 2021). However, it remains unclear how much of these funds the Romanian government allocates to the Renovation Wave.

2.6 Socioeconomic context: Energy poverty

Energy poverty in the EU

There is no consensus about the definition of energy poverty, neither in political contexts nor in academia (Aristondo & Onaindia, 2018; Karpinska & Śmiech, 2020; Matzinger et al., 2018). As a result, there is "a lack of concrete measures and resources to address the issue" (Magdalinski et al., 2021, p. 12). However, energy poverty has recently gained more and more attention in the academic community (Karpinska & Śmiech, 2020; Matzinger et al., 2018). Scholars provide different interpretations of energy poverty as a concept. Bouzarovski (2007) describes energy poverty as fed by a "vicious circle [where] high running costs for domestic heating deprive[] [a] household of the monetary means for making the investment that would reduce the running costs in the first place" (Bouzarovski, 2007, p. 1919). Furthermore, Barrella et al. (2022) stress that energy poverty can also occur in the form of 'hidden energy poverty' which describes a situation in which vulnerable individuals restrict their energy consumption below their needs to lower their energy bills. While this dimension of energy poverty is often not reflected in policies and metrics (Barrella et al., 2022), the EU has considered it in the EU-

SILC data set. Focusing on the root causes of energy poverty, Magdalinski et al. (2021) claim that there are three main causes of energy poverty: low household income, high energy prices, and bad energy performance of buildings. Aristondo and Onaindia (2018) distinguish between energy poverty in the Global South and the Global North; while the prevalent problem in the former is the availability of energy carriers, the main issue in the Global North is the affordability of energy carriers. In Great Britain, the prevalent definition of energy poverty is a household spending more than 10% of their income on keeping their home adequately warm (Matzinger et al., 2018). While some experts appreciate that this definition provides a clear energy poverty threshold, others criticize that it makes energy poverty assessments too rigid (Matzinger et al., 2018).

This study relies on the definition of energy poverty by Matzinger et al. (2018).
Matzinger et al. (2018) present two energy poverty definitions that are derived from the two main strands of poverty reporting, i.e. at-risk-of-poverty and poverty by deprivation. Energy poverty is thus not only attributable to limited financial means but also to other household characteristics (Matzinger et al., 2018).

<u>Definition 1</u>: A household member is at-risk-of-energy-poverty if they also are at-risk-of-poverty (60% below median income, based on the at-risk-of-poverty indicator used by Eurostat) and struggle or are unable to use basic energy services in their home (basic services include domestic hot water, heating and electricity) (Matzinger et al., 2018).

<u>Definition 2</u>: A household member is energy poor if they are at-risk-of-energy-poverty and experience at least three of the seven disadvantages listed below, whereby at least one disadvantage from each category has to apply (Matzinger et al., 2018).

Category 1: Quality of living space and energy use
- poor quality of the living space (e.g., damp walls)
- energy access
- ability to keep the home adequately warm
- necessary electric devices (Matzinger et al., 2018)

Category 2: Energy costs
- high energy costs compared to other expenditures for basic needs
- debts concerning energy bills
- high energy costs compared to household income (Matzinger et al., 2018)

While this study and most other academic studies investigate energy poverty in the context of heating, recent research suggests that energy poverty will increasingly lead to insufficient cooling during hot temperatures (Karpinska & Śmiech, 2020). This is especially true in urban areas exposed to the so-called heat island effect (Karpinska & Śmiech, 2020).

The EC has identified energy poverty as a crucial issue and prioritizes energy retrofitting of energy poor households in numerous documents including the EU Green Deal, the Renovation

Wave, and many other recommendations and directives (Schneller et al., 2021). Thus, energy poverty is addressed across multiple levels of governance. While the strategy and agenda concerning energy poverty are set by the EU at the supranational level, the EU27 are responsible for the design and implementation of energy poverty policies (Noka & Cludius, 2021). To further address energy poverty in the EU context, the Union established the EU Energy Poverty Observatory (EPOV) in December 2016, a hub that regularly collects data and resources on energy poverty (EC, n.d.-d). Frans Timmermans, the EC's Executive Vice-President for the European Green Deal, has explicitly stated that "no-one will be left behind" (Portal et al., 2021, p. 6) on Europe's path to climate neutrality. However, some argue that, so far, the necessary instruments needed to alleviate burdens for low-income groups have not been delivered and non-governmental organizations, trade unions and academics have voiced concerns about the energy transition's social costs (Portal et al., 2021). Aggravating the problem of increased costs, low-income households also tend to inhabit most energy-inefficient homes, as research by *Vlaams Steunpunt Wonen* shows (Portal et al., 2021). Low-income households introduce fewer energy efficiency measures in their homes, whether those measures be costly building renovations or cheaper measures like energy efficient lightbulbs and other appliances (Oikonomou et al., 2022). Another effect of the worse housing conditions of low-income households compared to average-income households is that low-income households have to consume (and thus pay for) more energy to achieve an equal level of basic needs satisfaction (Oikonomou et al., 2022).[8]

Energy poverty affects EU Member States to different degrees and the share of population considered at risk of energy poverty differs significantly according to different Eurostat indicators (Braungardt et al., 2022). Generally, Eastern European post-communist countries are more affected by energy poverty than other European countries (Schneller et al., 2021).

Further, EU countries rely on different approaches to combat energy poverty, the choice of which is partly determined by a country's political culture (Magdalinski et al., 2021). Some EU Member States view energy poverty as a social issue and a subcategory of general poverty; these states include Denmark, Estonia, Finland, Germany, Luxembourg, the Netherlands, Slovenia, and Sweden (Magdalinski et al., 2021). In contrast, other states consider energy poverty to be both a social and an energy policy issue (Magdalinski et al., 2021). For example, Spain views energy poverty as a result of low income which can be exacerbated by poor energy performance in the home (Magdalinski et al., 2021). Because of these divergent approaches, EU Member States generally develop different policies. The Member States with a purely social approach mostly implement palliative measures such as social tariffs (Magdalinski et al., 2021). Countries belonging to the second group are more likely to invest in preventive measures, such as renovations improving energy efficiency (Magdalinski et al., 2021). For instance, Spain, Belgium, and France have implemented a mix of both approaches (Magdalinski et al., 2021).

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[8] Generally, low-income households generally consume less energy because they usually inhabit less floor space than households with average incomes or because they suffer from 'hidden energy poverty' (Oikonomou et al., 2022).

Energy Poverty in Austria, Spain, and Romania

Overall, households in Spain and Romania are more affected by energy poverty than households in Austria. In 2021, 1.7 % of the Austrian population reported that they were unable to keep their home adequately warm, which is less than the EU average of 6.9% (Eurostat, 2022h). The reported figures were significantly higher in Spain (14.2%) and Romania (10.1%) (Eurostat, 2022h). In the same year, 4.8% of the Austrian population were in arrears with regard to their utility bills, hire purchase or mortgage or rent because of financial constraints; while the corresponding shares for Spain and Romania were 14.3% and 9.4%, respectively (Eurostat, 2022a). The EU average was slightly lower at 9.1% (Eurostat, 2022a). Eurostat's expenditure-based indicators reveal information about potential 'hidden energy poverty' when a household's energy expenditure is unusually low (POEU, 2020). For this indicator, in 2015, the share of Austrian households stood at 15%, with that of Spanish households at 13%, and that of Romanian households at 16.9% (POEU, 2020). Furthermore, if a household spends a high share of its income on energy expenditure, this possibly points to poor energy efficiency in the home as well as budgetary burdens (POEU, 2020). In Austria, this was the case for 16% of the population in 2015, slightly below the EU average of 16.2%; in Spain, the figure was slightly lower at 14.2% and in Romania it was slightly higher at 16.8% (POEU, 2020). In contrast to Austria, where values of energy policy indicators have remained relatively consistent during the past decade, and Romania, where indicator values have improved, the share of the Spanish population unable to keep the home adequately warm increased by 5.2% between 2008 and 2014 to 11.1% (POEU, 2020). A likely cause is the 2008 financial crisis (POEU, 2020). After 2014, the share decreased again; however, since 2019, the values of energy poverty indicators have gone up once again, with Spain becoming the EU Member State experiencing the steepest rise of citizens being at-risk-of-energy-poverty in the last several years (Gumbau, 2022).

Depending on the housing ownership status, the percentage of households experiencing energy poverty varies. In Austria, those who inhabit houses they own themselves (55% of the total population) are not likely to experience energy poverty (POEU, 2020). In contrast, in 2017, the aforementioned Eurostat energy poverty indicators are higher than average for inhabitants of social housing (corresponding to 15 % of the Austrian population) (POEU, 2020). For people who rent privately (30% of the population), the indicators are slightly higher (POEU, 2020). In Spain, energy poverty is the most severe in the social housing sector, with 17.4% of inhabitants being unable to keep the home adequately home, followed by private tenants (POEU, 2020)[9][10]. The Romanian context does not follow the same pattern. Because of the extensive privatization of the building stock after the breakdown of the Communist regime, 94.7% of Romanians live in owner-occupied housing, one of the highest rates of all Member States (Government of Romania, 2020). Close to half of all dwellings (47.5%) are situated in rural areas with most dwellings being single-family buildings (Government of Romania, 2020). Accordingly, as opposed to Austria and Spain, a high number of Romanian low-income households are (single-family) house owners.

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[9] Figures refer to the year 2017.

[10] In 2017, 9% of the Spanish population lived in social housing, while 14% were private tenants (POEU, 2020).

The degrees of urbanization diverge in the three countries, corresponding to different levels of energy poverty in thinly, intermediary, and densely populated areas.[11] As of 2021, the highest share of the Austrian population lived in rural areas (38.8%), while 30.1% lived in towns and suburbs and 31% lived in cities (Eurostat, 2022c). In Spain, the share of the population living in rural areas is considerably lower at 13.1%, with more people living in towns and suburbs (31.3%) and cities (55.6%) as of 2021 (Eurostat, 2022c). In line with Austria, the highest share of the Romanian population (41.8 %) lived in rural areas as of 2021, while 28.2% lived in towns and suburbs, and 30% lived in cities (Eurostat, 2022c). Generally, Austrians living in urban areas are more likely to suffer from energy poverty, with the opposite being true for Spain and mixed results for Romania (POEU, 2020). Since 2012, Austrians from urban areas have been two to three times more likely to be unable to keep the home adequately warm; peaking at about 6.5% of the urban population in 2012 compared to 1.3% in rural areas (POEU, 2020). In contrast, in Spain, residents living in rural areas generally struggle the most to keep their homes adequately warm (POEU, 2020).[12] The 2018 results in Romania are mixed: while urban and suburban areas had higher shares of residents with arrears on utilities at 17.2% and 17.0% than rural areas (11.1%), more Romanians living in rural areas struggled with keeping the home adequately warm (11.5%), compared to 8.1% in urban and 7.7% in suburban areas (POEU, 2020).

Furthermore, Romania and Spain each have several distinctive features. In the case of Romania, a particular issue linked to the degree of urbanization is that urban areas usually have more detailed data on the existing buildings and household living conditions and more local funds, facilitating effective policymaking targeted at low-income households (Schneller et al., 2021). This may explain why Romanian programs that support energy efficiency renovations are largely targeted at multi-family houses in urban areas but seldom at single-family buildings in rural and suburban locations (Schneller et al., 2021).

Another particularity of energy poverty in the Romanian context is the presence of informal dwelling communities, often inhabited by marginalized groups like the Roma (Schneller et al., 2021). These communities, in many cases, do not have access to utilities; an estimated 420,000 households informally access the energy grid in Romania, resulting in losses for electricity providers (Schneller et al., 2021). Other fuels used in informal dwellings are of low quality and often include moist firewood, trash, or plastics, the burning of which has damaging consequences for both the natural environment and the inhabitants' health (Schneller et al., 2021). Another problem is that the extreme poor and other vulnerable groups often lack documents, such as ID or property documents, which hinders their access to the public energy grid (Schneller et al., 2021). Moreover, the connection costs for public energy grids amount to more than an average monthly income (Schneller et al., 2021).

Another distinctive feature of Romania, is the notably small useful floor area of dwellings, with over 63% of dwellings covering an area below 50 m^2 (Government of Romania, 2020). In other

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[11] In 2021, 39% of the EU27 population lived in cities, 26% lived in rural areas, and 35% lived in towns and suburbs (Eurostat, 2022c). Looking at income-related living patterns, 16.7% of the total EU27 population had an income below 60% of the median equivalized income, out of which most EU inhabitants lived in cities (6.4%), closely followed by towns and suburbs (5.6%), and rural areas (4.7%) (Eurostat, 2022c).

[12] The data is only referring to the years between 2010 and 2018.

EU countries, such as Spain, the Netherlands or Denmark, the share of dwellings of a similar size is below 5% (Government of Romania, 2020). The contrast between multi-family and single-family housing is strong: the average heated area of multi-family dwellings is 48 m^2, compared to 73 m^2 in single-family housing (Government of Romania, 2020).

Lastly, the Romanian median income is far below the EU average; accordingly, Romanians spend a higher share of their incomes on energy expenditure and are potentially more prone to suffering from energy poverty (POEU, 2020).

A particularity in the Spanish context is that, in 2019, the Spanish government approved a national strategy targeting energy poverty, the 'National Strategy Against Energy Poverty 2019 – 2024' (POEU, 2020). The strategy goes on to present the results of a comprehensive investigation into energy poverty in Spain and suggests that, depending on the chosen energy poverty indicator, between 3.5 and 8.1 million Spanish citizens are energy poor, corresponding to 7.4 % and 17.3% of the Spanish population (POEU, 2020). The overarching goals of the National Strategy Against Energy Poverty 2019 – 2024 is to lower the number of at-risk citizens by at least 25% by 2025 and aim for a 50% long-term decrease, facilitated through different energy saving measures and social policies (Gumbau, 2022). Even though the National Strategy Against Energy Poverty presented a rather high-level plan, it is considered highly relevant "for its formal recognition of the problem and for the framework it introduced to analy[z]e and monitor it" (Mastropietro, 2022, p. 2).[13]

2.7 Socioeconomic context: Socio-ecological benefits from renovation

Buildings with low energy efficiency are more likely to be occupied by lower-income residents who often struggle with high upfront costs of investing in better energy infrastructure (Schneller et al., 2021). Therefore, addressing these households specifically can lead to high energy savings as well as marginal cost savings compared to the residents' income (Schneller et al., 2021). Furthermore, Oikonomou et al. (2022) mark out four areas of co-benefits related to the Renovation Wave:

i) Reduced health costs due to an improved standard of living: the health costs to society of outdoor air pollution in Europe as a consequence of residential heating and cooking were 29 billion € in 2018 (Oikonomou et al., 2022). As high levels of outdoor air pollution can mainly be attributed to wood and fossil fuel burning, these health costs could be eliminated if heating would rely instead on renewable, non-biomass electricity and induction cooking (Oikonomou et al., 2022). Further, unhealthy indoor environments, such as underheated homes and those suffering from mold and damp, are common contributors to respiratory and cardiovascular diseases (Oikonomou et al., 2022). Thus, renovation also provides a huge potential to improve indoor air quality (Oikonomou et al., 2022). Additionally, being unable to keep a living environment adequately warm or cool can negatively affect the health of persons belonging to this household and a lack thereof can even lead to cold- or heat-related morbidity (Oikonomou

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[13] More information on the strategy is included in *Appendix 4*.

et al., 2022). From a gender perspective, women are disproportionately affected by adverse health impacts because they are more sensitive to extremely cold or extremely warm temperatures (Sánchez-Guevara Sánchez et al., 2020).

ii) Improved mental health: The energy poor suffer from a worse level of emotional well-being than the non-energy poor (Oikonomou et al., 2022). One possible reason for this is the negative effects on a resident's mental health if they frequently have to worry about covering arrears (Oikonomou et al., 2022).

iii) Improved social inclusion: Energy poverty often implies that an individual has relatively little disposable income, compared to other income groups (Oikonomou et al., 2022). This also has repercussions for a person's self-perception and social inclusion, as they may have difficulty paying for social events (Oikonomou et al., 2022).

iv) Employment generation: On average, 18 jobs are created for every 1 million € invested in buildings' energy retrofitting (Oikonomou et al., 2022). Investments in building retrofitting stimulate the EU's economy, particularly in the construction industry which produces 9% of European Gross Domestic Product (EC, n.d.-a). Importantly, Small and medium-sized enterprises (SMEs) generate about 70% of the value-added in the building sector which makes them a key beneficiary of an increase in building renovations (EC, n.d.-a). As the EU is still in the recovery process following the Covid-19 pandemic, the building sector can be key for boosting economic activity.

2.8 Socioeconomic context: Overview of literature on a socially just Renovation Wave

This literature review is not exhaustive, but it includes all publications by academic authors published online after January 2020 and before October 19, 2022, which mention the term 'Socially Just Renovation Wave' in the EU context. The reviewed publications were identified by searching for publications referencing the following terms or a combination thereof: "Energy poverty", "(EU) Renovation Wave", and "Just Transition".

The Institute for European Energy and Climate Policy (IEECP) published a report titled 'A Socially Just EU Renovation Wave'; it is the first research report that investigates the national-level impacts of EU building policies on the lowest income quintile groups (Oikonomou et al., 2022). Specifically, the report quantifies the impacts of three policies, proposed under the EU Green Deal, on low-income groups in ten European countries from 2019 until 2050 (Oikonomou et al., 2022). The ten countries include Member States that have historically suffered from a high share of energy poverty: Bulgaria, Czechia, Greece, Hungary, Italy, Poland, Portugal, Romania, Slovakia, and Spain (Oikonomou et al., 2022). The report concludes that a combination of the three policies will eventually lower energy costs for low-income households if households have their investment needs covered through public funding channels (Oikonomou et al., 2022).[14] In quantitative terms, the average reduction in energy costs of low-income households in the 2050 scenario compared to 2019 is 34% (Oikonomou et al., 2022). As a result, households will have a higher disposable income (Oikonomou et al., 2022). In turn, continuing with 'business as usual' will bear significant costs for low-income households (Oikonomou et al., 2022). Furthermore, the study finds that introducing the ETS2 without other building policies that push energy renovation and incentivize shifts to clean heating could have serious consequences for low-income households (Oikonomou et al., 2022). As there is no national-level data available on price elasticities of demand in low-income households (Oikonomou et al., 2022), their study is based on elasticities for average households. This approach is limited in its informative value because low-income households, due to their restricted disposable income, are not as able to change their heating behaviors when fossil fuel prices increase (Oikonomou et al., 2022). It is more difficult for them to pay for the upfront investment needed to make switches to more energy efficient and renewables-based energy consumption (Oikonomou et al., 2022). The results illustrate the urgency of making the Renovation Wave socially just: not acting at all will likely leave vulnerable households worse off than they are now (Oikonomou et al., 2022).

Focusing on the development of a normative framework for a just energy transition, von Platten et al. (2021) produce such a framework in the context of the Renovation Wave and rising economic inequalities. The framework is based on four principles: i) The equal treatment principle, ii) The priority principle, iii) The efficiency principle; and vi) The principle of procedural fairness (von Platten et al., 2021).

Another relevant publication is the presentation, given by Müller and Kranzl (2022) at the European Council for an energy-efficient economy (eceee), because it relies on the same database as the quantitative analysis of this thesis. However, the presentation was based on different data sheets than this study, limiting the comparability between the two. The authors conclude that renovating inefficient buildings in Austria would simultaneously achieve decarbonization goals and reduce energy costs for low-income households living in rented dwellings (Müller & Kranzl, 2022).

Further, a report published by the European Federation of National Organizations Working with the Homeless (FEANTSA) highlights successful examples of energy efficiency renovation targeted at vulnerable and low-income groups and suggests that both the Renovation Wave and the Just Transition Mechanism should enable more of the projects presented, as they believe energy poverty is not yet sufficiently addressed (Portal et al., 2021).

Lastly, Braungardt et al. (2022) analyze the Social Climate Fund (SCF) proposal, focusing on the implications for vulnerable households. They calculate investment needs for EU Member States for a full replacement of the existing fossil fuel heating systems with heat pumps, assuming that the SCF would cover 100% of the replacement costs for vulnerable households (Braungardt et al., 2022). The authors conclude that "incentivi[z]ing replacement of fossil fuel heating by renewable heating systems increases total support needs in the short term but is the right approach for a long-term impact on emission reductions, thus reducing the need for direct income support" (Braungardt et al., 2022, pp. 32–33). This is because, even in the most

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[14] The three policies include a phase-out of fossil fuel boilers, minimum energy performance standards for buildings and an emissions trading system for the building sector (Oikonomou et al., 2022).

optimistic scenario, where the full replacement would take 14 years, households would still require direct financial support to alleviate the cost burden of the ETS2 in addition to investment support during those years (Braungardt et al., 2022). At low CO2 prices, the authors find that the volume of the SCF is large enough to compensate low-income households for CO2 costs (Braungardt et al., 2022).[15]

Overall, the body of literature investigating a socially just implementation of EU renovation can be significantly expanded. The discussion part includes future research recommendations.

2.9 Renovation policies targeting vulnerable households

Targeted support for low-income households can lead to more of these households taking up subsidy funding (Oikonomou et al., 2022). Common programs supporting vulnerable groups with building renovations include one stop shops, low-interest rate loans, and specific renovation schemes (Portal et al., 2021). This review of policies for Austria, Spain and Romania is not exhaustive and summarizes findings from the EPOV.

In the Austrian case, most larger-scale energy poverty measures have been based on direct transfers to energy poor households, heating allowances during the winter months and free energy efficiency auditing (POEU, 2020).

Meanwhile, the EPOV lists eight Spanish policies that target energy poverty (POEU, 2020). Five directly address low-income and/or vulnerable households (POEU, 2020). However, only two of those policies rely on renovation measures to alleviate energy poverty: the 'Housing renovation program for vulnerable households' (2017) and the Law 8/2013 on building renovation that prioritizes energy efficiency measures for vulnerable households in serious cases of energy poverty (2013) (POEU, 2020). The other three policies aimed at vulnerable households are the Social Bonus for Electricity (introduced in 2009), the Social Bonus for Heating (introduced in 2018), and the Disconnection Protection Catalonia (introduced in 2015) (POEU, 2020).

Historically, energy poverty in Romania has been understood as a subcategory of overall poverty (Schneller et al., 2021). Accordingly, the go-to solutions to alleviate energy poverty have largely been utility bill support or direct financial transfers to vulnerable households coordinated through national-level policies, e.g. through the 'Social tariff' that 11% of Romanian households received in 2016 (Schneller et al., 2021; POEU, 2020). Furthermore, the Romanian government supports low-income households in the winter months through financial aid for heating (POEU, 2020). Also, the Romanian government has designed several programs to improve energy efficiency in private households; however, only one of them specifically targets energy poor households (POEU, 2020).[16]

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[15] A figure on *Average yearly support needs per MS including investment needs for heat pumps considering an exchange rate of 7%* is included in *Appendix 1*

[16] Schneller et al. (2021) have criticized the fact that the heating benefits discriminate against lowest-income households by providing different rates of assistance for different heating fuels (Schneller et al., 2021). Thus, the highest benefits from the financial assistance for heating are provided to households using gas or district heating, neglecting the extreme poor, who generally heat with solid fuel, electricity or wood (Schneller et al., 2021).

3. Methods

This section presents the research question and hypotheses, the data used, the development of different price scenarios and the analysis approach.

3.1 Research question and hypotheses

The aim of the research is to investigate socioeconomic effects which could occur in the context of the EU Renovation Wave by 2030.

Accordingly, the research question of this study is*: What are the socioeconomic effects of decarbonization-related household expenditure on low-income households in the EU-27?*

Based on the research question, this study puts forward two hypotheses:

Hypothesis 1: In 2030, low-income private households in all EU Member States will spend a larger share of their income on heating than high-income households.

Hypothesis 2: If EU Renovation Wave measures are implemented in dwellings inhabited by low-income households by 2030, then low-income households will spend a lower share of their income on heating.

This thesis investigates the research question using a quantitative approach (described below). Further, the study intends to highlight the diversity of the European landscape in the context of energy poverty. The research question is therefore further explored through three examples: Austria, Spain, and Romania. The country-specific contexts of these three EU Member States are presented in the literature review and provide insights into the different challenges and opportunities of the EU Renovation Wave across the EU. In addition, following a presentation of the quantitative findings for the EU27, the results section provides more detailed insights for Austria, Spain, and Romania. These three countries were selected for several reasons. First, the three examples represent different EU regions. Austria was chosen as a central European country, Spain as a Southern European country, and Romania as a country from the Eastern European region. Second, the three countries have different energy mixes in heating (→ *Literature Review*), influencing the development of heating costs leading up to 2030 under different renovation scenarios. Third, energy poverty concerns the three countries differently, with a greater effect on Romania and Spain than Austria (→ *Literature Review*).

3.2 Data

The analysis is based on two main data sources: the Invert/EE-Lab database (TU Vienna & e-think, 2015) and Eurostat data (Eurostat, 2022e, 2022f). The latter is based on two datasets, namely the European Union Statistics on Income and Living Conditions (EU-SILC) and European Community Household Panel (ECHP) (Eurostat, 2022e, 2022f). Furthermore, the analysis relies on four different price scenarios. This section first presents the data sources as well as price scenarios and then describes the analysis approach.

Data Source 1: Invert/EE-Lab - Modelling the energy demand for space heating and cooling in building stocks

The Invert/EE-Lab (TU Vienna & e-think, 2015) is a techno-socio-economic simulation tool that assesses the effects of different policy packages bottom-up on the total energy demand, CO2 reductions, energy carrier mix, and costs for space heating, cooling, hot water preparation and lighting in buildings. The database contains data for all countries in the EU28[17] and includes results regarding different scenarios of development in the building stock and its energy demand in the EU28 up to 2030/2050/2080 with various scenario assumptions (TU Vienna & e-think, 2015). Invert/EE-Lab has already been used in over 35 projects, including the development of national policy packages on the refurbishment of the European building stock (TU Vienna & e-think, 2015). However, none of these projects focused on energy poverty and all have in common that their focus was more technical rather than socioeconomic.

The building block of the database's methodology is a nested logit approach that optimizes objectives of 'agents' under conditions of imperfect information (TU Vienna & e-think, 2015). It thereby models the agents' decision-making with respect to renovation of the building stock and space heating, cooling and hot water systems (TU Vienna & e-think, 2015). More specifically, applying a Weibul distribution, buildings and components that need to be replaced or removed are identified (TU Vienna & e-think, 2015). Considering regional climate data, energy needs and final energy demand are determined through a standard static monthly balance approach (TU Vienna & e-think, 2015).

Standard outputs on an annual basis include for example: the installation of heating and hot water systems by energy carrier and technology (number of buildings, number of dwellings supplied), refurbishment measures by level of refurbishment (number of buildings, number of dwellings), total energy delivered by energy carriers and building categories (Gigawatt hour (GWh)), total energy needs by building categories (GWh), on-site generation of renewable energy (solar thermal, PV, ambient energy), and total investment (in million €) (TU Vienna & e-think, 2015).

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[17] Describes the EU27 including the United Kingdom

This study uses the following variables of the Invert/EE-Lab[18]:

- Country
- Area per dwelling in m^2
- Type of housing (e.g., single-family households in district heating)
- Construction period of a dwelling
- Final energy demand space heating 2030 in kwh/ m^2
- Final energy demand domestic hot water 2030 in kwh/ m^2
- Final energy demand space heating and domestic hot water in GWh 2030
- Energy carrier gas in GWh 2030
- Energy carrier heating oil in GWh 2030
- Energy carrier coal in GWh 2030
- Energy carrier wood in GWh 2030
- Energy carrier electricity in GWh 2030
- Energy carrier district heat in GWh 2030
- Cumulated investment in heat supply systems 2030 in €/ m^2.

All of these variables were considered for two scenarios: the baseline scenario (business-as-usual) and the alternative 1 scenario (Fit-for-55 goals are reached). All variables were compared for the years 2019 and 2030. The variable *cumulated investment in heat supply systems 2030* additionally includes data for the years 2020 and 2025.[19]

Data Source 2: EU-SILC and ECHP data (Eurostat)
Two Eurostat variables were used in the quantitative analysis. The first is the *Average size of dwelling by income quintile and tenure status* in m^2 for income quintile 1-5, based on data from 2012 (Eurostat, 2012). The second is the variable *Distribution of income by quantiles - EU-SILC and ECHP surveys* in € for the year 2021 (Eurostat, 2022b).

A private household describes a person who lives alone or a group of persons living together, sharing essential resources for living (Eurostat, 2022i). The statistical population of the EU-SILC data is made up of all private households and their members residing in the territory of an EU Member State at the time of collection of data, generally excluding individuals residing in institutions or collective households (Eurostat, 2021). To compile the annual national probability sample surveys, Member States can either use administrative data and/or national surveys (Eurostat, 2021).

In addition to quantiles, the variable *Distribution of income by quantiles* also includes data on quintiles and deciles. The values describe the top cut-off point for the annual income of the respective group (Eurostat, 2022i). 'Income' refers to the equivalized disposable income after social transfers (Eurostat, 2022i). Disposable income means the income after tax and other

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[18] All names of the variables, as used in the model, are listed in *Appendix 2*.

[19] Regarding investments in renovation, this study assumes that investment resources are freely available at the same conditions for all households. In reality, investments might be more costly for low-income households due to unequal access to the capital market, i.e. if they have to take out loans at higher credit rates (Müller & Kranzl, 2022).

deductions that is available to a person or household for saving or spending (Eurostat, 2021). For example, the top cut-off value x of the first income quintile indicates that 20% of the population live on an income of less than x € per year (Statistik Austria, 2022). The disposable income of a household includes the following: all income received through work (wages and earnings from self-employment), transfers between households, private income from property and investment, and all social transfers and benefits (including old-age pensions) (Eurostat, 2021). The total disposable income of a household is 'equivalized' to account for differences in household composition and size (Eurostat, 2022i). A household's income is equivalized by dividing the total disposable income of a household by OECD equivalization factors (Eurostat, 2022i). Eurostat uses the OECD modified scale, which assigns a weight of 1.0 to the first person aged 14 years or more, a weight of 0.5 to other persons aged 14 years or more and a weight of 0.3 to persons aged 0-13 years (Eurostat, 2022i).

Because the Eurostat data does not include any values for the fifth quintile, this study refers to the 9th decile value instead.

3.3 Price Scenarios

Four different price scenarios are applied to the calculations. The four scenarios are designed separately for each country, with prices given in €/kWh. Each price scenario includes six different prices for the following energy carriers: natural gas, heating oil, coal, electricity, wood, and district heat. Renewable energy carriers, such as solar, wind or geothermal carriers, are not included in the price scenarios because it is assumed that these energy carriers do not entail additional costs after their installation. The cumulated investment costs of the Invert/EE-Lab account for investment in renewable energy carriers and thus reflect the deployment of renewables. Therefore, an increased uptake of renewable energy carriers in heating is reflected in a decrease of fossil-based energy carriers in the final energy demand as well as improved energy efficiency levels.

The four scenarios include the following:

- Scenario A: 2021 prices
- Scenario B: 2022 prices
- Scenario C: 2021 prices (+30%)
- Scenario D: 2021 prices (+50%).

Scenario A reflects price increases that have occurred over the past years. Scenario B reflects the steep price surges following the Russian invasion of Ukraine. Scenarios C and D reflect possible future prices in comparison to pre-war prices. Because energy prices are likely to rise until 2030 due to factors such as resource scarcity and greenhouse gas emission taxation (for example, ETS2), comparing the results under the four price scenarios can provide valuable insights into future impacts on low-income households.

The prices for scenario A were compiled using the following sources

(i) Eurostat data for gas prices (nrg_pc_202) (Eurostat, 2022g), electricity prices (nrg_pc_204) (Eurostat, 2022d), and heating oil (EC, 2022a),
(ii) price calculations by the Öko-Institut e.V. for coal and district heating (unpublished), and
(iii) price calculations for wood by IEECP (Rogulj et al., 2022), with an additional calculation for the Austrian wood price based on Biomasseverband.at (Biomasseverband.at, 2021).

Where recognizable, prices reflect taxes and levies.
The prices for scenario B were compiled using the same sources as in Scenario A, except for the gas and electricity prices, which were retrieved from the Household Energy Price Index for August 2022 (Household Energy Price Index, 2022). The prices include taxes and levies for residential prices, but only report the prices recorded in capital cities, not the whole country. A full table of data sources and assumptions for the four price scenarios is included *in Appendix 3*.

3.4 Analysis approach

The quantitative analysis follows a seven-step approach. The goal of the analysis is to calculate heating costs for different income groups under different renovation scenarios until 2030. Moreover, the heating costs are compared to the annual incomes of the lowest income groups. Thus, the main variable of interest is the 'percentage of disposable income spent on heating'.

Step 1: As final energy demand values in Invert/EE-Lab data are disaggregated by construction period and type of housing, the first step is to calculate the average final energy demand in kwh/ m^2 for private households in each country for both the baseline and alternative 1 scenario. This is done through dividing the sum of the dwelling area of all dwellings by the sum of final energy demand of all dwellings in space heating and domestic hot water, respectively. The values of space heating and domestic hot water are added together to create the overall final energy demand in heating.

Step 2: Applying the same logic as in step 1, the average final energy demand for owners and tenants, living in either single-family housing or multi-family housing, is calculated.

Step 3: The results of step 1 and step 2 are combined with the values of the EU-SILC variable *Average size of dwelling by income quintile and tenure status*, disaggregated by income quintile 1 to 5. Results show the final energy demand of a household living in an average-sized dwelling for each of the five income quintiles. Moreover, the results indicate the different levels of final energy demand for owners and tenants living in single-family housing (SFH) or multi-family housing (MFH), respectively, for each income quintile.

Step 4: To calculate the share of each energy carrier of the total final energy demand, the final energy demand of each of the six energy carriers in GWh is divided by the overall final energy demand in GWh. This allows for an approximation of the energy mix in heating for the EU27.

Step 5: Combining steps 3 and step 4, the final energy demand of each income quintile group is broken down by energy carrier.

Step 6: The results of step 5 are multiplied with the prices from each of the four price scenarios, calculating the energy costs of each income quintile under the four price scenarios. To determine the total energy costs, the energy costs of all energy carriers per income quintile are summed up. The results of this step illustrate the total energy costs per income quintile, as well as energy costs differentiated by ownership status (tenant vs. owner) and building type (single-family housing vs. multi-family housing) per income quintile.

Step 7: To determine the investment costs of 'Fit-for-55'-compatible renovation for each income quintile, the investment costs indicated in the Invert/EE-Lab dataset (for both the renovation of heat supply systems and building envelopes) are multiplied with the data from the variable *Average size of dwelling by income quintile and tenure status.* The results demonstrate the average investment costs of heating-related renovations.

4. Results

The analysis investigates changes in heating expenditure relative to the total expenditure of private households under different price and renovation scenarios and contextualizes these findings with three examples: Austria, Spain, and Romania. The results demonstrate different socioeconomic effects of decarbonization-related household expenditure on low-income households in the EU-27 and generally support the hypotheses. In 2030, low-income private households in all EU Member States will spend a larger share of their income on heating than high-income households; and, if EU Renovation Wave measures are implemented in dwellings inhabited by low-income households by 2030, low-income households will spend a lower share of their income on heating. Each sub-chapter of this section includes a concise description and analysis of the results. The results are further contextualized in the discussion section.

4.1 EU-27

Heating costs in 2019 vs. 2030

Description

The two chart graphs (*Figure 3* and *4*) illustrate that building renovation in line with 'Fit-for-55' can decrease annual heating costs for low-income households. Renovation measures include the installation of energy efficiency appliances and the deployment of renewables. This relationship becomes particularly visible when comparing 2019 and 2030 heating costs (*Figure 3*).

Figure 3 Heating costs 2019 and 2030 in €/hh (quintile 1)

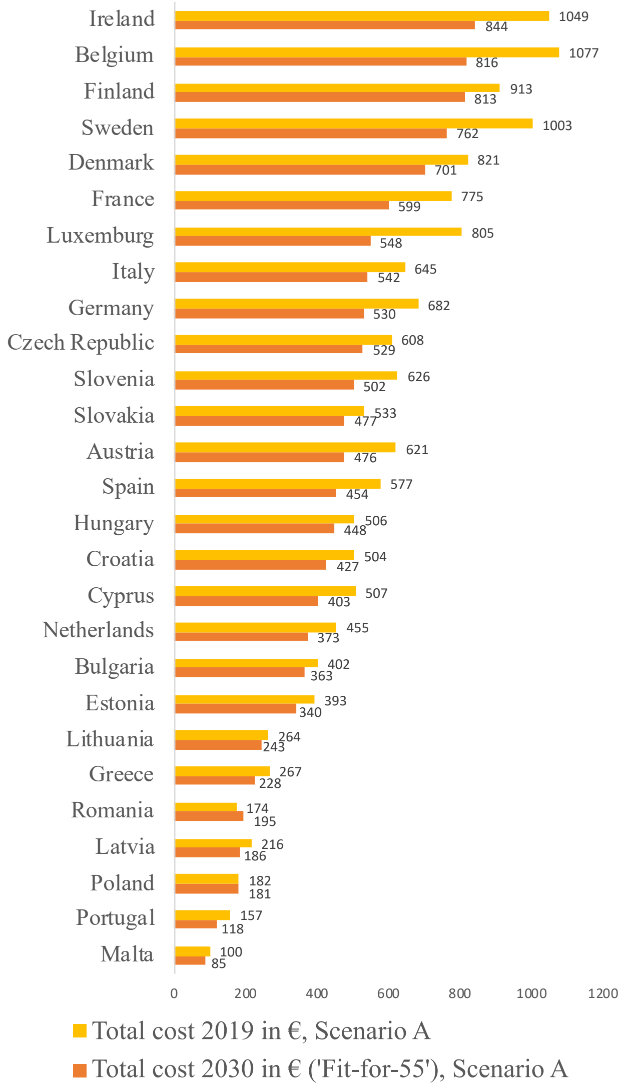


Fig.3: Own calculation based on (TU Vienna & e-think, 2015) and (Eurostat, 2012), hh=household

Compared with the heating costs of 2030 (Fit-for-55), the costs of 2030 (business-as-usual) decrease by a significantly lower rate (*Figure 4*). Generally, the results of both graphs exhibit a similar pattern of results: the higher the heating costs of a Member State, the larger the difference between the Member State’s 2019 and 2030 heating costs. Ireland, Belgium, and Finland have the highest heating costs in absolute numbers; Malta, Portugal and Poland have the lowest.

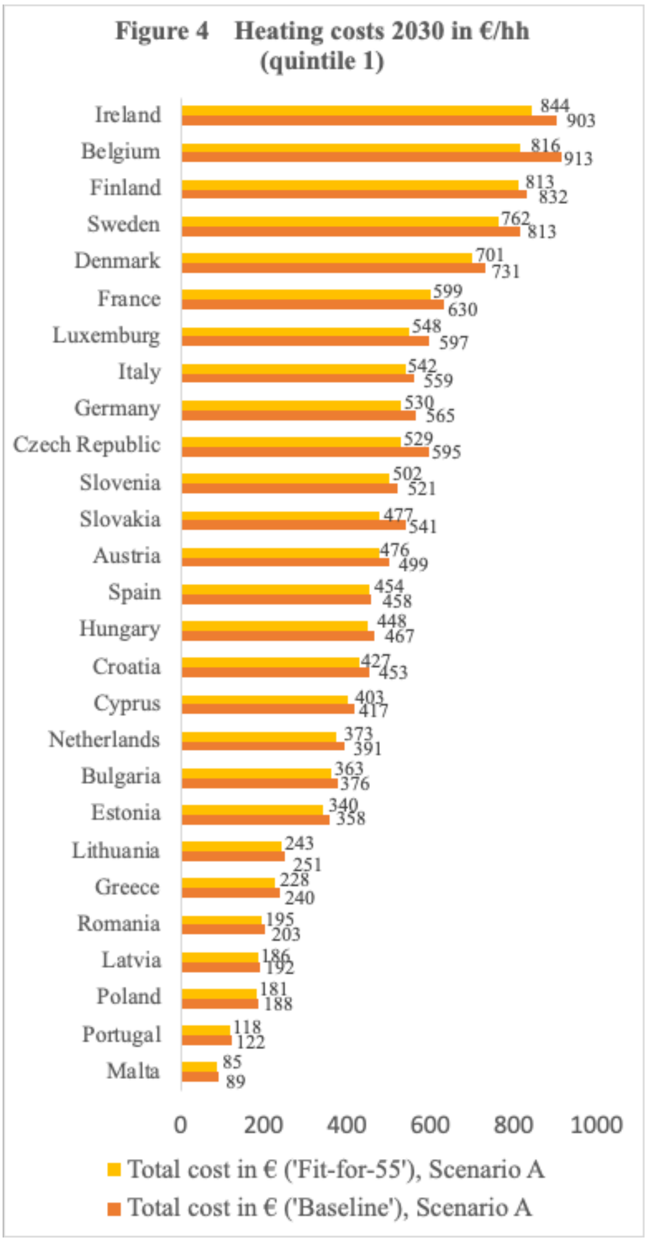


Figure 4 Heating costs 2030 in €/hh (quintile 1)

Fig.4: Own calculation based on (TU Vienna & e-think, 2015) and (Eurostat, 2012), hh=household

<u>Analysis</u>

Renovation can alleviate energy poverty under Fit-for-55.

In 11 countries, the costs can be reduced by more than 100 €. Considering the annual incomes of low-income households (Eurostat, 2022b), this can be assumed to alleviate the financial burden on low-income households significantly, especially from a long-term perspective. Following the underlying assumptions of the 'Fit-for-55' scenario in the Invert/EE-Lab, the improvement of energy efficiency in heat supply systems and the building envelope as well as the increase in renewables deployment lead to a lower final energy demand in 2030. However, the business-as-usual scenario also leads to a reduction in heating costs in 2030 compared to 2019. This finding is further contextualized in the discussion section.

The difference in heating costs between different countries can be partly attributed to different energy prices and meteorological contexts (POEU, 2020). For example, while Malta and

Portugal assumingly have relatively low heating costs due to a lower demand for heating, Poland has a higher final energy demand but comparatively lower prices.

Heating costs and low income under the 'Fit-for-55' scenario

Figure 5 Heating costs 2030 ('Fit-for-55') and percentage of income (quintile 1)

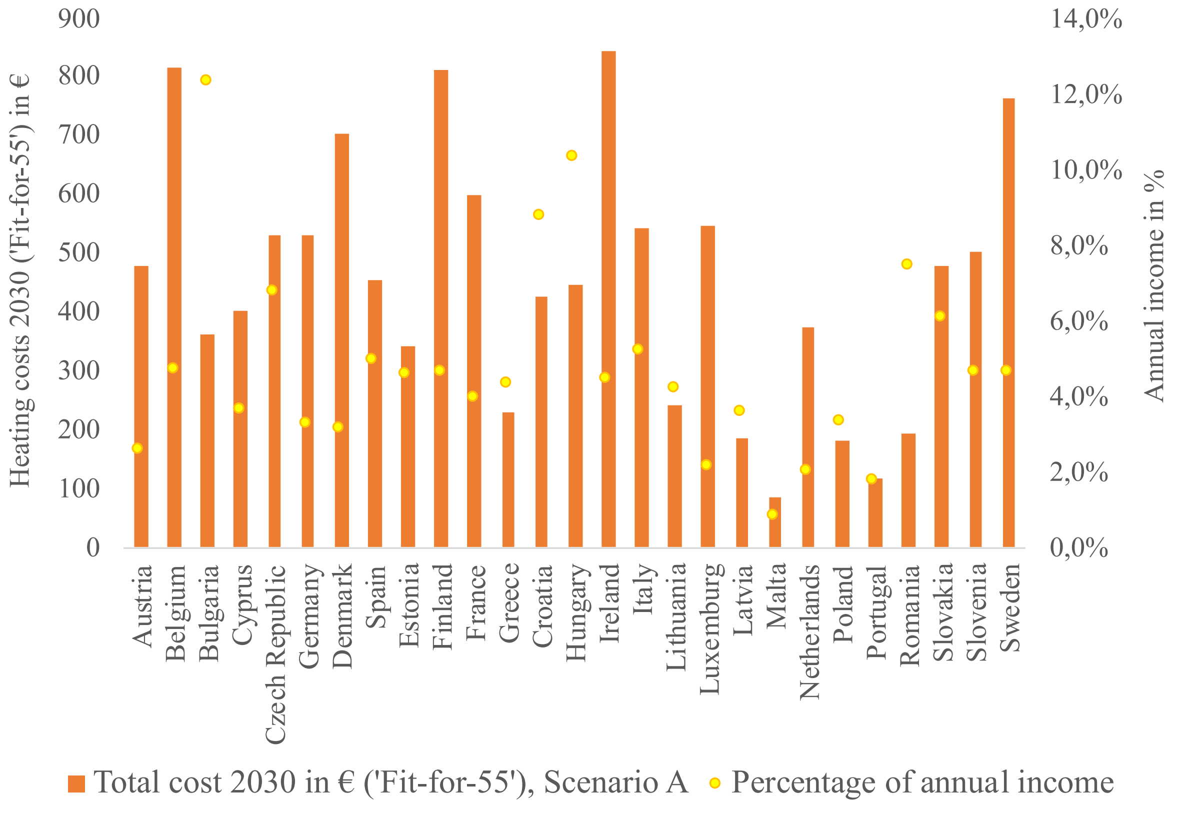


Fig. 5: Own calculation based on (TU Vienna & e-think, 2015), (Eurostat, 2012) and (Eurostat, 2022b)

Description

Low-income households in the following countries spend more than 6% of their annual income on heating: Bulgaria, Czechia, Croatia, Hungary, Romania, and Slovakia. Only Maltese low-income households spend less than 2% of their annual income on heating in 2030.

Surprisingly, even though Spain and Portugal experience similar weather conditions, Spanish households have to spend about twice as much of their income on heating as Portuguese households. Similar to Spain, the share for Italian low-income households is also slightly above 4%.

Analysis

Eastern European countries are disproportionately more at risk of becoming energy poor. However, considering the lower final energy demand in Southern Europe due to warmer temperatures, Italian and Spanish households must spend a surprisingly large share of their income on heating. This is in line with the findings on energy poverty in Spain presented in the literature review (POEU, 2020). Nonetheless, considering the income levels of quintile 1, even in countries that spend a relatively low share of their income on heating (e.g. Austria), these costs can be a considerable financial burden for low-income households (→ *Literature Review*).

Heating costs 2021 and 2022

Description

Figure 6 illustrates that the three lowest income quintiles in Eastern European states have to spend disproportionately more of their income on heating compared to other EU Member States. Accordingly, they are at a higher risk of energy poverty. With 2022 prices, the households in almost all EU Member States must spend about twice as much on heating compared with 2021 prices. In quintile 3, with 2022 prices, households have to spend similar shares of their income on heating as quintile 1 households with 2021 prices.

Figure 6 **Heating costs in percent of annual income**

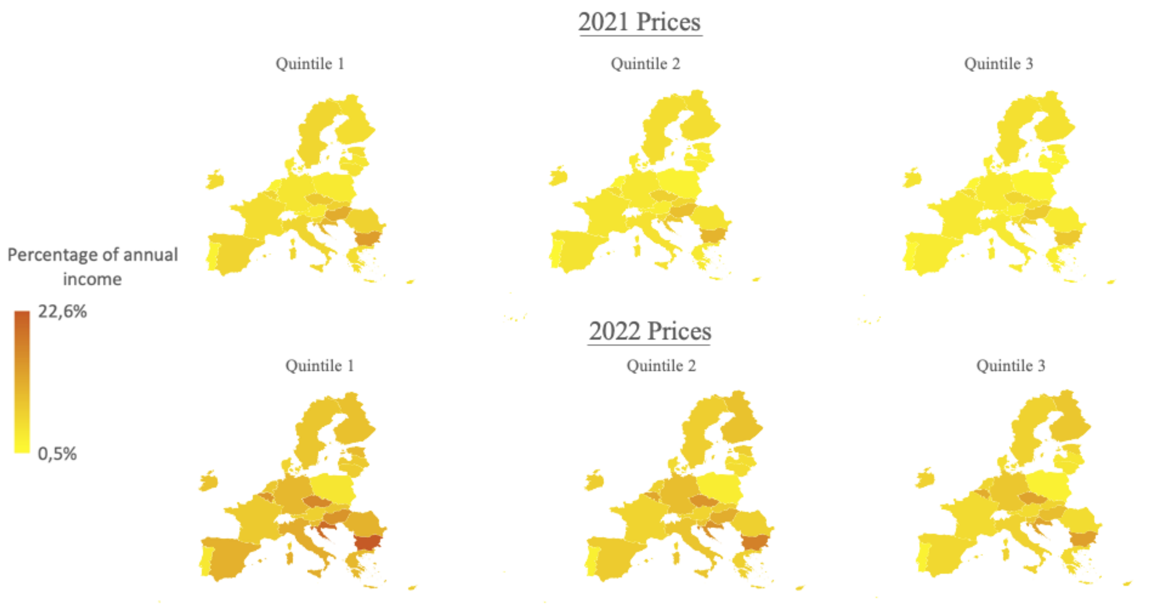


Fig. 6: Own calculation based on (TU Vienna & e-think, 2015), (Eurostat, 2012) and (Eurostat, 2022b)

Analysis

Figure 6 shows that the rising energy prices assumably increase the share of the population at risk of energy poverty. This rejects the notion that energy poverty only affects low-income households. However, comparability of the results across income quintiles is compromised as the same share of a household's income in quintile 3 is higher in absolute terms than the share of a household's income in quintile 1 in absolute terms. Thus, households in quintile 3 are not exposed to the same risk of energy poverty as households in quintile 1, even if they both spent the same share of their income on heating.

Description

Figure 7 visualizes significant price increases in 2022 compared to 2021. In 2022, the countries with the highest increase in heating costs are the Netherlands (by 313%), Germany (by 231%), and Belgium (by 226%). In the same year, the countries with the lowest increase in heating costs are Malta (by 114%), Hungary (by 130%), and Poland (by 130%). Scenarios C and D foreshadow that price increases by 30% and 50% from 2021 prices can have adverse effects for low-income households.

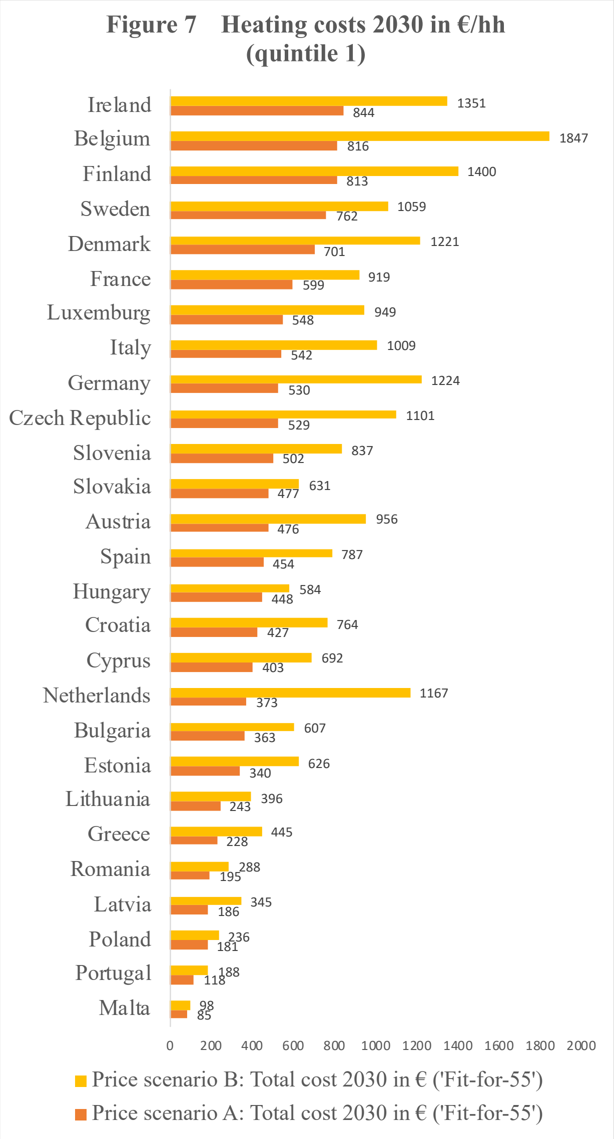


Figure 7 Heating costs 2030 in €/hh (quintile 1)

Fig. 7: Own calculation based on (TU Vienna & e-think, 2015) and (Eurostat, 2012)

Analysis

As in the previous illustrations, it can be assumed that the price hikes for energy in 2022 increase the risk of energy poverty across the EU27.

4.2 Austria, Spain and Romania

The three country examples (Austria, Spain, and Romania) explore the different socioeconomic landscapes in the context of a socially just renovation wave across the EU.

Distributional effects

Description

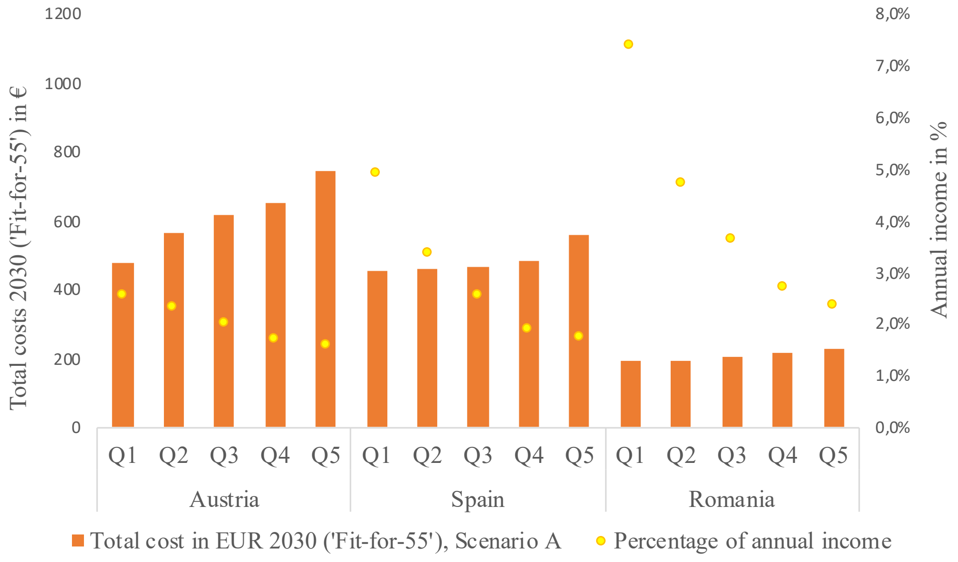
Compared to Austria and Spain, low-income households in Romania must contribute a significantly larger share of their income to heating expenditure than higher-income quintiles like quintiles 4 and 5 (*Figure 8 and 9*).

Analysis

The distributional effect is progressive for households in Austria and Spain, but slightly regressive in Romania.

In Austria, the lowest-income quintile must spend a smaller share of their overall income on heating compared to the highest-income quintile. Quintile 1 households spend 0.6% less of their income on heating in 2030 ('Fit-for-55') compared to 2019. Quintile 5 households spend 0.4 % less of their income on heating in 2030 ('Fit-for-55') compared to 2019.

Figure 8



Heating costs 2030 ('Fit-for-55') in € (all quintiles)

Fig. 8: Own calculation based on (TU Vienna & e-think, 2015), (Eurostat, 2012) and (Eurostat, 2022b)

In Spain, quintile 1 households spend 1.4% less of their income on heating in 2030 (Fit-for-55) compared to 2019, while households belonging to quintile 5 spend 0.5% less of their income on heating in 2030 ('Fit-for-55') compared to 2019.

In contrast, Romanian quintile 1 households spend 0.8% more of their income on heating in 2030 (‘Fit-for-55’) compared to 2019. Romanian quintile 5 households also spend more on heating in 2030, but the increase is not as pronounced (+0.2%). This divergence from the progressive effects in the other two countries is explained in the discussion.

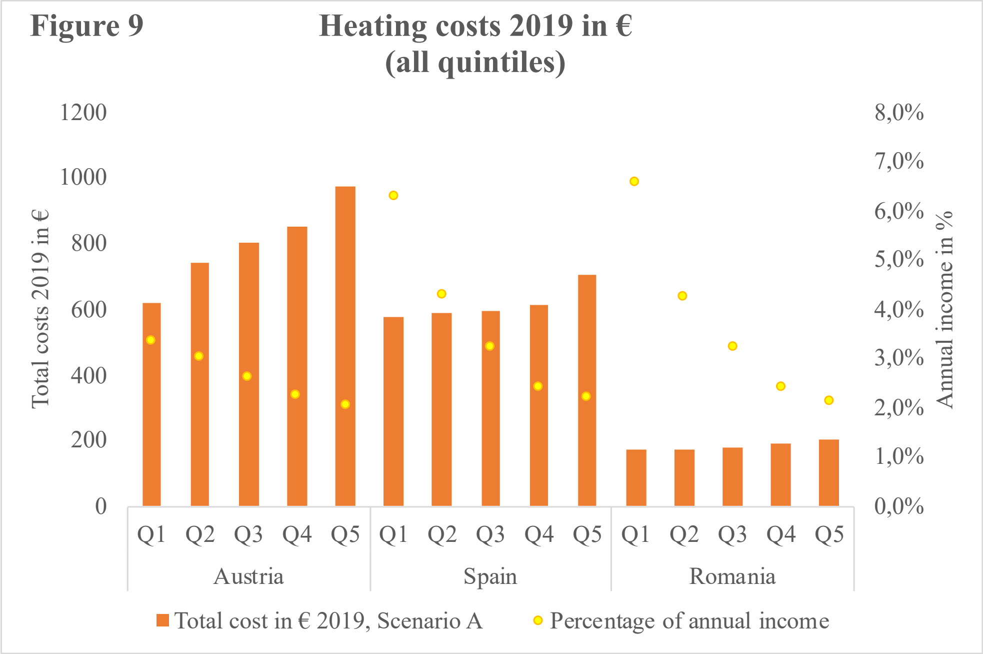


Fig. 9: Own calculation based on (TU Vienna & e-think, 2015), (Eurostat, 2012) and (Eurostat, 2022b)

Final energy demand by energy carrier

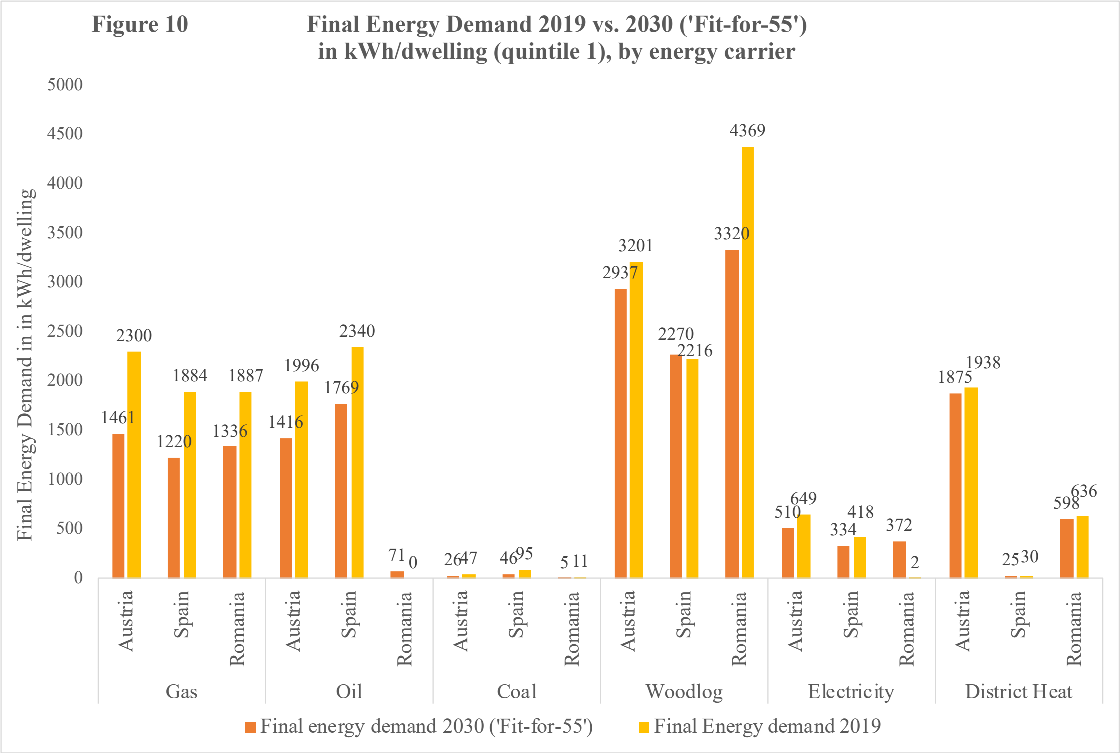


Fig. 10: Own calculation based on (TU Vienna & e-think, 2015) and (Eurostat, 2012)

Description

Gas, oil and wood are important energy carriers in all 3 countries. In Austria, district heat is also one of the most important energy carriers. The final energy demand of almost all energy carriers decreases in 2030 compared to 2019. The most significant demand reductions occur for gas (in all three countries), oil (in Austria and Spain) and wood (in Romania).

Analysis

Following the underlying assumptions of the 'Fit-for-55' scenario in the Invert/EE-Lab, both the improvement of energy efficiency in heating supply systems and the building envelope, and the deployment of renewables decrease final energy demand by 2030 in all countries except Romania.

Tenants and Owners

Description

Owners pay more than tenants for heating. Owners in SFH have even higher heating costs than owners in MFH, while tenants in SFH have higher heating costs than tenants in MFH.

Analysis

The literature review describes the different contexts regarding rural and urban living conditions in the three countries. In Austria and Spain, people who live in social housing or are tenants are more likely to suffer from energy poverty *(→ 2.6*). It can further be assumed that people living in social housing are less likely to inhabit SFH. In contrast, Romania has a high percentage of homeowners that live in single-family detached households located in rural areas, particularly exposing this group to the highest heating costs (SFH and Owner) (Schneller et al., 2021). Therefore, based on the Member State, the quantitative findings have different socioeconomic implications.

Figure 11

Heating costs 2030 ('Fit-for-55') in € by type of housing ownership

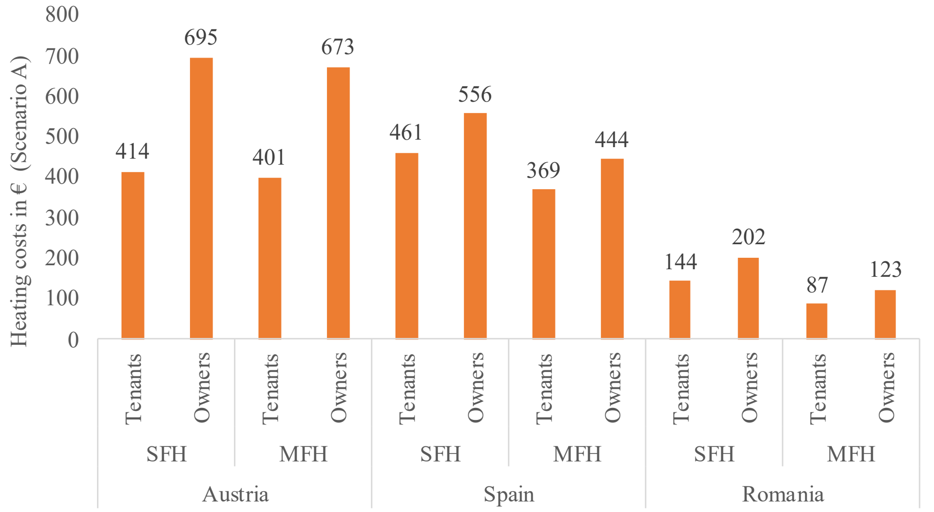


Fig. 11: Own calculation based on (TU Vienna & e-think, 2015) and (Eurostat, 2012) SFH=Single-Family Housing; MFH=Multi-Family Housing

Investment costs

Investment costs included in this analysis only consider investment costs related to the replacement of fossil-based heat supply systems with those proposed under ‘Fit-for-55’. It does not consider investment costs related to the building envelope. The investment costs are differentiated by three construction periods of the dwellings: 1880-1968, 1970-2000, and 2000-2030.

Figure 12

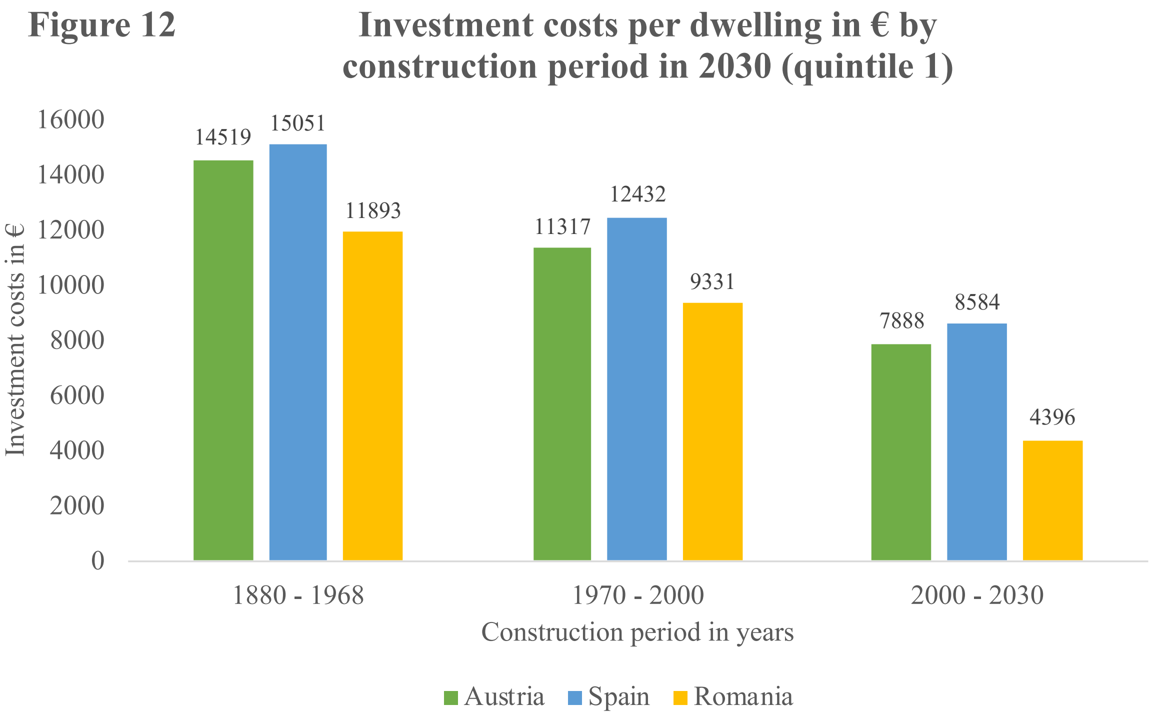


Fig. 12: Own calculation for scenario ‘Fit-for-55’, based on (TU Vienna & e-think, 2015) and (Eurostat, 2022b)

Description

In Spain, renovations are the most expensive, closely followed by Austria. Moreover, the investment needs between buildings from different construction periods vary considerably in all three countries. Dwellings constructed between 2000 and 2030 require about half of the investments required for dwellings that were constructed between 1880 and 1968.

Analysis

Considering the top cut-off points for annual incomes in quintile 1 (Austria = 18,647€, Spain = 9,216€, Romania = 2,646€) (Eurostat, 2022b), the results demonstrate that up-front investments like renovations are highly difficult for low-income households to undertake, regardless of the year in which the dwelling was built.[20] In comparison, quintile 5 households are confronted with higher costs for dwellings constructed between 1880 and 1968 (Austria = 22,691€, Spain = 18,440€, Romania = 14,058€), but also have a considerably higher income (Austria = 47,574€, Spain = 32,059€, Romania = 9,842€) (Eurostat, 2022b).

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[20] As the data base includes subsidies data for Austria, the costs for Spain and Romania might be overestimated.

5. Discussion

The discussion is divided into four parts. The first part discusses unexpected results of the analysis and the second compares the main findings to previous research. The third part then describes limitations of the analysis. Lastly, the discussion concludes with recommendations for future research.

Unexpected results

One unexpected result of the analysis regards the distributional effects of renovation (→ *4.2.1 Distributional effects*), demonstrating that Romanian households will experience regressive distributional effects. In contrast, other countries show progressive distributional effects. The divergence in the Romanian context can be explained by the comparatively high price of electricity in Romania in 2021. Electricity costs 15.7 €cents/kWh, while gas costs 3.4 €cents/kWh and wood costs 2 €cents/kWh. Overall, and in line with findings for the other countries, the results show that final energy demand in Romania decreases by 1,203 kWh in 2030 compared to 2019 (from 6,905 kWh to 5,702 kWh). Accordingly, the results suggest that renovation can prevent even stronger increases in heating costs by 2030.

Another unexpected finding is that the business-as-usual scenario, just like the 'Fit-for-55'-scenario, leads to a reduction in heating costs. Possibly, the assumptions in the Invert/EE-Lab model include that energy efficiency appliances become more efficient over time, and that rising temperatures lower the final energy demand for heating. However, further research is needed to identify the exact reasons for the reduction.

Comparison to previous research

As mentioned in the literature review, the only publication that has undertaken similar research is the report titled 'A Socially-Just EU Renovation Wave' (Oikonomou et al., 2022). Generally, the study by Oikonomou et al. and this thesis reach the same conclusion: renovations in line with 'Fit-for-55' can alleviate financial burdens for low-income households. However, while the projections for heating costs and final energy demand are similar in both studies for the case of Romania, the results for Spain show more divergence.

For Romania, the study by Oikonomou et al. (2022) calculates an annual final energy demand of 8,302 kwh/low-income dwelling, while this study determines the demand to be lower at 6,905 kwh/low-income dwelling. For 2030, the most ambitious policy scenario[21] of the study by Oikonomou et al. (2022) indicates that the final energy demand is reduced by 1,425 kWh/low-income dwelling to 6,876 kWh/low-income dwelling. In comparison, this study finds that the final energy of Romanian low-income households decreases by 1,203 kWh to 5,702 kWh/dwelling, under the 'Fit-for-55' scenario. The heating costs in 2030, according to the publication by Oikonomou et al. (2022), are 279 €/low-income dwelling. In contrast, this study calculates slightly lower heating costs of 195 €/low-income dwelling for Romania. For Spanish

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[21] ETS2 price, mandatory phase out of heating oil and solid fossil fuels in 2030 as well as natural gas in 2040, and establishment of MEPS for achieving energy class E in 2035 with 75% of total low-income households renovating until 2030

low-income households, both studies estimate a similar reduction of final energy demand following renovations but base their research on different levels of final energy demand. The analysis by Oikonomou et al. (2022) estimate a reduction of 824 kWh to 2,240 kWh/low-income dwelling in 2030, while this study calculates a decrease of 1,318 kwh to 5,664 kWh/low-income dwelling. Accordingly, the heating costs calculated differ significantly for 2030 (Oikonomou et al.: 252 €; this study: 454 €). Further, the estimated savings potential compared to 2019 is greater in this study (123 €) than in the publication by Oikonomou et al. (2022) (20€).
These divergences can potentially be explained by different approaches used to determine the final energy demand of low-income households. This study bases the final energy demand on the average size of dwelling per income quintile. In contrast, Oikonomou et al. (2022) determine final energy demand by estimating how much less energy low-income households consume compared to average households.

Overall, both studies provide valuable insights into an under-analyzed field of policy research, and each have different advantages. Advantages of the research by Oikonomou et al. (2022) include the coverage of different policy scenarios and the embeddedness of the quantitative findings in a comprehensive policy analysis. The advantages of this study are its up-to-date price scenarios and its more technical focus, which allows for differentiation by the construction period of dwelling, ownership status and type of housing (SFH and MFH). Moreover, this study provides cost calculations for all five income quintiles, not just low-income households, which makes it possible to identify progressive and regressive distributional effects. Future research should aim at combining both approaches.

Limitations

This thesis has seven limitations.

One limitation of this analysis is that the results only refer to heating costs and do not include electricity costs, cooling costs and other costs contributing to a residential household's energy bill. This weakens the comparability of the results with other research on energy poverty that focuses on more than just heating. Nonetheless, it still makes sense to perform separate calculations for both heating and cooling to be able to account for increasingly extreme temperature differences in some countries.

Another limitation of this study is that the Invert/EE-Lab data only provides average values per dwelling, regardless of the energy efficiency status. Therefore, it is not possible to assess how heating costs change if a household lives in a renovated dwelling. Accordingly, the 2030 Fit-for-55 scenario of the Invert/EE-Lab assumes that all energy efficiency improvements and deployment of renewables are evenly distributed across all households in a country. Moreover, even though investment costs can be distinguished by construction period and type of household, the values only indicate the average investment per dwelling, i.e., the investment needed within a country divided by all existing dwellings. In reality, the difference in heating costs between those who live in a recently renovated dwelling and those who do not, as well as their respective income levels, can be assumed to be even more stark. Nevertheless, this analysis provides important insights for energy poverty research by demonstrating trends in heating cost burdens and how they differ among EU Member States.

The structure of the Invert/EE-Lab data presents another limitation. The results of this study imply both an increased uptake of renewable energy carriers and improved energy efficiency levels under the 'Fit-for-55' scenario. This is due to the underlying assumption of the Invert/EE-Lab that the 'Fit-for-55' goal is reached through more renewables usage and higher energy efficiency. However, as renewable energy carriers are not included in the dataset, the analysis cannot provide a detailed assessment of how much the reduction of final energy demand in fossil-based energy carriers is attributable to increased renewables deployment or to increased energy efficiency levels.

Furthermore, costs by income quintile are calculated based on the final energy demand per m^2, assuming that all residents use the same amount of energy per m^2 of floor area. This approach omits the impact of 'fixed costs' for heating that do not necessarily depend on floor space, for example a connection fee to grid access. Moreover, costs may vary significantly between different households belonging to the same income quintile, depending on how much their floor space diverges from the average. The analysis also does not quantify the final energy demand for different household compositions such as 'one adult and two children' or 'adult living alone'.

Another limitation is that this thesis only investigates one dimension of energy poverty with respect to the energy poverty definition of Matzinger et al. (2018), that being the level of heating costs in relation to household income. Other dimensions as presented by Matzinger et al. (2018), such as poor quality of living space, energy access, or debts concerning energy bills, and the interrelations between these dimensions, are not taken into account.

The sixth limitation concerns the treatment of household income in this study. A downside of subdividing income groups into quintiles is that income disparities within one quintile cannot be acknowledged. Especially in the lower income quintiles, this proves problematic due to large income disparities. For example, the top cut-off point of annual incomes for the first decile in Austria is 14,140 €, while the top cut-off point for the second decile is 18,647 € in the same year (2021) (Eurostat, 2022b). Therefore, households belonging to the first decile must spend a significantly larger share of their annual income on heating. Furthermore, Eurostat data is only available for the top cut-off point for each income group and does not indicate the mean income of an income quintile (Eurostat, 2022b). Consequently, the results presented in this publication are likely to underestimate adverse effects on low-income households. Lastly, the reported income levels used in this study are from the year 2021. It can be assumed that income levels nominally increase until 2030 due to inflation dynamics and corresponding wage increases. Thus, it is possible that the percentage of income spent on heating in 2030 is overestimated in this study.

Finally, another limitation is that EU households living in informal communities are not sufficiently reflected in the data used. Because they often do not consume energy through conventional channels (Schneller et al., 2021), it can be assumed that these communities are not sufficiently included in data collection processes. Future research should seek ways to better include informal communities in data collection.

Recommendations for further research

Most data used in the context of energy poverty research is part of Eurostat and is usually connected to the variables 'ability to keep home adequately warm' and 'arrears (mortgage or rent, utility bills or hire purchase)'. Through the quantitative analysis of this study, several data gaps have been identified. These gaps make it difficult to assess and guide the implementation of a socially just Renovation Wave. Hence, a number of recommendations for future research are given.

First, this thesis proposes several new data variables for the Eurostat database.
It would be valuable to have a variable noting 'construction period of dwelling/energy efficiency standard by income group' to better assess the final energy demand and investment gaps for different low-income households. This would prove helpful in ameliorating policy effectiveness, for example when allocating investments financed through the Recovery and Resilience Facility or the SCF.
Equally important would be the collection of country-specific prices for different energy carriers and prices for heating as well as cooling. Thus far, only natural gas, electricity and heating oil prices are included in the Eurostat database. However, it is likely that the high volatility of energy prices will continue in the upcoming years and that fossil-based energy carriers will become even more expensive after the introduction of the ETS2. Therefore, a regular collection of price data by Eurostat would guarantee that research relying on energy price data exhibits a high level of comparability and can support sound policymaking. It is especially important to collect price data for district heating, based on renewable or non-renewable energy carriers, and for coal, as it is another fossil fuel carrier. Moreover, the collection of disaggregated data on prices for biomass and renewable energy carriers would also prove invaluable for future research. It is crucial that biomass and renewables are not subsumed under the same category because the burning of biomass as an energy carrier can have detrimental environmental consequences (Pearce, 2015).
Another recommendation addresses the collection of EU-SILC data on income quintiles. Thus far, EU-SILC data only includes either the mean income per country, without subdividing by income group, or the top cut-off number for each income group without including the mean or median value. This makes it challenging to assess the impact of measures on particularly vulnerable households.

Furthermore, future data collection and research could focus on the following:

The elasticity of demand, also in view of 'hidden' energy poverty, deserves more attention in order to make future research more precise. Oikonomou et al. (2022) establish that no national-level data is available which covers low-income households' price elasticities of demand. Yet, following the war in Ukraine and rising energy prices, elasticity of demand is likely to vary significantly between different income groups.

The results on potential investment costs in ‘Fit-for-55’-related renovation indicate that low-income households are faced with significant investment requirements. Considering that the ETS2 is supposed to be uniformly applied across all EU Member States, including in states that suffer from higher energy poverty levels than others, it is essential that low-income households receive the necessary financial resources to not be left behind. Braungardt et al. *(→ literature review)* have demonstrated that in principle, the SCF volume is sufficient to cover both investment costs for heat pumps and direct income support in the transition period. Moreover, Braungardt et al. (2022) stress that the SCF “needs to provide a strong framework […] [and] […] needs to provide clear criteria to operationalise vulnerability and to ensure that funding is directed at [vulnerable] households“ (Braungardt et al., 2022, p. 7), further suggesting that operationalization should take place at the national level. For monitoring and policy planning purposes, the Invert/EE-Lab database provides a good basis and should be expanded with data on subsidies in the EU27 to produce more accurate investment cost calculations.

Similarly, it is crucial to collect regularly updated data on subsidy schemes for renovation in different EU countries and information on who profited from these subsidies. Collecting this data will likely be part of the monitoring activities accompanying the Social Climate Fund. When the data collection process is being designed, it is key to ensure that socioeconomic criteria, such as income groups, are sufficiently considered. To signal the importance of connecting technical with socioeconomic data, the EU can hand out research projects, for example in the context of the Energy Poverty Observatory. Additionally, future research should monitor the state of measures addressing energy poverty more closely. Thus far, publications from the Energy Poverty Observatory or the Green Recovery Tracker often highlight best practice cases but do not present a comprehensive overview of all measures. Therefore, it is challenging to understand the state of play, identify funding streams (both EU and national) and evaluate how much funding is allocated to short-term versus long-term measures. The creation of the Energy Poverty Observatory demonstrates that the EU regards energy poverty as a defining issue on Europe’s path to climate neutrality; it is important to seize this opportunity to make the observatory more comprehensive well ahead of 2030.

6. Conclusion

In conclusion, the results demonstrate the following: In 2030, low-income private households in all EU Member States will spend a larger share of their income on heating than high-income households; and, if EU Renovation Wave measures are implemented in dwellings inhabited by low-income households by 2030, low-income households will spend a lower share of their income on heating. This thesis successfully responds to an existing research gap by analyzing the distributional effects of reaching the Renovation Wave’s 2030 goals in the EU27 countries, based on data from Invert/EE-Lab and Eurostat. The quantitative findings are further contextualized with three examples: Austria, Spain, and Romania.

The results comparing heating costs between 2019 and 2030 under the ‘baseline’ and ‘Fit-for-55’ scenarios show that building renovation in line with ‘Fit-for-55’ can decrease annual heating costs for low-income households. Under ‘Fit-for-55’ the costs can be reduced by more than 100 € in 11 countries. The difference in heating costs between different countries can be attributed to different levels of final energy demand, as well as diverging meteorological contexts and energy prices. Moreover, the results show that citizens in Eastern European countries are disproportionately more at risk of becoming energy poor. However, considering the lower final energy demand in Southern Europe due to warmer temperatures, Italian and Spanish households must spend a surprisingly large share of their income on heating. Furthermore, it can be assumed that the rising energy prices considerably increase the share of the population at risk of energy poverty, also affecting higher income quintiles. Also, the results indicate that distributional effects under the ‘Fit-for-55’ scenario are progressive for households in Austria and Spain, but slightly regressive in Romania. This can be explained by the comparatively high price of electricity in Romania in 2021. The results regarding energy carriers show that the final energy demand of almost all energy carriers decreases in 2030 compared to 2019. The most significant demand reductions occur for gas (in all three countries), oil (in Austria and Spain) and wood (in Romania). Looking at ownership structures, owners generally have higher heating costs than tenants and owners in single-family housing have higher heating costs than owners in multi-family housing. Finally, the results indicate that renovations in Spain are the most expensive, closely followed by Austria. Dwellings constructed between 2000 and 2030 require about half of the investments required for dwellings that were constructed between 1880 and 1968.

One recommendation for Eurostat data is to include information on construction periods of dwellings and energy efficiency standards by income group in order to better assess the final energy demand and investment gaps for different low-income households. Another recommendation is to collect information on country-specific prices for different energy carriers and heating costs. Furthermore, this study recommends a more detailed data collection on income. General research recommendations include to further investigate the elasticity of demand to make future calculations more precise and to perform better monitoring of subsidies and policies addressing low-income households beyond ‘best practice cases’ across EU Member States. Finally, more research is needed on ETS2 implications for low-income households. The Invert/EE-Lab database provides a good basis for further research in this field.

Overall, this thesis concludes by arguing that well-targeted policies, taking into account technical aspects of the building stock in combination with socioeconomic criteria, will be crucial in order to achieve a socially just EU Renovation Wave by 2050.

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8. Appendix

Appendix 1

Figure 16 **Average yearly support needs per MS including investment needs for heat pumps considering an exchange rate of 7%**

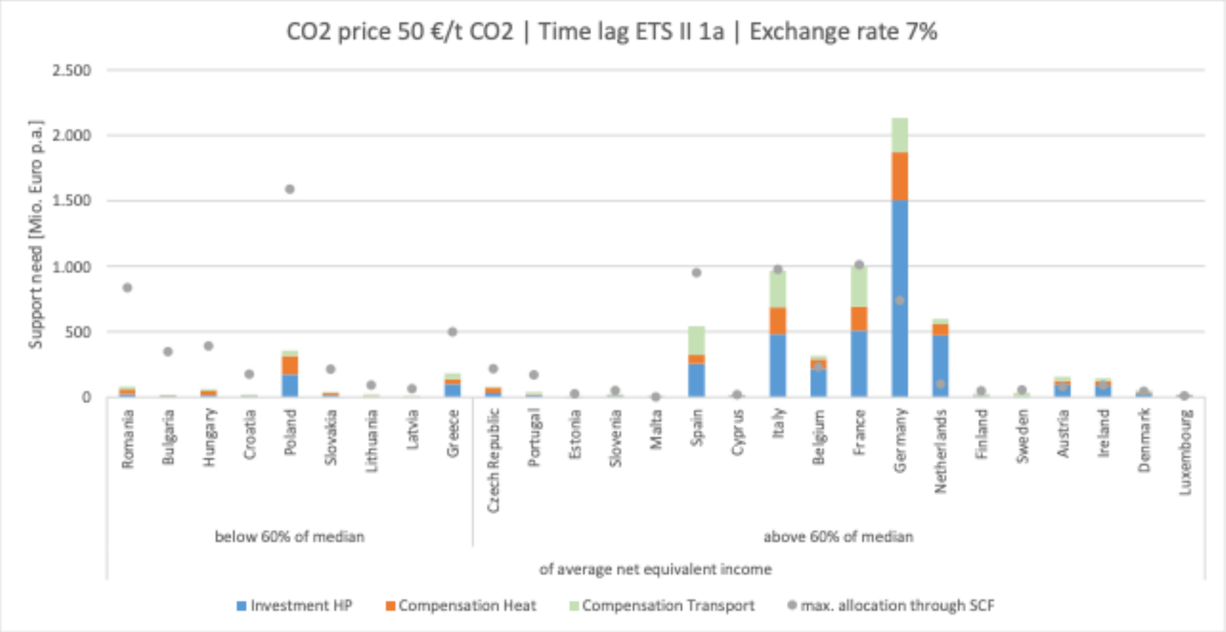

Figure by (Braungardt et al., 2022)

Appendix 2

List of variables used from data source 1

All variables were considered for two scenarios: The baseline scenario (business-as-usual) and the alternative 1 scenario (fit-for-55 goals are reached) for the years 2019 and 2030, respectively. The variables related to values of cumulated investment additionally include data for the years 2020 and 2025.

Variable name	**Description of variable**
country_name	Country
aream2_2030	Area per dwelling in m^2
bcat_name	Type of housing, e.g. Single-Family households district heating
constrperiod	Construction period of dwelling in year
fed_shkwhm2_2030	Final Energy Demand Space Heating 2030 in kWh/ m^2
fed_dhwkwhm2_2030	Final Energy Demand domestic hot water 2030 in kWh/ m^2
fed_sh_dhw_totalgwh_2030	Final Energy Demand Space Heating and domestic hot water in GWh 2030
ec_group_gasgwh_2030	Energy Carrier gas in GWh 2030
ec_group_oil_1_oilgwh_2030	Energy Carrier heating oil in GWh 2030
ec_group_coalgwh_2030	Energy Carrier coal in GWh 2030
ec_group_woodloggwh_2030	Energy Carrier woodlog in GWh 2030
ec_group_electricitygwh_2030	Energy Carrier electricity in GWh 2030
ec_group_District heat_urban_District heat [GWh]_2030	Energy Carrier district heat in GWh 2030

cum_inv_hsup_exist_build [EUR/m2] where val != 0_2030	Cumulated investment until in heat supply systems 2030 in €/ m^2
cum_inv_env_exist_build [EUR/m2] where val != 0_2030	Cumulated investment until in building envelopes 2030 in €/ m^2

Appendix 3

Country	Gas price (HH) Scenario A in EUR/kWh	Heating oil Scenario A in EUR/ kWh	Coal (heating) Scenario A in EUR/ kWh	Woodlog (heating) Scenario A in EUR/ kWh	Electricity price (HH) Scenario A in EUR/ kWh	District heat price Scenario A in EUR/ kWh
AUT	0,06655	0,0782	0,05248707	0,0397	0,22505	0,0189
BEL	0,0572	0,06808	0,05577632	0,05330689	0,2848	0,0194
BGR	0,0538	0,108938	0,03435824	0,05330689	0,10575	0,0093
CYP	0,07315	0,083651	0,05184341	0,05330689	0,214	0,019
CZE	0,0558	0,073683	0,03707581	0,05330689	0,18425	0,0187
DEU	0,06695	0,0783	0,07394011	0,05330689	0,32135	0,0212
DNK	0,1071	0,151791	0,08442637	0,05330689	0,3174	0,0289
ESP	0,08865	0,07585	0,0542417	0,054	0,25695	0,0187
EST	0,05925	0,0896	0,0322518	0,05330689	0,16315	0,0169
FIN	0,15445	0,108574	0,03815855	0,05330689	0,18035	0,0163
FRA	0,07395	0,09189	0,04527383	0,05330689	0,1984	0,0187
GRC	0,07315	0,083651	0,04323449	0,05330689	0,1827	0,019
HRV	0,0386	0,068843	0,03568586	0,05330689	0,1302	0,0127
HUN	0,0306	0,128025	0,02813498	0,05330689	0,1002	0,012
IRL	0,07015	0,07404	0,03330633	0,05330689	0,27645	0,0127
ITA	0,0854	0,130843	0,05439581	0,05330689	0,23095	0,019
LTU	0,03445	0,063736	0,02840888	0,05330689	0,14125	0,0195
LUX	0,05385	0,0706	0,04366585	0,05330689	0,19885	0,0194
LVA	0,03645	0,076115	0,03376122	0,05330689	0,16445	0,015
MLT	0,0854	0,1	0,03388473	0,05330689	0,1301	0,019
NLD	0,1029	0,1361	0,03770785	0,05330689	0,1365	0,0194
POL	0,04245	0,081569	0,03334971	0,05330689	0,1561	0,0121
PRT	0,07675	0,125	0,05679068	0,05330689	0,21295	0,0187
ROU	0,0396	0,0977	0,03885573	0,02	0,1569	0,0173
SVK	0,0417	0,073683	0,04062007	0,05330689	0,1646	0,023
SVN	0,0567	0,104034	0,03845855	0,05330689	0,16865	0,0165
SWE	0,15445	0,12055	0,0422918	0,05330689	0,2359	0,0203

Assumptions: Gas prices were not available for some countries. Thus, the price of Cyprus is assumed equal to Greece, the price of Finland is assumed equal to Sweden, and the price of Malta is assumed equal to Italy. Gas and electricity prices include taxes and levies. The wood log price for Austria is the average of reported prices for pellets, firewood, and wood chips (‘Waldhackgut’) from September 2021. The wood log prices for Spain and Romania are assumed equal to those calculated for 2019 in (Oikonomou et al., 2022). The wood log prices for the remaining Member States are assumed equal to the Spanish wood log price. Heating oil prices refer to prices for September 2021, assuming that 1l heating oil = 10 kWh and include levies and taxes. Coal prices are taken from unpublished calculations by the Öko-Institut e.V. District heat prices are also taken from unpublished calculations by the Öko-Institut e.V.. The prices of Luxembourg and Belgium are assumed equal to that of the Netherlands, the prices of Cyprus, Greece and Malta are assumed equal to that of Italy, the Portuguese and Spanish prices are assumed equal to that of France, and the Irish price is assumed equal to that of the UK. All prices refer to prices for residential/private/end-user households.

Country	Gas price (HH) Scenario B in EUR/ kWh	Heating oil Scenario B in EUR/ kWh	Coal (heating) Scenario B in EUR/ kWh	Woodlog (heating) Scenario B in EUR/ kWh	Electricity price (HH) Scenario B in EUR/ kWh	District heat price Scenario B in EUR/ kWh
AUT	0,1999	0,1577	0,05248707	0,0709	0,384	0,0189
BEL	0,1903	0,12497	0,05577632	0,09488627	0,507	0,0194
BGR	0,1994	0,176925	0,03435824	0,09488627	0,1528	0,0093
CYP	0,2146	0,141637	0,05184341	0,09488627	0,37	0,019
CZE	0,1971	0,138027	0,03707581	0,09488627	0,41	0,0187
DEU	0,2218	0,149886	0,07394011	0,09488627	0,446	0,0212
DNK	0,313	0,211296	0,08442637	0,09488627	0,5452	0,0289
ESP	0,183	0,1379	0,0542417	0,09612	0,295	0,0187
EST	0,2036	0,1427	0,0322518	0,09488627	0,4205	0,0169
FIN	0,2355	0,1775	0,03815855	0,09488627	0,3275	0,0163
FRA	0,1136	0,153041	0,04527383	0,09488627	0,2502	0,0187
GRC	0,2146	0,1606	0,04323449	0,09488627	0,2918	0,019
HRV	0,0953	0,126604	0,03568586	0,09488627	0,1481	0,0127
HUN	0,0258	0,162941	0,02813498	0,09488627	0,0936	0,012
IRL	0,1109	0,131075	0,03330633	0,09488627	0,3526	0,0127
ITA	0,1666	0,182504	0,05439581	0,09488627	0,5442	0,019
LTU	0,093	0,126502	0,02840888	0,09488627	0,24	0,0195
LUX	0,1054	0,1301	0,04366585	0,09488627	0,2141	0,0194

LVA	0,1554	0,136145	0,03376122	0,09488627	0,3468	0,015
MLT	0,1666	0,1	0,03388473	0,09488627	0,122	0,019
NLD	0,3408	0,186	0,03770785	0,09488627	0,6934	0,0194
POL	0,0547	0,147811	0,03334971	0,09488627	0,1781	0,0121
PRT	0,1431	0,1851	0,05679068	0,09488627	0,2552	0,0187
ROU	0,0627	0,2064	0,03885573	0,03572	0,162	0,0173
SVK	0,0527	0,138027	0,04062007	0,09488627	0,1903	0,023
SVN	0,1208	0,154965	0,03845855	0,09488627	0,2266	0,0165
SWE	0,2355	0,167278	0,0422918	0,09488627	0,3256	0,0203

Assumptions: The gas and electricity prices only include the prices reported for capital cities, in August 2022. For this study, it is assumed they represent prices for the whole country. To stay consistent with the approach from Scenario A, the natural gas price of Cyprus is assumed equal to Greece, the price of Finland is assumed equal to Sweden, and the price of Malta is assumed equal to Italy. The wood log price for Austria is the average of reported prices for pellets, firewood, and wood chips ('Waldhackgut') from August 2022. The price increase from 2021 Austrian wood log prices to 2022 is 78%. This price increase was assumed for the wood log prices of the other Member States. Heating oil prices refer to prices for September 2022, assuming that 1l heating oil = 10 kWh and include levies and taxes. Coal prices are taken from unpublished calculations by the Öko-Institut e.V. and are assumed equal to the prices in Scenario A. District heat prices are assumed equal to 2021 because of a lack of data. However, since district heat is often fossil-fuel based, the 2022 prices for district heat are likely to be undervalued. All prices refer to prices for residential/private/end-user households.

Country	Gas price (HH) Scenario C in EUR/ kWh	Heating oil Scenario C in EUR/ kWh	Coal (heating) Scenario C in EUR/ kWh	Woodlog (heating) Scenario C in EUR/ kWh	Electricity price (HH) Scenario C in EUR/ kWh	District heat price Scenario C in EUR/ kWh
AUT	0,086515	0,10166	0,06823319	0,05161	0,292565	0,02457
BEL	0,07436	0,088504	0,07250921	0,06929896	0,37024	0,02522
BGR	0,06994	0,1416194	0,04466571	0,06929896	0,137475	0,01209
CYP	0,095095	0,1087463	0,06739643	0,06929896	0,2782	0,0247
CZE	0,07254	0,0957879	0,04819855	0,06929896	0,239525	0,02431
DEU	0,087035	0,10179	0,09612214	0,06929896	0,417755	0,02756
DNK	0,13923	0,1973283	0,10975428	0,06929896	0,41262	0,03757
ESP	0,115245	0,098605	0,07051421	0,0702	0,334035	0,02431
EST	0,077025	0,11648	0,04192734	0,06929896	0,212095	0,02197
FIN	0,200785	0,1411462	0,04960611	0,06929896	0,234455	0,02119
FRA	0,096135	0,119457	0,05885598	0,06929896	0,25792	0,02431

GRC	0,095095	0,1087463	0,05620484	0,06929896	0,23751	0,0247
HRV	0,05018	0,0894959	0,04639161	0,06929896	0,16926	0,01651
HUN	0,03978	0,1664325	0,03657547	0,06929896	0,13026	0,0156
IRL	0,091195	0,096252	0,04329823	0,06929896	0,359385	0,01651
ITA	0,11102	0,1700959	0,07071455	0,06929896	0,300235	0,0247
LTU	0,044785	0,0828568	0,03693155	0,06929896	0,183625	0,02535
LUX	0,070005	0,09178	0,05676561	0,06929896	0,258505	0,02522
LVA	0,047385	0,0989495	0,04388958	0,06929896	0,213785	0,0195
MLT	0,11102	0,13	0,04405015	0,06929896	0,16913	0,0247
NLD	0,13377	0,17693	0,04902021	0,06929896	0,17745	0,02522
POL	0,055185	0,1060397	0,04335463	0,06929896	0,20293	0,01573
PRT	0,099775	0,1625	0,07382788	0,06929896	0,276835	0,02431
ROU	0,05148	0,12701	0,05051244	0,026	0,20397	0,02249
SVK	0,05421	0,0957879	0,0528061	0,06929896	0,21398	0,0299
SVN	0,07371	0,1352442	0,04999612	0,06929896	0,219245	0,02145
SWE	0,200785	0,156715	0,05497934	0,06929896	0,30667	0,02639

The calculations are based on the same assumptions as Scenario A.

Country	Gas price (HH) Scenario D in EUR/ kWh	Heating oil Scenario D in EUR/ kWh	Coal (heating) Scenario D in EUR/ kWh	Woodlog (heating) Scenario D in EUR/ kWh	Electricity price (HH) Scenario D in EUR/ kWh	District heat price Scenario D in EUR/ kWh
AUT	0,099825	0,1173	0,07873061	0,05955	0,337575	0,02835
BEL	0,0858	0,10212	0,08366448	0,07996034	0,4272	0,0291
BGR	0,0807	0,163407	0,05153736	0,07996034	0,158625	0,01395
CYP	0,109725	0,1254765	0,07776511	0,07996034	0,321	0,0285
CZE	0,0837	0,1105245	0,05561371	0,07996034	0,276375	0,02805
DEU	0,100425	0,11745	0,11091016	0,07996034	0,482025	0,0318
DNK	0,16065	0,2276865	0,12663955	0,07996034	0,4761	0,04335
ESP	0,132975	0,113775	0,08136255	0,081	0,385425	0,02805
EST	0,088875	0,1344	0,0483777	0,07996034	0,244725	0,02535
FIN	0,231675	0,162861	0,05723782	0,07996034	0,270525	0,02445
FRA	0,110925	0,137835	0,06791075	0,07996034	0,2976	0,02805
GRC	0,109725	0,1254765	0,06485174	0,07996034	0,27405	0,0285
HRV	0,0579	0,1032645	0,05352878	0,07996034	0,1953	0,01905
HUN	0,0459	0,1920375	0,04220247	0,07996034	0,1503	0,018
IRL	0,105225	0,11106	0,04995949	0,07996034	0,414675	0,01905
ITA	0,1281	0,1962645	0,08159371	0,07996034	0,346425	0,0285
LTU	0,051675	0,095604	0,04261332	0,07996034	0,211875	0,02925

LUX	0,080775	0,1059	0,06549878	0,07996034	0,298275	0,0291
LVA	0,054675	0,1141725	0,05064183	0,07996034	0,246675	0,0225
MLT	0,1281	0,15	0,0508271	0,07996034	0,19515	0,0285
NLD	0,15435	0,20415	0,05656178	0,07996034	0,20475	0,0291
POL	0,063675	0,1223535	0,05002457	0,07996034	0,23415	0,01815
PRT	0,115125	0,1875	0,08518601	0,07996034	0,319425	0,02805
ROU	0,0594	0,14655	0,05828359	0,03	0,23535	0,02595
SVK	0,06255	0,1105245	0,06093011	0,07996034	0,2469	0,0345
SVN	0,08505	0,156051	0,05768783	0,07996034	0,252975	0,02475
SWE	0,231675	0,180825	0,0634377	0,07996034	0,35385	0,03045

The calculations are based on the same assumptions as Scenario A.

Appendix 4

iii. ‘National strategy against Energy poverty 2019 – 2024’

It mentions the goal to "guarantee access to affordable, safe, sustainable and modern energy for all" (POEU, 2020, p. 105). In Spain, attention to energy poverty is not only growing at the national level but also at the local and regional level, like in Madrid and Aragon (POEU, 2020). To monitor energy poverty, it follows the recommendations of the EPOV and relies on the four indicators included above (Mastropietro, 2022). The measures presented in the national Strategy include the following: interventions on the energy efficiency of buildings, a disconnection ban for periods of extreme weather events, information campaigns for consumers and the definition of a baseline supply of energy for vulnerable residents who are unable to pay their bills (Mastropietro, 2022). However, due the Covid-19 pandemic, the implementation of the Strategy has been delayed and the Spanish government had to instead introduce several emergency measures to respond to rising energy poverty during the pandemic (Mastropietro, 2022). The impact of these policies on energy poverty has not been quantified yet (Mastropietro, 2022). A representative of the NGO ECODES says that two years after publication of strategy, the lack of progress is disappointing (Gumbau, 2022). Apparently, only half of the measures have been launched and most of them are delayed (Gumbau, 2022). The ‘bono social’ is a discount rate for power bills that households in need can access (Gumbau, 2022). Before the energy crisis, vulnerable households received a 25% reduction and ‘severely’ vulnerable households received a 40% reduction; since the energy crisis began, these discounts were increased to 40% and 70%, respectively (Gumbau, 2022).

Appendix 5

Country & Document	**Mentions “energy poverty” or “low-income household(s)/families”**
AUT (LTRS)	Energy poverty: 17 Low-income household(s)/families: 9 (pages total: 204)

AUT (NRRP)	Energy poverty („Energiearmut“): 9 Low-income household(s)/families (“Haushalte mit niedrigen Einkommen”): 1 (pages total): 78
ESP (LTRS)	Energy poverty: 283 Low-income household(s)/families: 2 (pages total: 576)
ROU (LTRS)	Energy poverty: 45 Low-income household(s)/families:5 (pages total: 136)