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The persistence of energy poverty in the EU

Socioeconomic insights into EU's long-term energy poverty

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Contents

Abstract

This report offers a comprehensive analysis of the persistence of energy poverty in the European Union (EU). The primary objective is to analyse the duration and magnitude of energy poverty over time and to identify the socioeconomic and demographic factors contributing to this persistence. Employing longitudinal data from the European Union Statistics on Income and Living Conditions (EU-SILC), the study uses multilevel, mixed-effects regression models to assess the impact of individual-level factors such as sex, age, and household size changes. It also examines macro-level variables like social protection expenditure and energy intensity per dwelling. The research highlights the significant proportion of the EU population that experiences energy poverty persistently and uncovers pronounced differences across Member States, with certain countries exhibiting higher rates of longstanding energy poverty. The report acknowledges data limitations, such as missing information for specific countries and years, which restricted the analysis of expenditure-based indicators and certain socio-demographic characteristics. Despite these constraints, the study provides valuable insights into the persistency of energy poverty across the EU, supporting the need for standardised energy poverty indicators that integrate expenditure data. The findings underscore the importance of integrated policy interventions and further research to address this enduring social challenge.

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Executive summary

The study investigates the prevalence and persistence of energy poverty across the European Union (EU), utilising data from the European Union Statistics on Income and Living Conditions (EU-SILC) alongside various national-level and individual/household-level variables. The key focus is on developing a methodology for an indicator to measure and address the persistence of energy poverty for policy purposes. The report presents empirical evidence on factors contributing to the risk and persistence of energy poverty and offers policy recommendations to tackle these issues effectively.

Policy context

Energy poverty is a critical and growing concern within the EU, affecting citizens' quality of life and social inclusion. The EU's regulatory framework and policy initiatives, such as the Social Climate Fund and the recast Directive on energy efficiency, aim to alleviate energy poverty and promote a fair transition towards a low-carbon economy. This study contributes to the policy discourse by providing an understanding of deeper energy poverty dynamics and identifying targeted measures to support vulnerable populations.

Key conclusions

The study concludes that persistent energy poverty is a complex problem influenced by individual, household and national factors. Persistent monetary poverty and heavy housing cost burdens significantly increase the risk of chronic energy poverty, while higher public expenditure on social exclusion benefits and housing allowances can reduce this risk. Improvements in building energy efficiency are critical to reducing both energy costs for households and environmental impacts. Finally, persistent energy poverty indicators are suggested as new conventional social indicators for EU policymaking.

Main findings

The study's proposed indicators and methodology offer a comprehensive approach to measuring and addressing energy poverty at the EU level. It establishes that a significant proportion of EU citizens experience transient and persistent energy poverty, with variations across Member States. At the same time the study indicates that direct financial support and social exclusion combating benefits play a pivotal role in mitigating the impacts of energy poverty; while the energy efficiency of residential buildings is a key determinant of energy poverty, indicating the need for policies that support energy-efficient renovations and constructions.

Related and future JRC work

This report is a continuation of JRC's work aiming to decode energy poverty dynamics in the EU, and sets the stage for future research on energy poverty. Several existing JRC-led publications already provide quantitative and qualitative data and analysis on energy poverty (see Koukoufikis et al., 2023, Menyhert, 2023; Papadimitriou et al., 2023; Vandyck et al., 2023; Koukoufikis and Uihlein 2022). This publication emphasises the importance of longitudinal studies and the use of multilevel mixed-effects logistic regression models to understand the persistence of energy poverty. Future JRC work will continue to refine the indicators and methodologies, explore the impacts of policy interventions, and aim to integrate energy poverty metrics into broader social inclusion and environmental sustainability frameworks.

Quick guide

The report begins with an introduction that sets the stage for the subsequent analysis. It then discusses the policy context and relevant literature, providing a foundation for the report's narrative. The data and methodology section follows describing the techniques and data sources utilized in the research, paving the way for the core of the report—the findings. These findings are presented in two parts: descriptive findings that offer an initial overview of the data, followed by a more complex multivariate analysis, which includes both Structural Equation Modelling and Multilevel mixed effects logistic regression models for individual indicators. The report concludes with a discussion that synthesizes the insights drawn from the findings, offering valuable implications for policy.

1 Introduction

Energy poverty remains a critical challenge in the European Union (EU), affecting the wellbeing and social inclusion of its citizens. It is a condition in which households are unable to access or afford adequate energy services, which is increasingly recognised as a detriment to health, comfort, and productivity. The urgency of this issue is underscored by the European Union's commitment to the European Green Deal and its implications for a just transition to a low-carbon economy. Energy poverty intersects with EU policy goals, including climate action, social equity and energy efficiency, highlighting the need for robust policy measures

This study is an inquiry into the persistence of energy poverty across the EU. Persistent energy poverty refers to a situation where a household experiences energy poverty over a prolonged period, typically measured over several years. It indicates a chronic inability to meet basic energy needs rather than a temporary financial difficulty. By contrast, transient energy poverty, which is often more easily identified by existing indicators, describes a temporary experience of energy poverty, possibly influenced by short-term fluctuations in income, energy costs or other circumstantial changes. This report focuses on persistent energy poverty and responds to the need for an improved understanding of its nature and dynamics, which is essential for developing effective policy responses. At the same time it contributes to the literature by introducing new methodologies and energy poverty indictors to examine the medium and long-term effects of energy poverty.

The significance of the policy question lies in its direct impact on the lives of EU citizens and the broader objectives of energy justice and social inclusion. Persistent energy poverty not only affects immediate living conditions but also has long-term implications for social stratification and environmental sustainability. Addressing this issue aligns with the EU's principles of equity and cohesion and is vital for achieving the targets set out in the European Pillar of Social Rights.

The evidence shows that despite a remarkable decline in the proportion of individuals living in households which were unable to keep their home adequately warm between 2012 and 2021, the figures have since increased 3.7 percentage points by 2023. This suggests that combatting energy poverty needs a long-term approach and sustainable policies to provide suitable financial, social and technical facilities. In this respect, effective policymaking requires an exploration of the socioeconomic dynamics which increase the risks for becoming trapped in energy poverty.

To provide insights, this work is based on the conventional Eurostat persistent at-risk-of-poverty definition and uses European Union Statistics on Income and Living Conditions (EU-SILC) longitudinal data sets ([1]). Although there are some studies on monetary poverty and material deprivation by using EU-level longitudinal data sets in the literature, there is a lack of such research on the persistency of energy poverty. According to Eurostat's definition, the persistent at-risk-of-poverty rate refers to: "*the percentage of the population living in households where the equivalised disposable income was below the at-risk-of-poverty threshold for the current year and at least two out of the preceding three years*" ([2]).

Thanks to the EU-SILC, which is the longstanding EU-level survey providing 4-year panel data, it is possible to calculate persistent at-risk-of-poverty rates. The figures demonstrate that one out of every ten people living in the EU had been below the at-risk-of-poverty threshold for at least three years over the 2017-2020 period, including the last year of this interval, though the magnitude and patterns of persistent financial poverty vary extensively across the 27 EU Member States ([3]). In addition, a previous study found that, in the EU as a whole (excluding Germany), the persistent material deprivation rate had been around 12.5% for the 2014-2017 period (Karagiannaki, 2021).

The three main energy poverty indicators recommended by the Energy Poverty Advisory Hub, namely being unable to keep the home adequately warm, having arrears on utility bills and having a leak, damp or rot in the dwelling (Gouveia et al., 2022), are also available in the longitudinal EU-SILC data sets used for analysing

[1] Eurostat https://ec.europa.eu/eurostat/web/main/data/database (Last accessed on 13/02/2024).
[2] Eurostat https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:At-risk-of-poverty_rate (Last accessed on 18/01/2024).
[3] Eurostat https://ec.europa.eu/eurostat/web/main/data/database (Last accessed on 13/02/2024).

persistent risk of poverty and persistent material deprivation [4]. However, to our knowledge, there has been no attempt to implement a similar methodology to establish persistency rates for any of these three energy poverty indicators. This analysis therefore aims to fill this gap and a) measure the prevalence and persistence of energy poverty across the EU using harmonised and regulated data from the EU-SILC; b) develop and propose an alternative methodology for an indicator that reflects the persistent nature of energy poverty, facilitating cross-country comparisons and policy evaluation; c) identify socioeconomic and demographic factors that contribute to the risk and persistence of energy poverty, providing a basis for tailored policy interventions; and d) offer policy insights that leverage the findings to improve energy affordability, reduce social exclusion, and enhance the energy efficiency of residential buildings.

By achieving these aims, the report inform policymakers of the underlying factors contributing to energy poverty and to guide the design and implementation of policies that properly address this complex issue. The anticipated outcome could lead to the creation of a standardised, actionable framework that improves energy security for vulnerable populations and supports the EU's transition to a fair and sustainable energy future. The findings presented in this report may also provide insights into the differences in persistent energy poverty across EU Member States and across socio-demographic groups within each country.

The report includes four main sections. In the first section, we briefly provide the policy context and review the literature on recent trends in energy poverty in the EU. Methodological studies on the cross-sectional and longitudinal energy poverty indictors are reviewed, aiding an understanding of the complexity of the topic and of the methods used to analyse it. The next section briefly describes the data sets and methodology used in this study. The third section presents our findings and the last section offers policy insights derived from them.

[4] Longitudinal data is a type of data collected from the same subjects repeatedly over a period of time to observe changes and developments.

2 Policy context and literature

Energy poverty is a condition that undermines social inclusion and threatens the wellbeing of EU citizens. Tackling energy poverty is not only a matter of social justice, but also a prerequisite for achieving climate neutrality by 2050. Indeed, dealing with its impact on citizens is an EU priority in the context of the European Green Deal, which pledges not to leave any person or any place behind (European Commission, a). This objective reflects Article 34 of the Charter of Fundamental Rights of the European Union ([5]), which recognises the entitlement of EU residents to social security and social assistance to combat social exclusion and poverty (EU, 2012). Furthermore, Principle 20 concerning access to essential services within the European Pillar of Social Rights identifies energy as one of the six fundamental services that should be universally accessible (European Commission, b). The Commission's Report on Access to Essential Services in the EU underscores that securing energy access continues to be a challenge for a segment of the population (European Commission 2023).

Energy poverty is linked to a range of policy areas including housing, social welfare, energy market regulation and environmental sustainability. As such, it requires a coordinated and integrated policy response that can address the underlying structural issues, such as income inequality, inefficient housing stock and energy market dynamics. Recognising this, the EU has sought to integrate measures to combat energy poverty within key policy initiatives. The Clean Energy for All Europeans package, for instance, emphasises the right to affordable energy and the need to support vulnerable consumers. Additionally, the Social Climate Fund, introduced with the Fit for 55 package ([6]), is designed to alleviate the societal effects of climate change measures, particularly concerning the anticipated Emissions Trading System for residential buildings and road transport (ETS 2). Its purpose is to offer financial assistance to Member States, enabling them to support individuals impacted by energy poverty. These efforts demonstrate the EU's commitment to ensuring that the transition to a green economy is just and inclusive, leaving no one behind. In this evolving policy landscape, the need for robust, data-driven analysis to inform policy decisions has never been greater. However, while a lot of attention has been given to the topic of energy poverty and several indicators have been proposed to measure it, work to investigate persistency rates for these indicators has been limited. As a result, the complexity of energy poverty may be underestimated, the scope of the information needed may be ill-defined, the available data may not be processed, and opportunities to collect additional data and evidence may be missed ([7]). The findings and recommendations of this report are intended to contribute to that critical discourse, providing insights into the prevalence and persistence of energy poverty and offering evidence-based strategies to address its root causes.

Having established the critical intersection of energy poverty with the European Union's broader social and environmental objectives, it is important to consider the body of academic research that informs our understanding of this complex phenomenon. The literature review explores the multidimensional nature of energy poverty, examining its definition, measurement, and the diverse methodologies employed to assess its prevalence and impact. It underscores the significance of the policy context and provides a critical foundation for the empirical analysis which follows. By bridging the gap between policy imperatives and academic insights, we set the stage for a comprehensive assessment of energy poverty that is both informed by theory and grounded in the lived realities of EU citizens.

In the literature, there are various concepts used for the analysis of energy inequality, but the term energy justice is more comprehensive as it deals with a wide range of socioeconomic aspects encapsulating distributional, procedural, and recognition justice (see McCauley et al., 2013; Chapman et al., 2018; Siciliano et al., 2021, Dudka et al., 2024). Sovacool et al. (2017) identified nine principles of energy justice, including availability, affordability and sustainability, which align with the facets of energy poverty within the distributional justice framework.

The literature on energy poverty and how it can be measured is extensive. The study of Ferrall-Wolf and her colleagues reviewed more than 4 000 articles which had been published between 1983 and 2023 (Ferral-

[5] See: https://fra.europa.eu/en/eu-charter/article/34-social-security-and-social-assistance#explanations

[6] See: https://ec.europa.eu/commission/presscorner/detail/en/IP_23_4754

[7] See EPAH (2023) on the pillars of diagnosing energy poverty

Wolf et al., 2023). They revealed that the term "energy poverty" was the most frequently used keyword in the literature of energy justice, used in more than a quarter of the reviewed articles. Moreover, the weight of the "fuel poverty" theme in the literature increased over time, together with related themes like "poverty" and "consumption" (Ferral-Wolf et al., 2023). Siksnelyte-Butkiene (2021) categorises 43 studies into three areas: energy access, energy poverty assessment, and poverty vulnerability, pointing to the widespread use of multidimensional energy poverty indicators (for definition, see also Pelz et al., 2018) and the popularity of single metrics like the share of energy expenditure in household income and low income high cost indicators (LICH).

Another detailed literature review on energy poverty in EU Member States was conducted by Palma and Gouveia (2022), in which 29 studies were examined from southern European countries, 17 from western and northern Europe and six from central and Eastern Europe. Their findings show that there are some variations in the use of indicators for energy poverty assessment across these three groups. While expenditure-based metrics and income data are widely used, western and northern Europe also incorporate energy prices, contrasting with southern Europe's preference for building data and climate factors. Their analysis noted a general trend towards region-specific rather than nationwide studies, highlighting a gap in EU-wide energy poverty research.

Despite the abundance of studies on energy vulnerability and energy poverty in the related literature, there is a lack of research on the persistency of energy poverty. Most methodological and empirical studies in this field have been conducted very recently. We have not been able to find any previous study suggesting or attempting to develop an EU-level indicator, or a set of indicators measuring the persistency of energy poverty. Furthermore, there are very few cross-country studies, and those which do exist cover different time periods, making comparison difficult.

The only cross-country study which we have found on the persistency of energy poverty in the EU is that of Karpinska and Smiech (2020). This is based on an analysis of the persistency of being unable to keep the home adequately warm by using EU-SILC 2018 longitudinal data for 2015-2018. The multivariate analysis for clustering the transition probabilities of this study indicates that there are distinct groups of European countries for the relation between the transition in energy poverty and the transition in (subjective) monetary poverty (which is measured according to the answer categories of the question whether the household is able to make ends meet). The first group includes Austria, Switzerland, Estonia, Finland, Norway and Sweden, where high levels of mobility are observed between states of being poor and non-poor in each indicator as well as across low energy poverty, poverty and severe poverty persistence. In the other group, which involves Bulgaria, Greece, Lithuania and Romania, households experience high levels of persistency in all conditions of energy poverty and subjective monetary poverty. In the remaining Member States, monetary poverty is likely to be more persistent than energy poverty, whereas exit rates for energy poverty are much higher than for monetary poverty. Based on these findings, the authors recommend tailored social policies and measures to foster territorial connectivity of the EU with the countries, which have very low transition across states of energy and monetary poverty. Tools to combat poverty more generally can also be used to address energy poverty (Karpinska and Smiech, 2020).

In another study with a similar methodology focusing on Poland in 2014-2017, Karpinska and Smiech showed that energy poverty (measured as being unable to keep the home adequately warm) was less likely to be persistent than subjective poverty or subjective severe poverty (Karpinska and Smiech, 2021).

The results of Pourkanali and his colleagues from a 5-year panel survey show that income level, household type and level of education are among the predominant factors influencing the likelihood of energy poverty and the transition and persistence of energy poverty states in Spain (Pourkhanali et al., 2023). The authors analysed the persistence of three energy poverty indicators, which are a) Fuel Poverty Index (FPI); b) the share of expenditure on energy is 10% or more of household income (TPR); and c) the income spent on energy by the household is greater than the twice the national median (2M). According to their findings, over the 2016-2021 period, 34% of households in Spain had a transient energy poverty status while 5% of the overall population was exposed to chronic energy poverty ([8]). Pourkanali and his colleagues argue that their results indicate the need for long-term policies including energy efficiency for dwellings and compensatory measures

[8] The term transient energy poverty refers to being energy-poor for at least one year, but less than 70% of the period covered in the study.

like social assistance and direct subsidies to allow people to escape from energy poverty permanently (Pourkhanali et al., 2023).

Drescher and Janzen implemented a similar analysis to examine the determinants and persistence of energy poverty in Germany by using national 7-year panel survey data (Drescher and Janzen, 2021). The authors used both expenditure metrics (i.e. 2M, TPR and Low Income High Cost indicator (LICH)), and consensual-based (self-declared inability to heat the house comfortably in colder months) indicators to measure the energy poverty. Their findings show that the overlap between expenditure-based and consensual indicators are limited. They also demonstrate that energy poverty in Germany is mainly affected by household type, level of educational attainment, labour force status, characteristics of the dwelling, and the primary energy source. The persistency rates (in which persistence is defined as experiencing energy poverty in 70% of the observed periods) range between 3% and 7.5% according to the indicator used for energy poverty. The authors conclude that the consensual and expenditure-based approaches should be used together for exploring the dynamics of energy poverty as the metric indicators do not represent the actual energy needs of households, thus they are likely to omit data on households that under-consume energy due to financial constraints (Drescher and Janzen, 2021).

Winkler's study on the persistence of energy poverty in Portugal by using the EU-SILC longitudinal data for 2017-2020 period demonstrates that around 16.5% of the population were unable to keep the home adequately chronically (Winkler, 2021). The findings reveal that the decreasing impact of increase in the household's income level on chronic energy poverty is bigger than its impact on the temporary energy poverty in this country. Moreover, the analysis results point out that there are interregional differences such as the transient nature of energy poverty is most evident in Madera while life events like child birth, deaths, employment-, and income-shocks are less likely to increase the risk of energy poverty entries. On the other hand, household's equivalized disposable income, the household composition, and the highest educational level within the household are the main determinants affecting the transition probabilities across the states of energy poverty in Portugal (Winkler, 2021).

Another recent study conducted by Halkos and Kostakis, exploring the persistence and transience of energy poverty in Greece, is based on the same methodology used by Pourkhanali et al for Spain, and Drescher and Janzen for Germany, using the EU-SILC 2020 Greece longitudinal data sets (Halkos and Kostakis, 2023). Their results indicate that the risk of chronic energy poverty in Greece throughout the 2017-2020 period was much greater than that of Spain and Germany according to the other two studies. However, the results also show that being energy-poor in the initial year significantly increases the risk of being energy-poor in the following year. Factors which influence the persistency of energy poverty include educational attainment levels, income levels, economic activity, dwelling characteristics, ethnicity and marital status. The findings also suggest a link between the extreme climatic conditions in Greece and energy poverty (Halkos and Kostakis, 2023).

Outside the European context, Alem and Demeke's descriptive and multivariate analyses of the persistency of energy poverty in Ethiopia provide useful insights. According to their findings, being in energy poverty in a particular year significantly increases the likelihood of being in energy poverty in subsequent years (Alem and Demeke, 2020). Alem and Demeke's (2020) analysis revealed that as clean energy prices rose, Ethiopian households opted for cheaper, more polluting fuels. Even though electricity costs halved from 2004 to 2009, the high cost of advanced electric appliances deterred households from making the switch.

A study on chronic energy poverty in China during the 2011-2018 period using panel survey data (Li and Lou, 2022) includes an analysis of unidimensional energy poverty (only considering affordability) and multidimensional energy poverty (taking into account affordability, accessibility and availability). The study's chronic unidimensional energy poverty index (CUEP) refers to the incidence and duration of energy poverty while the chronic multidimensional energy poverty index (CMEP) examines the depth, incidence and duration of chronic energy poverty. The findings suggest that 90% of the Chinese population was exposed to transient (temporary) energy poverty between the years 2011 and 2018, while three quarters experienced CUEP; the figures for multidimensional transient and chronic poverty were also high (more than two thirds and just below half of the overall population respectively). The figures vary according to the educational level of the head of household, the type of work done and the region of China. The analysis also shows that the rate of escape from unidimensional energy poverty is higher than that of multidimensional energy poverty; but the average duration spent in the latter is shorter than that of unidimensional energy poverty. The authors conclude that higher energy efficiency levels can reduce the duration of energy poverty, by increasing the probability of moving between states, though this effect is seen more strongly in multidimensional energy poverty (Li and Lou, 2022).

In summary, despite the wealth of research on energy poverty indicators, there is limited attention given to the persistence of energy poverty in the EU. Country-specific studies often rely on multivariate probit models with varied indicators which present challenges in terms of data uniformity, hindering direct comparison. The analysis presented in this study aims to fill this gap, covering all EU countries and proposing a new methodology for a policy-relevant indicator for persistent energy poverty.

3 Data and methodology

This study seeks to identify the socioeconomic factors which influence the persistency of energy poverty affecting individuals in the EU. Although it is not possible to identify them all, the literature review and quantitative analyses provide insights into the factors influencing long-term energy poverty and the methodology to be used in future research.

There are two hypotheses tested in the analysis. The first states that "*Basic socio-demographic characteristics determine individuals' risk of being persistently energy-poor*" (H1). The second states that "*Facing micro-level and macro-level financial affordability constraints increases an individual's likelihood to be persistently energy-poor*" (H2). Two multivariate analysis methods are used in testing these hypotheses: multilevel mixed effects logistic regression models, and structural equation modelling (SEM). Descriptive analysis results for selected background variables are also presented, which are helpful to assess the current state of persistent energy poverty in the EU.

The main data source used in the analysis is EU-SILC longitudinal microdata sets. The aim of EU-SILC is to collect timely and comparable cross-sectional and longitudinal data on income, poverty, social exclusion and living conditions, in which the output is harmonised and regulated by EU legislation. The survey has been implemented since 2003, though the start of the data collection varied across EU Member States and other non-member countries joining the project (Eurostat, 2022). EU-SILC has a rotational sampling design, which allows for 4-year longitudinal panel data and an annual cross-sectional data set. Around a quarter of the sampled individuals in the given annual cross-sectional component (a 1-year portion of the total sample) have been tracked for 4 years, around half have been followed for three years, and three quarters have been interviewed in the last two years (Eurostat, 2014). As indicated on the Eurostat web page, nine tenths of the data collection is made up of annual variables while the remaining variables are from the modules collected every three or six years, or ad-hoc modules conducted to reply to policy needs ([9]). The EU-SILC datasets involve a long list of individual-level and household-level socio-demographic, income-related, labour market-related and health-related variables. This enables the researchers to explore different aspects and factors influencing socioeconomic inequality in EU countries. Finally, both cross-sectional and longitudinal components have relatively big sample sizes for each country, ensuring statistically more reliable findings than other surveys such as the European Social Survey (ESS) and Eurobarometer.

On the other hand, it should be noted that not all variables published in the cross-sectional component are included in the longitudinal data sets provided to the users ([10]). Besides, despite the fact that the cross-sectional data sets are available for all 27 Member States since 2010, the longitudinal data involving full 4-year panel data sets are not available for Germany except for 2018 and 2019; and they are not published for Ireland for 2010 and 2011, for Slovakia for 2017, or for Portugal for 2021. They are not available for Croatia before 2013 since this country joined EU-SILC implementation in 2010.

There are three variables in the EU-SILC longitudinal data used to identify energy poverty:

- Ability to keep home adequately warm (HH050);
- Having arrears on utility bills in last 12 months (HS021); and
- Having leaking roof, damp walls/floors/foundation, or rot in window frames or floor (HH040).

The utility bills asked about in EU-SILC include not only domestic energy, but also water, sewage and rubbish bills. The Household Budget Survey (HBS) findings indicate that in 2020, the share of water, sewage and rubbish in the total expenditure for utility bills as defined in EU-SILC was 40% or more in Austria, the Netherlands, Italy, Spain and Luxembourg, and around one third or more in Germany, France, Poland, Latvia and Denmark. This proportion was significantly more than half in Finland ([11]). Therefore, unlike the two other variables, the arrears on utility bills do not specifically reflect the household's inability to pay energy expenses, but our analysis shows a general consistency.

[9] Eurostat https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions (Last accessed on 13/02/2024).

[10] For the differences in the content between EU-SILC cross-sectional and longitudinal data sets, see https://www.gesis.org/en/missy/

[11] Eurostat https://ec.europa.eu/eurostat/web/main/data/database (Last accessed on 25/07/2024).

The variables offered in the survey for the ability to keep the home adequately warm and for having a leak, damp or rot in the dwelling are dichotomous (1 "Yes", 2 "No"). However, having arrears on utility bills can be answered with 1 "Yes, once", 2 "Yes, twice or more" or 3 "No". Moreover, there is a flag for this variable as -2 "Not applicable (no utility bills)" since the question is asked only to the households with some utility bills. In order to standardise the response categories of this variable with the two energy poverty-related dichotomous variables, and to include the entire sampled population in the analysis, the 1 "Yes, once" and 2 "Yes, twice or more" categories are combined as "Yes having arrears at least once", and the households which answered 3 "No" or were flagged as -2" Not applicable (no utility bills)" were combined under the category "No arrears on utility bills" ([12]).

Eurostat's methodology to measure the persistent at-risk-of-poverty state has been adopted to analyse the selected EU-SILC variables. In this respect, a household is assumed to be persistently energy-poor for each of these variables if it faced the given problem in the last year of 4-year panel, and at least two out of the preceding three years. There are three advantages of using this methodology. Firstly, it is possible to make comparisons with other conventional, long-term, socioeconomic inequality measures: the persistent at-risk-of-poverty rate and persistent material deprivation rate. Secondly, the definition of persistency corresponds with the methodology in the literature used for chronic energy poverty (being exposed to poverty for 70% of the time covered in the period (see Drescher and Janzen, 2021; Pourkhanali et al., 2023). Finally, it enables us to use a single, standardised definition of persistent energy poverty which can be compared across countries and over time.

The latest EU-SILC longitudinal data published at the time of preparation of this study is for 2018-2021. Unfortunately, data for the indicator on having a leak, damp or rot in the dwelling is not available in the longitudinal datasets after EU-SILC 2020. However, this report aims to analyse the persistency patterns for all abovementioned three indicators and interrelation between each other. Furthermore, Portugal and Germany are not represented in the longitudinal data for 2021. For these reasons, this analysis uses the 2017-2020 panel as the last analysis period. For the descriptive country-level analysis, 2013, 2016, 2018 and 2020 EU-SILC longitudinal data sets are used. The only exception is Germany, where the 2019 data set is the latest available. For the multivariate analyses, the 2013 and 2020 data sets are used (with 2019 for Germany) in multilevel mixed effects logistic regression models. Finally, only the EU-SILC 2020 longitudinal data set (2019 for Germany) has been used for SEM.

The unit of analysis is individuals rather than household, since EU-SILC follows up individuals, not households, in the consecutive years of the panel. If a household member has left the family during the year, they are found and interviewed in their new household, while their old household continues to be the part of the sample. Household-level analysis of EU-SILC longitudinal data is therefore not ideal.

Since the dependent variables are dichotomous, the logistic regression technique has been selected to explore the likelihood of individuals to be energy-poor. In doing this, a pooled microdata set has been used, which includes all EU Member States in EU-SILC 2013 and 2020 longitudinal data sets, and 2019 for Germany. The latter is treated as part of the EU-SILC 2020 wave, as the descriptive longitudinal analysis for other countries and the cross-sectional analysis for Germany do not indicate major changes in the patterns for energy poverty between 2019 and 2020. The aim of choosing multiple data points in the regression analysis is to explore differences in persistence of energy poverty between two distinct periods after controlling other socioeconomic and socio-demographic factors. In addition, multilevel mixed effects logistic regression models have been employed for obtaining findings that are more elaborate. In these models, individual and household-level socioeconomic background and socio-demographic characteristics have been used as micro-level fixed effects with contextual socioeconomic indicators as macro-level fixed effects. Moreover, the panel period has been used as another fixed effect to examine the major factors affecting the likelihood of persistency of energy poverty. The socioeconomic background characteristics are at-risk-of-poverty threshold status and whether housing costs are a heavy financial burden. The socio-demographic characteristics are sex, broad age groups and change in household size. The macro-level socioeconomic indicators are energy prices, social protection expenditure, and the average energy efficiency per dwelling. The country-level data

[12] This re-categorisation also allows the comparison of this variable with the data collected until 2007, where the answers were 1 "Yes" and 2 "No".

used as contextual variables in the models have been retrieved from two data sources. The prices ([13]) and the social protection expenditure ([14]) data have been obtained from the Eurostat data web page. The data on temperature adjusted energy intensity per dwelling (in GJ) and heating degree days (hdd) to calculate average energy efficiency in the country have been retrieved from International Energy Agency (IEA) Energy Efficiency Indicators ([15]) data (particularly for the residential sector). In the random effects component of the models the observations are 27 Member States, in which the individual respondents have been embedded. The findings for the random effects component of the analysis show the extent to which the random interaction across countries explains the variation in the likelihood of persistent energy poverty.

Paterson and Goldstein (1991) underline that the purpose of multilevel modelling is to consider the heterogeneity of social events (Paterson and Goldstein, 1991), in which the populations are assumed to be heterogeneous groups. This can be summarised as:

$$y_{ij} = b_0 + b_1 x_{ij} + u_j + e_{ij}$$

where *ij* demonstrates the presence of the observation *i* in the group *j*. Moreover, u_j that is shown over and above any given value of the dependent variable, each individual group in the upper level in the model has its own contribution. This points out a random variable with an assumption for a constant variance and a zero mean. This model enables the employment of independent variables in the random equation of the regression to explore the impact of any group-level variable in the model on the between-group variation in this level (Paterson and Goldstein, 1991).

The multilevel mixed effects logistic regression can be formulated as:

$$Logit(odds) = B_{00} + (B_{10} + u_{1j}) * x_{ij} + u_{0j}$$

in which B_{00} indicates the fixed intercept of the model, B_{10} refers to the slope of the level 1 variable, u_{1j} shows the residual term associated with the level-1 predictor, x_{ij} denotes level-1 variables, and u_{0j} denotes the Level-2 residual (Sommet and Morselli, 2017).

In these models, the interclass correlation coefficient (ICC) refers to the proportion of random effects variance in the total variance of the model. This is explained by the grouping structure of the multilevel model. This coefficient can be calculated as:

$$\rho = \frac{\sigma_{u_0}^2}{\sigma_{u_0}^2 + \sigma_e^2}$$

In this formula, σ^2_{u0} denotes the variance of the level-2 residuals (representing the variance of the random component of the model, which is the variability at the higher level of the hierarchy e.g. between countries) and σ^2_e indicates the overall variance of the model level-1 residuals (representing the variance of the fixed effects component that is the variability at the lower level of the hierarchy e.g. between responders within the same country). Therefore, the ICC refers to the amount of variation unexplained by any predictors in the given multilevel model. This value can be attributed to the grouping variable, as compared to the model's overall unexplained within and between variances (Statistical Consulting, 2015).

The analysis conducted in this study is based on a simple theoretical setting for the factors influencing the persistency of energy poverty in the EU (Figure 1). It is assumed that the length of the duration that the individual is exposed to energy poverty is determined by the micro-level and macro-level socioeconomic constraints ([16]). Micro-level constraints such as household income level and the housing cost burden affect the

13 Eurostat Harmonised index of consumer prices (HICP)-annual data (average index and rate of change) (prc_hicp_aind) https://ec.europa.eu/eurostat/data/database

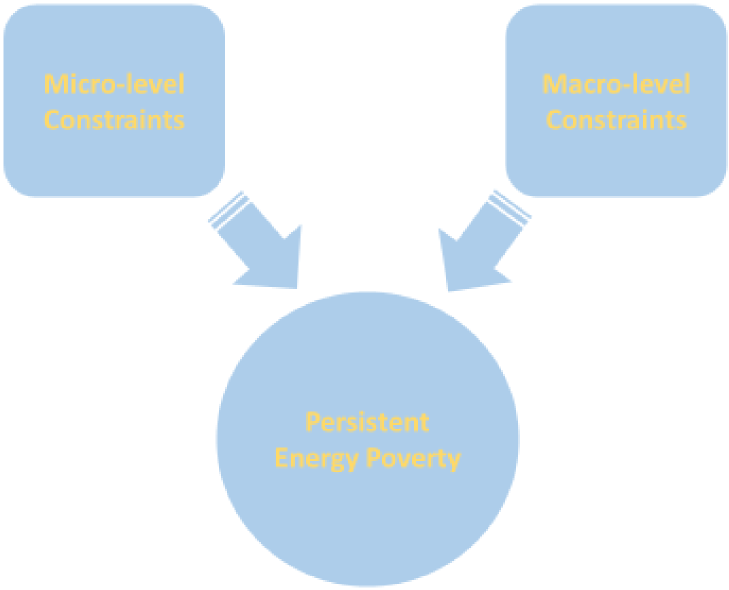
14 Eurostat Social protection- Net social protection benefits (spr_net_ben) https://ec.europa.eu/eurostat/data/database

15 International Energy Agency IEA Energy Efficiency Indicators https://doi.org/10.1787/615d9e12-en . Retrieved from OECD iLibrary https://www.oecd-ilibrary.org/energy/data/iea-energy-efficiency-indicators_615d9e12-en

16 Micro-level constraints refer to individual or small-scale factors that limit options or behaviour, while macro-level constraints are larger societal, economic, or political forces that influence outcomes for groups or populations.

household's (as well as individual's) ability to have means for energy adequacy (which refers to affordability) and efficiency. On the other hand, macro-level factors (which are the country-level determinants for this study), such as changes in the energy prices and governmental expenditure on social protection and housing, are likely to influence the overall context in the county for the conditions of access to more feasible and affordable energy services.

Figure 1. Factors affecting persistency of energy poverty



Source: JRC elaboration

The theoretical model of the study has been tested by using the SEM technique. The methodology of SEM is based on a structural model examining a given a hypothesis about the causal relations among selected variables; in other words it is a hypothesis-driven multivariate analysis method (Stephan and Friston, 2009). In SEM, the strength of each connection between given variables (donated as $y_i \rightarrow y_j$) is identified by a path coefficient to a partial regression coefficient, which refers to the dependence of variance of y_i on the variance of y_j when all other effects on y_j are held constant. This model can be formulated as:

$$y = Ay + u$$

In which y is an $n \times s$ matrix of n area-specific time series with s, A refers to an $n \times n$ matrix of path coefficients (with zeros for absent connections), and u denotes an $n \times s$ matrix of zero mean Gaussian error terms. The latter error terms operate the modelled system. Minimisation of the difference between the observed and the modelled covariance matrix Σ provides the parameter estimations. For each set of parameters, the formula for Σ can be obtained by transforming the basic SEM equations given above, which leads to:

$$y = (I - A)^{-1u}$$

$$\Sigma = yy^T$$

$$= (I - A)^{-1_{uu^T}}(I - A)^{-1^T}$$

In these equations, I represents the identity matrix. The first part of the driven equation is assumed to be a generative model describing the causal relation between the system's connectional structure and the system function. Besides, the measured time series y results from applying a function of the interregional connectivity matrix – that is, $(I-A)^{-1}$– to the Gaussian innovations u (Stephan and Friston, 2009).

Diagrams are employed for the visualisation of the hypotheses and variable interactions in the SEM; this is called path models (Hair, Page, and Brunsveld, 2020; Hair, Ringle, and Sarstedt, 2011 in Hair et al., 2021). In these models, constructs referring to latent variables are demonstrated as circles or ovals. The indicators (or manifest) variables are the collected observed data, which are shown as rectangles. The arrows in the path models refer to the links between constructs or constructs and their assigned indicators. In partial least square (PLS)-SEM, directional relationships are represented by single-headed arrows, which are predictive relationships. They can be also considered as causal relationships with some strong theoretical assumptions (Hair et al., 2021).

Furthermore, in the "Descriptive findings" section, the probabilities for changing the state of energy poverty (i.e. "Energy-poor" and "Not energy-poor") between two consecutive years in the 2017-2020 period are presented for each of three energy poverty indicators analysed in this study. The target population of this particular analysis is the individuals who were energy-poor (i.e. unable to keep home adequately warm, or having arrears on utility bills, or having a leak, damp or rot in the dwelling) in the first year of the period. The probabilities are calculated by using the increment-decrement life tables method. The formula for this calculation is:

$$q(x)_{ij} = \frac{d(x)_{ij}}{l(x)_i}$$

where $l(x)_i$ is the total population in the beginning of the period in state *i*, $d(x)_{ij}$ denotes the number of individuals leaving state *i* to enter state *j* within the given period, $q(x)_{ij}$ and refers to the probability of leaving *i* to enter state *j* for the given year x. In the increment-decrement dynamic system, the initial population in the beginning of every following year is determined as:

$$l(x+1)_i = l(x)_i - \sum d(x)_{in} + \sum d(x)_{ni}$$

in which $\Sigma d(x)_{in}$ shows the total exits from state *i* to all other states *n*, while $\Sigma d(x)_{ni}$ refers to total entries from all other states *n* to state *i* between the years *x* and *x+1* (for the detailed methodology for increment-decrement life tables, see Hayward and Grady, 1990; Land et al., 1994; Preston et al., 2000).

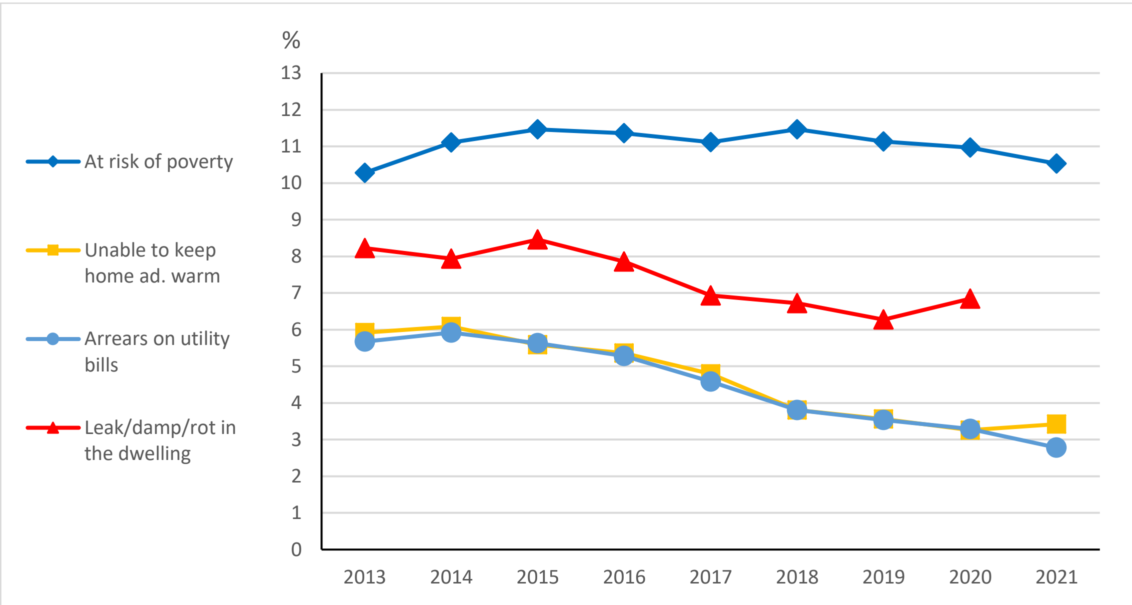
4 Findings

In this section, we present the findings of our comprehensive analysis of energy poverty in the EU, drawing upon a rich dataset that spans multiple years and encompasses a diverse range of socio-demographic variables. Utilising advanced statistical models, we explore the intricate dynamics of energy poverty persistence, assessing the influence of both micro-level factors, such as household income and housing costs, and macro-level socioeconomic constraints. Our multivariate analysis sheds light on the varying degrees of energy poverty across EU Member States, revealing significant regional disparities and the impact of different energy poverty assessment indicators. The insights garnered from this investigation aim to deepen our understanding of the phenomenon and provide a solid empirical basis for informed policymaking in the realm of energy justice and social welfare.

4.1 Descriptive findings

The results indicate that in 2021, some 3.5% of individuals in the EU were unable to keep their homes adequately warm (Figure 2) for at least three years in the four-year period, including the last survey year. This figure was around 6% in 2013 and 2014, and gradually decreased until 2021. A similar trend is observed for persistency in having arrears on utility bills over the same period, which was slightly below 3% in 2021. The proportion of people with a persistent leak, damp or rot in their dwelling was higher than the persistency rates for the other two indicators throughout the period; the change was less remarkable, and it fluctuated across years. Despite a two percentage point decrease in unfavourable physical conditions for energy efficiency from 2013 to 2019, the proportion of individuals persistently having a leak, damp or rot in the house was just below 7% in 2020. The findings also demonstrate that the persistent at-risk-of-poverty rate was almost stagnant over the 2013-2021 period, at around 10-11% in each year.

Figure 2. Persistency rates for monetary poverty and energy poverty indicators, 2013-2021

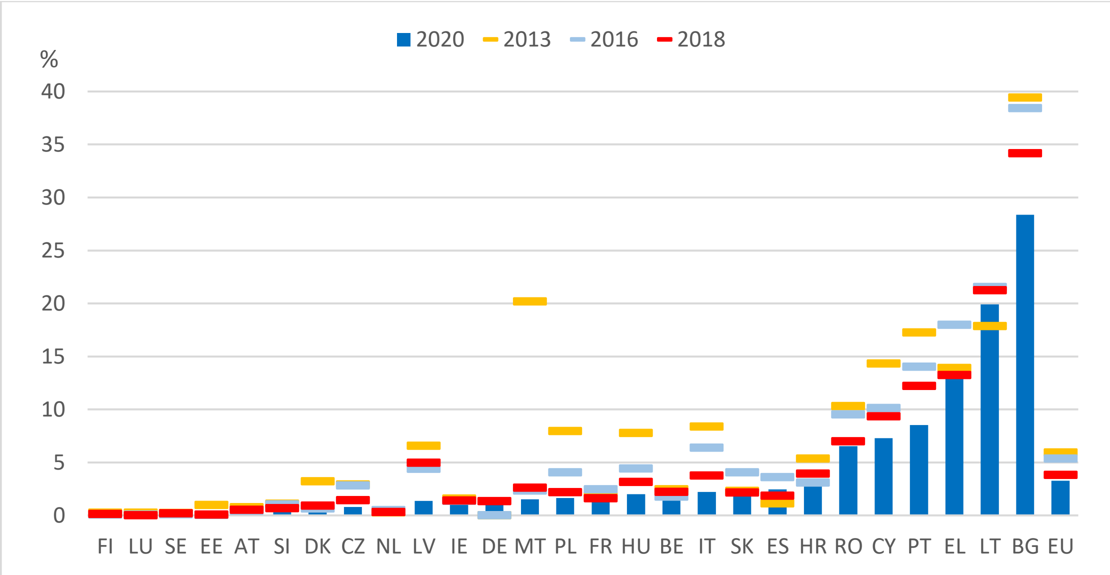


Note: DE is excluded from the EU total because of the absence of the data in seven of the nine years in the given period. Values for SK in 2017 and PT in 2021 are estimated based on the trends in the other years to obtain the EU average in these years. For PT, the 2021 persistent at-risk-of-poverty rate is obtained from Eurostat. No leak/damp/rot in the dwelling data in 2021.

Source: Eurostat and EU-SILC longitudinal microdata sets, JRC analysis

Although the changes in the persistency of energy poverty in individual Member States align to a large extent with the changes in the EU average, there are significant differences in the magnitude and trends across countries (Figure 3). The empirical findings show that by 2020, the highest proportion of individuals who were persistently unable to keep their home adequately warm was in Bulgaria (28%), approximately 8.5 percentage points ahead of Lithuania, the second highest. The figure for Greece was also over 10%. Although the persistency rates for 2017 to 2020 period were much lower in Portugal, Cyprus and Romania, they are still well above the EU average. At the other extreme, in Finland and Luxembourg, the share of the population unable to warm their homes persistently in 2020 was only 0.1%. In a further seven countries it was lower than 1% (Sweden, Estonia, Austria, Slovenia, Denmark, Czechia and the Netherlands).

Figure 3. Proportion of individuals persistently unable to keep their home adequately warm, 2013-2020



Note: DE is excluded from the EU total because of the absence of the data in seven of the nine years in the given period. For DE, the figure in 2020 refers to 2019.

Source: EU-SILC longitudinal microdata sets, JRC analysis

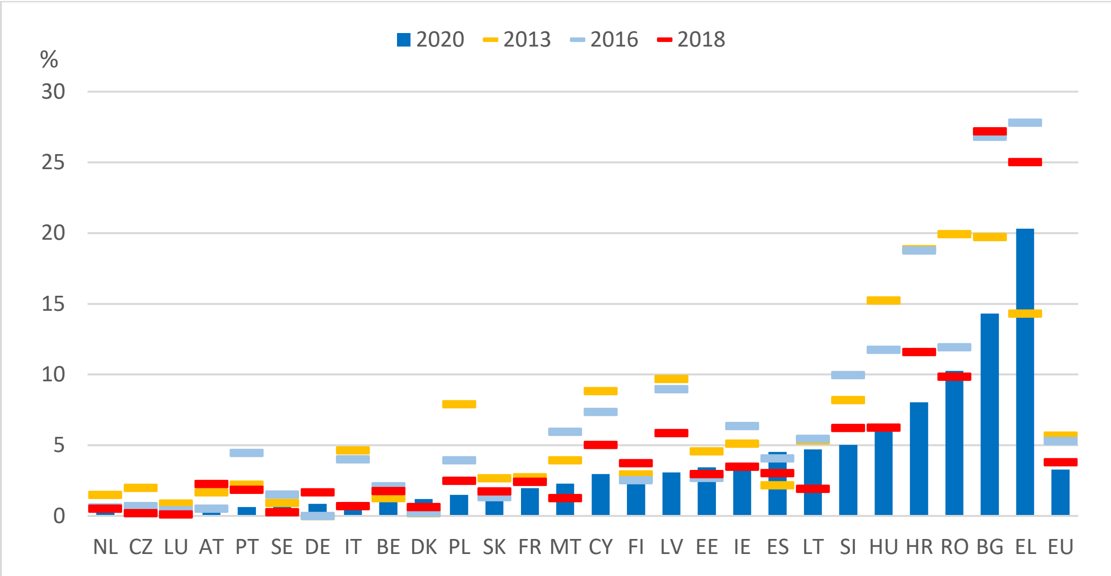
The results indicate that between 2013 and 2020, in almost all countries with available data, the proportions either remained unchanged (especially in countries with very small proportions) or decreased. The exceptions are Spain and Lithuania, which saw an increase of around 1-2 percentage points over the period. The most remarkable decline in persistency rates for being unable to keep the home warm was observed in Malta (19 percentage points) and Bulgaria (11 percentage points). In Portugal, Cyprus Poland, Italy and Hungary, the proportion also decreased by more than 5 percentage points.

One out of every five people in Greece had persistent arrears on their utility bills in 2020 (Figure 4). This proportion was 6 percentage points higher than in 2013. The figures were 14% and 10% in Bulgaria and Romania, respectively, followed by Croatia (8%) and Hungary (5%). In the Netherlands, Czechia, Austria, Luxembourg, Portugal, Sweden, Germany, Belgium and Italy, only 1% or less had arrears for at least three years including 2020. The most significant decline occurred in Croatia (11 percentage points), Romania (9.5 percentage points), Hungary (9.5 percentage points), Latvia and Cyprus (6-6.5 percentage points).

The empirical findings reveal that in the majority of Member States with available data, the proportion of people with some persistency in terms of having a leak, damp or rot in the dwelling was likely to be significantly higher than those who couldn't warm their home adequately or pay their bills (**Figure 5**). Finland scores the lowest in 2020 with 1.4%, followed by Czechia, Sweden, Slovakia, Malta, Poland and Austria at 3-4%. In terms of being unable to heat the home, the persistency rate in Finland, Czechia and Sweden is significantly lower than 1%.

At the other extreme, Hungary (17.5%), Cyprus and Belgium (both 15.5%) have the highest persistency for a leak, damp or rot in the dwelling. The figure exceeded 10% in six other countries in 2020. As mentioned above, there is no clear downward trend in this indicator for the EU as a whole over the period; the proportion decreased by 1 percentage point or more in 14 Member States, while some eight countries experienced an increase between 2013 and 2020. The biggest decreases were observed in Slovenia, Romania, Italy, Croatia, Estonia and Malta (5-10 percentage points), while there were increases of 3-4 percentage points in Belgium, Ireland and Luxembourg.

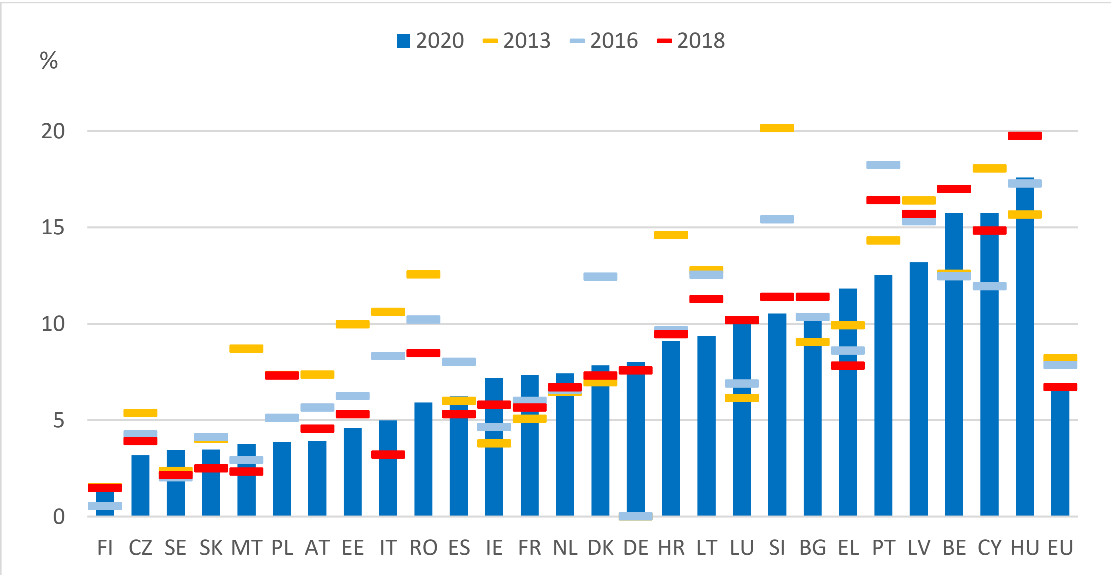
Figure 4. Proportion of individuals with persistent arrears on utility bills, 2013-2020



Note: DE is excluded from the EU total because of the absence of data in seven of the nine years in the given period. For DE, the figure in 2020 refers to 2019.

Source: EU-SILC longitudinal microdata sets, JRC analysis

Figure 5. Proportion of individuals with persistent leak/damp/rot in the dwelling, 2013-2020



Note: DE is excluded from the EU total because of the absence of the data in seven of the nine years in the given period. For DE, the figure in 2020 refers to 2019. HU and EU figures are inconsistent due to inconsistent data in HU for 2017.

Source: EU-SILC longitudinal microdata sets, JRC analysis

The results of the correlation analysis for the selected monetary and energy poverty indicators demonstrate that the strongest relation is between arrears on utility bills and ability to keep the home warm (**Table 1**). This finding corresponds to the link between these two indicators for the cross-sectional measurement of energy poverty. On the other hand, trends vary in some countries on the persistency of being unable to keep the home adequately warm or pay utility bills. This differentiation is also visible in the ranking of the 27

Member States according to the persistency rates of these two indicators. These two facts suggest that there are different patterns affecting energy poverty in each EU Member State.

The correlation coefficients show that there is a moderate relationship between the persistent at-risk-of-poverty rates of countries and those for being unable to keep the home warm or pay utility bills. The link with the former is slightly stronger than the latter. On the other hand, there is an extremely weak causal relationship between the persistent at-risk-of-poverty rate and the persistency of having a leak, damp or rot in the dwelling. According to the findings, there is a moderate link between a dwelling's persistently unfavourable conditions and the other two energy poverty indicators, but it is much looser than the correlation between being unable to warm the home and having arrears on utility bills.

Table 1. Correlation coefficients between persistent at-risk-of-poverty and energy poverty indicators, 2020

	Persistent poverty rate	**Unable to warm home**	**Arrears on utility bills**	**Leak/damp/rot in dwelling**
Persistent poverty rate	1.000			
Unable to warm home	0.557**	1.000		
Arrears on utility bills	0.482**	0.646***	1.000	
Leak/damp/rot	0.045	0.299	0.268	1.000

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. P values are affected by small number of cases (n=27). DE values refer to 2019.*

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Between 2017 and 2020, 18% of individuals in the EU were unable to keep their home adequately warm for at least one year (**Table 2**), a figure that exceeds the annual rate in 2020 by about 10 percentage points. Around 8% of individuals faced this issue for two years or more. Notably, in Lithuania and Cyprus, over 40% struggled with adequate heating for at least one year during this period. Greece, Portugal, Bulgaria and Italy also exceeded 30%. On the other hand, the Netherlands was just below 4% and Austria 4%, with Czechia, Denmark, and Finland close to 5%. In 12 countries total, the proportion was less than 10%. Fewer people faced persistently inadequate heating for two years or more. However, they represented around one third of the overall population in Bulgaria and Lithuania, more than one fifth in Greece, Cyprus and Portugal, and more than 10% in Italy and Romania. Sweden and Luxembourg reported rates below 1%, and Austria, Finland, Estonia, the Netherlands, Slovenia, and Denmark saw rates of 1-2%.

From 2017 to 2020, 15.5% of individuals in the EU experienced arrears on utility bills for at least one year, with 7.5% facing this issue for two years or more. Greece recorded the highest rates, with 57% for at least one year and 39% for two years. In Bulgaria, over two fifths of the population had arrears on utility bills for one year or more; the figure was around one third of the overall population in Croatia, and it exceeded 20% in Slovenia, Cyprus, Romania, Hungary and Ireland. At the other extreme, the figure was just above 2% in the Netherlands, 3.5% in Sweden and around 5% in Luxembourg and Czechia. In Bulgaria, some 29% of individuals had arrears for two years or more over the same period, while this share exceeded 10% in six other Member States. The figures were lower than 2% in Sweden, the Netherlands, Czechia and Luxembourg, and less than 5% in nine other countries.

Regarding housing conditions, the proportion of individuals who had a leak, damp or rot in their dwellings for at least one year between 2017 and 2020 was just below 30% in the EU as a whole. In Cyprus, two thirds of the overall population resided in a dwelling with unfavourable physical conditions for energy efficiency for at least one year or more. This proportion was more than 40% in Portugal, Latvia, Slovenia and Italy. The figures were less than 20% in only nine EU Member States, while the lowest results were in Slovakia (10%), Finland and Malta (11-11.5%). In the EU as a whole, some 14% of the population had a leak, damp or rot in the dwelling for at least two years over the period. In Cyprus, around two fifths of people faced this problem while a quarter or more of the population faced similar issues in Hungary, Portugal, Latvia and Slovenia. The lowest rates for two years or more were reported in Finland (4%), followed by Slovakia, Malta, Czechia and Sweden, at 6-7%.

Table 2. Proportion of individuals according to the total years spent as energy-poor in last four years by energy poverty indicator, 2020 (%)

	Unable to keep home ad. warm				Having arrears on utility bills				Having leak/damp/rot in dwelling			
	1	2	3	4	1	2	3	4	1	2	3	4
BE	6.8	2.1	1.8	1.3	5.8	1.6	1.5	0.2	2.3	2.9	1.5	15.4
BG	1.6	2.7	2.4	27.4	12.3	2.6	13.1	13.5	1.4	1.6	1.2	10.3
CZ	2.9	0.7	0.5	0.4	4.3	0.7	0.3	0.1	7.4	2.6	2.1	2.4
DK	2.6	1.4	0.4	0.4	4.0	2.8	0.1	1.1	11.0	5.0	4.4	4.0
DE	4.5	1.3	0.9	0.8	4.4	0.8	1.1	0.3	9.2	5.7	4.2	5.4
EE	6.9	0.8	0.5	0.1	7.2	3.5	3.5	0.8	18.1	8.0	3.8	2.1
IE	4.1	1.4	0.5	1.0	12.9	3.7	2.6	1.7	13.2	5.5	4.4	3.5
EL	15.6	8.8	6.6	8.4	18.2	14.0	11.5	13.3	6.8	1.4	5.0	7.0
ES	13.6	5.2	2.0	1.0	8.4	4.5	3.0	1.7	18.2	9.6	5.1	1.6
FR	7.9	2.7	2.1	0.8	7.3	3.4	2.5	0.8	12.7	6.2	4.6	3.4
HR	7.8	2.5	1.5	2.4	13.4	8.0	4.7	5.9	1.5	1.6	1.7	8.6
IT	18.2	8.3	3.3	1.0	8.2	2.3	1.2	0.1	25.0	10.3	3.8	1.3
CY	19.4	11.7	8.1	2.8	11.3	7.8	3.2	0.9	27.4	19.1	13.2	7.2
LV	16.6	2.9	1.4	0.1	10.1	5.5	2.7	0.9	17.8	9.8	8.6	6.0
LT	10.8	9.4	6.7	15.1	7.9	1.7	2.1	3.5	6.5	3.1	4.2	7.5
LU	6.2	0.6	0.0	0.1	3.9	0.7	0.5	0.3	11.4	7.1	4.9	5.9
HU	8.7	2.7	1.5	1.0	10.7	4.3	3.4	4.0	67.0	12.3	8.2	12.5
MT	9.6	4.2	1.5	0.3	8.3	1.9	1.9	1.3	5.1	1.2	3.0	2.4
NL	2.2	0.6	0.5	0.4	1.1	0.7	0.1	0.4	15.8	6.7	4.6	4.0
AT	2.9	0.6	0.2	0.3	4.5	2.0	0.6	0.0	11.3	4.9	2.3	2.5
PL	5.7	1.6	1.2	0.8	9.5	3.0	1.6	0.7	9.4	4.1	3.4	2.8
PT	17.0	9.1	6.8	5.5	4.7	2.4	1.1	0.2	20.4	11.1	8.8	7.4
RO	5.9	2.6	2.4	5.1	7.3	3.2	4.7	7.4	5.3	2.3	1.9	4.9
SI	5.4	1.4	0.6	0.1	12.0	5.8	4.2	2.4	18.4	10.1	7.6	5.3
SK	6.4	3.9	1.7	1.0	13.9	3.7	1.7	0.5	4.4	1.5	1.7	2.8
FI	4.0	1.0	0.2	0.1	6.5	4.1	2.6	1.5	6.8	2.8	1.0	0.5
SE	5.8	0.4	0.1	0.2	2.4	0.5	0.4	0.3	10.9	3.3	2.8	1.3
EU	9.7	4.0	2.2	2.1	7.8	3.2	2.5	1.9	15.4	6.5	4.0	3.8

Note: Empty cells refer to no data or unpublishable findings due to an insufficient number of cases. Figures in bold italic refer to findings with low reliability due to the small number of observations. The EU total does not include DE. For DE, figures refer to 2019. HU and EU figures are inconsistent due to inconsistent data in HU for 2017.

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

The share of persistently energy-poor among those who were energy-poor in the last year of the four-year period is useful to examine the extent to which those who are energy-poor in a given year are exposed to long-term poverty. The higher the proportion, the less likely they are to escape energy poverty in the long-run. The findings indicate that around 47-48% of energy-poor individuals in 2020 were persistently energy-poor over the 2017-2020 period (**Table 3**). Nevertheless, this proportion varies across countries, across energy poverty indicators and over time within the same country. For example, in Bulgaria, a staggering 95% of individuals who could not adequately heat their homes in 2020 had been facing this issue persistently. Similarly high rates were observed in Lithuania and Romania, with figures surpassing 70%, and in Greece, where nearly two-thirds of individuals experienced consistent heating challenges. In contrast, less than 5% of the energy-poor in Luxembourg were persistently unable to heat their homes, with Finland at 8% and Sweden, Estonia, and Denmark all below 20%.

When it comes to arrears in utility bills, more than 70% of individuals facing the issue in 2020, in Romania, Lithuania and Greece, also had persistent arrears over the four-year period. This indicator was 62% in Croatia, and exceeded 50% in eight other Member States. Notably, Italy reported that less than 20% of its population with arrears were persistently affected, and in Czechia, the figure was below a quarter. In Austria, Portugal. Belgium and Luxembourg, the figures were less than 30%.

In the context of individuals having a leak, damp or rot in their housing units, Belgium had the highest rates of persistency in 2020 (95%). This proportion was also above 90% in Bulgaria and Croatia, and exceeded 80% in Malta, Lithuania and Greece. The lowest figures were in Italy (25%), Spain (30%) and Finland (35%). In only nine countries was the proportion of individuals persistently living in such conditions less than the half of those who were suffering them in that year.

There are remarkable differences in the proportions between 2013 and 2020 for all three energy poverty indicators and in almost all countries with available data. For instance, in Malta, the figures for being unable to keep the home adequately warm declined from 95.5% to 24.5%, while they increased from 8% to 46% in the Netherlands. In total, there were nine countries with a growing proportion of residents unable to keep their home warm, 14 countries in which a growing proportion were suffering arrears on their utility bills and 16 countries in which the proportion of those with a leak, damp or rot was increasing. The direction of change for each country in terms of each energy poverty indicator also varies. For instance, in Finland, the proportion of those unable to keep their home adequately warm decreased by 13 percentage points, but those having arrears on utility bills increased by 14 percentage points, while the share if those with a leak, damp or rot remained almost unchanged at only 1 percentage point. Therefore, it can be argued that there is no sufficient empirical evidence for consistency in the trends relating to the share of persistent energy poverty within the total energy-poor.

It should be noted that in only seven of the 27 Member States did the individuals who were persistently unable to keep their home adequately warm over the period 2017-2020 constitute the majority of those facing the problem in the final year alone. The persistency rate was over half in 12 Member States for arrears on utility bills, and 18 Member States for having a leak, damp or rot in the dwelling. These findings suggest that the individuals were much less likely to escape from persistently unfavourable physical conditions affecting their energy efficiency than from arrears on utility bills or being unable to keep their houses adequately warm.

On the other hand, the results indicate that there is some link between the persistency rate and the proportion of persistently energy-poor individuals within the overall energy-poor in a given year. The correlation coefficients for being unable to keep the home adequately warm is 0.77, and 0.66 for having arrears on utility bills in 2020. Although the link is looser between the persistency rate and the proportion of persistence among those suffering a leak, damp or rot, it is still statistically significant (0.38).

The increment-decrement life table analysis has been implemented to explore the transition between the states of being energy-poor and non-energy-poor across the years 2017-2020 for the individuals who were energy-poor at the beginning of the time interval. The findings show that in the EU as a whole, the probability of exiting from energy poverty in the initial two years is higher than in the following 2-year periods for all three energy poverty indicators (**Figure 6**). In this respect, some half of the energy-poor were likely not to be poor in the second year. Therefore, it can be argued that the more individuals spend time in energy poverty, the harder it is for them to escape it in later years. The probability of escaping poverty reduces significantly for all three indicators between the second and third years, and between the third and fourth; this is most

Table 3. Proportion of individuals persistently energy-poor within the total energy-poor population in the last year of the 4-year period by energy poverty indicator, 2013-2020 (%)

	Unable to keep home ad. warm		Having arrears on utility bills		Having leak/damp/rot in dwelling	
	2013	2020	2013	2020	2013	2020
BE	45.3	44.0	32.6	27.0	77.0	95.2
BG	85.7	95.0	67.3	58.5	83.1	93.6
CZ	50.6	46.2	59.7	22.6	67.4	65.8
DK	68.7	18.0	***7.5***	***32.4***	41.7	56.8
DE		54.4		46.4		65.3
EE	33.9	14.3	49.7	58.5	57.1	44.8
IE	27.1	53.1	43.3	51.9	56.4	46.6
EL	50.0	65.5	44.3	70.5	77.5	84.8
ES	17.5	26.7	35.0	48.0	36.8	29.7
FR	28.2	38.7	46.1	36.1	44.0	49.6
HR	46.6	50.5	61.7	62.3	86.3	92.9
IT	43.5	29.5	41.5	19.1	50.1	25.1
CY	41.2	40.8	42.5	43.8	54.4	44.0
LV	55.5	20.0	52.6	54.7	56.1	66.1
LT	61.8	76.0	55.8	74.2	79.2	86.1
LU	15.7	4.7	35.6	28.5	43.5	73.7
HU	58.7	45.5	69.3	55.9	66.0	75.5
MT	95.6	24.7	52.5	43.0	87.0	88.4
NL	8.2	46.4	74.7	59.3	47.4	49.0
AT	29.2	38.5	31.9	25.7	57.5	50.9
PL	72.3	48.8	65.0	34.9	84.2	61.1
PT	56.4	49.9	26.7	26.7	45.3	55.4
RO	73.7	72.3	71.1	77.5	81.2	73.2
SI	23.4	20.7	44.8	53.9	71.8	58.3
SK	44.9	33.2	40.9	30.4	51.9	73.4
FI	20.8	7.7	45.2	59.3	33.9	34.9
SE	50.0	11.5	37.4	43.2	33.9	41.8
EU	50.9	46.8	53.1	48.2	55.2	46.9

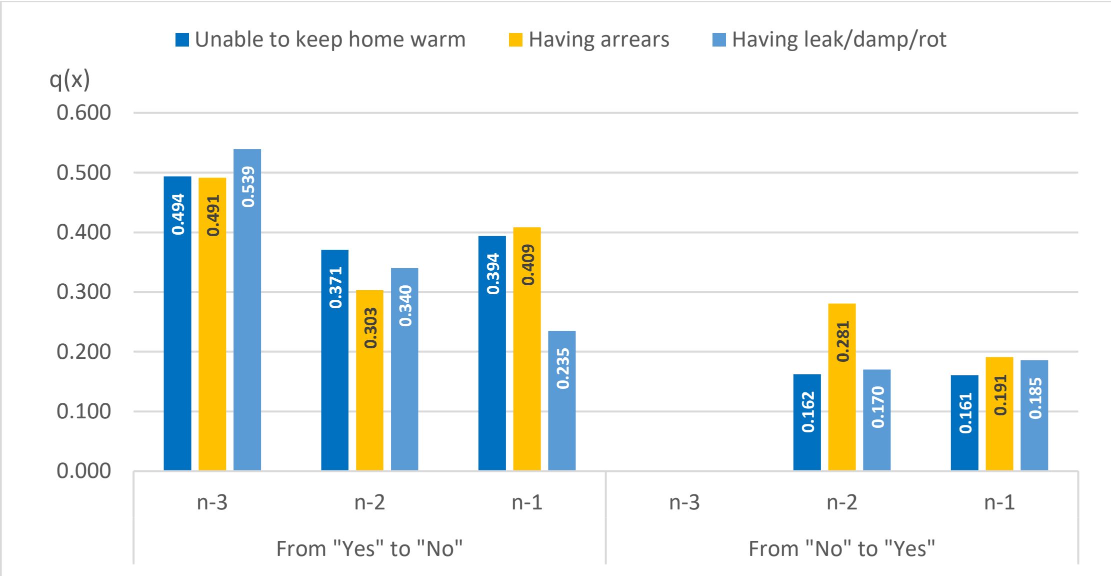
Note: Empty cells refer to no data or unpublishable findings due to insufficient number of cases Figures in bold italic refer to findings with low reliability due to the small number of observations. The EU total does not include DE. For DE, figures for 2020 refer to 2019.

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

pronounced in the category of having a leak, damp or rot in the dwelling, and least visible for having arrears on utility bills.

On the other hand, a significant portion of those who were energy-poor in the first year, but not in the second, are likely to return to energy poverty in the third and fourth year. This is true for more than a quarter of those with arrears on utility bills between the second and third years, and almost one fifth between the third and fourth years. The probabilities were around 0.16 for being unable to keep the home warm and 0.17-0.18 for having a leak, damp or rot in the dwelling. These findings suggest that escaping any of these three forms of energy poverty in the first half of the 2017-2020 period did not guarantee continued success in the following years.

Figure 6. Increment-decrement life tables probabilities for transition between “energy-poor” and “non-energy-poor” for those who were energy-poor in year n-3 by energy poverty indicator, EU, 2017-2020



Note: The EU total does not include DE

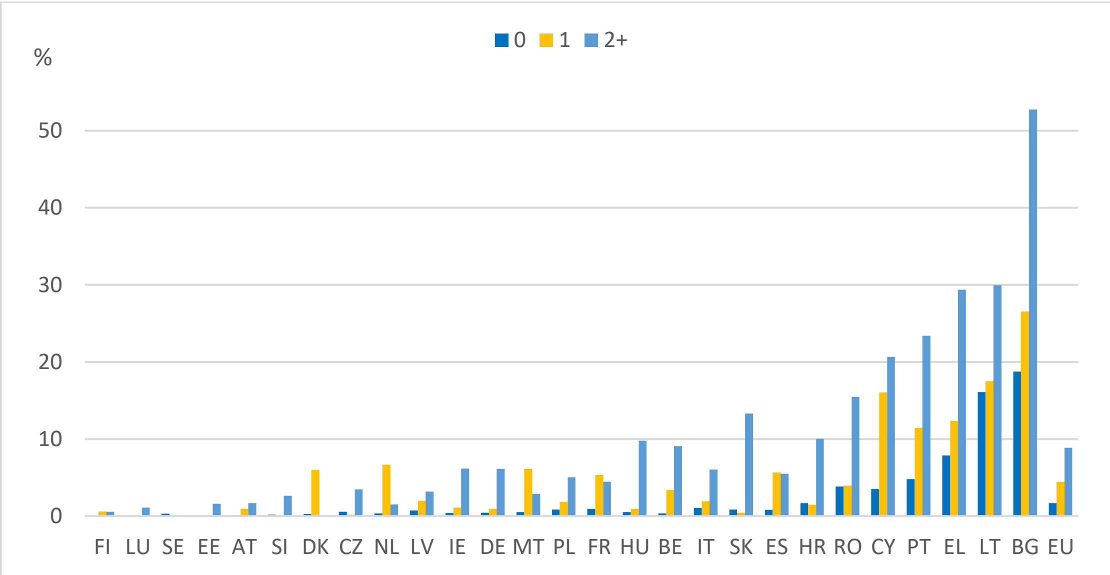
Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Although the patterns of probability for the transition between energy poverty and non-energy poverty are similar in the majority of Member States, there are significant variations in magnitude across countries and among sub-periods in the given time interval (**Table 8**). For instance, in 18 Member States, the likelihood of escaping energy poverty during the first two years was greatest in terms of keeping the home adequately warm and paying the bills. In 22 Member States, this was true for having a leak, damp or rot in the dwelling. There were significant differences between the sub-periods in 17 Member States for keeping the home warm, in 14 Member States for having unfavourable physical conditions in the dwelling, and in only 13 countries for having arrears. Likewise, the probability of returning to energy poverty could be over 0.3 between the third and the forth years, as observed for being unable to keep the home warm in Denmark or having a leak, damp or rot in Cyprus. The probability of returning to energy poverty in the same interval was negligible for keeping the home warm in Bulgaria, having arrears in the Netherlands and having a leak or damp in Belgium.

The empirical findings at both the EU level and within individual countries reveal that there is a cyclical nature to energy poverty. The point at which an individual emerges from a state of poverty can act as a protective factor against relapsing, yet it does not provide absolute assurance. Furthermore, it is important to recognize that each Member State may exhibit unique patterns of persistence and life cycle characteristics related to energy poverty.

The findings reveal that there is a very strong relationship between persistent energy poverty and long-term monetary poverty. In 2020, the proportion of individuals who were persistently unable to keep their homes adequately warm among those who had spent two or more years below the at-risk-of-poverty threshold, was almost three times higher than the EU population as a whole (**Figure 7**). In Bulgaria, more than half of the people in the same category were unable to heat their homes adequately for at least three years including the last year during 2017-2020 period; this figure is almost the twice the country's average. In Greece, Portugal, Cyprus, Slovakia and Lithuania, the proportion unable to heat their homes among those who had experienced monetary poverty for at least two years exceeded the country averages by at least 10 percentage points. At the other end of the scale, in 19 Member States, less than 1% of those unable to heat their homes had not previously been at risk of poverty. However, it should be noted that in Bulgaria, almost one fifth of those who had not experienced monetary poverty during the 2017-2020 period were persistently unable to keep their houses adequately warm. This proportion was 16% in Lithuania and just below 8% in Greece. However, this positive relation, between the increase in the number of years below the at-risk-of-poverty threshold and the persistency rate for being unable to keep the home warm, is not true in all Member States. In Denmark, the Netherlands and Malta, the rates for those who experienced only one year below the poverty threshold were significantly higher than for those who were below the threshold for two years or more; it is also the case to a lesser extent in France and Spain, while the difference between these two categories was negligible in Finland and Sweden.

Figure 7. Proportion of individuals persistently unable to keep the home adequately warm by years spent below the at-risk-of-poverty threshold, 2020



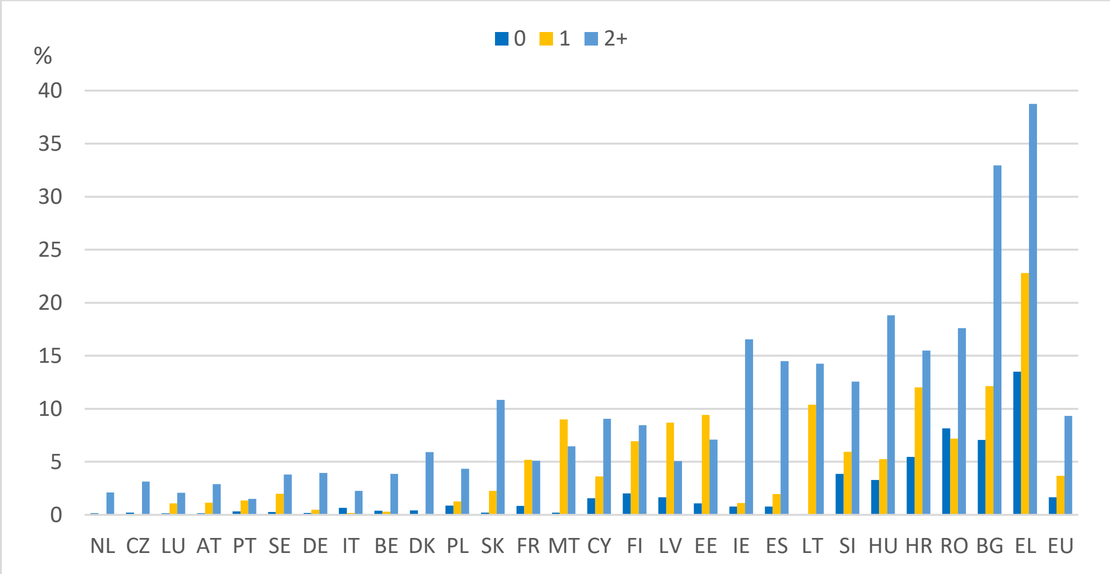
Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019. At-risk-of-poverty threshold = 60% of national median

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Years spent at risk of poverty are linked more strongly with persistently having arrears than with persistently being unable to warm the home. In the EU as a whole, the rate for persistently having arrears on utility bills was less than 2% for those who were not monetary poor in any of the years between 2017 and 2020. The figure increased to 3.5% for those who were below the threshold for one year, and slightly exceeded 9% for those who were below it for at least two years (**Figure 8**). Almost two fifths of the population in the latter category in Greece had persistent arrears on utility bills in 2020, and over 30% in Bulgaria. In Hungary, those who could not pay their bills represented 19% of people who had been at risk of poverty for at least two years, and only 6% of the country's total population. This differential is also large in Ireland, Spain, Lithuania, Slovakia, Croatia and Romania. In 19 Member States, the proportion of individuals at risk of poverty in only one out of four years was 2 percentage points higher than the average rate for the overall country population; this exceeded 5 percentage points in Malta, Estonia, Lithuania and Latvia. In Greece, 13.5% of those who had not experienced monetary poverty in any year of the period were nevertheless suffering persistent arrears on their utility bills.

The results indicate that the causal relationship between the persistency of having a leak, damp or rot in the dwelling and of years spent below the at-risk-of-poverty threshold is more noticeable in some countries including Germany, Croatia, Slovenia and Poland (**Figure 9**). It is less evident in others including Finland, Malta, Denmark, the Baltic countries and Bulgaria, especially when the figures are examined for the people who experienced only one year of monetary poverty and those who had never been below the at-risk-of-poverty threshold in 2017-2020. However, there is clear evidence in all Member States of the influence of long-term exposure to monetary poverty on the physical state of the dwelling. In this regard, the proportion of the population persistently suffering from a leak, damp or rot was at least 5 percentage points larger than the country average in 16 Member States, with a difference of over 15 percentage points in Hungary and Lithuania, and more than 10 percentage points in Slovenia, Bulgaria, Germany, Ireland, Slovakia and Portugal. In Hungary, Cyprus and Belgium, more than a fifth of those who had experienced at least one year of monetary poverty had a persistent leak, damp or rot in their dwelling.

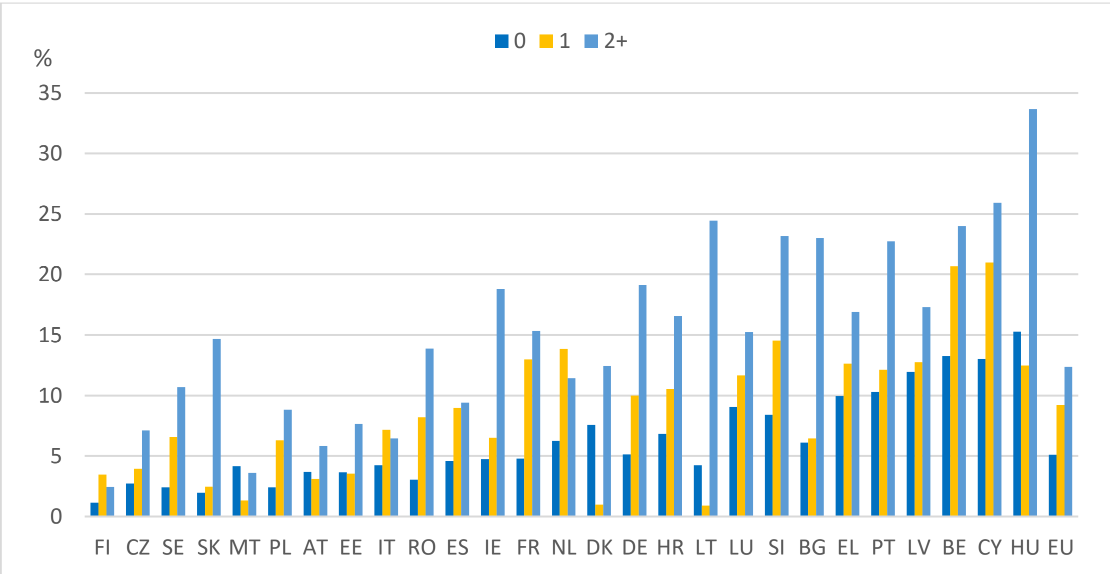
Figure 8. Proportion of individuals with persistent arrears on utility bills by years spent below the at-risk-of-poverty threshold, 2020



Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019. At-risk-of-poverty threshold = 60% of national median

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Figure 9. Proportion of individuals persistently having a leak/damp/rot in the dwelling by years spent below the at-risk-of-poverty threshold, 2020

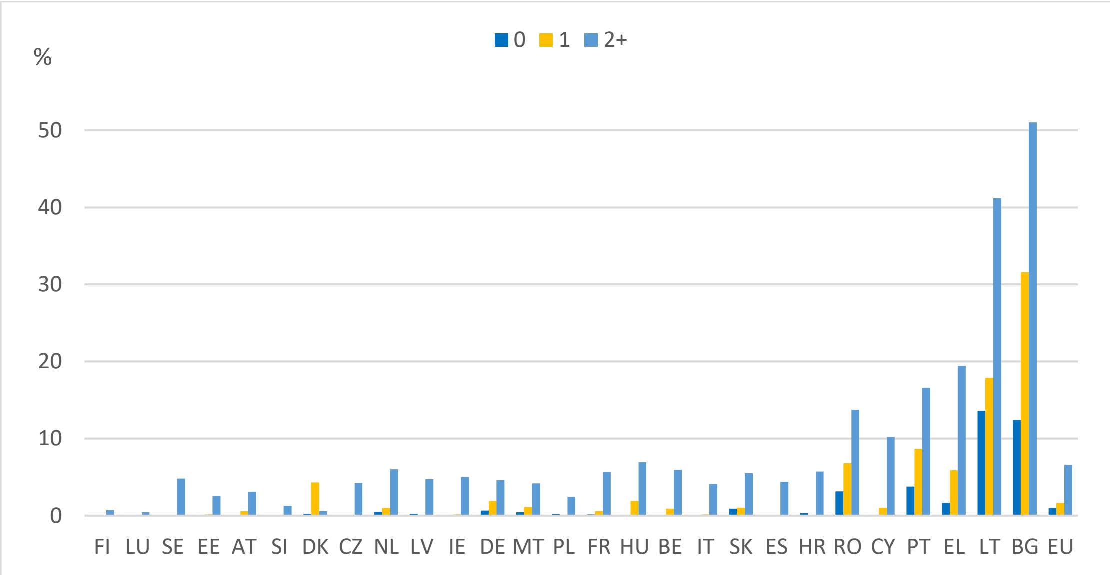


Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019. HU and EU figures are inconsistent due to inconsistent data in HU for 2017. At-risk-of-poverty threshold = 60% of national median

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

As may be expected, the evidence shows that those who were exposed to a heavy burden of housing costs in proportion to their household income for a longer period had higher persistency rates in terms of being unable to keep their home adequately warm. In the EU as a whole, those who suffered disproportionate housing costs for at least 2 years between 2017 and 2020 were twice as likely as the general population to be unable to heat their home (**Figure 10**). Only 1-2% of those who carried this burden for less than a year were unable to heat their homes. In Bulgaria, more than half of those who suffered this heavy burden for two to four years were persistently unable to heat their homes sufficiently. The figure slightly exceeded 40% in Lithuania and was just below 20% in Greece. In Bulgaria, Greece, Lithuania, Portugal, Germany and Denmark, there is little distinction between those who did not suffer disproportionate housing costs and those who suffered them for just one year. Denmark was the only Member State in which the highest rate in 2020 was among those who suffered heavy housing costs for just one year.

Figure 10. Proportion of individuals persistently unable to keep their home adequately warm by years spent with a heavy burden of housing costs over household income, 2020



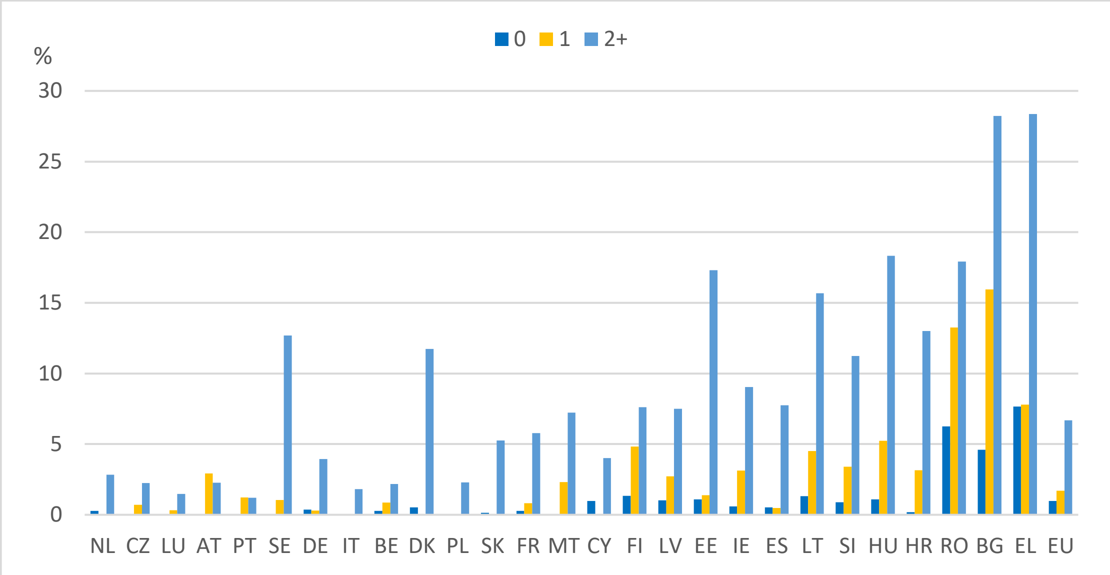
Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Having a heavy burden of housing costs for at least two years correlates with being unable to keep the home adequately warm in a similar pattern to its correlation with persistent arrears on utility bills. The persistency figures of these two energy poverty indicators for years with disproportionate housing costs set against the EU total as a whole are almost identical (**Figure 11**). The rate for those with a heavy burden of housing costs for two years was just above 28% in Greece and Bulgaria; around 17-18% in Hungary, Romania and Estonia; and more than one tenth of the overall population in this category in Lithuania, Croatia, Sweden, Denmark and Slovenia. In Austria, the highest figure was among those who experienced a heavy burden of housing costs for only one year between 2017 and 2020.

Unlike the two other energy poverty indicators, across the EU, the persistence of having a leak, damp or rot, for those who had not experienced disproportionate housing costs, was some 2 percentage points higher than for those who had experienced such costs for one year (**Figure 12**). Those exposed to such costs for two years or more represented 10% of the overall individuals in this category. For individuals, who had heavy burden due to housing costs for at least two years, the figures were 10% or more in 21 Member States. Among these, the proportion of those with a persistent leak, damp or rot was almost one third of the population in this category in Denmark, and it was around one quarter of the individuals in Latvia, Belgium and the Netherlands. The findings exceeded 10% in 7 countries for those who had heavy burden of housing costs, merely one year. In Belgium and Portugal, it was also the case for the population, which was not exposed to a heavy burden of housing costs in any year throughout 2017-2020 period.

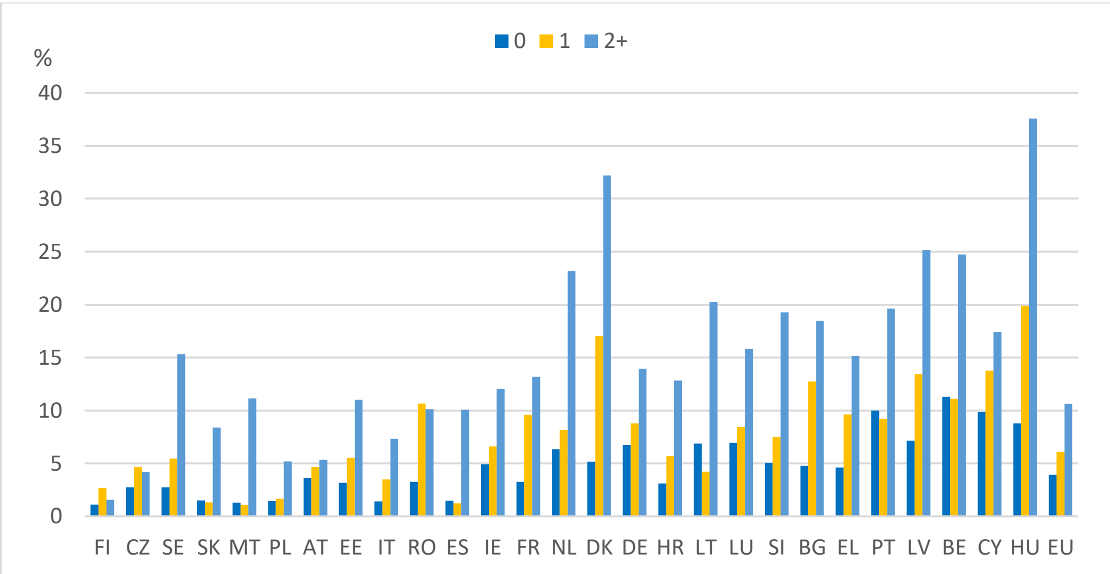
Figure 11. Proportion of individuals with persistent arrears on utility bills by years spent with a heavy burden of housing costs over household income, 2020



Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019.

Source: EU-SILC longitdudinal microdata data sets (version 05/10/2023), JRC analysis

Figure 12. Proportion of individuals persistently having leak/damp/rot in the dwelling by years spent in having a heavy burden of housing costs over household income, 2020

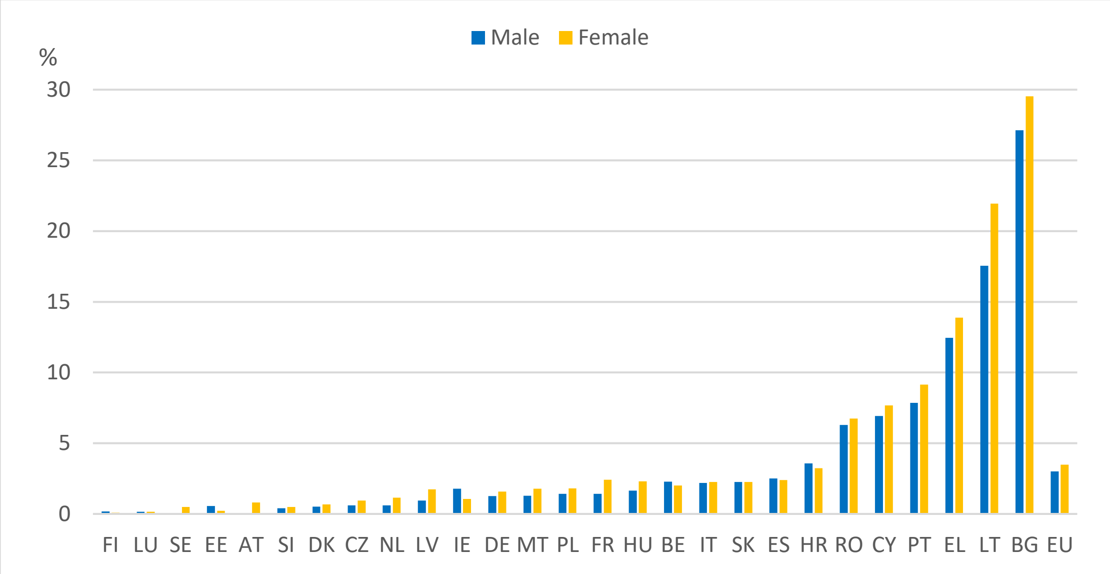


Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019. HU and EU figures are inconsistent due to inconsistent data in HU for 2017

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

The findings suggest that in the EU as a whole, and in the majority of Member States, there is no significant differentiation between men and women in persistently being unable to warm the home adequately (**Figure 13**). However, the rate was more than 1 percentage point higher for women in France, Greece and Portugal, around 2.5 percentage points higher in Bulgaria, and more than 4 percentage points higher in Lithuania.

Figure 13. Proportion of individuals persistently unable to keep home adequately warm by sex, 2020

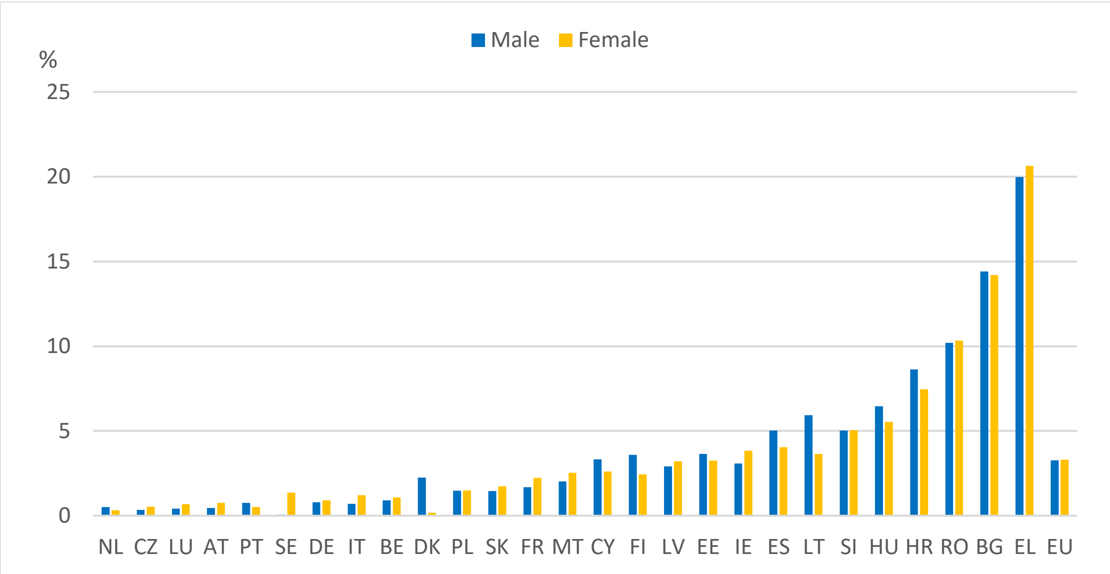


Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Despite the negligible gender difference in most Member States in terms of persistent arrears on utility bills, the men outnumber the women in Lithuania, Denmark, Finland, Croatia and Spain. Only in Sweden are there more women than men with persistent arrears on their utility bills, by around 1 percentage point (**Figure 14**).

Figure 14. Proportion of individuals with persistent arrears on utility bills by sex, 2020

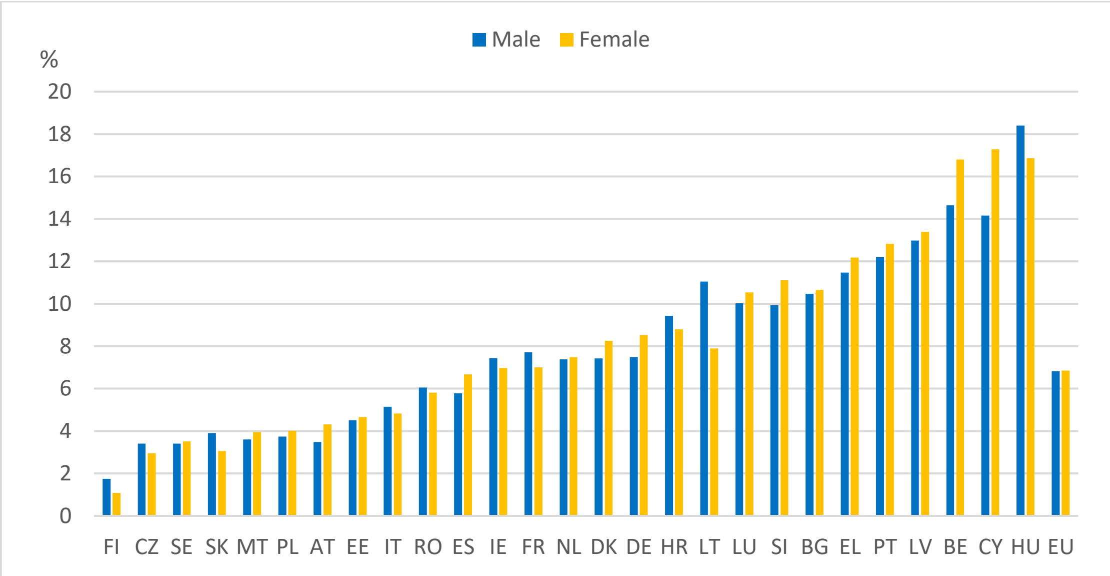


Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

As with the two other energy poverty indicators, there is no evidence for a gender gap in the vast majority of Member States, in terms of persistently having a leak, damp or rot in the dwelling (**Figure 15**). It should however be noted that in Cyprus, Belgium, Slovenia and Germany, women were significantly more likely to suffer such conditions, while in Lithuania and Hungary, the opposite was true.

Figure 15. Proportion of individuals persistently having leak/damp/rot in the dwelling by sex, 2020

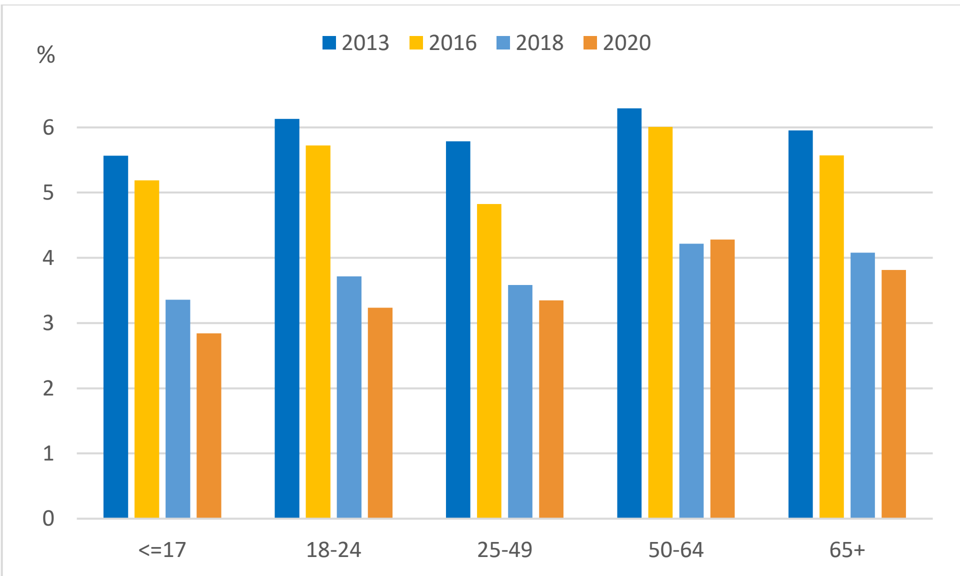


Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019. HU and EU figures are inconsistent due to inconsistent data in HU for 2017.

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

According to the descriptive analysis, although age does not seem to be an important factor affecting the persistency of being unable to keep the home adequately warm in the EU as a whole throughout 2013-2020 (**Figure 16**), the pattern varies across Member States. In this regard, those aged 65 and over at the end of the period in Bulgaria, Lithuania, Portugal, Croatia and Denmark were more likely to be persistently unable to warm their homes adequately during the 2017-2020 period. This was the case for those who were younger than 18 by 2020 in Lithuania, Romania, Spain, and Belgium; and for the 18-24 age group in Greece, Portugal, Cyprus, Hungary and Ireland; and only in France for those aged between 50 and 64 (**Table 7**).

Figure 16. Proportion of individuals persistently unable to keep home adequately warm by age in the end of 4-year period, EU, 2013-2020

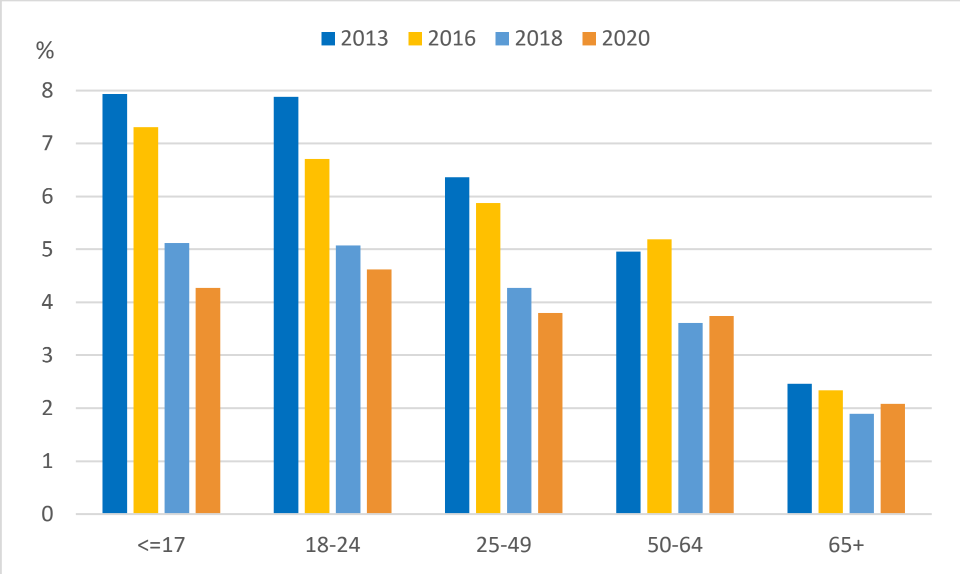


Note: The EU total does not include DE

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

On the other hand, there is some correlation between age and the persistency rates for having arrears on utility bills in the EU as a whole. The proportion of individuals in the younger age groups with persistent arrears during the given 4-year intervals throughout the 2013-2020 period was higher than for the older age groups. It gradually decreases in every following age group, with the lowest rates for those aged 65 and over (**Figure 17**). In 15 Member States, the figures for under 18 in 2020 exceeded the national average by at least 1 percentage point; the gap for this age group was 7.5 percentage points in Lithuania, and 4-5 percentage points in Greece, Bulgaria and Romania. The 18-24 age group were at a similar disadvantage in 8 countries; the gap with the country average was around 3 percentage points or more in Finland, Latvia, Hungary, Bulgaria and Greece. In Greece, Bulgaria, Croatia and Finland, the 25-49 age group were at a significant disadvantage relative to those aged 50 and over.

Figure 17. Proportion of individuals with persistent arrears on utility bills by age in the end of 4-year period, EU, 2013-2020

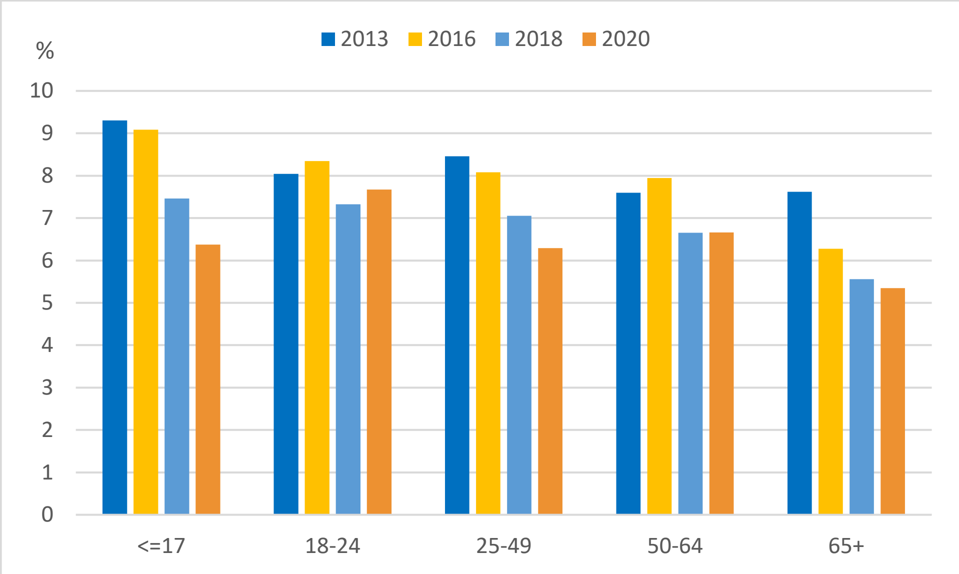


Note: The EU total does not include DE

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

A similar relationship, though to a lesser extent, can be seen at EU level between age and the persistency of having a leak, damp or rot in the dwelling (**Figure 18**). However, the findings do not indicate the same pattern in all Member States. In Hungary, Belgium, Bulgaria, Luxembourg and Spain, the problem was biggest for the two youngest age groups, while in Croatia, Portugal and Greece, it was biggest for the 65+ group. In the other Member States, the difference across the age groups was either negligible or there is no clear pattern for the relationship between persistency of this indicator and age.

Figure 18. Proportion of individuals persistently having leak/damp/rot in the dwelling by age in the end of 4-year period, EU, 2013-2020



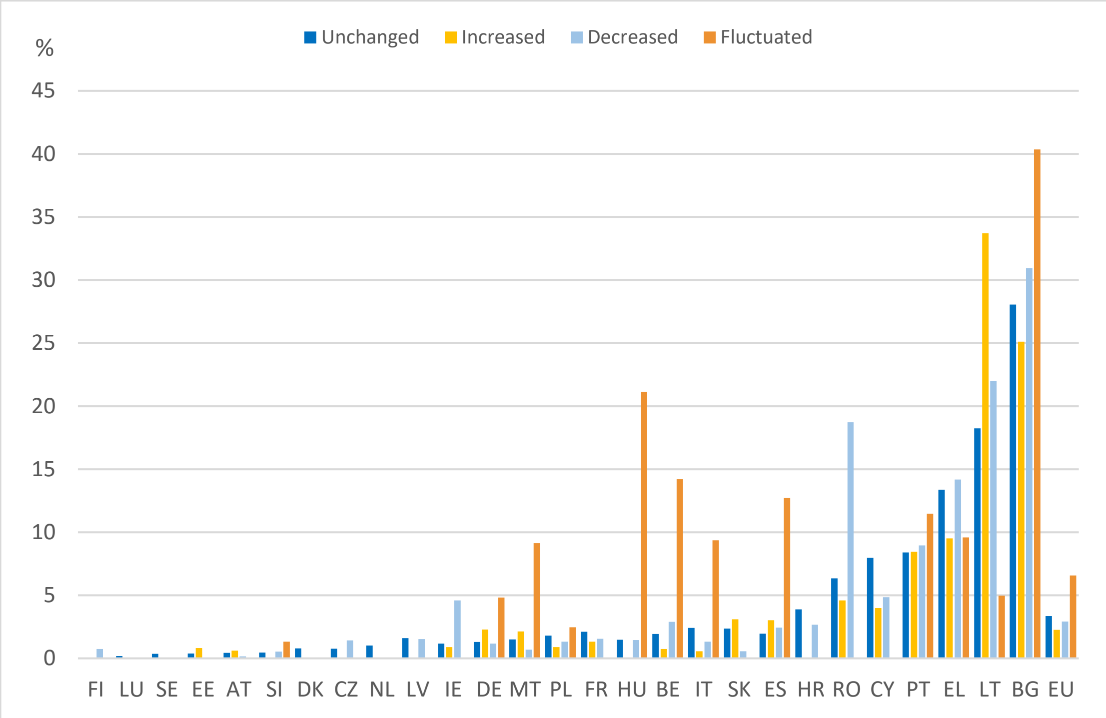
Note: The EU total does not include DE. HU and EU figures are inconsistent due to inconsistent data in HU for 2017

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

It is hard to explore the effects of the household structure in the longitudinal analysis. The preliminary descriptive analysis demonstrates that more than a quarter of the overall EU population had a different household composition by the end of 4-year period than the one they started with. Change in household size has been chosen for the purposes of this analysis.

The results show that a change in household size has no significant effect on the persistency of being unable to keep the home adequately warm in most Member States in 2020 (**Figure 19**). However, the individuals who experienced some fluctuations in household size over the period (i.e. an increase and a decrease in different years over the period) were much more likely to face the persistency of this problem in Germany, Malta, Hungary, Belgium, Italy, Spain, Portugal and Bulgaria. In addition, those whose household decreased in size by the end of 4-year period, in Bulgaria, Romania, Lithuania, Greece and Ireland, had relatively higher figures. Only in Lithuania was the reverse true, i.e. those whose households increased in size were more persistently unable to keep their homes warm.

Figure 19. Proportion of individuals persistently unable to keep home adequately warm by change in household size over the 4-year period, 2020

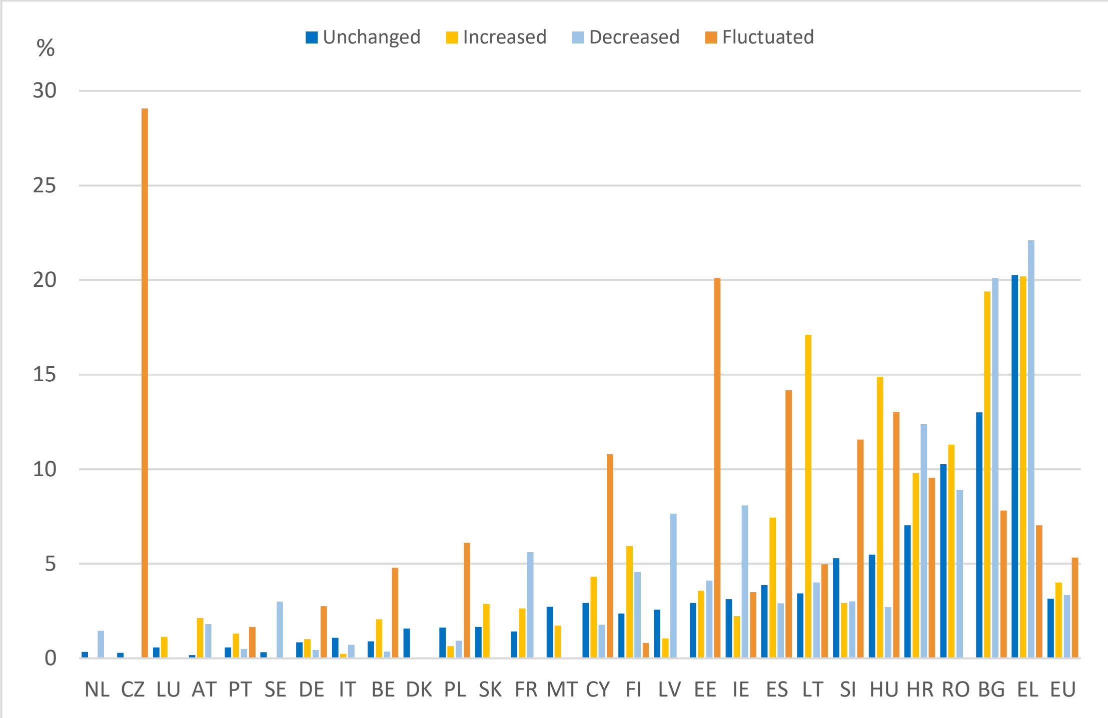


Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

There is a different pattern for the persistency of having arrears in utility bills and having a leak, damp or rot in the dwelling. The analysis suggests that the persistency of these two energy poverty indicators is more sensitive to the household composition. At EU level, those with fluctuating household sizes were the most disadvantaged. However, those whose households grew in size by 2020 show the highest rates for both indicators in a total of 11 Member States (the Member States differ per indicator) (**Figure 20** and **Figure 21**). Among these, the gap between this group and the country average in terms of arrears on utility bills was 12.5 percentage points in Lithuania, 9 percentage points in Hungary and 5 percentage points in Bulgaria. Similar differentials were found in Portugal, Lithuania, Cyprus, France and the Netherlands for having a leak, damp or rot in the dwelling. Finally, the proportion of persistency in arrears among the individuals experiencing a decrease in household size was significantly higher than the other groups in Bulgaria, Ireland, Latvia, Croatia and France. For a leak, damp or rot, it was significantly higher in Romania, Bulgaria and France.

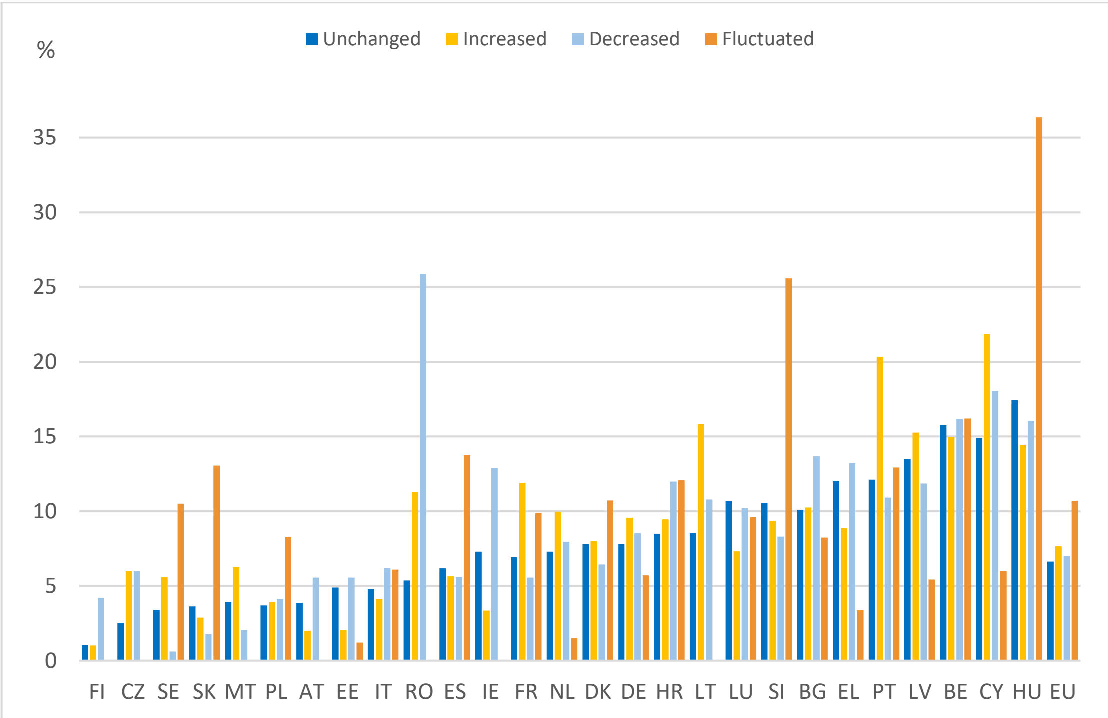
Figure 20. Proportion of individuals with persistent arrears on utility bills by change in household size over the 4-year period, 2020



Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019.

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis

Figure 21. Proportion of individuals persistently having leak/damp/rot in the dwelling by change in household size over the 4-year period, 2020



Note: The EU total does not include DE. For DE, figures for 2020 refer to 2019. HU and EU figures are inconsistent due to inconsistent data in HU for 2017.

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis.

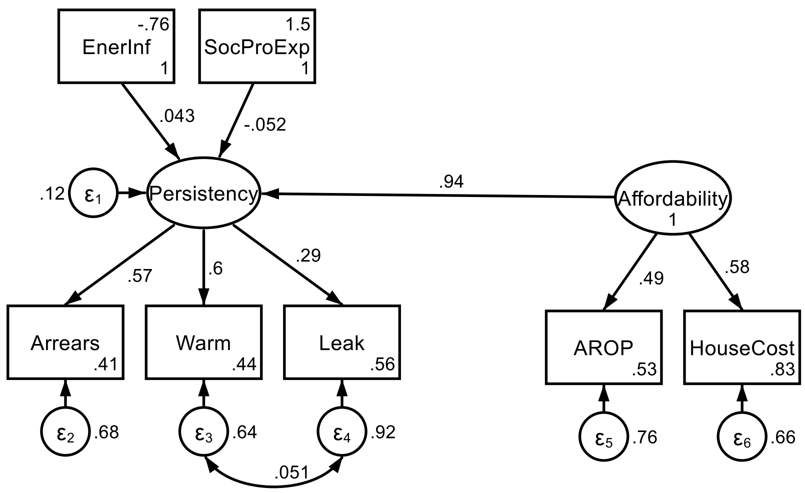
4.2 Multivariate analysis

This section analyses the relationships between individual and country-level factors that influence the persistence of energy poverty within the EU. Employing a multilevel mixed-effects logistic regression model, we dissect the web of socioeconomic variables to uncover their impact on energy poverty outcomes. This section highlights the significance of each variable and offers an understanding of their interplay across Member States. Through this detailed examination, we aim to provide valuable insights into the complex nature of energy poverty and its determinants, setting the stage for targeted policy interventions.

4.2.1 Structural Equation Modelling

In order to test the theoretical model for exploring patterns in the persistency of energy poverty in Europe, the SEM method has been implemented with EU-SILC 2020 longitudinal microdata sets. The years spent in each of three energy poverty indicators have been employed as the observed variables of the latent variable for the persistency of the energy poverty. The latent variable for the financial affordability (based on observed variables for the years spent below the at-risk-of-poverty threshold and the years with a heavy financial burden because of housing costs) has been used as an exogenous factor influencing the persistency of energy poverty. The change in the housing energy prices between the beginning and end of the 4-year period and the average share of the total social protection expenditure on housing allowances and the social exclusion benefits in the overall GDP of the country over the same period have also been used as exogenous variables affecting persistent energy poverty.

Figure 22. SEM results for the persistency of energy poverty in the EU, 2020



Note: For DE, figures for 2020 refer to 2019. HU and EU figures for having leak/damp and rot in the dwelling are inconsistent due to inconsistent data in HU for 2017

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), Eurostat Prices and Social Protection data, JRC analysis

The model is able to explain 89% of overall variance in the persistency of energy poverty patterns by using the selected variables for 2017-2020. According to the SEM results, years spent in having arrears on utility bills and being unable to keep the home warm have an almost equal weight on the persistency of energy poverty, whereas years spent with a leak, damp or rot in the dwelling have a smaller, albeit still statistically significant, effect (**Figure 22**). There is a significant positive link between the number of years of being unable to warm the home sufficiently and the years spent with unfavourable physical conditions for energy efficiency, but the model has rejected a covariance between having arrears on utility bills and being unable to keep the home warm.

The SEM findings demonstrate that “financial affordability” (which is the latent variable based on years spent below at risk of poverty threshold and the years with a heavy burden of housing costs in the SEM) has a very strong impact on the persistency of energy poverty in the EU as a whole. It should be noted that the years spent with a heavy financial burden of housing costs on household income have slightly more influence on affordability as a latent variable, than years spent below the at-risk-of-poverty threshold. This may reflect the fact that the relative opinion of the households about their current financial situation may be more important than the actual monetary income level in the persistency of energy poverty measured by the given EU-SILC indicators. Finally, the SEM model confirms that an increase in the share of social protection expenditure, particularly as social transfers to financially poor households and transfers as housing allowances, significantly lowers the possibility of longer term energy poverty, while increasing energy prices are likely to aggravate it.

4.2.2 Multilevel mixed effects logistic regression models for individual indicators

Unable to keep home adequately warm

Random intercept multilevel mixed effects logistic regression models indicate that the full model, which includes all fixed effects variables for socio-demographic background characteristics, socioeconomic and energy poverty status of the household and the country-level contextual variables, have considerably a good level of overall variance explained (McFadden’s R^2 is 0.21, **Table 4**). The interclass correlation coefficient (ICC) of the same model demonstrates that some 29% of this variation is due to random effects across the countries, which are not measured by the fixed effects employed in the analysis; this value is just below 37% for the empty model ([17]). These findings suggest that although the models are likely to explore the impact of the factors on persistently being unable to keep the home warm in a 4-year period in the EU with the given independent variables, there are other individual and/or national-level variables to explain the huge variation across countries. Otherwise, it can be argued that there is probability of a huge amount of volatility for the country-specific persistency rates for being unable to keep the home warm even after being controlled by major socio-demographic and socioeconomic characteristics of the individuals.

Table 4. Model summaries and random effects estimates for the random intercept multilevel mixed effects logistic regression models for persistency of being unable to keep home adequately warm, 2013-2020

	Empty Model		Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
var(_cons)	1.923***	(0.472)	1.928***	(0.477)	1.936***	(0.479)	1.482***	(0.426)	1.369***	(0.331)	1.670**	(0.602)
ICC	0.369	(0.057)	0.369	(0.058)	0.370	(0.058)	0.311	(0.062)	0.294	(0.050)	0.337	(0.081)
McFadden's R^2			0.013		0.014		0.208		0.209		0.223	
N												
Level 1	218,089		218,089		218,089		218,089		218,089		171,078	
Level 2	27		27		27		27		27		20	

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. No data for DE in 2013. DE values for 2020 refer to 2019. For Model 5, no data for BG, EE, HR, CY, LV, MT and RO.*

Source: EU-SILC 2013, 2019 and 2020 longitudinal microdata, Eurostat Prices and Social Protection data, and IEA Residential Sector data, JRC analysis.

[17] A higher ICC indicates that a greater proportion of variance is due to differences between groups, suggesting that the group-level factors (like country-specific policies or economic conditions) play a significant role in explaining why some groups have higher or lower rates of energy poverty. Conversely, a lower ICC would suggest that individual-level factors are more influential.

Alternative scenarios in the multilevel mixed effects logistic regression models change the findings for some fixed effects (**Table 9**). For instance, the likelihood of being persistently unable to keep the home adequately warm during the 2010-2013 period was almost twice that observed in the 2017-2020 period, if the period variable is used in the models alone (Model 1), or only with socio-demographic background characteristics (Model 2). However, the odds ratio for the 2010-2013 period becomes statistically insignificant when the country-level contextual effects are introduced (Model 4). Likewise, women are more likely to be persistently unable to keep the home warm and the coefficients are statistically more consistent in the basic model, in which only socio-demographic characteristics are employed, whereas the statistical variance between men and women is still statistically significant, but marginal, after this variable is controlled with other household-level and country-level socioeconomic fixed effects (models 3 and 4). Before being controlled by other socioeconomic variables, there is no impact of age on the dependent variable of the analysis. Nevertheless, after other controls are introduced, it is found that the individuals up to age 49 are much less likely to have persistency in being unable to keep the home warm adequately than those who are 50 years or older. In the model, where only socio-demographic characteristics are used, there is no statistically significant variation in being persistently unable to warm the home across the categories for the change in household size over the period, except for a relatively high odds ratio of those who live in fluctuating households. On the other hand, after the socioeconomic background variables are used as controls, the likelihood for those who experienced a decrease or increase in their household composition becomes significantly less than for individuals whose household size remained same, while variation between those whose household size fluctuates or remains constant disappears.

The findings clearly demonstrate that there is a strong relationship between the years spent below the at-risk-of-poverty threshold, having arrears on utility bills, having unfavourable physical conditions for energy efficiency and having a heavy financial burden due to housing costs, and the persistency of being unable to keep the home warm. For all these variables, the additional years spent facing such socioeconomic problems increase the likelihood, though the difference between having these issues for 2 years and 3-4 years is more remarkable than the increase between 1 and 2 years. In this respect, the highest impact of long-term socioeconomic problems is observed for having a heavy burden because of housing costs; the individuals with such a burden for 3 or 4 years are 5 times more likely to be persistently unable to keep the home warm than those who never had this problem in the given 4-year periods.

Finally, the results for the contextual fixed effects show that overall changes in energy prices between the first and last year of the 4-year periods do not have a statistically visible effect on the persistency of being unable to warm the home adequately. On the other hand, the analysis reveals that the likelihood of the persistency declines remarkably for every 1 percentage point increase in the total share of the gross expenditure on social exclusion benefits and the housing allowances within the GDP of the country after all socio-demographic and socioeconomic conditions are controlled in the model. Although the data are not available for all countries, an additional model has been conducted by involving energy efficiency per dwelling, which is defined as the ratio of per dwelling temperature corrected energy intensity (in kw) for space heating purposes relative to the heating degree days (hdd), as another contextual variable to explore the impact of the overall energy efficiency of dwellings in the country (Model 5). The evidence for this variable shows that there is a significant relationship between the variation in the overall energy efficiency level across the countries and the persistency of being unable to keep the home warm; the lower the energy efficiency of the buildings in the country, the higher the likelihood that people will be persistently energy-poor. It should be noted that the patterns for the other fixed effects variables remained unchanged to a large extent, even after controlling the energy efficiency on the macro level.

Arrears on utility bills

The results of the multilevel mixed effects logistic regression models for persistently having arrears on utility bills suggests that a significant amount of variation can be explained by the variables selected for the analysis of the dependent variable (McFadden's R^2 is 0.22, see **Table 5**). The variance explained of the model increases significantly when the socioeconomic background variables for the household (i.e. years spent below the at-risk-of-poverty threshold, with heavy financial burden because of housing costs, unable to keep the home warm and having leaks/damp or rot in the dwelling) are involved in the analysis. In addition, the ICC of the full model, including all socio-demographic, socioeconomic and contextual fixed effects, is around 0.18, which refers to a smaller portion of the variance due to the random effects across Member States compared to the random effects found in the models for the persistency of being unable to keep the home warm. Based on McFadden's R^2 and ICC findings, it can be argued that the likelihood of persistently having arrears on utility bills is mainly influenced by the socioeconomic background characteristics of the individuals.

Table 5. Model summaries and random effects estimates for the random intercept multilevel mixed effects logistic regression models for persistency of having arrears on utility bills, 2013-2020

	Empty Model		Model 1		Model 2		Model 3		Model 4	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
var(_cons)	1.073***	(0.212)	1.052***	(0.212)	1.085***	(0.222)	0.779***	(0.150)	0.708***	(0.168)
ICC	0.246	(0.037)	0.242	(0.037)	0.248	(0.038)	0.192	(0.030)	0.177	(0.035)
McFadden's R^2			0.010		0.028		0.224		0.224	
N										
Level 1	218,089		218,089		218,089		218,089		218,089	
Level 2	27		27		27		27		27	

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. No data for DE in 2013. DE values for 2020 refer to 2019.*

Source: EU-SILC 2013, 2019 and 2020 longitudinal microdata, Eurostat Prices and Social Protection data, JRC analysis.

The models for the persistence of having arrears on utility bills suggest different patterns for the impacts of fixed effects on the dependent variable than those observed in the models for the persistency of being unable to keep the home adequately warm (**Table 10**). First, there is no statistically significant variation between men and women in having long-term arrears on utility bills. Secondly, unlike being unable to warm home persistently, there is a clear disadvantage in having arrears for at least three years including the last year of the 4-year period for the young age groups relative to their counterparts aged 65 or over. The findings demonstrate that there is no noteworthy decline in the odds ratios until the 50-64 age group. Secondly, the change in household size does not have any significant effect on the persistency of arrears over the given periods. This is also the case for the differentiation of the likelihood between the 2010-2013 and 2017-2020 periods.

On the other hand, the impact of the years spent with socioeconomic and dwelling-related problems on the persistency of the arrears is similar to the patterns found for the inability to keep the home warm. A longer duration with financial or housing-related issues increases the likelihood of having arrears throughout the given period. The odds ratios for those who experienced at least two years at risk of poverty, being unable to keep the home warm and with a heavy burden due to housing costs, are above 2 relative to those who did not experience any of these problems during the 4-year periods in concern. Although the figure is also high for those who had a leak, damp or rot in the dwelling for two years, it is slightly lower than the former three groups (1.75). The odds ratio for those who were unable to keep the home adequately warm for 3-4 years exceeded four, whereas those who had unfavourable physical conditions in the dwelling for at least 3 years were 6.6 times more likely to have persistent arrears on utility bills.

According to the results, the impact of contextual variables on the persistency of the arrears on utility bills does not correspond to their effect on being unable to keep the home adequately warm. Despite the fact that the odds ratios show an inverse relation between the changes in the energy prices as well as the share of the social exclusion benefits and housing allowances in the country's GDP with the likelihood of persistently having arrears, their influence on the dependent variable is statistically insignificant after being controlled by other fixed effects.

Leak, damp or rot in the dwelling

The model findings for the persistency of having a leak, damp or rot in the dwelling show that only a small portion of the variance can be explained by the selected fixed effects variables (**Table 6**). In addition, the share of the random effects due to the differences across countries is much smaller (ICC values around 0.10) than the models for the persistency of the inability to keep the house warm and having arrears on utility bills. Based on these findings, it can be argued that the analysis of the factors affecting the persistency of having unfavourable conditions for the energy efficiency of the dwelling needs the employment of more elaborate socioeconomic and contextual variables.

Table 6. Model summaries and random effects estimates for the random intercept multilevel mixed effects logistic regression models for persistency of having leak/damp/rot in the dwelling, 2013-2020

	Empty Model		Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
var(_cons)	0.346**	(0.111)	0.346**	(0.111)	0.350**	(0.112)	0.284***	(0.086)	0.402**	(0.129)	1.155*	(0.545)
ICC	0.095	(0.028)	0.095	(0.028)	0.096	(0.028)	0.079	(0.022)	0.109	(0.031)	0.260	(0.091)
McFadden's R^2			0.001		0.003		0.068		0.069		0.065	
N												
Level 1	218,403		218,403		218,403		218,403		218,403		171,391	
Level 2	27		27		27		27		27		20	

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. No data for DE in 2013. DE values for 2020 refer to 2019. For Model 5, no data for BG, EE, HR, CY, LV, MT and RO.*

Source: EU-SILC 2013, 2019 and 2020 longitudinal microdata, Eurostat Prices and Social Protection data, and IEA Residential Sector data, JRC analysis.

The empirical results suggest that none of the socio-demographic background characteristics in the multilevel mixed effects models, which are namely sex and the age of the individual and the change in the household size over the period, or the period, has statistically significant impact on persistently having a leak, damp or rot in the dwelling (**Table 11**). On the contrary, spending more years in monetary poverty, with arrears on utility bills or with a heavy financial burden due to housing costs, results in being more exposed to being faced by persistent physical problems in the dwelling. On the other hand, the differentiation across the years spent at risk of poverty is much smaller than that observed for arrears on utility bills and having a heavy burden due to housing costs.

On the macro level, price changes in the maintenance costs for the dwelling over the given periods do not affect the persistency of having a leak, damp or rot in the dwelling. However, the findings indicate that an increase in the total share of the social protection expenditure on social exclusion benefits and the housing allowances in the overall GDP of the country substantially decreases the likelihood of individuals having such long-term dwelling related issues. In addition, further analysis for the countries with available data indicates that there is a marginal, but statistically significant, inverse relationship between the ratio of per dwelling temperature corrected energy intensity (in kw) for space heating purposes relative to the heating degree days and the probability of persistently having a leak, damp or rot in the dwelling (Model 5). It should be noted that, the validity of using energy intensity per dwelling as a measure of energy efficiency has been debated in existing literature (Filippini et al., 2014; Chen et al., 2022). Nonetheless, the results in this report emphasise the need to further investigate the influence of temperature-adjusted energy intensity on energy poverty, despite potential limitations associated with this metric.

5 Conclusion

The extensive analysis of energy poverty in the European Union, as outlined in this report, underscores a complex issue that affects a significant portion of the EU population. There are several ways of analysing and interpreting the available data and with this work by leveraging EU-SILC longitudinal microdata we illuminated the persistent nature of this pressing issue. The findings highlight that nearly half of the individuals classified as energy-poor in 2020 had been persistently so over the 2017-2020 period in the EU, according to the indicators used. This statistic underscores the enduring vulnerability of certain segments of the population to energy poverty, a situation exacerbated by socioeconomic disparities and inefficiencies in housing and energy consumption.

The persistence of energy poverty is a fact in all EU countries, though there are significant discrepancies across EU Member States. Our multivariate and multilevel mixed-effects logistic regression models have revealed these stark disparities, with countries such as Bulgaria, Lithuania, and Greece facing higher rates of persistent energy poverty. *In Bulgaria and Greece, more than 10% of the population was persistently energy-poor according to all three indicators examined in the study.*

Although the persistency of energy poverty is much lower than the persistent at-risk-of-poverty rate in the EU, *almost one fifth of the EU's population was unable to keep their home adequately warm for at least one year in the 2017-2020 period*. The figures for having arrears on utility bills was around 15%, and just below 30% of the EU population dealt with a leak, damp or rot in their dwellings. These findings highlight the need for nuanced policy interventions that can address both the immediate and long-term aspects of energy poverty.

Our study has demonstrated that the duration of time individuals spend in conditions of energy poverty is closely linked to their financial and housing stability. Individuals with prolonged periods of low income or excessive housing costs are more likely to experience persistent energy poverty, as are those residing in dwellings with inadequate physical conditions for energy efficiency.

According to the empirical findings presented in this study, it can be argued that the persistent energy poverty indicators based on the same methodology of Eurostat for the persistent at risk of poverty rate can be used as conventional social indicators for policy-making in social exclusion and poverty in the EU. The evidence shows that they are likely to provide a high level of comparability across countries and over time. Therefore, they are useful not only to measure the cross-country differences, but also to follow the trends in improvements in energy poverty and energy efficiency related issues in the long run.

We have identified that individual and household characteristics, such as age and household size, and socioeconomic constraints like income level and disproportionate housing costs, are critical factors that influence the likelihood of an individual experiencing persistent energy poverty. Furthermore, macro-level variables, including energy prices, social protection expenditure, and average energy intensity per dwelling, play a pivotal role in shaping the energy poverty landscape across the EU. It should be noted that the findings for the latter indicator should be considered carefully as there are several climatic and cultural factors affecting energy consumption in dwellings. In sum, the analyses results suggest that the first hypothesis (H1) of the study regarding the effect on the socio-demographic characteristics on the persistence of energy poverty is partially verified while the second hypothesis (H2) about the impacts of socio-economic constraints is fully confirmed.

Based on these findings it becomes clear that targeted interventions are necessary to break the cycle of energy poverty. Indeed several policy insights can be extracted from the data and when integrated into broader social policy agendas could ensure a comprehensive and just response to energy poverty:

- Enhanced financial support for vulnerable groups: The persistent nature of energy poverty calls for more efficient financial measures tailored to support disadvantaged groups. Direct financial assistance should be complemented by investment in energy efficiency to reduce long-term energy costs for households. The data suggests that every additional year spent in poverty or with a heavy housing cost burden significantly increases the risk of persistent energy poverty.
- Improvement of building energy efficiency: One of the most impactful strategies for combating energy poverty is to focus on improving the energy efficiency of buildings. Policies in this domain should provide both direct financial support for renovations (e.g. via Social Climate Fund) and effective counselling to guide households through the process. This multi-tiered approach should

involve national, local, and individual levels to ensure that interventions are democratic, cost-efficient, and responsive to unique needs.

- Integration of energy poverty into social policy: The persistent risk of energy poverty should be integrated into broader social policy agendas to ensure a comprehensive response. This includes aligning energy poverty mitigation efforts with other social protection initiatives to address the root causes of poverty and social exclusion.
- Inclusive policymaking process: The principles of procedural justice and recognition demand that policymaking processes are open, fair, and inclusive. This means actively involving the affected individuals and groups in decision-making to ensure that policies are representative and do not inadvertently discriminate or misrepresent their needs.
- Standardisation and disaggregation of indicators in the EU: Data collection at EU level should be continuous and further standardised and should reflect in more detail the actual economic realities of households. To enhance the effectiveness and comparability of energy poverty assessments, the inclusion of expenditure-based indicators in data collection efforts is crucial. This will allow for consistent longitudinal tracking and more informed comparisons between Member States.
- Adoption of tailored energy poverty indicators: The diversity of energy poverty assessment methods across Member States, as revealed by the literature, suggests that a one-size-fits-all indicator may not be suitable. The development and adoption of tailored indicators that account for regional differences in climate, building practices, and socioeconomic conditions could therefore be encouraged.
- Promotion of sustainable energy sources and inclusivity: Policies should keep promoting the transition to sustainable energy sources, ensuring that clean and renewable energy is affordable and accessible for all. This shift is necessary not only for environmental reasons but also to prevent vulnerable households from reverting to cheaper, more polluting energy sources. At the same time, the participation of low income households in the transition via collective energy investment schemes (e.g. energy communities) should be encouraged.

The results of our analysis call for further research – particularly disaggregated, region-specific studies – to refine our understanding of energy poverty and inform future policy development. With nearly half of energy-poor individuals in 2020 having been persistently so over the preceding years, it is clear that there is an urgent need for policies that not only alleviate immediate energy poverty but also prevent its recurrence.

Indeed, this work faced some limitations due to data constraints. Only self-reported energy poverty indicators were examined, as expenditure-based measures, which may show different patterns, were not consistently available across the EU. Data gaps for Germany, Slovakia, Portugal, and other countries at various times, along with inconsistencies such as Hungary's 2017 data issues, influenced our analysis period and country coverage. The removal of the indicator for leaks, dampness, or rot from EU-SILC after 2020 further limited our study. Additionally, due to the EU-SILC's structure and the changing nature of socio-demographic characteristics over time, variables like education level, economic activity, and household composition were excluded from the analysis. Detailed descriptive and multivariate analyses for these background characteristics by using EU-SILC cross-sectional data have been conducted in another recent study of the authors (Koukoufikis et al., 2024). Despite these factors being significant in influencing energy poverty, we believe their effects are largely captured through the inclusion of key socio-demographic and socioeconomic variables in our models.

In conclusion, the persistence of energy poverty in the EU is a complex challenge that requires a concerted effort from policymakers, researchers, and stakeholders. By continuing to invest in data-driven research and implementing evidence-based policies, the EU can make significant strides.

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List of abbreviations and definitions

EPAH	Energy Poverty Advisor Hub
EU	European Union
EU-SILC	European Union Statistics on Income and Living Conditions
GDP	Gross Domestic Product
HDD	Heating Degree Days
ICC	Intraclass Correlation Coefficient
IEA	International Energy Agency
KW	Kilowatt
LICH	Low Income High Cost
PLS-SEM	Partial Least Squares Structural Equation Modeling
PP	Percentage Points
SEM	Structural Equation Modelling

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Annex 1. Tables of selected descriptive analysis and multivariate analysis model summaries

Table 7. Proportion of individuals persistently energy poor by energy poverty indicator and age in the last year of the period, 2020 (%)

	Unable to keep home warm					Arrears on utility bills					Leak, damp, rot in dwelling				
	<=17	18-24	25-49	50-64	65+	<=17	18-24	25-49	50-64	65+	<=17	18-24	25-49	50-64	65+
BE	3.2	2.8	2.1	2.1	1.1	1.2	1.0	1.2	1.2	0.2	19.1	18.9	16.4	15.1	11.3
BG	26.3	28.7	25.1	26.6	35.0	19.7	18.3	15.4	11.0	12.4	12.3	12.9	10.8	10.4	9.0
CZ	0.8	0.9	0.6	1.3	0.6	1.5	0.0	0.4	0.2	0.1	2.7	2.9	3.3	3.5	3.1
DK	0.5	0.0	0.0	0.4	2.0	5.3	0.0	0.2	0.8	0.3	7.3	5.6	9.4	10.3	4.0
DE	1.5	1.3	1.8	1.3	1.1	1.7	1.4	1.2	0.3	0.2	11.1	8.9	8.8	8.1	4.7
EE	0.2	0.0	0.5	0.4	0.5	5.9	5.3	4.3	2.2	0.7	2.8	6.2	3.5	6.6	5.4
IE	2.0	2.5	2.2	0.6	0.1	5.4	3.6	4.3	3.5	0.0	10.7	6.4	8.3	4.5	4.6
EL	13.7	17.6	12.7	12.5	12.8	24.9	23.2	23.0	20.1	12.2	10.9	9.0	12.1	9.9	14.9
ES	4.1	2.6	2.0	2.9	1.5	7.1	3.9	4.8	5.2	1.6	8.2	8.5	6.4	6.3	3.5
FR	2.0	1.1	1.8	3.1	1.3	3.5	2.9	2.2	1.3	0.8	10.5	6.4	7.5	7.4	5.2
HR	2.5	1.6	3.1	3.6	4.8	9.9	7.6	9.4	8.9	4.1	8.0	7.5	8.3	10.2	10.4
IT	2.0	1.7	3.0	2.3	1.5	1.0	0.7	1.3	1.2	0.3	2.9	5.0	5.2	5.6	5.1
CY	8.0	11.5	7.3	6.5	5.5	3.8	3.7	2.9	3.5	1.3	15.7	17.5	14.5	15.6	17.7
LV	1.3	0.9	0.9	1.6	2.2	3.8	9.0	3.0	2.8	1.2	18.8	14.3	12.8	14.4	7.9
LT	27.6	16.2	18.6	14.6	23.3	12.4	1.8	5.1	4.0	0.4	10.1	12.4	10.2	8.6	7.3
LU	0.0	0.0	0.4	0.0	0.0	0.0	1.6	0.6	0.6	0.0	16.9	13.3	10.6	11.3	6.8
HU	1.5	4.7	1.9	1.7	1.9	7.2	13.2	6.9	5.4	1.7	21.3	22.2	17.5	15.4	16.0
MT	1.6	1.7	1.2	1.9	1.6	3.8	2.8	2.5	2.2	0.5	3.1	3.2	3.5	6.5	2.4
NL	0.3	1.7	1.0	1.3	0.4	0.6	0.0	0.4	0.9	0.0	7.6	10.1	8.7	7.8	4.0
AT	0.0	0.2	0.3	0.9	0.4	0.4	1.9	0.2	1.1	0.0	4.2	5.7	3.7	4.6	2.0
PL	0.9	1.6	1.2	1.8	2.5	1.8	2.4	1.2	2.1	0.8	4.5	3.3	3.7	3.7	4.0
PT	4.9	10.2	6.0	9.5	11.6	1.1	0.8	0.2	1.0	0.5	12.4	10.3	11.9	11.5	15.1
RO	8.5	5.3	5.5	6.7	6.6	14.5	9.5	9.2	8.7	10.3	7.2	5.3	4.5	6.1	7.3
SI	0.1	0.4	0.3	0.6	0.9	8.4	4.3	5.4	4.8	2.3	11.6	8.3	11.0	9.8	10.5
SK	2.6	2.6	2.0	2.1	2.5	3.0	0.7	1.8	1.5	0.6	2.9	3.3	3.2	4.6	3.3
FI	0.0	0.3	0.1	0.0	0.3	3.0	7.0	4.5	2.0	0.7	2.0	1.1	1.6	1.8	0.4
SE	0.6	0.0	0.4	0.0	0.0	1.3	0.8	0.3	0.8	0.6	4.9	0.9	3.7	5.1	1.2
EU	3.4	3.2	3.0	3.6	3.2	4.9	3.8	3.5	3.2	1.8	7.9	7.2	6.9	7.0	5.8

Note: The EU total does include DE. For DE, the figures refer to 2019.

Source: EU-SILC longitudinal microdata data sets (version 05/10/2023), JRC analysis.

Table 8. Increment-decrement life tables probabilities for transition between "energy poor" and "non-energy-poor" for the ones, who were energy poor in year n-3 by energy poverty indicator, 2017-2020

	Unable to keep home warm						**Having arrears on utility bills**						**Having leak/damp/rot in dwelling**					
	From "Yes" to "No"			From "No" to "Yes			From "Yes" to "No"			From "No" to "Yes			From "Yes" to "No"			From "No" to "Yes		
	n-3	n-2	n-1	n-3	n-2	n-1	n-3	n-2	n-1	n-3	n-2	n-1	n-3	n-2	n-1	n-3	n-2	n-1
BE	0.519	0.326	0.423		0.173	0.122	0.536	0.484	0.677		0.136	0.126	0.085	0.135	0.071		0.023	0.020
BG	0.032	0.060	0.048		0.115	0.012	0.073	0.071	0.477		0.020	0.169	0.058	0.097	0.080		0.023	0.010
CZ	0.617	0.275	0.225		0.136	0.021	0.800	0.676	0.660		0.126	0.196	0.426	0.331	0.392		0.184	0.087
DK	***0.429***	***0.443***	***0.315***		***0.000***	***0.377***	0.541	0.458	0.209		0.123	0.259	0.459	0.226	0.144		0.223	0.327
DE	0.503	0.376	0.238		0.229	0.138	0.612	0.375	0.577		0.133	0.101	0.356	0.250	0.269		0.322	0.167
EE	0.885	0.081	0.626		0.256	0.016	0.674	0.356	0.563		0.508	0.198	0.602	0.516	0.507		0.210	0.157
IE	0.379	0.352	0.194		0.062	0.164	0.520	0.444	0.487		0.153	0.247	0.575	0.254	0.210		0.291	0.401
EL	0.457	0.248	0.224		0.193	0.177	0.332	0.269	0.311		0.346	0.266	0.412	0.049	0.022		0.000	0.062
ES	0.737	0.429	0.497		0.163	0.244	0.553	0.525	0.227		0.447	0.293	0.520	0.609	0.269		0.186	0.479
FR	0.503	0.383	0.555		0.207	0.193	0.529	0.341	0.631		0.433	0.254	0.456	0.391	0.178		0.311	0.236
HR	0.474	0.175	0.185		0.208	0.102	0.410	0.329	0.381		0.228	0.163	0.122	0.102	0.116		0.193	0.042
IT	0.538	0.614	0.754		0.146	0.133	0.707	0.555	0.612		0.164	0.108	0.768	0.622	0.147		0.181	0.168
CY	0.409	0.516	0.623		0.202	0.209	0.479	0.722	0.496		0.283	0.123	0.440	0.363	0.395		0.345	0.335
LV	0.814	0.740	0.564		0.152	0.120	0.527	0.711	0.445		0.269	0.122	0.460	0.433	0.236		0.349	0.196
LT	0.319	0.134	0.148		0.361	0.209	0.481	0.180	0.214		0.227	0.126	0.212	0.179	0.263		0.257	0.051
LU	0.884	0.354	0.000		0.000	0.000	0.721	0.143	0.512		0.312	0.126	0.453	0.355	0.077		0.304	0.007
HU	0.587	0.527	0.448		0.088	0.164	0.489	0.184	0.269		0.189	0.240	0.791	0.252	0.291		0.081	0.098
MT	0.756	0.509	0.473		0.337	0.206	0.414	0.337	0.418		0.025	0.264	0.445	0.209	0.342		0.159	0.121
NL	0.436	0.544	0.302		0.289	0.414	0.409	0.522	0.239		0.138	0.000	0.391	0.332	0.260		0.160	0.159
AT	***0.606***	***0.473***	***0.452***		***0.244***	***0.000***	0.908	0.937	0.768		0.250	0.096	0.482	0.452	0.225		0.199	0.098
PL	0.558	0.419	0.370		0.095	0.132	0.715	0.447	0.645		0.207	0.141	0.455	0.282	0.513		0.171	0.092
PT	0.388	0.305	0.436		0.254	0.178	0.659	0.525	0.743		0.108	0.230	0.388	0.351	0.368		0.246	0.285
RO	0.289	0.155	0.178		0.064	0.079	0.297	0.113	0.189		0.143	0.105	0.261	0.228	0.140		0.142	0.032
SI	0.689	0.623	0.760		0.117	0.157	0.519	0.378	0.446		0.260	0.165	0.496	0.309	0.405		0.261	0.219
SK	0.490	0.259	0.261		0.388	0.144	0.730	0.404	0.531		0.176	0.072	0.410	0.179	0.287		0.083	0.138
FI	0.791	0.572	0.834		0.119	0.195	0.568	0.354	0.514		0.498	0.145	0.671	0.547	0.353		0.124	0.211
SE	***0.756***	***0.227***	***0.269***		***0.000***	***0.000***	***0.846***	***0.000***	***0.161***		***0.399***	***0.273***	0.512	0.463	0.336		0.221	0.304
EU	0.494	0.371	0.394		0.162	0.161	0.491	0.303	0.409		0.281	0.191	0.539	0.340	0.235		0.170	0.185

Note: Empty cells refer to no data or unpublishable findings due to insufficient number of cases. Figures in bold italic refer to findings with low reliability due to small number of observations. The EU total does not include DE. DE values refer to 2016-2019 period.

Source: EU-SILC 2019 and 2020 longitudinal microdata, JRC analysis.

Table 9. Model summaries and regression coefficients for the random intercept multilevel mixed effects logistic regression models for persistency of being unable to keep home adequately warm, 2013-2020

	Empty Model		Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
FIXED EFFECTS												
Sex												
Female					1.113***	(0.030)	1.070*	(0.035)	1.069*	(0.035)	1.085	(0.047)
Male (ref.)												
Age in year n+3												
<=17					1.085	(0.107)	0.650***	(0.039)	0.650***	(0.038)	0.630***	(0.046)
18-24					1.064	(0.100)	0.658***	(0.051)	0.660***	(0.051)	0.622***	(0.054)
25-49					0.988	(0.130)	0.763**	(0.069)	0.767**	(0.071)	0.753*	(0.092)
50-64					1.058	(0.089)	0.915	(0.065)	0.922	(0.064)	0.914	(0.077)
65+ (ref.)												
Change in the household size												
Increased					0.952	(0.086)	0.740**	(0.075)	0.738**	(0.074)	0.783*	(0.078)
Decreased					0.951	(0.068)	0.795**	(0.061)	0.805**	(0.058)	0.765***	(0.058)
Fluctuated					1.850**	(0.384)	1.172	(0.304)	1.143	(0.278)	1.167	(0.287)
Same (ref.)												
Years in AROP												
1							1.758***	(0.133)	1.745***	(0.134)	1.810***	(0.149)
2							2.057***	(0.162)	2.040***	(0.163)	2.155***	(0.190)
3+							3.208***	(0.296)	3.192***	(0.307)	3.411***	(0.361)
No years (ref.)												
Years with arrears in utility bills												
1							1.671**	(0.251)	1.664**	(0.247)	1.724***	(0.248)
2							2.352***	(0.425)	2.319***	(0.401)	2.342***	(0.423)
3+							3.757***	(0.740)	3.726***	(0.748)	3.443***	(0.535)
No years (ref.)												

Years with leak/damp/rot												
1							1.276**	(0.090)	1.297***	(0.090)	1.295**	(0.107)
2							1.625***	(0.205)	1.626***	(0.205)	1.669***	(0.238)
3+							3.099***	(0.318)	3.071***	(0.322)	3.285***	(0.398)
No years (ref.)												
Years with heavy burden of housing costs												
1							1.452*	(0.237)	1.480*	(0.233)	1.820***	(0.307)
2							1.772**	(0.313)	1.826***	(0.315)	2.446***	(0.349)
3+							4.856***	(1.020)	4.934***	(1.034)	6.780***	(1.405)
No years (ref.)												
Contextual variables												
Energy price change between years n and n+3 (%)									1.839	(2.196)	2.559	(3.615)
Average share of soc.ex.bens and h.allws. in GDP in period (%)									0.462***	(0.086)	0.332***	(0.095)
Ratio of per dwelling TC energy intensity (kw/dw) relative to HDD											0.470**	(0.134)
Period												
2010-2013			1.938**	(0.409)	1.927**	(0.401)	1.673**	(0.309)	1.295	(0.335)	1.302	(0.409)
2017-2020 (ref.)												
Constant	0.027***	(0.007)	0.019***	(0.006)	0.017***	(0.006)	0.005***	(0.002)	0.009***	(0.003)	0.140	(0.153)
RANDOM EFFECTS												
var(_cons)	1.923***	(0.472)	1.928***	(0.477)	1.936***	(0.479)	1.482***	(0.426)	1.369***	(0.331)	1.670**	(0.602)
ICC	0.369	(0.057)	0.369	(0.058)	0.370	(0.058)	0.311	(0.062)	0.294	(0.050)	0.337	(0.081)
McFadden's R^2			0.013		0.014		0.208		0.209		0.223	
N												
Level 1	218,089		218,089		218,089		218,089		218,089		171,078	
Level 2	27		27		27		27		27		20	

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. No data for DE in 2013. DE values for 2020 refer to 2019. For Model 5, no data for BG, EE, HR, CY, LV, MT and RO.*
Source: EU-SILC 2013, 2019 and 2020 longitudinal microdata, Eurostat Prices and Social Protection data, and IEA Residential Sector data, JRC analysis.

Table 10. Model summaries and regression coefficients for the random intercept multilevel mixed effects logistic regression models for persistency having arrears on utility bills, 2013-2020

	Empty Model		Model 1		Model 2		Model 3		Model 4	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
FIXED EFFECTS										
Sex										
Female					1.037	(0.035)	1.006	(0.036)	1.005	(0.035)
Male (ref.)										
Age in year n+3										
<=17					3.205***	(0.655)	2.906***	(0.600)	2.906***	(0.562)
18-24					2.811***	(0.663)	2.478***	(0.583)	2.484***	(0.553)
25-49					2.292***	(0.453)	2.449***	(0.455)	2.458***	(0.465)
50-64					1.853***	(0.313)	1.921***	(0.297)	1.930***	(0.305)
65+ (ref.)										
Change in the household size										
Increased					1.351*	(0.183)	1.203	(0.143)	1.199	(0.140)
Decreased					1.235*	(0.114)	1.076	(0.099)	1.078	(0.097)
Fluctuated					2.111***	(0.387)	1.473	(0.348)	1.442	(0.361)
Same (ref.)										
Years in AROP										
1							1.463*	(0.275)	1.455*	(0.264)
2							2.142***	(0.390)	2.127***	(0.355)
3+							2.867		2.852***	(0.524)
No years (ref.)										
Years in being unable to keep house warm										
1							1.858***	(0.190)	1.867***	(0.157)
2							2.476***	(0.256)	2.487***	(0.205)
3+							4.342***	(0.704)	4.330***	(0.661)

No years (ref.)										
Years with leak/damp/rot										
1							1.220	(0.152)	1.229	(0.150)
2							1.753**	(0.308)	1.748***	(0.279)
3+							2.060***	(0.358)	2.047***	(0.337)
No years (ref.)										
Years with heavy burden of housing costs										
1							1.967***	(0.239)	1.996**	(0.478)
2							1.986***	(0.352)	2.026*	(0.561)
3+							6.539***	(0.025)	6.633***	(2.121)
No years (ref.)										
Contextual variables										
Energy price change between years n and n+3 (%)									0.673	(0.878)
Average share of soc.ex.bens and h.allws. in GDP in period (%)									0.615	(0.246)
Period										
2010-2013			1.805***	(0.019)	1.754***	(0.018)	1.478	(0.296)	1.500	(0.318)
2017-2020 (ref.)										
Constant	0.033***	(0.007)	0.024***	(0.005)	0.010***	(0.003)	0.002***	(0.001)	0.003***	(0.001)
RANDOM EFFECTS										
var(_cons)	1.073***	(0.212)	1.052***	(0.212)	1.085***	(0.222)	0.779***	(0.150)	0.708***	(0.168)
ICC	0.246	(0.037)	0.242	(0.037)	0.248	(0.038)	0.192	(0.030)	0.177	(0.035)
McFadden's R^2			0.010		0.028		0.224		0.224	
N										
Level 1	218,089		218,089		218,089		218,089		218,089	
Level 2	27		27		27		27		27	

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. No data for DE in 2013. DE values for 2020 refer to 2019*

Source: EU-SILC 2013, 2019 and 2020 longitudinal microdata, and Eurostat Prices and Social Protection data, JRC analysis.

Table 11. Model summaries and regression coefficients for the random intercept multilevel mixed effects logistic regression models for persistency having leak, damp or rot in dwelling, 2013-2020

	Empty Model		Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
FIXED EFFECTS												
Sex												
Female					1.039	(0.023)	1.010	(0.027)	1.010	(0.027)	1.015	(0.030)
Male (ref.)												
Age in year n+3												
<=17					1.413**	(0.152)	1.049	(0.139)	1.049	(0.139)	1.071	(0.164)
18-24					1.205*	(0.109)	0.905	(0.103)	0.906	(0.103)	0.927	(0.121)
25-49					1.197*	(0.101)	1.017	(0.110)	1.018	(0.109)	1.059	(0.127)
50-64					1.133	(0.076)	1.027	(0.085)	1.031	(0.084)	1.060	(0.095)
65+ (ref.)												
Change in the household size												
Increased					1.201**	(0.066)	1.097	(0.083)	1.098	(0.085)	1.103	(0.091)
Decreased					1.134*	(0.066)	1.022	(0.072)	1.029	(0.071)	0.995	(0.060)
Fluctuated					1.278*	(0.131)	0.925	(0.073)	0.910	(0.075)	0.912	(0.077)
Same (ref.)												
Years in AROP												
1							1.508***	(0.109)	1.509***	(0.111)	1.493***	(0.123)
2							1.877***	(0.315)	1.873***	(0.318)	1.899**	(0.364)
3+							1.911***	(0.251)	1.910***	(0.249)	1.771***	(0.251)
No years (ref.)												
Years with arrears in utility bills												
1							1.629***	(0.198)	1.619***	(0.200)	1.585**	(0.216)
2							2.411***	(0.227)	2.381***	(0.220)	2.482***	(0.260)
3+							3.050***	(0.517)	3.025***	(0.510)	2.979***	(0.693)

No years (ref.)												
Years with heavy burden of housing costs												
1							1.463***	(0.131)	1.478***	(0.132)	1.425***	(0.138)
2							1.893***	(0.153)	1.918***	(0.155)	1.913***	(0.165)
3+							2.357***	(0.220)	2.365***	(0.223)	2.325***	(0.256)
No years (ref.)												
Contextual variables												
Maintenance and repair of the dwelling price change between years n and n+3 (%)									0.641	(1.844)	2.529	(6.111)
Average share of soc.ex.bens and h.allws. in GDP in period (%)									0.591*	(0.146)	0.501***	(0.076)
Ratio of per dwelling TC energy intensity (kw/dw) relative to HDD											0.602*	(0.129)
Period												
2010-2013			1.218	(0.197)	1.205	(0.197)	1.080	(0.139)	0.981	(0.115)	1.012	(0.081)
2017-2020 (ref.)												
Constant	0.084***	(0.010)	0.077***	(0.011)	0.062***	(0.009)	0.035***	(0.005)	0.055***	(0.021)	0.427	(0.373)
RANDOM EFFECTS												
var(_cons)	0.346**	(0.111)	0.346**	(0.111)	0.350**	(0.112)	0.284***	(0.086)	0.402**	(0.129)	1.155*	(0.545)
ICC	0.095	(0.028)	0.095	(0.028)	0.096	(0.028)	0.079	(0.022)	0.109	(0.031)	0.260	(0.091)
McFadden's R^2			0.001		0.003		0.068		0.069		0.065	
N												
Level 1	218,403		218,403		218,403		218,403		218,403		171,391	
Level 2	27		27		27		27		27		20	

*Note: Significant at "***" p<0.001; "**" p<0.01; "*" p<0.05. No data for DE in 2013. DE values for 2020 refer to 2019. For Model 5, no data for BG, EE, HR, CY, LV, MT and RO.*

Source: EU-SILC 2013, 2019 and 2020 longitudinal microdata, Eurostat Prices and Social Protection data, and IEA Residential Sector data, JRC analysis.

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