The research project is implemented in the framework of H.F.R.I call "Basic research Financing (Horizontal support of all Sciences)" under the National Recovery and Resilience Plan "Greece 2.0" funded by the European Union –NextGenerationEU (H.F.R.I. Project Number: 016638).

Energy/Fuel and human Poverty: public policy and Recommendations in Southern Europe

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1. Introduction

Ensuring access to sustainable and affordable energy is a cornerstone of the 7th Sustainable Development Goal (SDG), emphasizing the critical role of energy in global development. The European Union (EU) also considers energy a fundamental right for all individuals, as outlined in its energy policies. It advocates for energy efficiency measures across its member states to address the disparities in its access. However, despite these efforts, energy poverty affects a significant portion of the EU population, undermining well-being and societal development. Southern European countries, in particular, are disproportionately affected (Aristondo & Onaindia, 2018a; Bollino & Botti, 2017; Faiella & Lavecchia, 2021; Gouveia et al., 2019; Halkos & Kostakis, 2023; Thomson & Snell, 2013) underscoring the region's vulnerability due to economic, climatic, and structural challenges.

The measurement of energy poverty has been widely debated in academic and policy circles, often leading to divergent or even contradictory conclusions. Identifying and evaluating energy poverty is inherently complex, as the phenomenon encompasses multiple dimensions, including economic, social, demographic, and spatial factors. According to Hills (2012), Herrero (2017), and Sareen et al. (2020), the multi-dimensionality of energy poverty necessitates robust and inclusive methods to ensure reliable results. Such methodologies are vital for informing targeted and effective policy measures.

The EFORE-SE project addresses this challenge by proposing credible measurement approaches tailored to Southern European countries. Its primary goal is to identify which households are most affected by energy poverty, enabling public policies to be more responsive and inclusive. This aligns with the recommendations of the European Commission, which stresses the importance of developing harmonized indicators for energy poverty across member states while considering regional disparities. In particular, the deliverable D2.3 of the project, as the continuation of the previous deliverables D2.1 and D.2.2, respectively,

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begins with a comparative analysis at the macro level between the EU-27 and Southern European countries (Greece, Cyprus, Italy, Spain, and Portugal) for 2012–2023. This timeframe covers key events such as the economic crisis, the recovery period, and the COVID-19 pandemic, providing a comprehensive view of the evolving challenges in energy poverty (European Parliament research service, 2023; Halkos & Gkampoura, 2021; Romero et al., 2023) and highlighting the importance of understanding how demographic and socio-economic parameters influence energy poverty, particularly in regions with distinct vulnerabilities. Furthermore, the phenomenon is closely related to human poverty.[1]

The analysis focuses on macroeconomic and social parameters associated with energy poverty, including income inequality, unemployment, housing conditions, and energy consumption patterns. By identifying disparities, this approach provides insights into energy poverty's root causes and impacts while shedding light on how societal development and policy directions influence its prevalence (Ben Cheikh et al., 2023; Dubois & Meier, 2016).

The following analysis phase involves an in-depth review of established indicators used to measure energy poverty. This includes critically evaluating their advantages and limitations, drawing on methodologies proposed by Boardman (1991), Hills (2012), and Moore (2012). The project identifies gaps in current measurement approaches and formulates specific research questions to address these gaps. For instance, Thomson et al. (2017) discussed the limitations of energy expenditure-based metrics juxtaposed with alternative approaches considering energy needs and deprivation. This analysis section enhances the understanding of energy poverty and sets the stage for more advanced econometric modeling. By bridging identified gaps, the project contributes to the

[1] In this project, human poverty is proxied by the components of the AROPE (At Risk of Poverty or Social Exclusion) indicator, as defined in the EU-SILC dataset. The AROPE indicator combines three major dimensions: (i) relative income poverty, using the EU's at-risk-of-poverty threshold; (ii) enforced lack of socially perceived necessities, expressed by the severe material and social deprivation indicator; and (iii) weak labour market attachment, concerning population living in (quasi-)jobless households.

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growing body of knowledge on energy poverty, offering new perspectives for research and policy.

Moreover, the project investigates country-specific analyses for Greece, Spain, Italy, and Portugal. This involves descriptive statistical analysis of each country's socio-economic and macroeconomic profiles, energy sectors, and energy poverty levels (Betto et al., 2020; Costa et al., 2024; Gouveia et al., 2019; Halkos & Kostakis, 2023). Additionally, a review of previous and recent literature, including policy reports by IEA (2023), Gouveia et al. (2022), Energy Efficiency Directive ((EU) 2023/1791), and Gouveia et al. (2023), provides a comprehensive picture of each country's societal and policy landscape. Although these regions share similar climatic conditions, significant differences in socio-economic and energy profiles are evident. This understanding is critical for interpreting the observed variations and is a foundation for advanced econometric modeling.

In summary, the EFORE-SE project aims to advance the understanding of energy poverty in Southern Europe by integrating comparative and country-specific analyses. The findings emphasize the need for targeted and inclusive policies that might address the unique challenges faced by each region. Moreover, through this work, the project contributes to the broader EU effort to achieve energy justice and sustainability, aligning with the principles of the Green Deal and the 2030 Agenda for Sustainable Development.

2. Overall status of European countries

Various statistical data in the Eurostat database highlight several similarities and divergences between EU-27 and South Europe. The data presented serves as a foundation for understanding how the factors incorporated in the descriptive analysis influence energy poverty. First, some key demographic statistics are presented in Table 1.

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Table 1: Basic demographic statistics for EU-27 and South European countries (2012-2023).

	EU - 27		**South European countries**	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*
Total population (nr. of persons)	445,103,023	2,532,953.1	21,547,977	54,268.6
Males	48.8%	0.1%	48.7%	0.1%
Females	51.2%	0.1%	51.3%	0.1%
Population density (persons/km^2)	108.4	0.6	347.6	21.2

Source: Eurostat 2024

The EU-27, with a population of approximately 445 million people, has a similar gender distribution with the subgroup of South European countries, representing 21.5 million people (almost 49% are males and 51% are females). A notable difference lies in population density; the EU-27 has 108 persons per square kilometer, with relatively slight variation, while the southern countries show a significantly higher population density (348 persons per square kilometer), with high variation. This is an important backdrop for recognizing regional differences in socio-economic and energy-related trends.

Their economic status severely influences households' ability to satisfy their essential needs. Income is considered a key determinant of energy poverty, proxied at this analysis step by the member state's gross domestic product (GDP). Real GDP per capita in chain-linked volumes (2010) is analyzed. Furthermore, the literature involves income inequality in energy poverty research. Consequently, alongside economic growth, inequality should be investigated too. Income inequality is expressed as the ratio of total income received by the top quantile (20% of the population with the highest income) to that received by the lowest quantile (20% of the population with the lowest income).

As observed in Figure 1, the average GDP for EU-27 is 27,119 €/capita, while the value for South European countries is 21,886€/capita. On the contrary, income inequality is higher in the south of Europe (5.4) than in the EU (5.0). A

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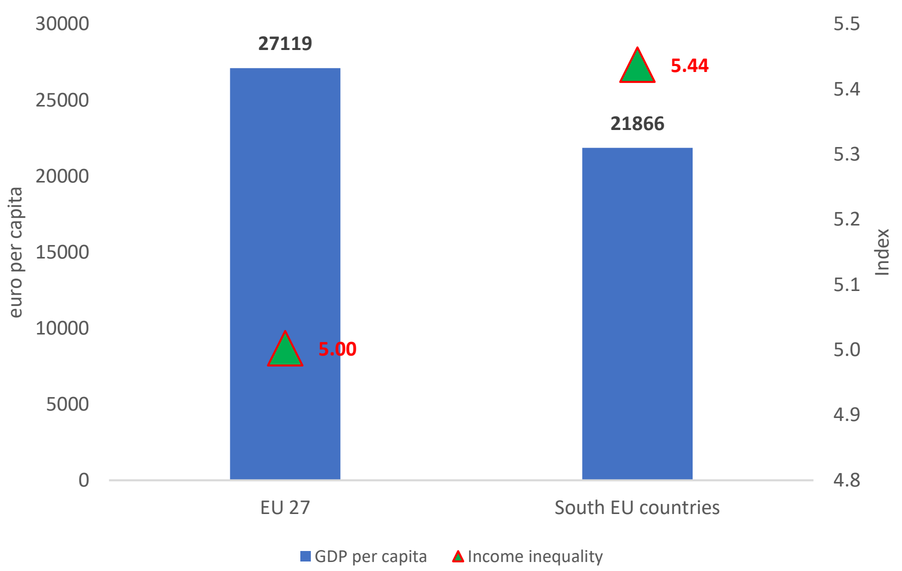
severe social inequality is illustrated in Figure 1, which clearly shows the opposite trends of the variables among the two groups. EU-27 has, on average, higher economic growth with fewer inequalities, while South European countries are less developed and have greater inequality within the subgroup.

Figure 1: Real GDP per capita and income inequality in EU-27 and South European Countries, average values 2012-2023.



Source: Eurostat 2024

Regarding educational attainment, it seems that South European countries have a uniform distribution of each category (almost one-third of the population has attained i) up to lower secondary, ii) up to post-secondary non-tertiary, and iii) tertiary or more than tertiary education) as indicated in Figure 2. Although the EU-27 has approximately the same proportion of tertiary educated people as the southern countries (30%), the upper secondary category is significantly higher than the south, reaching 47%, and profoundly, the lower category proportion is smaller (almost 23%). Therefore, middle education levels are higher in the EU-27 than in the south of Europe, and the lower educational level is higher in the South than the average of the whole EU.

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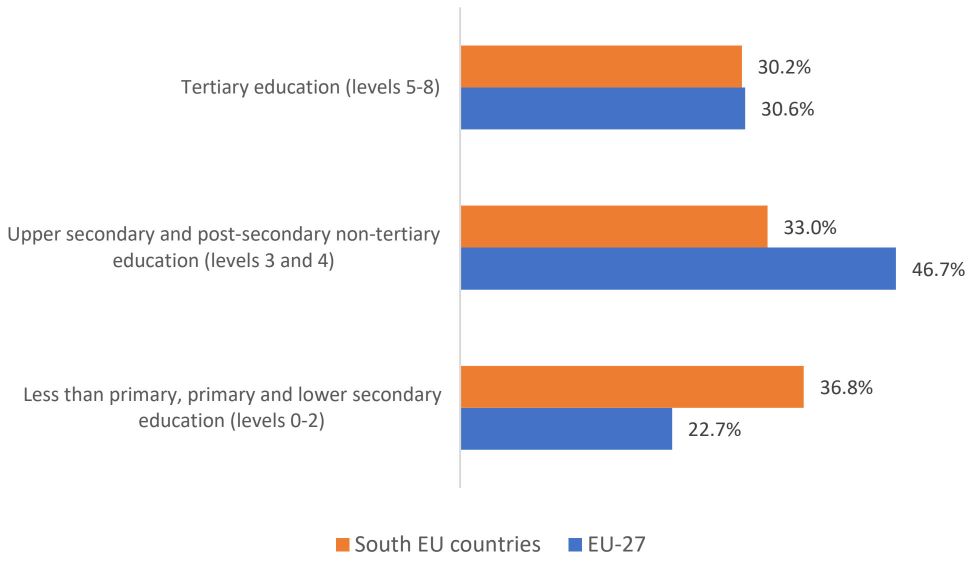
Figure 2: Educational attainment level in EU-27 and Southern EU countries (2012-2023) for people 25-74 years old



Source: Eurostat 2024

Although the EU presents very low values of absolute poverty compared to other regions worldwide, poverty is a sensitive issue in Europe. Specific groups of people live in poor conditions, struggling to meet the needs of the developed world. All human poverty indicators depicted in Figure 3 show that South European countries exhibit more concerning values than the EU-27 average, highlighting a notable social and economic disparity. Subjective poverty reflects individuals' perceptions of poverty based on their experiences. In South Europe, 38% of households are affected by poverty, compared to 31% in the EU-27.

The indicator at-risk-of-poverty or social exclusion explores three factors that express poverty. First, it includes individuals whose disposable income is below the risk of poverty threshold (60% of the national median income after social transfers). Then, it involves people who are severely materially deprived (constraining at least 7 out of 13 items), and lastly, people who live in households where adults between 18-64 years old have worked equal or less than 20% of their total work-time potential within the last year. The difference in this indicator

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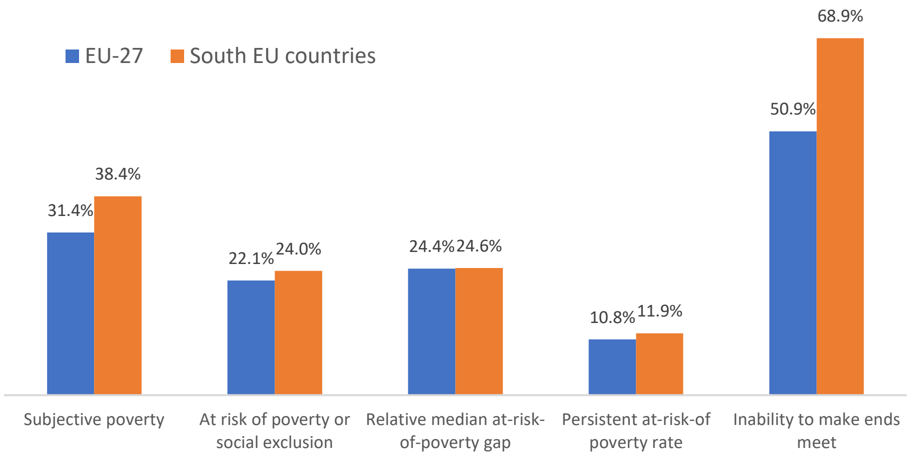
between the two groups is minor: 22% in the EU-27 and 24% in the south. To capture the intensity and persistence of poverty within regions, the indicator "Persistent-at-risk-of-poverty rate" is also examined. This indicator represents the share of people whose disposable income is below the risk-of-poverty threshold in the current year and at least two of the preceding three years. The values are 10.8% for the EU-27 average and 12% for the southern countries.

The relative poverty gap represents the income households should have to reach the national poverty threshold, which is nationally specified at 60% of the median income. This indicator is not differentiated between the two groups (24%). It is also important to emphasize that this percentage is profoundly concerning in both cases, as the poorest individuals in the EU need to increase their income by 24% to reach the upper threshold of the median income among poor people in their respective countries. In contrast, significant variation is observed regarding households' ability to make ends meet. Nearly half of the population in the EU-27 faces difficulty, some difficulty, or high difficulty in managing their finances. This proportion is notably higher in South Europe, reaching 69%, compared to 51% in the EU-27.

Figure 3: Poverty indicators for EU-27 and South European countries (2012-2023).



Source: Eurostat 2024

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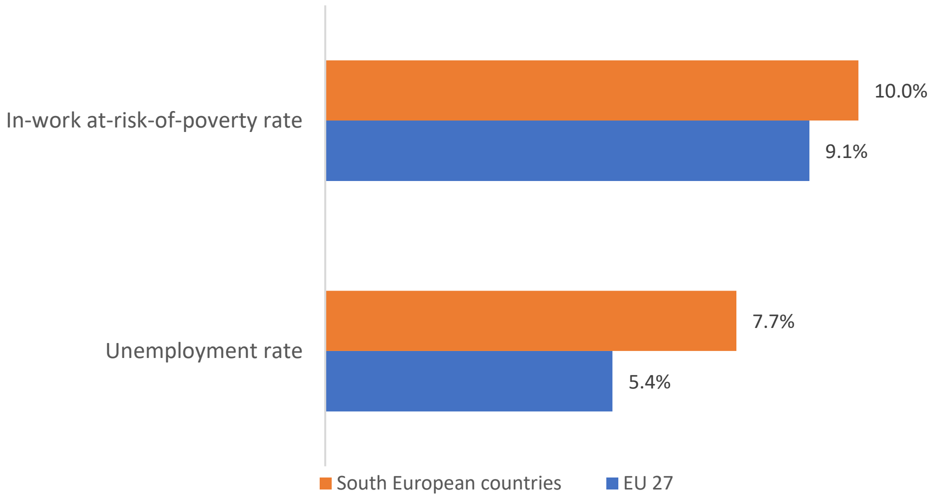
The in-work-at-risk-of-poverty rate indicates the share of persons that, despite being employed, have an income that falls behind the national poverty line. The values in Figure 4 are comparable for the EU-27 (9%) and South European countries (10%). These relatively high percentages point to systemic challenges in the labor market, including wage disparities, job insecurity, and economic instability among workers. Additionally, the labor market struggles with unemployment, particularly in South European countries, where, on average, 8% of the population is unemployed.

Figure 4: Unemployment rate in EU-27 and Southern European countries (2012-2023) for people 25-74 years old, and "in-work at-risk-of-poverty.



Source: Eurostat 2024

Apart from income and other macro- and socio-economic aspects that reflect energy poverty, studying the energy sector (i.e., energy prices, consumption, etc.) is important to understand the phenomenon's synergies better. As observed in Figure 5, total household energy consumption per capita is significantly higher in the EU-27 than in the southern countries. The average consumption per capita for the EU-27 is 566 kilograms of oil equivalent (KGOE), while the average consumption for the South European countries is 350 kilograms. This may be attributed to several reasons, such as higher energy needs

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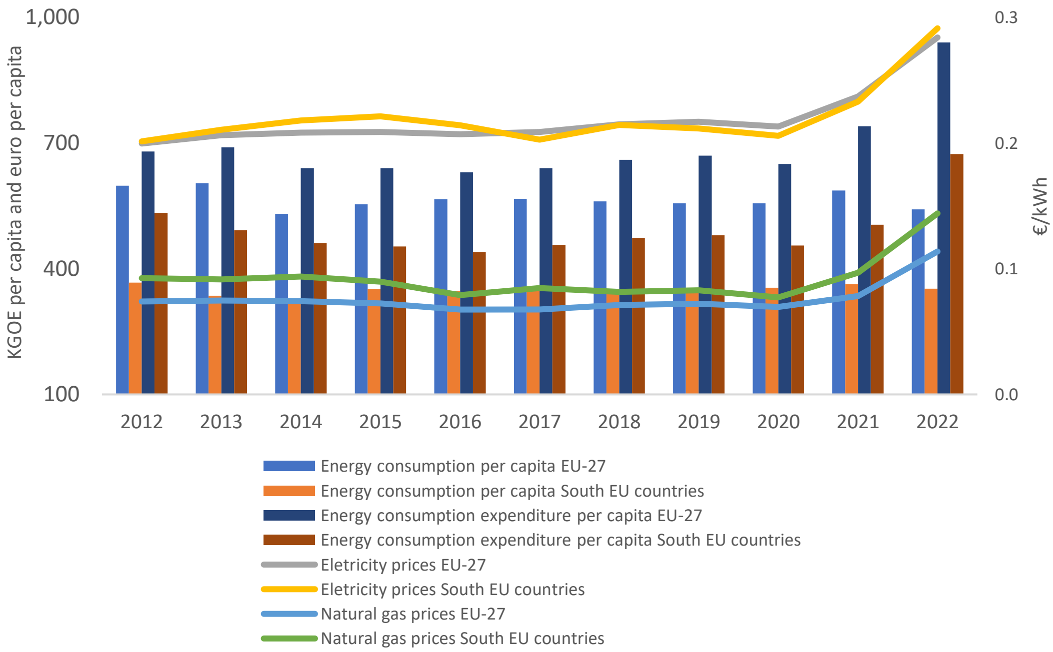
during winter in northern countries. Electricity prices are lower in South Europe. This is also depicted in the final energy expenditure, including all fuel types. Dividing the total energy expenditure per capita at EU-27, energy expenses are higher for EU-27 (689 €) than southern countries (493 €). Additionally, electricity prices are comparable in both regions, with only minor variations. While natural gas prices follow a similar pattern, they are higher in South European countries. After 2020, prices rose in both regions, peaking in 2022.

Figure 5: Electricity prices for households, energy expenditure of households per capita, energy consumption in households per capita, for EU-27 and South European countries (2012-2022).



Source: Eurostat 2024

Valuable insights into energy poverty can be drawn from Eurostat datasets. Across all indicators, South Europe experiences considerably more significant challenges in addressing this issue (Figure 6). 13% of South Europeans have arrears on utility bills, while the average share for EU-27 citizens is 8%. 18% of the population in the south declare unable to keep their home adequately warm, which is double the proportion of the average EU-27, despite the winter months in the southern countries being milder compared to the rest of Europe. Moreover,

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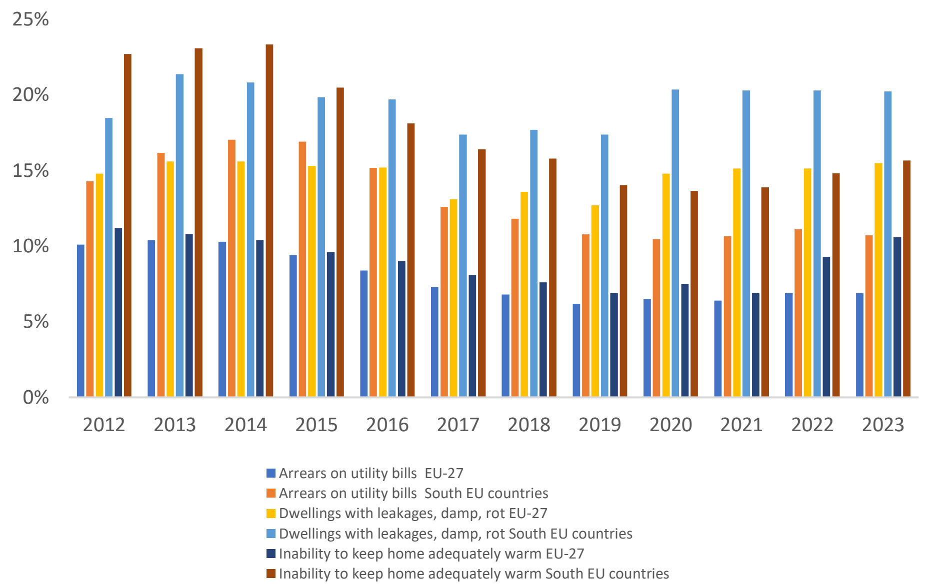
19% of households in South Europe reside in buildings with leaks, dampness, and rot, whereas the average EU-27 appears to have either better-quality building stock or a greater capacity to heat homes adequately (14.5%).

Figure 6: EU-SILC energy poverty indicators for EU-27 and South European countries.



Source: Eurostat 2024

3. Energy poverty indicators

Assessing energy poverty is complex, as it is a private matter confined to the household and varies across time and location. Additionally, it is a challenging, multi-faceted concept sensitive to cultural factors (Simcock et al., 2016). The methodology for measuring energy poverty depends on the intended scope and is shaped by factors such as data availability, research resources, and current policy priorities targeting the most vulnerable social groups. Additionally, the geographical focus plays a crucial role at a pan-European, national, or regional level. In some instances, more granulated analysis is necessary to pinpoint energy-poor households at the local level for effective policy intervention (Thomson et al., 2017).

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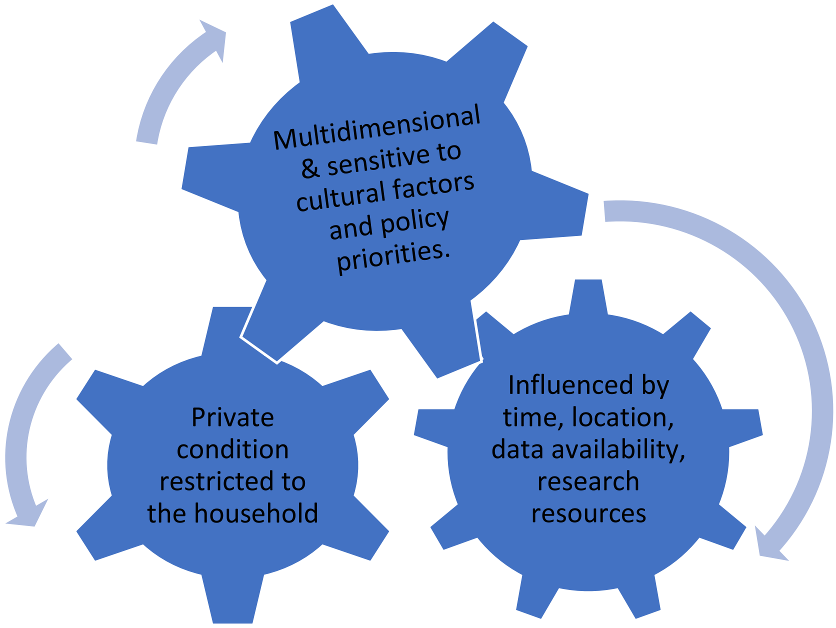
Figure 7: General difficulties in measuring energy poverty.



Understanding and interpreting energy poverty is fundamental to applying efficient policies. Energy poverty's complex nature and impact require thorough assessment while monitoring its multiple dimensions. Indicators help capture the various facets of energy poverty and are vital to recognize and evaluate the vulnerability of energy-poor households (Gouveia et al., 2023). Furthermore, the metrics of energy poverty play a crucial role in recognizing energy poverty as a unique form of material deprivation that reflects a distinct area of research and policy that goes beyond and interacts with monetary poverty and other types of material hardship.

Some countries have developed national energy poverty indicators. For example, in Greece, according to the official National Energy Poverty Index (NEPI), a household is classified as energy-poor if the following two conditions apply simultaneously: (i) the annual cost of the total final energy consumed by the household is lower than 80% of the expenditures theoretically required to cover the minimum final energy consumption of this household, and (ii) the total equivalized income of the household, which is influenced by the household's size and composition and calculated using the modified OECD equivalence scale, is lower than 60% of the median equivalized income of all households in Greece, according to the definition of relative poverty.

A growing research interest has been witnessed concerning measuring energy poverty, assessing existing indicators, and providing new, differentiated, or adapted ones. Nowadays, numerous and complex energy poverty indicators have been developed. The literature presents diverse conclusions concerning indicators' performance, their potential to capture weaknesses, and recommended policies (Herrero, 2017). Academic research and authorities have categorized energy poverty indicators into three approaches: objective, subjective, and direct.

A) Objective approach

The "Objective approach" indicators are mainly income and energy expenditure-oriented and/or energy-cost-oriented. There is a plethora of objective indicators examining energy expenses against absolute or relative thresholds. This approach requires the definition of a threshold or the energy poverty line. The common characteristic of all objective indicators is that they consider the share of expenses devoted to energy with total household expenditure or household income. They are recognized as objective and quantifiable measures. Objective indicators could be subcategorized into three typologies:

- Identifying excessive energy consumption.
- Being below the monetary poverty line after delivering energy costs.
- Recognizing low actual consumption, conveying hidden energy poverty.

To meet the requirements of objective indicators, researchers and authorities can utilize data from the Household Budget Survey (HBS). When applying objective indicators, certain factors must be considered, such as whether to use an absolute or relative expenditure threshold and the methods for quantifying energy needs and expenses and measuring household incomes.

The fundamental indicator introduced by Boardman for the United Kingdom, which is widely known as "the 10% rule", defines households as energy-poor if adequate energy expenses exceed 10% of their income (Boardman, 1991). This pioneering method established energy poverty research, providing simplicity in measurements, communication, and flexibility. Nevertheless, it should be highlighted that this indicator was applied in the United Kingdom (UK) in the 1990s; therefore, its implementation may not satisfy other circumstances (Romero et al., 2018). Another significant aspect is that the 10% rule considers the *required* energy expenses; however, since its formula cannot be easily adapted to other countries, most literature uses the *actual* energy expenses instead. This sets the risk of leading to invalid results (Thomson et al., 2017). For example, cases like households with low incomes that tend to under-consume energy in order to satisfy other essential needs may be excluded from energy poverty status. Alternatively, higher-income households that live in low-efficient dwellings or, on the contrary, if they are used to over-consumption because of affordability, may be classified as energy poor (Peter Heindl, 2015). Consequently, utilizing this single indicator without considering the household's socio-economic status and the building's energy efficiency may leave the vulnerable population behind and/or identify affluent households as energy-poor.

Following the 10% rule and to address its limitations, the UK moved from an absolute to a relative mode measurement, the Low Income–High-Cost indicator (LIHC) introduced by Hills (Hills, 2012). This indicator identifies households as energy poor if i) they have high required energy expenditure above the national median according to household conditions, and ii) after energy costs, their income is below the 60% median poverty line. Although this approach consists of a deeper analysis, it is criticized for being complex, non-transparent, and concealing price increases (Moore, 2012). Furthermore, it is criticized for restricting the energy poverty problem to a technical issue concerning energy efficiency, pursuing primarily affiliated investments, without addressing institutional arrangements with energy market operation (Herrero, 2017). Furthermore, the LIHC indicator is a doubly relative metric, making time series analysis challenging and making it difficult to distinguish drivers and impacts (Romero et al., 2018). Currently, energy poverty in the UK is computed using a new indicator: the Low Income-Low Energy Efficiency Indicator. This approach aims to classify households as energy-poor if they have low incomes (cases that fall below the poverty line after the required energy expenditure) and live in residences with poor energy efficiency (UK GOV, 2024).

Another objective indicator widely employed in research and policy implications is the "High share of energy expenditure in income (2M)" suggested by the European Poverty Advisory Hub EPAH. According to this approach, households are considered energy-poor if energy expenses are above twice the national median, providing a simple identification of households with high energy costs compared to income. Nevertheless, low-income households with low consumption are not included in the analysis, so this indicator should be combined with income and energy efficiency parameters.

Another indicator introduced by EPAH is the "Low absolute energy expenditure (M/2)", which accounts for cases where expenses are abnormally low (specifically below half the national median). This indicator can capture hidden energy poverty. However, it conceals the risk of putting in the same condition households with high income and low energy requirements (i.e., small household size, prosperous income, dwelling in energy efficient residences) and low income and high-size households that dwell in low efficient buildings. This indicator should be combined with socioeconomic, demographic, and building characteristics parameters.

The Minimum Income Standard (MIS) method, first introduced by (Moore, 2012), categorizes households as energy-poor if energy services cannot be satisfied after the costs of essential human needs. This indicator addresses energy

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poverty at its economic core by identifying vulnerable populations with disproportionately high energy expenditures using an absolute minimum income threshold. However, establishing a minimum income based on objective criteria remains a significant challenge (Romero et al., 2018).

At this point, it should be mentioned that indicators that consider the 60% monetary poverty line mainly concentrate on more vulnerable households that are the most severely affected by energy poverty. As a consequence, other vulnerable groups may be excluded from this condition. Table 2 presents the primary objective energy poverty indicators, classification patterns, and key characteristics.

Table 2: Objective energy poverty indicators

Objective indicators		
Indicator name	**Classifying energy poverty if:**	**Characteristics**
10% rule	Energy expenditure for adequate energy exceeds 10% of a household's income	Simplicity in measurements. In communication and flexibility. Formulated according to the UK conditions during the 1990s. Usually, actual costs instead of required costs are employed.
Low income – high cost	i) High required energy expenditure above the national median ii) income is below the median poverty line after energy costs.	In-depth analysis. Complex. Non-transparent. Concealing price increases. Restriction of energy poverty problem to a technical issue concerning energy efficiency. Doubly-relative metric.
High share of energy expenditure in income (2M)	Energy expenditure is above twice the national median	Simple identification of households with high energy costs compared to income. Low-income households with low consumption are excluded.
Low absolute energy expenditure (M/2)	Energy expenditure is abnormally low (below half the national median)	It can capture hidden energy poverty. Risk of putting in the same condition small households with high-income and energy-efficient dwellings and bigger households with low-income and deteriorated residences.
Minimum Income Standard (MIS)	Energy services cannot be satisfied after the costs of essential human needs.	It addresses energy poverty at its economic root. Difficulty in defining minimum income with objective criteria.

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B) The consensual approach

This approach lies in self-reported considerations concerning indoor energy services' conditions and the level of necessities that are met. Microdata concerning energy expenses and living conditions is unavailable at the European level. However, such information is provided through the Statistics on Income and Living Conditions (EU-SILC) dataset in comparable annual data (cross-sectional and longitudinal). More specifically, this technique involves 'consensual' indicators, investigating the population's energy poverty status and asking households whether:

- they can keep their home adequately warm
- they have arrears on utility bills
- their homes suffer from leakages, damp, or rot

Over 95% of the EU population almost universally considers these elements essential. The "ability to keep the home adequately warm" is a core self-reported indicator and the default measure for identifying households experiencing energy poverty. It addresses the issue directly and clearly, with response options limited to "yes" or "no."

Being "in arrears on utility bills" is also a good proxy for energy poverty since when people struggle to deliver their utility bills, the absolute consequence is that they find it challenging to afford sufficient energy services. Furthermore, positive responses reveal that people might face disconnections in energy supply. This indicator asks respondents whether they have fallen behind on utility payments (electricity, water, gas) in the past 12 months. The possible responses are: "yes, once," "yes, twice or more," and "no."

Concerning the third self-reported indicator that investigates energy efficiency and housing conditions, the question is whether households live in buildings with "leaking roofs, damp walls/floors/foundation, or rot in window frames or floor". Buildings with damp, leakages and rot might be entirely or unheated for long periods, potentially impacting energy poverty. Furthermore, such dwelling characteristics are responsible for the building's further deterioration over time, enhancing its inability to provide good indoor thermal conditions and energy consumption. Buildings facing such conditions are usually old, non-renovated, and have low energy efficiency.

The subjective approach fosters several strengths. First, collecting self-reported data is more manageable than expenditure data. Secondly, energy efficiency, which is a significant energy poverty determinant and addressing factor, reinforces the case of consensual indicators (Petrova et al., 2013). Furthermore, these indicators satisfy a significant dimension in measuring energy poverty, which is none other than capturing broader attributes of energy poverty, like social exclusion and material deprivation (Healy & InstituteIreland, 2003). Self-reported beliefs concerning warmth and comfort help researchers capture broader aspects of energy poverty following a bottom-up procedure.

On the other hand, applying self-reported indicators lies in specific limitations, which should not be overlooked. One of the most important disadvantages of this approach is that it can lead to non-realistic results, excluding households that are indeed energy-poor. For example, vulnerable populations may provide false responses for many reasons (i.e., denial of their condition and lower standards). Furthermore, it should be noted that adequate warmth is not an objective perception within a society and may differentiate across societies with different cultural habits (Bouzarovski, 2014). Another critical point is that these indicators are binary-shaped, leaving little potential to investigate the intensity of energy poverty thoroughly. While evaluating the efficiency of these indicators, it should be considered that the survey participants can mostly reply "yes" or "no", failing to reveal differentiation in households' experiences and providing the reasons why households are unable or cannot afford to keep their homes. Finally, self-reported indicators may not overlap with expenditure measures since they are subject to wrongly perceived assumptions concerning goods and services standards. For example, households above the average income may present

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themselves as energy-poor due to their consumption preferences (McKay, 2004). Table 3 presents the primary subjective energy poverty indicators, classification patterns, and key characteristics.

Table 3: Subjective energy poverty indicators

<u>**Subjective (consensual) indicators**</u>			
Indicator name	**Possible responses**	**General characteristics**	**Specific characteristics**
Ability to keep home adequately warm	Yes No	Simple data collection. Wider aspects affiliated with energy poverty are captured (social exclusion, material deprivation). Bottom-up process. Risk of having biased or untrue results (false responses, wrong perceptions). Binary-shaped indicators leave no room for investigation of energy poverty intensity.	Direct and clear indicator. Captures the default definition of energy poverty. Adequate warmth is not a universally perceived condition and is subject to cultural habits.
Arrears in utility bills during the last 12 months	Yes, once Yes, twice or more No		Fair proxy for energy poverty. Disconnections in the energy supply can be revealed. Other housing costs, like water, are not involved in the energy poverty aspect.
Presence of damp, leakages, or rot in the dwelling	Yes No		Involvement of building's energy efficiency.

<u>*C) The direct approach*</u>

The direct approach compares the energy services (i.e., heating and lighting) achieved at home with a set of standards (often used as the pre-defined standard 18-21^{o}C for indoor temperature, defined by the World Health Organization - WHO). This approach is slightly employed in research because it yields many difficulties. First, it should be noted that relevant datasets are not adequate and reliable. Additionally, this approach is subject to misleading results because of intermittent occupancy. Furthermore, there are technical difficulties in

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defining minimum temperature thresholds and measuring temperature. Additionally, the ethical obstacle of entering homes to measure their private energy condition should not be ignored (Thomson et al., 2017). Table 4 presents the direct energy poverty measuring approach.

Table 4: Direct measurement of energy poverty

Direct approach		
Indicator name	**Description**	**Characteristics**
Direct measurement	The level of energy services achieved is compared to a pre-defined standard.	Unavailable data. Difficulty in defining minimum temperature threshold. Technical and ethical difficulties in measuring temperature.

In 2019, the European Commission required all member states to assess and evaluate energy poverty within their territories and incorporate the findings into their National Energy and Climate Plans. When energy poverty is recognized as a significant social issue, member states must implement measures and policies to address and mitigate it. The European Energy Poverty Advisory Hub (EPAH) collects information and practices on this matter at the subnational and local levels. The EPAH's 2022 report emphasizes macro indicators and demonstrates how member states can be assisted in understanding the problem better and applying practical policy implications to meditate on the problem effectively. It consists of a thorough review and in-depth analysis of existing indicators introduced by the Energy Poverty Observatory (EPOV), a previous EU initiative (Gouveia et al., 2022).

The following year, EPAH published a new report on the latest updates and improvements to existing energy poverty indicators. It reorganizes and updates existing indicators, eliminating redundancies and introducing new (sub)topics and indicators. Indicators are categorized into four primary topics and respected subtopics.

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a) The Climate topic features indicators that depict climate conditions and related phenomena.

b) The Facilities/Housing (subtopics Building Stock and Energy Consumption and Equipment) emphasize the characteristics, quality, and accessibility of the building stock, as well as housing and other facilities directly linked to energy poverty.

c) The Mobility topic highlights vulnerability related to transport and mobility, seeking to establish a connection between transport poverty and household energy poverty. Transport poverty refers to the inability of individuals or households to afford or access reliable transportation services, which can significantly impact their energy poverty status.

d) Finally, the Socioeconomic aspects (Subtopics Socioeconomic and Living Conditions, Energy Expenditure and Energy Markets, and Health) topic focuses on a range of socioeconomic variables that act as causes, drivers, or consequences of energy poverty, providing insights into the social and economic impacts on individuals and communities. While some factors are directly tied to energy poverty, others, though not directly caused by or resulting from it, contribute to or emerge from a vulnerability context that either leads to or results from an energy poverty situation. This relationship can sometimes be bidirectional, creating a causal loop where worsening energy poverty intensifies its underlying causes (Gouveia et al., 2023).

4. Research gaps and key research questions

Although the EU focuses on unity and cohesion between its member states, significant differences are observed in the descriptive statistical analysis for the values of EU-27 and the subgroup of South European countries. Substantial socioeconomic factors like economic growth, income inequality, unemployment rate, household energy consumption, etc. remain evident. Furthermore, according to all energy poverty indicators, South Europe encounters considerably more significant challenges in addressing energy poverty despite experiencing milder winter climates than many central and northern EU countries. Therefore, a thorough spatial analysis is needed to understand better the synergies of energy poverty in South European countries.

Implying descriptive statistics for demographic, socioeconomic, energy, and energy poverty-related data provides a broader and integrated picture concerning the conditions of each country involved in the project (Greece, Spain, Italy, and Portugal). This analysis shapes an overall aspect of societies examined and enriches knowledge of the synergies of energy poverty. This step is critical before employing more advanced econometric methods since it helps recognize energy poverty determinants and interdisciplinary dimensions. In particular, since little knowledge is provided concerning a detailed spatial analysis of energy poverty, the statistical socioeconomic and household energy behavior analysis is a key step to concluding the correct and targeted econometric methodology.

The comparative analysis between the countries will detect quantifiable changes across societies with similar climatic conditions but different regions and climate zones, disparities in political systems, socioeconomic conditions, demographic characteristics, and how they meet their energy requirements. The cross-country empirical analysis is expected to shed light on the use, benefits, and barriers of energy poverty indicators, revealing overlaps or disparities aiming to enrich the current theoretical framework. Besides, the comparative analysis concerning the differences and the similarities observed between the countries generates new considerations concerning the synergies of energy poverty, with a significant international impact. Consequently, the first research question is:

- *Research question 1:* What are the disparities and/or similarities between the four Southern European countries investigated in the energy poverty occurrence?

Furthermore, the following steps include advancing econometric analysis within and regional investigation for each country. This step will offer a multidisciplinary empirical analysis of determinants affecting society. Therefore, the following research questions arose:

- *Research question 2*: Which households are considered vulnerable to energy poverty in South European countries?
- *Research question 3:* Are common and specific characteristics drivers of energy poverty between and within countries?

Another vital parameter lies in existing energy poverty indicators. After thoroughly investigating and studying existing official indicators, it is concluded that all types of measuring energy poverty have advantages and disadvantages. Energy poverty is a multidimensional phenomenon, capturing and reflecting various aspects of social conditions, fiscal factors, households' economic status, macroeconomic characteristics of countries, policies and regulations, and households' characteristics and habits. Therefore, investigating energy poverty should be done multi-treatment, too.

Relying on a single indicator sets high risks of entrenched understandings of the phenomenon and restricting to relatively narrow aspects concerning which households deserve support. Literature has identified significant gaps between indicators. Classifying households with specific characteristics as energy-poor, based on one indicator, does not necessarily mean that employing other metrics will coincide. Additionally, the combination of several objective and consensual indicators should provide not only less biased but also more inclusive results as well. Employing a wide combination of indicators can provide fruitful and pioneering considerations concerning overlapping indices or unobserved or excluded cases. Furthermore, measuring it may shed light on hidden and permanent energy poverty, a sensitive and significant topic.

Furthermore, the Household Budget Survey (HBS) provides information required to compute objective indicators. One of the key limitations of using the HBS dataset is that only actual energy expenditure is reported (Herrero, 2017). This project includes actual and required energy consumption sufficient to cover

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each household's needs. Furthermore, a comparative analysis between the two approaches will provide significant and innovative considerations, aiming for more targeted policy implications. Consequently, the following research question is:

- *Research question 4:* What specific characteristics should energy poverty indicators employ to be more inclusive to reveal hidden energy poverty and permanent energy poverty status?

The research team employs and develops advanced research tools and techniques to satisfy the required empirical analysis of individual observations (e.g., econometric techniques, spatial analysis techniques, statistical methods, and micro or panel techniques). The interdisciplinary status of energy poverty alongside cross-country analysis and different data sources analysis (microdata from EU-SILC, microdata from EUROSTAT) enhances interdisciplinarity. Integration and collaboration of multiple academic disciplines emerge to explore the multidimensional issue of energy poverty sufficiently. Links between purely economic parameters and several scientific objectives like environmental, social, and behavioral sciences, physics etc., emerge.

Empirical analysis of energy poverty synergies provides insights concerning the sustainability of policy implications already applied. Disseminating the project's results (uploaded on the project's website through well-ranked scientific journals and international conferences), the research team reveals the significance of the problem. Furthermore, updated considerations for targeted regional and national policy implications are provided, offering potential for further research. The estimated indicators adapted to southern European countries will motivate more targeted and efficient policy recommendations. Proposed policy implications are expected to trigger stakeholders' willingness to invest in the selection process of energy-efficient solutions and improve vulnerable households' welfare. Consequently, the final research question is set as follows:

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- *Research question 5: Is current policy implication sufficient? How could authorities better address energy poverty?*

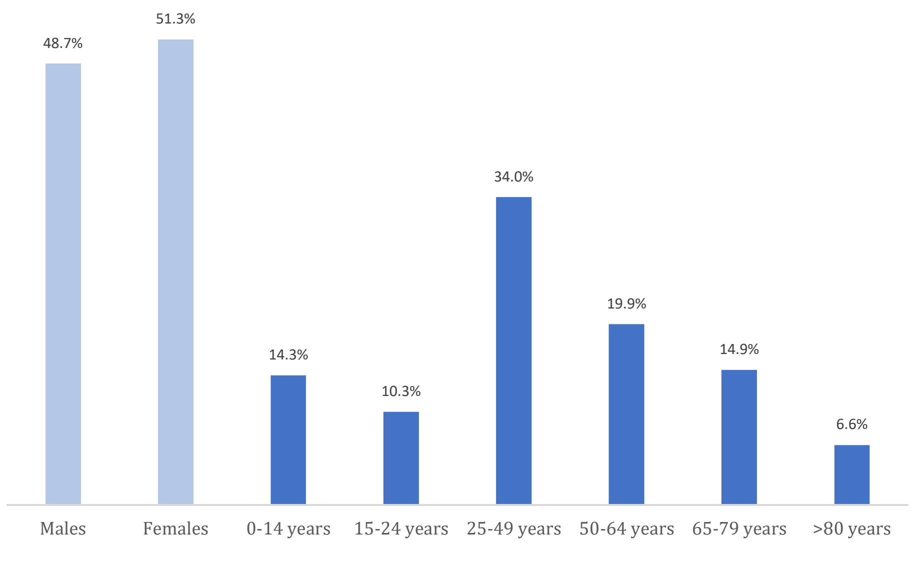
5. Empirical results

5.1. The Greek case study

5.1.1. Socioeconomic profile of Greece

Analyzing the socioeconomic characteristics of a country is essential for understanding its broader developmental landscape. The analysis of Greece's socioeconomic profile begins with key demographic data. The population of Greece is estimated to be around 10 million people, and the average population density is 82.4 persons per square kilometer. Figure 8 offers an overview of the male-to-female ratios and the age distribution within the Greek population. Approximately 48.7% are males and 51.3% females. Concerning the age distribution, it is observed that 14% are infants and children (0-14 years), 10% are young people aged 15-24 years old, 34% are middle-aged persons (25-49 years old), 20% are 50-64 years, 15% are 65-79 years and 6.6% are 80 years old or above.

Figure 8: Average demographic statistics for Greece (2012-2023).



Source: Eurostat 2024

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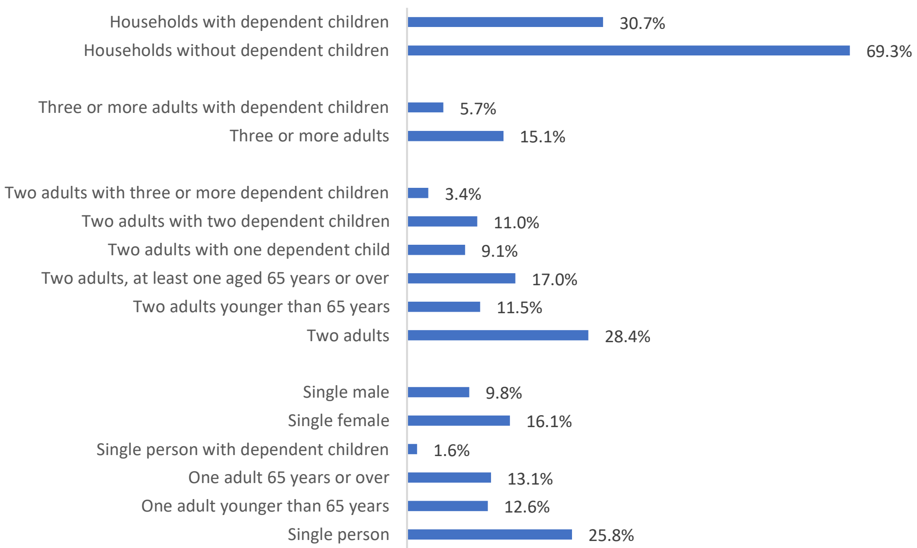
The household type distribution is presented in Figure 9. As indicated, 26% are single-person households, 10% males and 16% females. The age ranges for singles are very uniform, at 12.6% below age 65 and 13% above age 65. The percentage of families with no dependent children stands at 69%, while those with dependent children are 31%. Among households with two adults, 11.45% consist of adults under 65, whereas 17% have at least one adult aged 65 or older. For two-adult households containing dependent children, 9% have one child, 11% have two children, and 3.3% have three or more children. Lastly, 15% comprise three or more adults, of which 5.7% also have dependent children.

Figure 9: Household types distribution in Greece (2012-2023).



Source: Eurostat 2024

Figure 10 presents the educational attainment levels in the Greek population and reveals that 26% have completed less than primary, primary, or lower secondary education. Meanwhile, 43% have achieved upper secondary or post-secondary non-tertiary education, and 31% have attained tertiary or higher education. These proportions are broadly comparable to the EU-27, with the share of tertiary education exceeding the average observed in Southern European countries.

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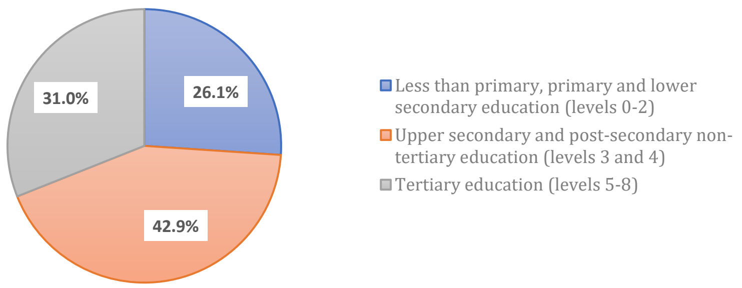
Figure 10: Average educational attainment level in Greece, for 2012-2023.



Source: Eurostat 2024

The analysis of GDP per capita for the period 2012-2023 reveals significant fluctuations. As demonstrated in Figure 11, Greece experienced a sharp decline in GDP during the economic crisis, reflecting the severe impact of strict austerity measures. From 2012 to 2017, GDP remained consistently low, with slight improvement observed until 2019. However, the COVID-19 pandemic caused a notable drop in GDP in 2020, followed by a moderate recovery in the subsequent years. Greece also exhibits high income distribution ratios, indicating pronounced income and wealth inequality. This trend aligns with GDP fluctuations. From 2012 to 2016, income inequality remained high and steady, decreasing slightly between 2017 and 2019. From 2020 to 2023, inequality levels stabilized, except for 2021, when an increase likely linked to the pandemic was observed. Compared to the EU-27 and Southern European countries, Greece has lower GDP per capita and higher income inequality, highlighting slower economic growth and more significant disparity in income distribution within its peer group.

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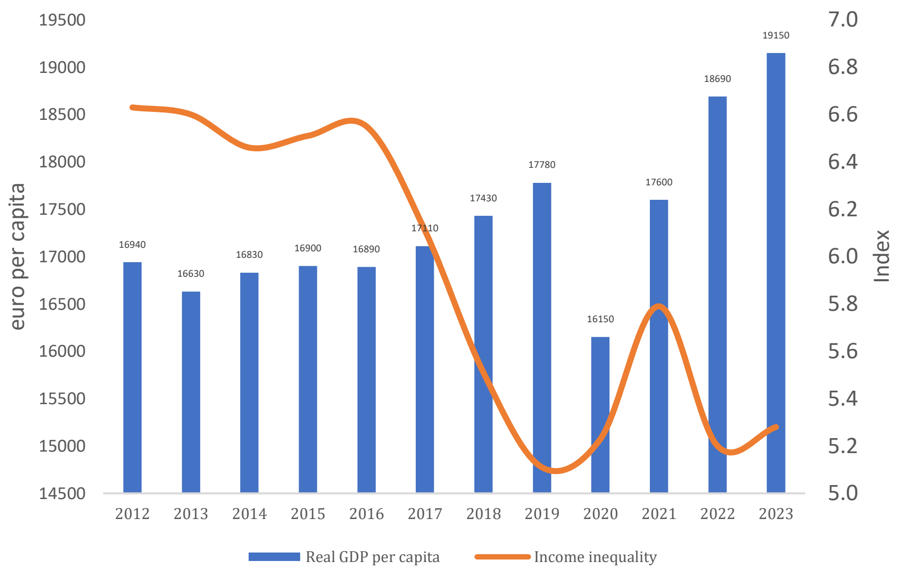
Figure 11: Real GDP per capita and inequality of income distribution in Greece (2012-2023)



Source: Eurostat 2024

The 2010s decade has been a challenging period for Greece with a severe impact on poverty and social exclusion within the population, which is clearly illustrated in Figure 12. For 2012-2023, the average subjective poverty reached 73.54%, demonstrating that a significantly high share of the Greek population perceives themselves as living in poverty based on their experiences. The relevant percentages for EU-27 and South Europe are significantly lower (less than 40%). Furthermore, 29% of the population is classified at risk of poverty or social exclusion, again lower than both groups. The proportion of people who face difficulties in making ends meet is worryingly high (91.5%) and far away from the relative ratios of the EU and South EU. 13% of Greek citizens are persistently at risk of poverty, and 12% are employed people at risk of poverty. Finally, another disconcerting percentage is the mean relative poverty gap, which reaches 28.6%. This outcome highlights severe relative poverty problems since the income of people living in poverty lags 28.6% behind the national poverty threshold in Greece. Consequently, persons in poverty must increase their income by 27.66% to reach the national poverty threshold. Summarizing all poverty indicators, Greece struggles deeper with poverty than EU-27 and South European countries.

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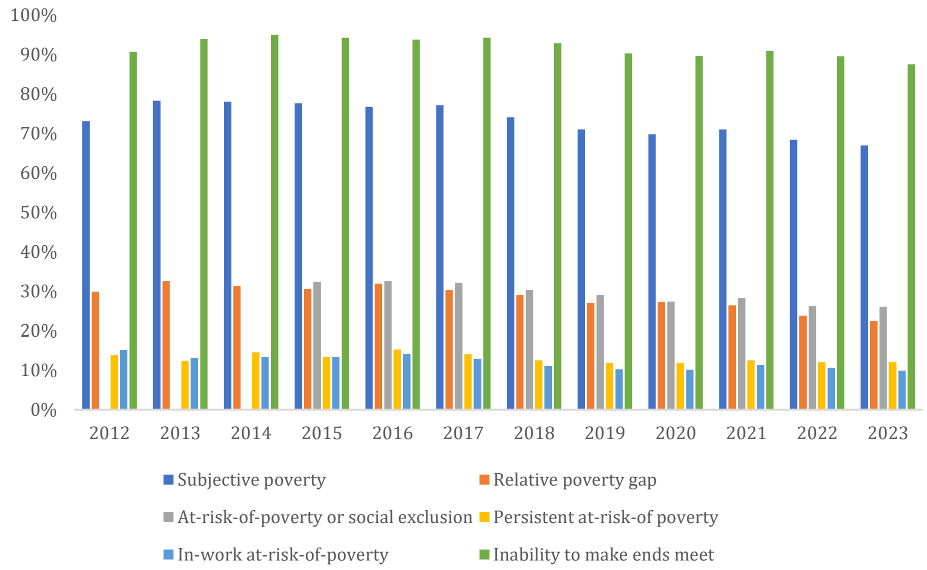
Figure 12: Subjective poverty, at-risk-of-poverty or social exclusion, relative poverty gap, inability to make ends meet (2012-2023), persistent at risk of poverty, in work at risk of poverty, for Greece.



Source: Eurostat 2024

As far as the employment conditions in Greece are concerned, Figure 13 demonstrates that jobless households and unemployment rate present high percentages for the period 2012-2020; in particular, 16.6% are considered jobless households, and the average unemployment rate is 13.5%, while the EU-27 unemployment rate is approximately 5% and South European countries 8%. From 2021 to 2023, the proportions show a decreasing trend. The average part-time employment is 8.8%, and the proportion of employees with limited-duration contracts is 7.4%.

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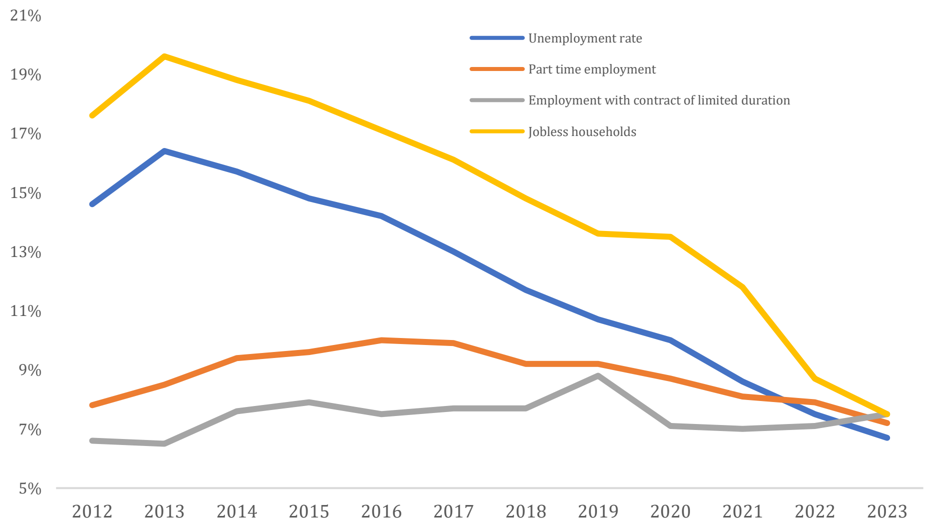
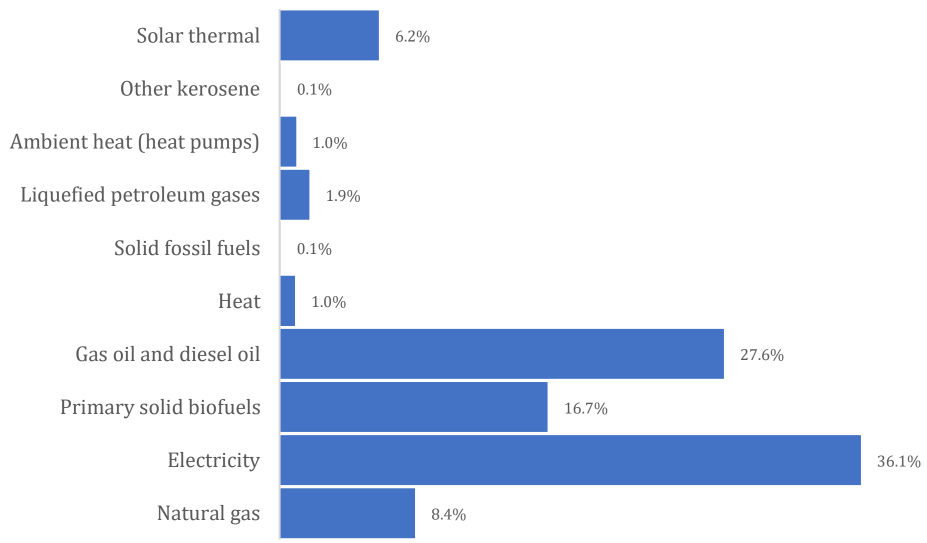
Figure 13: Employment statistics for Greece (2012-2023).



Source: Eurostat 2024

The average household energy consumption by product type for 2012-2022 is distributed as follows: 36% electricity, 28% gas oil and diesel oil, 17% primary solid fuels, 8% natural gas, and 6% solar thermal energy (Figure 14).

Figure 14: Average energy consumption of households by energy type, Greece (2012-2022).



Source: Eurostat 2024

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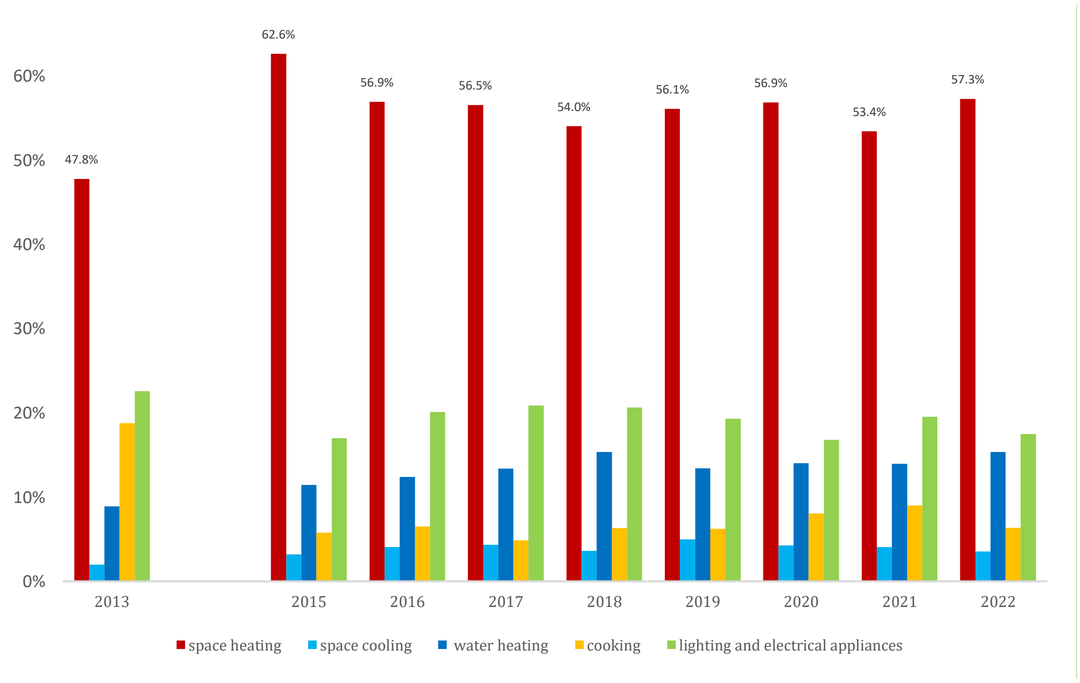
Furthermore, as observed in Figure 15, "space heating" represents the highest share of household energy consumption, remaining above 50% in all years (apart from 2013). "Lighting and electrical appliances" is the second highest energy use at around 19%. "Water heating" gradually increased over the years, from 9% in 2013 to 15% in 2022. Then, "cooking" and "space cooling" follow at lower percentages (approximately 13% and 4% respectively). Data for 2014 is not available.

Figure 15 Greek households' energy use (2013-2022)



Source: Eurostat 2024

The energy sector analysis proceeds with evaluating households' final energy consumption, energy expenditure, and annual electricity and natural gas prices, as illustrated in Figure 16. Per capita energy consumption declined during 2013-2014 and 2018-2019. Energy expenditure decreased between 2012 and 2013 but rose sharply in 2021 and 2022. Electricity prices peaked during 2014-2018 and significantly increased after 2020, reaching their highest level in 2022. Natural gas prices followed a downward trend until 2020 but rose sharply thereafter.

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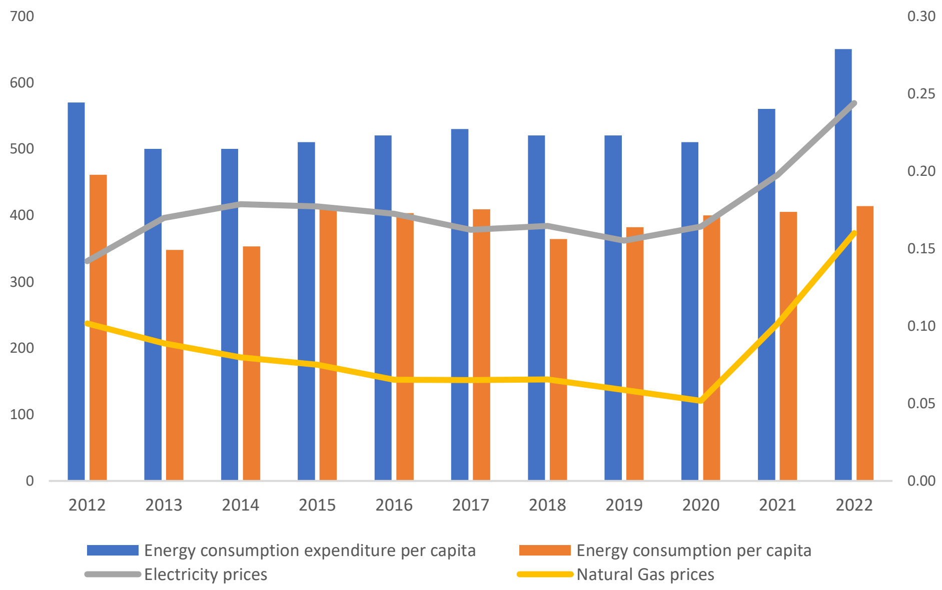
Figure 16: Final energy consumption, energy expenditure, electricity and natural gas prices for Greek households (2012-2022).



Source: Eurostat 2024

Figure 17 summarizes the trends reflected in the subjective energy poverty indicators. Across the period in the examination, all indicators illustrate a coherent picture: in the heart of the economic crisis, energy poverty affected more people. The economic crisis had a notable impact on energy poverty, with all indicators showing a significant increase up to 2015 and from 2015 to 2016. Subsequently, the phenomenon exhibited a downward trend until 2021 but began to rise again during 2022-2023. Indicators related to arrears and the ability to keep homes adequately warm remain significantly higher in Greece compared to the EU-27 and South Europe averages, despite the relatively mild winters.

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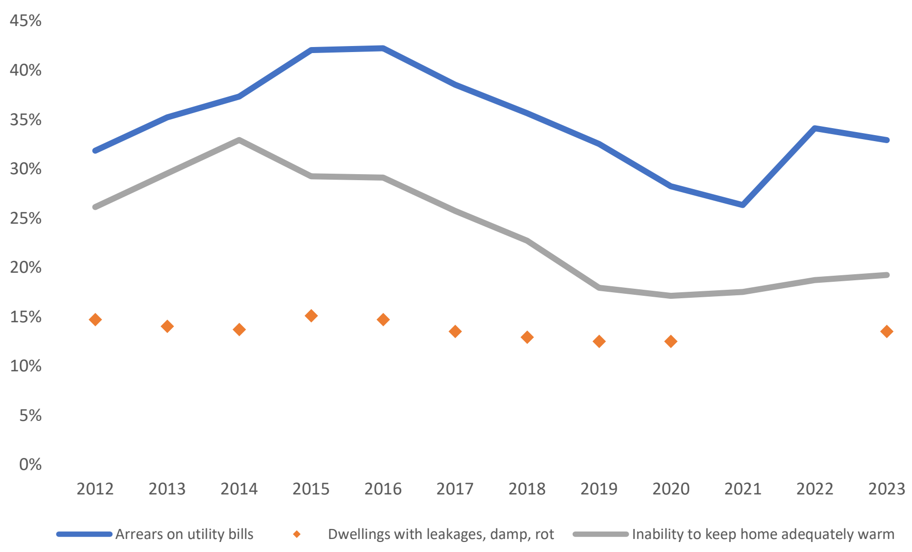
Figure 17: EU-SILC energy poverty indicators for Greece (2012-2023).



Source: Eurostat 2024

The apparent argument that energy poverty affects the poorest population is revealed in Figure 18 for all indicators by exploring the appearance of energy poverty in the total population, people under the national poverty threshold, and people above it. More than half of the population below the poverty line (58.4%) have arrears on utility bills, 44% cannot keep their homes warm, and approximately 17% dwell in homes with leakages, damp, or rot. The relative ratios for people above the poverty line and the total population are significantly lower (especially for the indicators concerning arrears and inability to keep home warm), but still are worryingly high.

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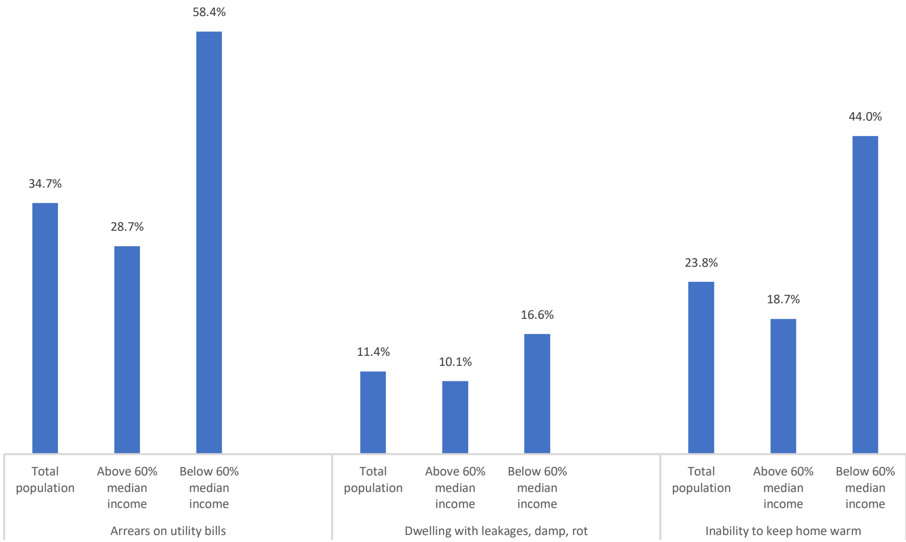
Figure 18: Average values of energy poverty EU-SILC indicators in Greece (2012-2023), by energy poverty threshold.



Source: Eurostat 2024

Similar observations can be seen in Figure 19. Half the population at risk of poverty or social exclusion live in buildings that are not comfortably warm during winter; only 7.8% have improved their residence's energy efficiency during the last 5 years. Concerning households not at risk of poverty or social exclusion, 21% of them report their dwellings are not comfortably warm, and 13% have had their homes improved in terms of energy efficiency during the last 5 years. Concerning the total population, 28.5% of households struggle with home warmth in winter, 34% are not comfortably cold in summer, and 6% live in dwellings too dark.

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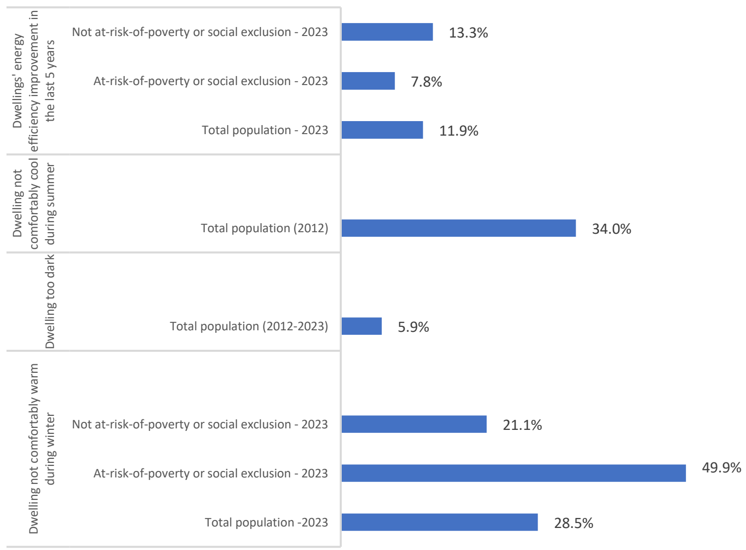
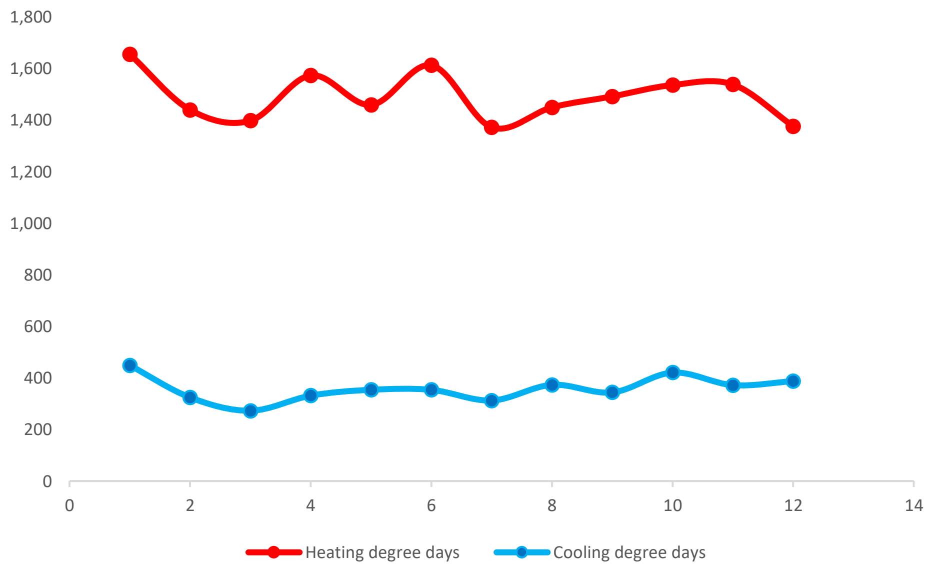
Figure 19: Dwellings' characteristics affiliated with energy poverty in Greece.



Source: Eurostat 2024

Figure 20 presents the Cooling and Heating degree days, with an average number of 358 cooling degree days and 1,491 heating degree days.

Figure 20: Cooling and Heating degree days for Greece (2012-2023)



Source: Eurostat 2024

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5.1.2. Results Derived From Previous Quantitative Analysis For Greece

Among all European countries, Western and Southern countries, and particularly the Balkans, seem to suffer more intensely from energy poverty. The economic crisis that started during the end of the 2000s significantly affected households' available income. In the particular case of Greece, a country struggling to survive during the deep crisis, energy poverty became a major social issue, which is recognized in affiliated literature (Atsalis et al., 2016; Halkos & Gkampoura, 2021; Kalfountzou et al., 2022). In the heart of the economic crisis (during 2011-2016), Greece experienced the highest increase in energy poverty on the European continent. Despite the efforts to reduce the phenomenon, energy poverty was still higher in 2019 compared to 2004 (Halkos & Gkampoura, 2021). During 2007-2014, Greece presented the highest energy affordability issues in the EU, with significant energy efficiency issues and inequalities in heating service deprivation (Dubois & Meier, 2016). The impact of the economic crisis and the austerity measures implied by the IMD and the EU is evident no matter the metric approach adopted. According to objective techniques such as the 10% rule, 20-25% of Greek households were identified as energy poor in 2013, while the proportion was significantly lower for previous years (9-13% in 2008 and 2-5% in 2004). In the same vein, subjective indicators from the EU-SILC revealed that the share of the population unable to keep their homes adequately warm doubled from 2010 to 2014, reaching 32.5% of the population. Nonetheless, taking into account the same metric for the period before the economic crisis, it is evident that energy poverty affected a noticeable proportion of households even before the crisis, but at a significantly lower extent (12-17.4% for the period 2003-2010) (Atsalis et al., 2016).

Differentiated measuring approaches often reveal disparities between the findings, as observed several times in international literature. However, the economic crisis had devastating effects on Greece. Undoubtedly, declining incomes and rising heating oil prices exacerbate energy poverty in the country. Despite fluctuations, peaks, and troughs, objective and subjective indicators

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consistently reveal a profoundly concerning trend. On the other hand, the observed disparities among indicators should not be overlooked during a thorough national-level energy poverty investigation. The subsequent policy implication affects the welfare of vulnerable populations who should not be left behind. Established indicators have repeatedly resulted in less inclusive findings for the case of Greece. For example, employing expenditure-based and actual energy consumption indicators is categorized as energy poor in half the proportion compared to required energy expenditure formulas (Ntaintasis et al., 2019). Similarly, Papada & Kaliampakos (2018) employed required energy formulas in their study, revealing that the mean energy expenditure is 18% of households' income. Also, 70.4% are classified as energy-poor, while 30.9% suffer from extreme energy poverty. Furthermore, surveys based on interviews highlighted higher energy poverty percentages compared to official consensual EU-SILC indicators "inability to keep home adequately warm" and "living in dwellings with leakages, damp or rot", in some cases exceeding the percentages of the highest values across the EU (Papada & Kaliampakos, 2016).

The most critical driver of energy poverty lies in income concerns. What is more worrisome is that income inequality sharpens energy poverty among poor households to a significant extent compared to non-poor ones. The overwhelming majority of households living below the poverty line (90%) are considered energy-poor, whereas this percentage drops by half among households not considered in poverty (Papada & Kaliampakos, 2016). According to the EU-SILC data, households at the lowest income decile grapple with energy poverty, being unable to keep their homes adequately warm (40%), facing arrears in utility bills (44%), and living in residences with leakages, damp or rot (25%). Further investigation on the impact of income reveals that income inequality generates and is generated by general inequality. This argument is confirmed if low-income households prefer short-term energy efficiency interventions or are reluctant to invest in them, probably because they cannot afford to (Damigos et al., 2021). This outcome verifies permanent energy poverty risk.

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Disposable income is directly affected by economic activity. First, unemployment severely reflects energy poverty (Halkos & Kostakis, 2023; Kalfountzou et al., 2022), which is a profound consideration since people who are not employed cannot meet their needs. However, the impact of unemployment on energy poverty is not a single-direction relationship. Energy deprivation is negatively associated with individual development, communication, and information (González-Eguino, 2015), leading vulnerable groups to social exclusion and less prosperous opportunities. Unemployed individuals experiencing energy poverty likely find themselves trapped in a vicious cycle.

Secondly, another economically inactive group, the older people and pensioners, are more likely to experience energy poverty. This is a worrying fact since this population group is more subject to health issues. Energy poverty can lead to severe health problems. Even before the economic crisis, energy deprivation was associated with cardiovascular issues, respiratory problems demanding hospital treatment, and deaths within Greece. During the crisis, affiliated instances intensified since the mortality rate related to energy poverty increased by 75%. Cardiovascular episodes rose from 3.5% between 2003 and 2010 to 6.1% during 2011-2014, and respiratory diseases increased from 3.9% to 6.9% (Atsalis et al., 2016). It should be considered that specific population groups like the elders need more sufficient energy services than the average. It is observed that when older people experience health deterioration, they are more likely to struggle to afford their energy bills. Consequently, the particular needs of the elders are not expected to be satisfied, leading to further health problems because of energy poverty.

Another significant determinant of the occurrence of energy poverty is the educational level. Literature confirms that as the educational level increases, it is less likely to suffer from energy poverty (Halkos and Kostakis, 2023; Lyra et al., 2022; Sardianou, 2024). This can be attributed to the fact that people with higher education are better informed on sustainability issues and adopt energy efficiency interventions. However, the significance of this driver lies in inequality as well, since people with lower education attainment are less qualified for better job opportunities. Additionally, except as a vital driver, education is considered a significant social impact of energy poverty too (González-Eguino, 2015), leaving fewer opportunities for individual prosperity and development and indicating a risk of permanent energy poverty and under-qualified statuses.

Also, energy poverty is related to dwellings' characteristics (Papada & Kaliampakos, 2018; Sardianou, 2024). Buildings' energy efficiency is a vital determinant of energy poverty; however, vulnerable people usually live in low-energy buildings (Lyra et al., 2022), because these households cannot afford to renovate their dwellings to decrease their energy requirements. Residences with leakages, damp, and restrictions on other essential needs are associated with objective indicators of energy poverty (Papada & Kaliampakos, 2016). Detached buildings are considered the most subject to energy poverty (G. Halkos & Kostakis, 2023; Kalfountzou et al., 2022; Papada & Kaliampakos, 2016), probably because they cannot benefit from heating systems' economy of scale.

The residence's location is also considered to be associated with energy poverty. Households in higher climatic zones and at higher altitudes (Papada & Kaliampakos, 2016) and regions with unusual temperatures (Halkos & Kostakis, 2023) face an increased risk of energy poverty. Regional comparison analysis within Greece has been limited so far; however, some studies demonstrate applicable considerations, even with disparities in some cases. This may be the subject to which the measuring methodology was adapted, indicating the regions' differentiated energy needs and social standards. For instance, the research of (Kalfountzou et al., 2022) demonstrated that according to the 10% rule and the 2M indicator, Central Macedonia is considered more vulnerable, while according to M/2 indicator, the region of Attica (a densely populated urban area containing the capital of Greece) is classified more prone to energy poverty. The second argument is confirmed by (Halkos & Kostakis, 2023), who concluded that urban areas are at higher energy poverty risk, and partially confirmed by Lyra et al. (2022), who argued that households in buildings with ten or fewer residences in

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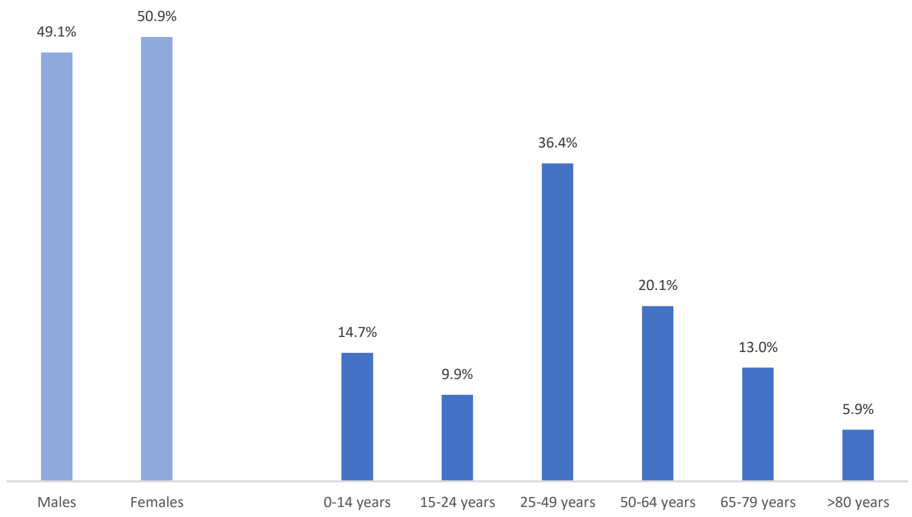
Attica or the islands, face more complex difficulties. Likewise, several demographic characteristics like gender, marital status, migration etc. enact with energy poverty, although such parameters are rarely employed in Greek empirical analysis. Previous research demonstrates that being single and having a migration background increases energy poverty probability (Halkos & Kostakis, 2023).

5.2. The Spanish case

5.2.1. Socioeconomic profile of Spain

Concerning the Spanish demographic structure, the average population is estimated at around 47 million persons, and the average population density is 92.77 persons per square kilometer. As observed in Figure 21, 49.1% are males and 50.9% females. Concerning the age distribution, approximately 15% are infants and children (0-14 years), 10% are young people aged 15-24 years old, 36% are middle-aged persons (25-49 years old), 20% are 50-64 years, 13% are 65-79 years and 5.9% are 80 years old or above.

Figure 21: Average demographic statistics for Spain (2012-2023).



Source: Eurostat 2024

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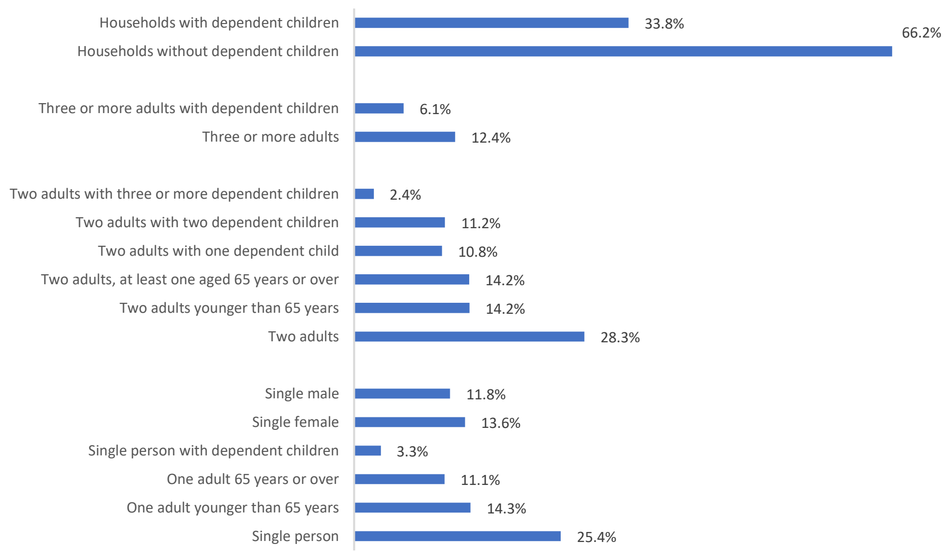
Figure 22 illustrates the composition of Spanish household types. Around 25% are singles (concretely, 12% are males and 14% are females). As for the age profile of singles, the number of people younger than 65 is slightly larger than those above that age. 66% of households do not have dependent children, while 34% are households with dependent children. 14% are households with two adults younger than 65 years old, and 14% with at least one adult aged 65 years or over. Concerning two-adult households, 11% have one dependent child, 11% have two children and 2.4% have three or more children. Finally, 12% are households with three or more adults, and 6% have dependent children.

Figure 22: Household types distribution in Spain (2012-2023).



Source: Eurostat 2024

Figure 23 refers to the educational level of the Spanish population. Approximately 37.8% have completed less than primary, primary, and lower secondary education. Individuals with secondary or post-secondary non-tertiary education are 26.2%, while 36% have attained tertiary or higher education. These shares are quite different from those of South European countries as 22.4% have low educational levels, 48.8% have medium ones, and 28.8% have high ones. In this sense, the educational attainments of the Spanish population have a U-shaped

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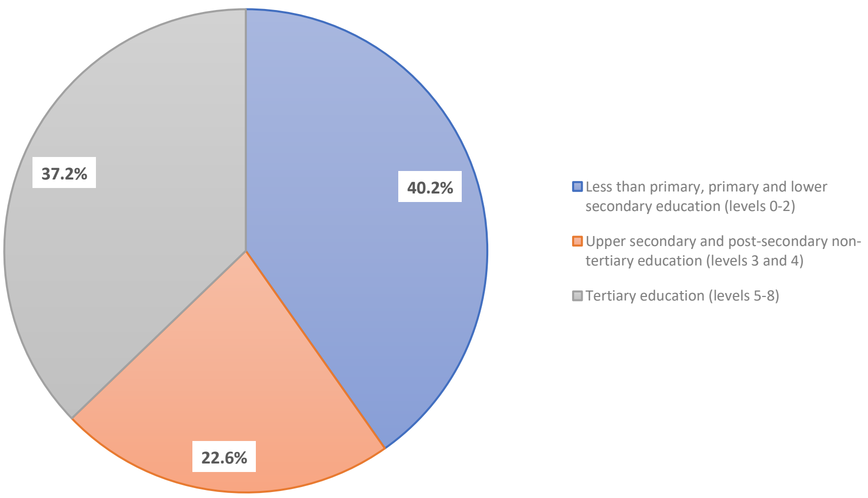
form, as low-educated and high-educated individuals are overrepresented relative to EU standards.

Figure 23: Average educational attainment level in Spain for 2012-2023.



Source: Eurostat 2024

Building on the demographic overview, examining Spain's economic landscape is essential. Figure 24 presents data on the country's GDP per capita and income inequality, two key indicators of economic health and social equity. The analysis of GDP shows a clear increasing trend between 2013 and 2019, followed by a deep recession during COVID-19 and an immediate recuperation in 2021, allowing Spain to reach the pre-COVID GDP per capita levels in 2023. As in many other Southern European countries, inequality levels are quite high in Spain, although the trend has decreased throughout the period, even considering the slight increase due to COVID-19. Spanish GDP is lower than EU-27 and South European countries, and income inequality is higher, showing that Spain has lower growth and increased income inequality dispersion, easily explained by the existence of dynamic regions such as Catalonia, Madrid, and Basque Country alongside lagging ones such Andalusia or Extremadura.

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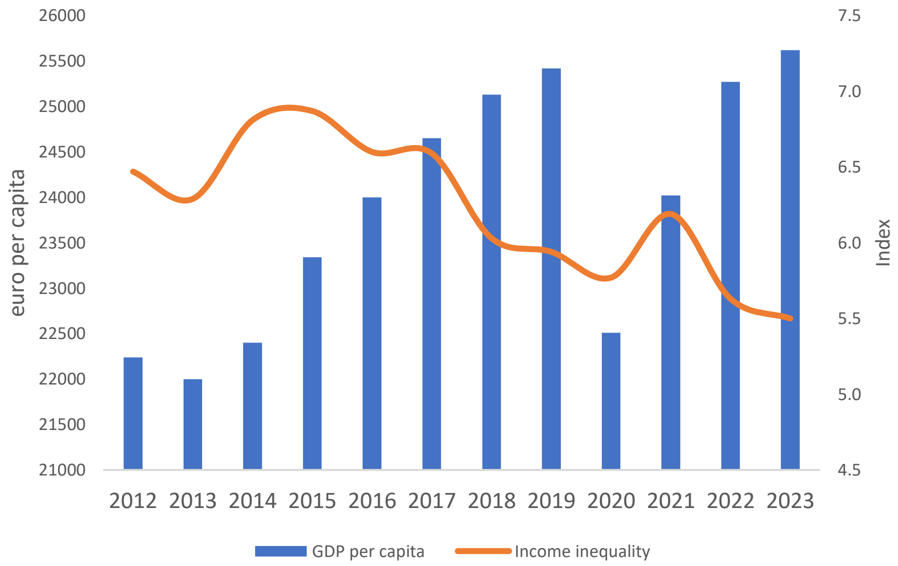
Figure 24: GDP per capita and inequality of income distribution in Spain (2012-2023).



Source: Eurostat 2024

In terms of poverty, the 2010s have been a challenging period for Spain, with a persistent gap in terms of welfare compared to the whole EU area. As observed in Figure 25, for 2012-2023, the average subjective poverty reached 27.8%, demonstrating that a significantly high share of the Spanish population perceives themselves as living in poverty, resulting in EU-27 and South Europe being much lower (23%). Furthermore, 27% of the population are classified as at risk of poverty or social exclusion, again over the global levels for the EU. The proportion of people who face difficulties in making ends meet is moderately high (12.2%), but the trend has decreased over the period, and current values are much lower than those around 15% in the early 2010s. As for the population at persistent risk of poverty, the trend is unclear even if shares decrease from 2020, and figures from 2023 (9.2%) are not very far away from those in 2013 (10.7%). Therefore, the relative poverty gap is over that of the EU-27, although the distance has been shortening in recent years.

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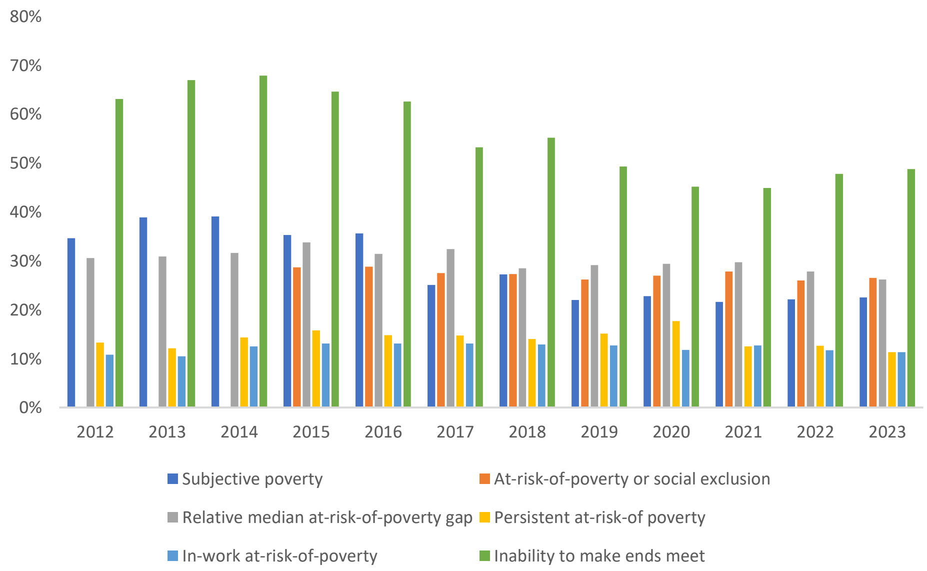
Figure 25: Subjective poverty, at-risk-of-poverty or social exclusion, relative poverty gap, inability to make ends meet (2012-2023), persistent at-risk-of-poverty, in-work at-risk-of-poverty, for Spain.



Source: Eurostat 2024

Figure 26 presents information concerning the labor sector in Spain. Unemployment rates in Spain (especially in Southern regions like Andalusia and Extremadura) have been much higher than in the rest of the EU, reaching 30% at specific points. As for 2012-2023, there has been a decreasing trend throughout the period except for short-term inflection points caused by COVID-19. Jobless households showed a similar evolution but were also very high, just below 10% in 2023. Data for the whole country shows a quite different picture compared to the EU-27 (with unemployment rates around 5%) and Southern European countries (around 8%). The average part-time employment is 14.5%, and the proportion of employees with short-term contracts is 20%.

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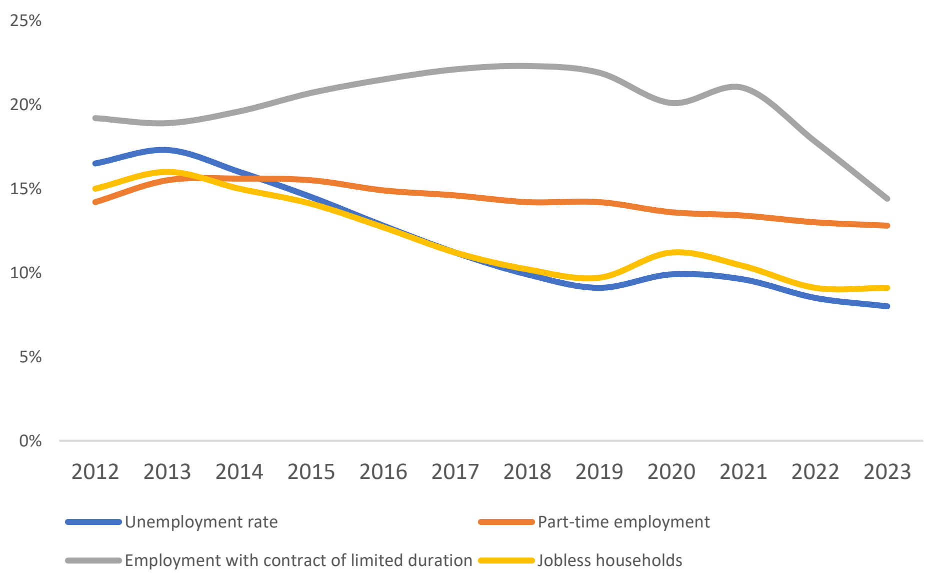
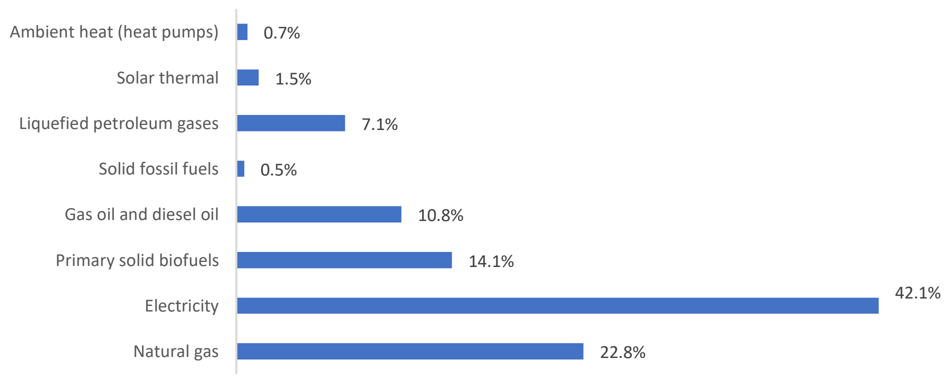
Figure 26: Employment statistics for Spain (2012-2023).



Source: Eurostat 2024

The average percentages of energy product types consumed by households for the period 2012-2022 are presented in Figure 27 and are defined as follows: 42% electricity, 23% natural gas, 14% primary solid fuels, 11% gas oil and diesel oil, 7% liquefied petroleum gases and 2% solar thermal energy, but these figures have a substantial regional variation as regional energy-mix is quite diverse.

Figure 27: Average energy consumption of Spanish households by energy type (2012-2022).



Source: Eurostat 2024

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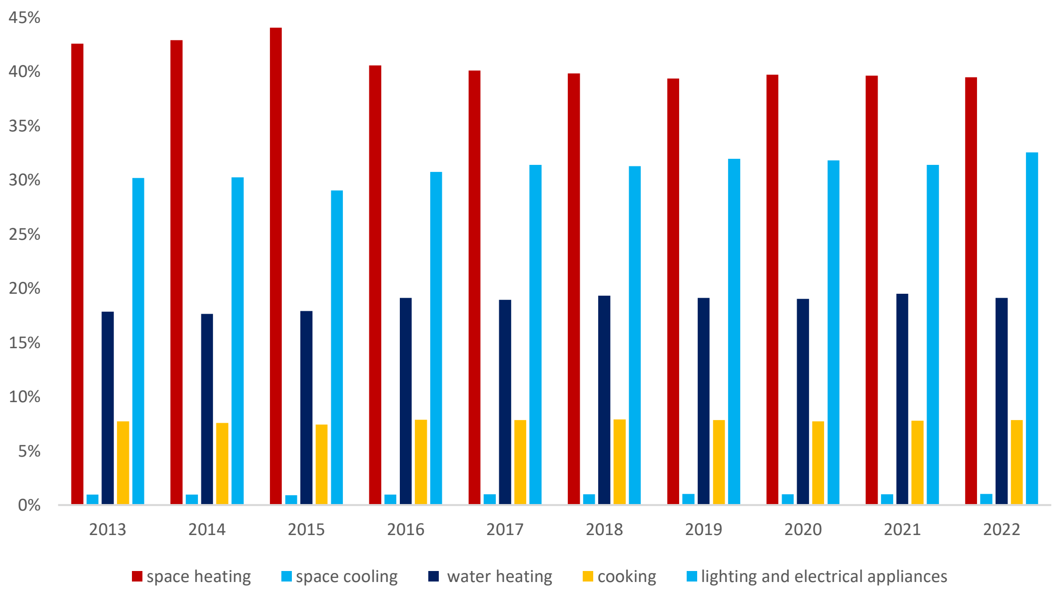
Furthermore, Figure 28 presents Spanish households' disaggregated final energy consumption by end-use from 2013 to 2022. "Space heating" remains the largest category at around 41%, followed by "lighting and electrical appliances", a noticeable increase from 29% in 2015 to almost 33% in 2022. Then, "water heating" at around 19% is the third highest energy use. Spanish households consume approximately 9% of total energy in "cooking" and only 1% for "space cooling".

Figure 28 Spanish households' energy use (2013-2024)



Source: Eurostat 2024

Exploring the Spanish energy sector further, Figure 29 reveals that electricity prices remained relatively stable between 2012 and 2021, ranging from a minimum of 0.21 €/Kilowatt-hour to a maximum of 0.24 €/Kilowatt-hour, with an average of 0.23 €/Kilowatt-hour. However, in 2022, electricity prices surged significantly, exceeding 0.30 €/Kilowatt-hour. Similarly, natural gas prices, which averaged 0.098 €/Kilowatt-hour during the same period, substantially increased in 2022, reaching 0.157 €/Kilowatt-hour. Energy expenditure followed a similar trend. The direct impact of rising energy costs is evident in final energy consumption: while the average consumption from 2012 to 2021 was 315 KGOE

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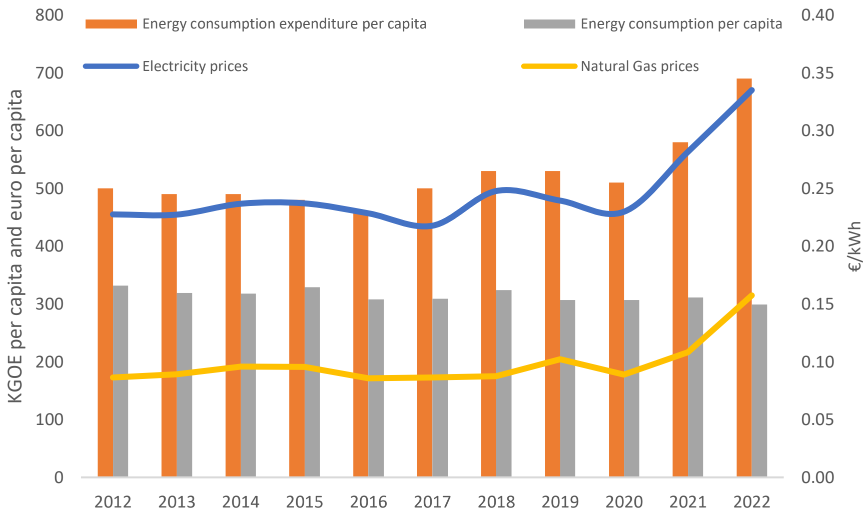
per capita (ranging from 307 to 332 KGOE per capita), it declined to 299 KGOE per capita in 2022.

Figure 29: Final energy consumption, energy expenditure, electricity and natural gas prices for Spanish households (2012-2022).



Source: Eurostat 2024

As depicted in Figure 30, subjective energy poverty indicators reveal a complex and concerning situation. Arrears on utility bills, reflecting unpaid amounts for services like electricity and gas, declined until 2019 but stagnated at elevated levels following COVID-19 (rising from 7.5% in 2012 to 9.6% in 2023). Structural or maintenance issues impacting the habitability and comfort of dwellings, such as leaks, have sharply increased, with the percentage of affected dwellings climbing from 12% in 2012 to 23% in 2023. Another critical indicator, the inability to keep homes adequately warm, highlights the direct effects of poverty, influenced by geographic and climatic factors. However, this indicator has also dramatically risen, jumping from 9.1% in 2013 to 20.8% in 2023. The situation has significantly deteriorated since 2019, likely driven by the economic downturn triggered by the COVID-19 pandemic in 2020 and exacerbated by the energy crisis following the Russian-Ukraine war in 2022.

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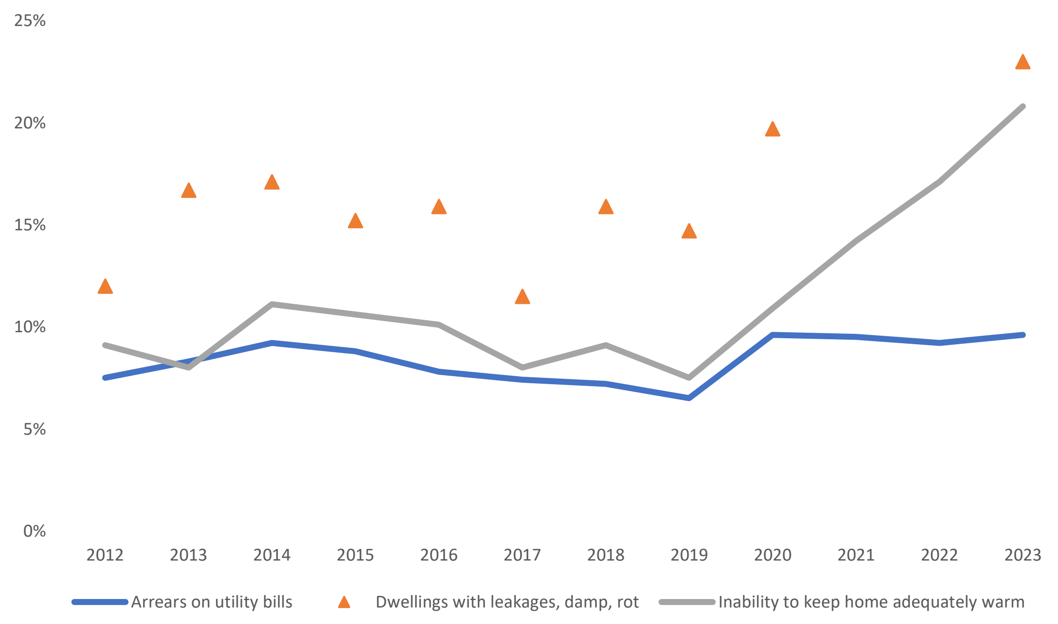
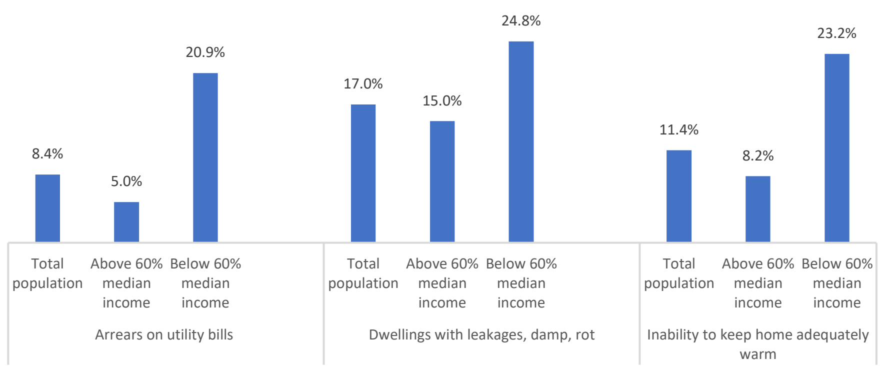
Figure 30: EU-SILC energy poverty indicators for Spain (2012-2023).



Source: Eurostat 2024

Regarding the distribution of previous energy poverty indicators, in all cases (arrears on utility bills, dwellings with leakages, and inability to keep home adequately warm), the mean values are driven by less adverse circumstances. This is observed by observing the mean values in Figure 31 for all three indicators and the same values for the cases over and below 60%.

Figure 31: Average values of energy poverty EU-SILC indicators for Spain (2012-2023), by energy poverty threshold.



Source: Eurostat 2024

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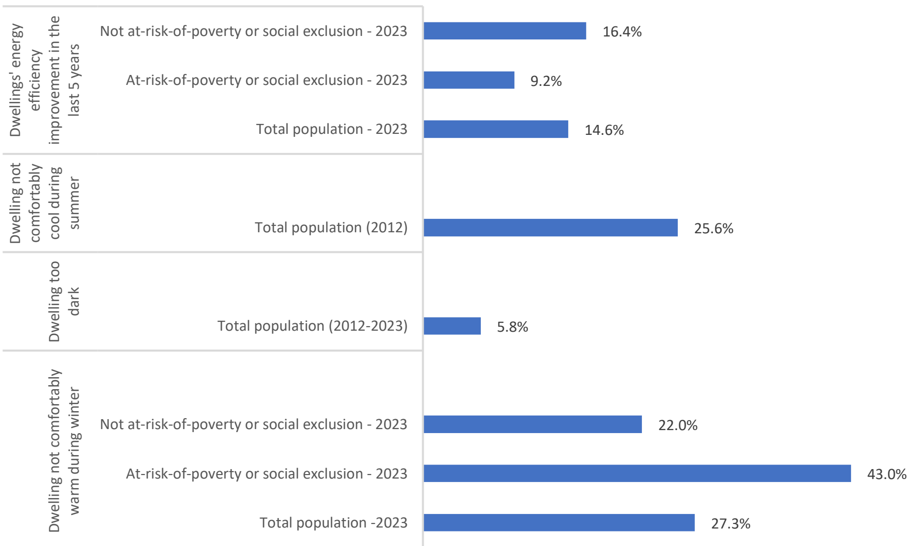
What is particularly concerning is the deterioration in living standards for individuals at risk of poverty and social exclusion, as highlighted in Figure 32. In this sense, comparing the dwellings' energy efficiency improvements in the last 5 years (data from 2023), the overall figures are 14.6%. However, when the population is distributed between those at risk of poverty and social exclusions, their share (9.2%) is much lower than those without this risk (16.40%), which increases the social divide. A similar result is obtained for the indicator related to dwellings not comfortably warm during winter, which is 27.3% of total dwellings, but 43% of dwellings of people at-risk-of-poverty and social exclusion and 22% for those not affected by these circumstances.

Figure 32: Dwellings characteristics affiliated with energy poverty in Spain.



Source: Eurostat 2024

Figure 33 presents the Cooling and Heating degree days, averaging 272 and 1,661 heating degree days.

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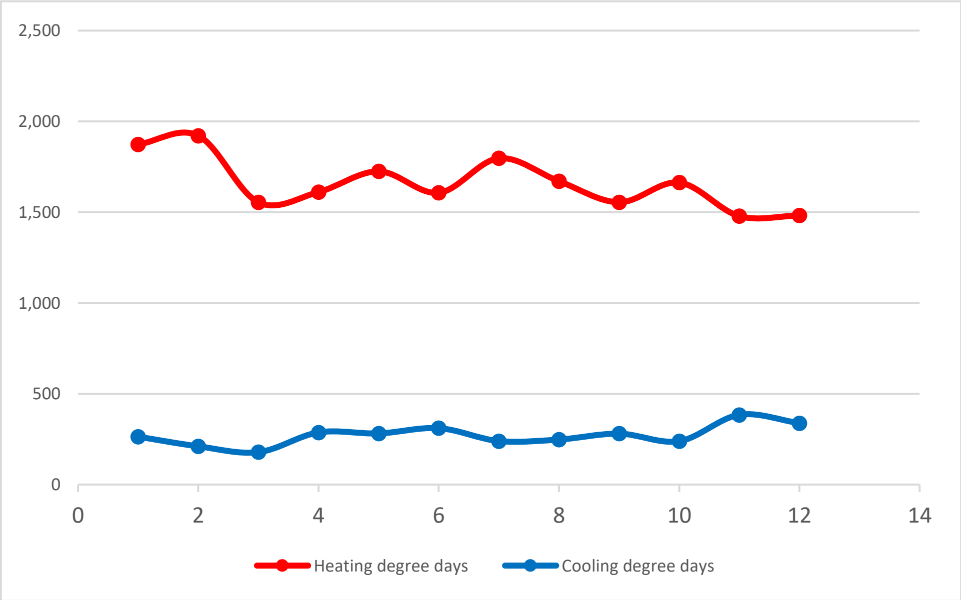
Figure 33: Cooling and Heating degree days for Spain (2012-2023).



Source: Eurostat 2024

5.2.2. Results Derived from Previous Quantitative Analysis For Spain

Spain has been suffering from energy poverty with severe social impacts. Costa et al. (2024) showed that in the Spanish case, energy poverty is a chronic issue that worsens during economic downturns because those at higher risk are retired people and women living alone, while the employment status of household members significantly affects the likelihood of experiencing energy poverty. It ranks fourth in Europe for the highest rate of winter deaths linked to energy poverty. Even though in 2004, 9.5% of Spanish families could not keep their homes adequately warm, it was not before the economic crisis that Spanish authorities aimed to alleviate energy poverty. In 2009, the Spanish Government introduced the Bono Social de Electricidad measure to reduce energy poverty. The subsidy emphasized the vulnerable population, discounting electricity prices for pensioners, unemployed people, and large household sizes. Although initially well-received, the policy later sparked controversy over who would bear the costs. However, it is questioned whether the subsidy indeed reached all vulnerable populations, and 10 years after its implementation, energy poverty was still

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increasing in the country. For example, in 2019, the share of Spanish households unable to warm their homes ranked 9.1%; demonstrating almost no improvement since 2004. The main reason for its unsuccessful evolution was the inability to identify vulnerable households. In 2017, authorities focused on income parameters, while under the COVID-19 impact, the eligibility criteria for application were temporarily broadened. In 2021, the government attempted to target the poorest segments of society and exclude higher-income households, directly affecting the eligibility of large households. A reform of the implemented subsidy is argued, employing structural challenges, like energy-efficient buildings, since vulnerable groups are particularly at risk due to insufficient heating equipment and poor energy efficiency during low-temperature periods. Introducing complementary policies, such as initiatives to renovate the least energy-efficient buildings, could significantly improve the situation (García Alvarez & Tol, 2021).

Confirming that energy poverty in Spain is a severe social issue, Aristondo & Onaindia (2018b) analyzed the phenomenon for the years 2005, 2008, 2012, and 2016 under consensual approaches, concluding that the problem deteriorated between 2005 and 2016, especially for people living in thinly populated areas, immigrants, people with no educational background, females, separated, people that experience health issues, and people with low or no work intensity. Furthermore, it was found that rented and semi-detached houses have a higher risk of experiencing energy poverty. Finally, examining the disparities in energy poverty across different groups, the analysis revealed that the country of birth is the classification showing the most significant differences between groups over the years.

The same authors examined energy poverty across two distinct groups: three types of areas categorized by population share and various regions. This confirms that the problem worsened between 2004 and 2015, highlighting that rural areas and the regions in the southern part of the country are more vulnerable. Energy poverty was measured using the three dimensions a) inability to keep home adequately warm, b) arrears on utility bills, and c) presence of leakages, damp or rot, enabling the measurement of energy poverty based on the number of dimensions in which individuals experience deprivation. Considering that poor people are deprived in at least one dimension, it was concluded that for people deprived in two or three dimensions, the ratio increased by more than 25% (Aristondo & Onaindia, 2018a).

Barrella et al. (2022) argue that the Minimum Income Standard (MIS) indicator addresses energy poverty at its economic root and note that most studies in Spain rely on the Spanish Regional Integration Minimum Income (RMI in Spanish), which uses a relative rather than an objective energy expenditure threshold. They propose a novel MIS-based approach focused on Spain, aiming to compare the outcomes of the RMI with more objective metrics to determine whether energy poverty is accurately evaluated in the Spanish context. The analysis incorporates two thresholds: the RMI for 2014–2019 and reference budgets from EU projects, specifically the ImPRoVe project for 2014 and the EU pilot project for 2015. The study detected important differences. For example, in Catalonia in 2014, energy poverty was ranked at almost 7% when using the RMI; however, it was approximately 21% when the ImPRoVe reference budget was employed. Although at the beginning of comparing the RMI and EU pilot projects, no disparities were observed, when they proceeded in a more thorough analysis, it was found that the RMI approach did not identify specific households as energy-poor, in contrast to the EU project, which would classify, for example, 10.6% vulnerability in single-parent households with two dependent infants in Madrid. Several key conclusions are worth highlighting, including the notable regional disparities observed, the crucial need to establish an appropriate income standard, and the importance of involving different housing typologies in the analysis. These factors are vital in accurately evaluating energy poverty and informing more effective policy measures.

Current measuring approaches in Spain provide gross figures that worsen the ability to identify vulnerable populations. Additionally, Spain's diverse climate,

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shaped by its orography and geographical location, compels each Autonomous Community and local council to develop tailored measures to address their unique characteristics, especially considering the substantial decentralization of public competencies that make regional governments responsible for these issues. Aiming to address these issues, the paper by Castaño-Rosa et al. (2020) examines a real-life case study in Seville, investigating how low-income households that dwell in low-efficient buildings in social housing in the most deprived areas could be identified. The study employs the Index of Vulnerable Homes, a metric that involves the Monetary Poverty Indicator, Energy Indicator, Comfort Indicator, and Health-Related Quality-Life Cost. This paper analyzed the energy poverty in six buildings consisting of seventy-one residences before and after an energy efficiency treatment.

In contrast to current indicators, the Index of Vulnerable Homes made it possible to identify energy poverty vulnerability in the selected residential buildings both prior to and following the intervention. The costs of energy poverty result in substantial social costs that are often ignored. Furthermore, potential savings for the National Health Service were highlighted, particularly in improving households' quality of life. Finally, it was concluded that the metric applied can identify cases of low-income households that remain vulnerable even after energy performance upgrade treatments. This outcome suggests that vulnerability is not only subject to energy efficiency but also arises from a lack of financial resources, leaving households unable to meet their basic energy requirements.

5.3. The Italian case

5.3.1. Socio-economic profile of Italy

Concerning the Italian demographic characteristics, the 2023 population of Italy is around 59.5 million people, and the average population density is relatively high, approximately 202.23 persons per square kilometer. Figure 34 presents the gender and age distribution of the Italian population. Almost 49% are males and 51% are females. Concerning the age distribution, approximately 13% are infants

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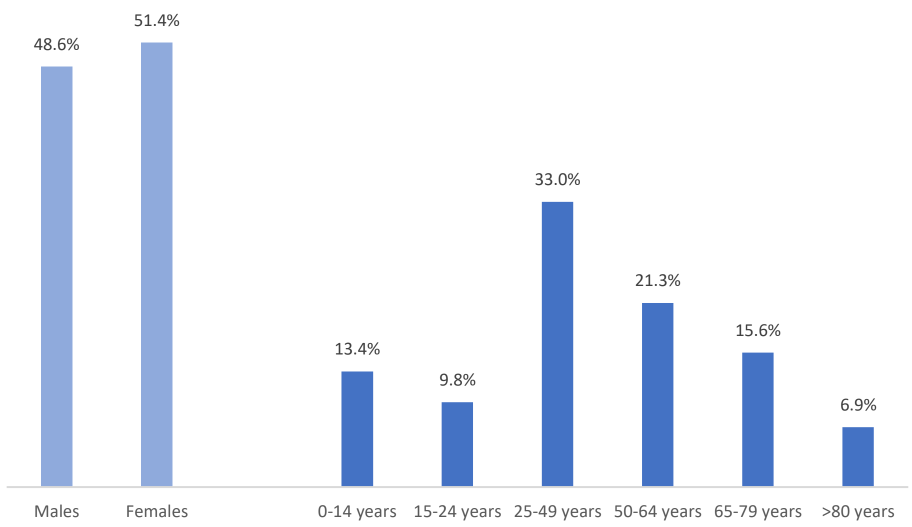
and children (0-14 years), 10% are young people aged 15-24 years old, 33% are middle-aged persons (25-49 years old), 21% are 50-64 years, 16% are 65-79 years and 7% are 80 years old or above.

Figure 34: Average demographic statistics for Italy (2012-2023).



Source: Eurostat 2024

As observed in Figure 35, referring to the household type distribution, almost 25% are singles (14% are males and 19% are females). Concerning the age profile of singles, 18% are younger than 65 years old, and 15% are 65 years old or above. 70% of households do not have dependent children, while 30% are households with dependent children. 10% are households with two adults younger than 65 years old, and 15.5% with at least one adult aged 65 or over. Concerning two-adult households, 10% have one dependent child, 10% have two children, and 2.2% have three or more children. Finally, 11.5% of households have three or more adults, and almost 5% have dependent children.

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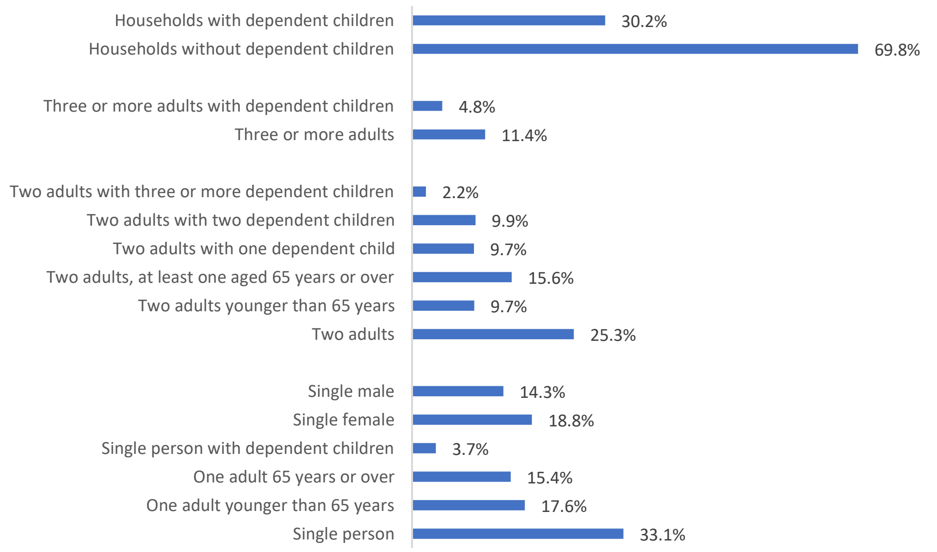
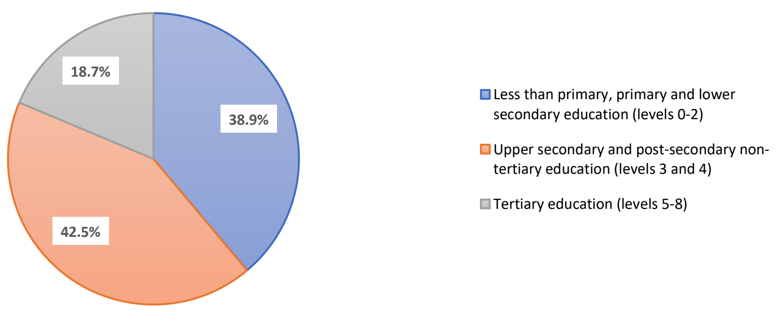
Figure 35: Household types distribution in Italy (2012-2023).



Source: Eurostat 2024

Regarding the educational level, Figure 36 reveals that 39% have completed less than primary, primary, and lower secondary education. Individuals in upper secondary or post-secondary non-tertiary education are 42%, while 19% have attained tertiary or higher tertiary education. The percentage of people who have completed tertiary education is lower than the EU-27 average.

Figure 36: Average educational attainment level in Italy, for 2012-2023.



Source: Eurostat 2024

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Economic growth expressed by the country's GDP and income inequality are presented in Figure 37. These figures provide a comprehensive picture of Italy's economic structure and challenges. COVID-19 has seriously impacted the economy and affected the country's competitiveness. In 2020, Italy's GDP per capita had the lowest value since 2015 (latest decade). After that, due to the recovery fund, it started increasing, although moderately. Income inequality increased up to 2016 and presented a declining trend afterward. Although Italy's GDP per capita is the highest among Southern European countries and closely aligns with the EU-27 average, income inequality exceeds the EU-27 and Southern European average. This disparity could be attributed to the long-lasting North-South issue (Northern regions experience more industrialization, higher productivity, and better infrastructure, while the Southern regions face higher unemployment rates, lower investment, and slower economic growth). Furthermore, the North-South divide impacts economic growth and income inequality; northern regions outperform EU per capita GDP while the southern regions struggle to grow. No wonder energy poverty affects vulnerable populations, increasing social inequalities.

Moving to current figures, Italian GDP is projected to grow by 0.5% in 2024 and 0.8% in 2025. In 2024, GDP growth will be supported by foreign demand (+0.7 percentage points), while domestic demand will have a negative impact (-0.2 percentage points). In 2025, the growth of the Italian economy is expected to be driven primarily by domestic demand. Private household consumption will continue to benefit from a strengthening labor market and increased real wages. Gross fixed capital formation is expected to grow weakly in 2024 due to the phasing out of fiscal stimulus for construction. The negative effect of this phase-out will likely be even more significant in 2025, when, despite the positive impact of measures implemented under the National Recovery Plan (Piano Nazionale di Ripresa e Resilienza) and a reduction in interest rates, investment growth is projected to be essentially flat. The employment growth rate in 2024 is predicted to outpace GDP growth (+1.2%), with improvements in the labor market contributing to a reduction in the unemployment rate from 7.5% in 2023 to 6.5%

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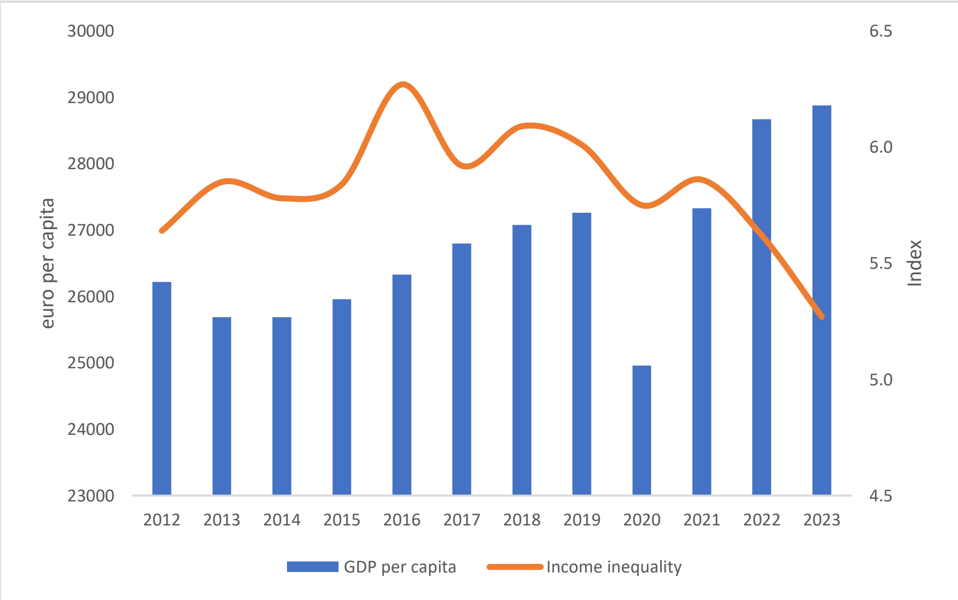
in 2024. A further slight decline to 6.2% is forecast for 2025. The return of the inflation rate to lower levels, supported by the decline in energy goods prices observed in 2024, underpins the deceleration of the household spending deflator (+1.1% in 2024, down from +5.1% in 2023)

Figure 37: Real GDP per capita and inequality of income distribution in Italy (2012-2023).



Source: Eurostat 2024

Figure 38 reveals significant information concerning poverty indicators. Subjective poverty presents a declining trend for the studied period, with an average value of 30.3%, slightly lower than EU-27 and significantly lower than average South European countries. Furthermore, approximately 25% of the population is classified as at risk of poverty or social exclusion, 13.7% are persistently at risk of poverty, 11.3% are employed people at risk of poverty, and the mean relative poverty gap is almost 28%. Italy's mean observations are higher than those of the EU-27 and South Europe. The share of people struggling to make ends meet is at 69%, almost like the average for the group of South European countries and much higher than the EU–27.

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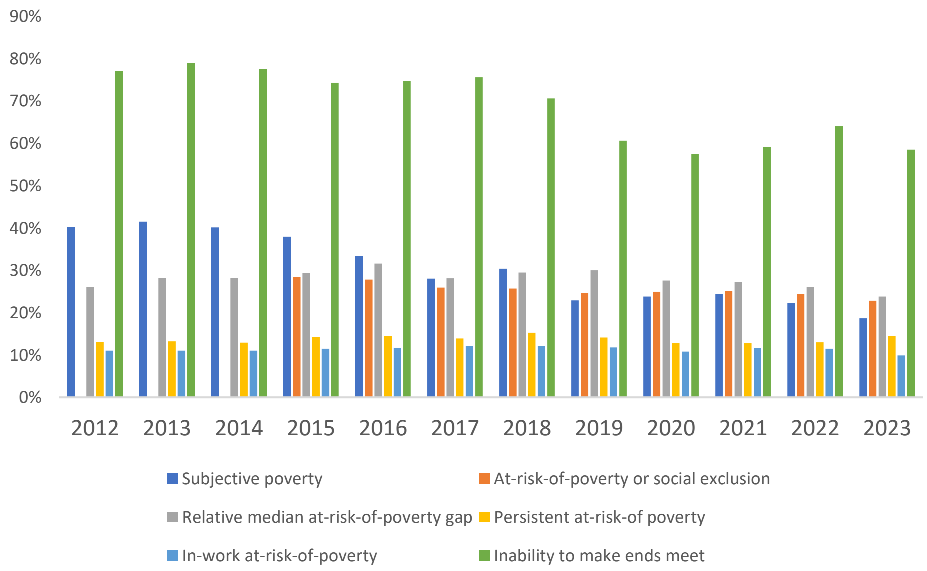
Figure 38: Subjective poverty, at-risk-of-poverty or social exclusion, relative poverty gap, inability to make ends meet (2012-2023), persistent at risk of poverty, in work at risk of poverty, for Italy.



Source: Eurostat

As far as the labor sector is concerned, the impact of the economic crisis is noticeable. As observed in Figure 39, until 2014, unemployment and jobless households were increasing. However, in the period after, both indicators present a decreasing trend, except for the pandemic years, reaching almost 6% unemployment rate (higher than EU-27 and lower than South Europe) and 12.4% jobless households (higher than EU-27 and South Europe). The average part-time employment is 18.1%, and the proportion of employees with limited-duration contracts is 11.7%.

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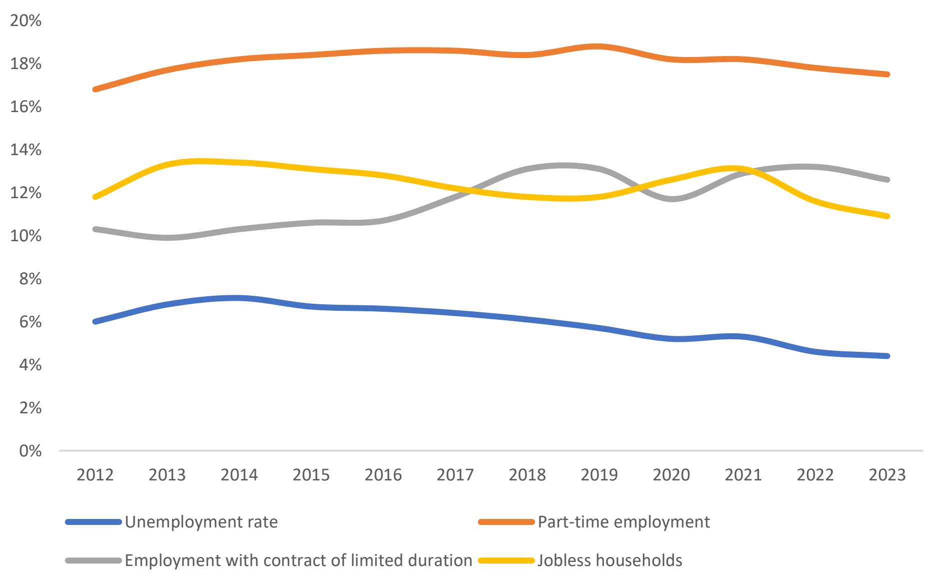
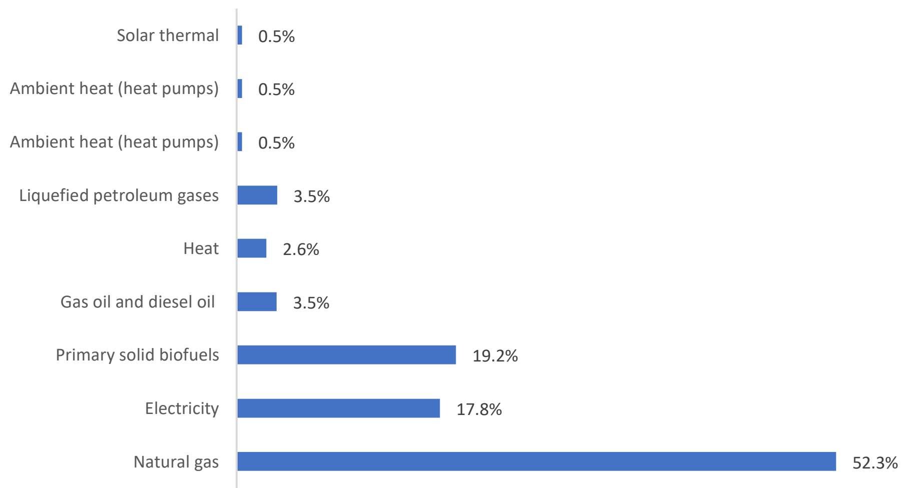
Figure 39: Employment statistics for Italy (2012-2023).



Source: Eurostat 2024

The average percentage of energy product type consumed by households for 2012-2022 is presented in Figure 40 and is defined as follows: 52% natural gas, 19% primary solid biofuels, 18% electricity, and others with low percentages.

Figure 40: Average energy consumption of Italian households by energy type (2012-2022).



Source: Eurostat 2024

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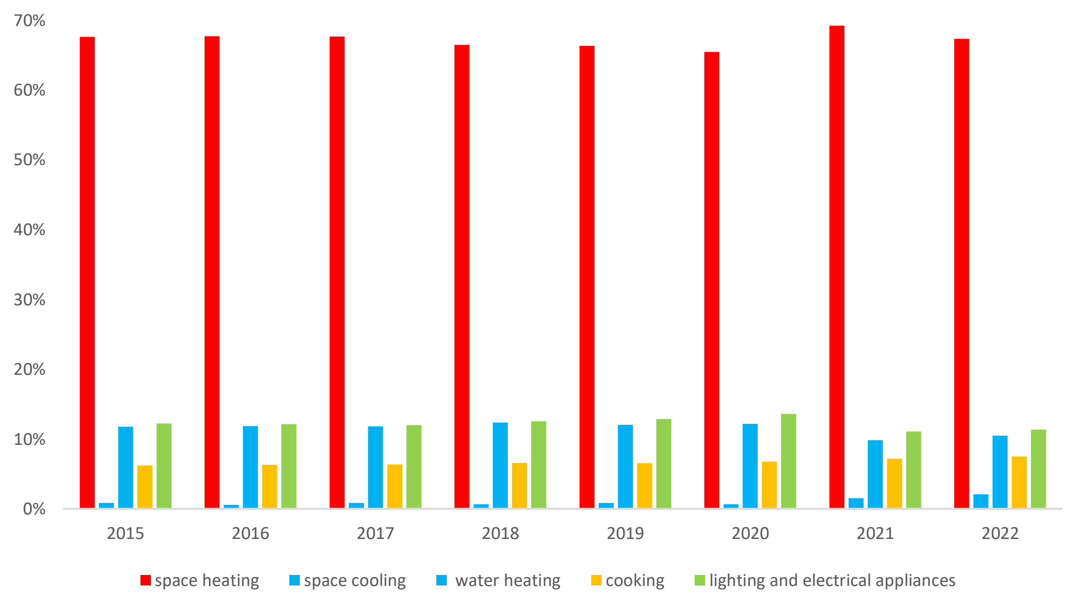
Figure 41 illustrates the evolution of household energy consumption in Italy. Specifically, it presents the disaggregation by end use for the period 2015–2022 (data for previous years is not available). As observed, "space heating" remains the dominant use at around 67%. Then, "lighting and electrical appliances" and "water heating" reach approximately 12% each, followed by "cooking" at 7% and "space cooling", at 1%.

Figure 41 Italian households' energy use (2015-2022)



Source: Eurostat 2024

Figure 42 illustrates that electricity prices remained relatively stable from 2012 to 2021, with minor fluctuations and an average of approximately 0.23 €/kilowatt-hour. However, similar to other instances, electricity prices surged significantly in 2022, exceeding 0.31 €/kilowatt-hour. A comparable trend is observed in natural gas prices. Energy expenditure also followed a relatively steady trajectory with occasional peaks and dips, averaging 634 €/per capita, but in 2022, it skyrocketed to 1,100 €/per capita, doubling the 2020 figure. The average final energy consumption during the studied period, prior to 2022, was 539 KGOE/capita (ranging from a minimum of 490 KGOE/capita to a maximum of 577 KGOE/capita); in 2022, it declined to 509 KGOE/capita.

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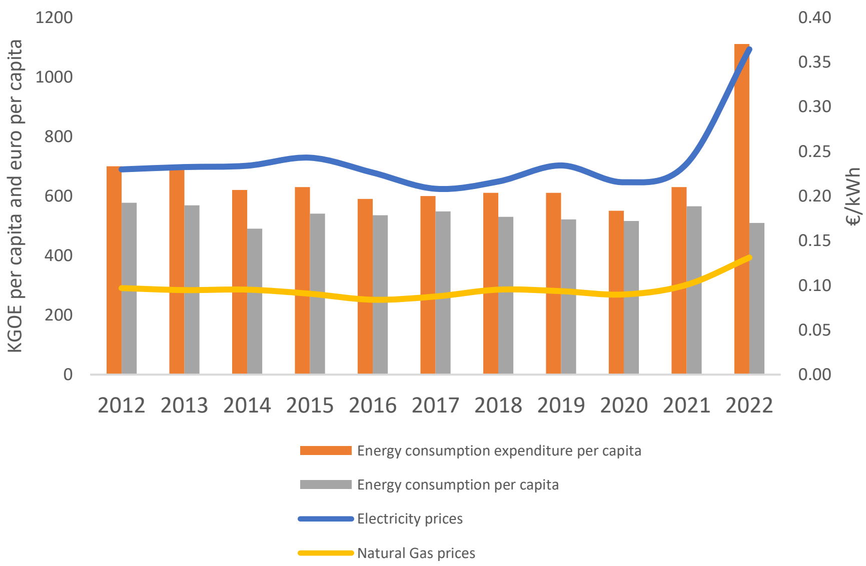
Figure 42: Final energy consumption, energy expenditure, electricity and natural gas prices for Italian households (2012-2022).



Source: Eurostat 2024

Continuing with the subjective energy poverty indicators shown in Figure 43, the arrears on utility bills rose until 2015 but began to decline thereafter, maintaining an average value of 7.7%, comparable to the EU-27 average. However, in 2021, the indicator demonstrates a small peak. Concerning the indicator referring to the presence of leakages, damp, or rot in the house (mean 19.3%), from 2012 to 2014, it is ascending. On the contrary, it presents a valuable improvement in the years after, reaching 13.8% in 2018. Nevertheless, the indicator started increasing again during the years of the pandemic. The indicator concerning the inability to keep home adequately warm presents a universal decreasing trend from 2012 (21.3%) to 2022 (9.5%). The average value (14%) is higher than EU-27 and lower than South Europe.

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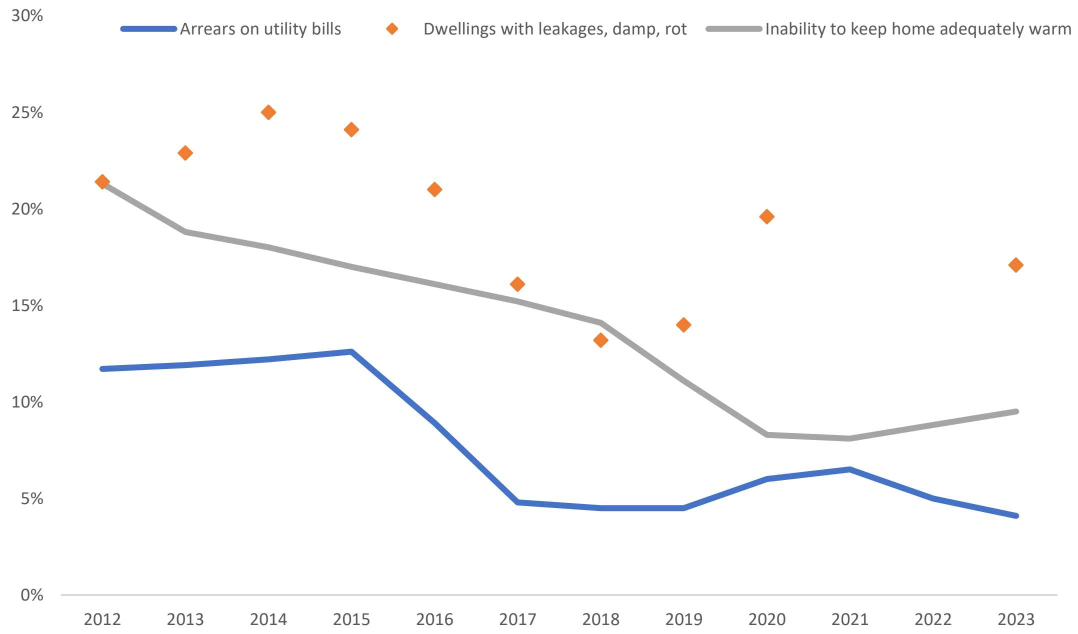
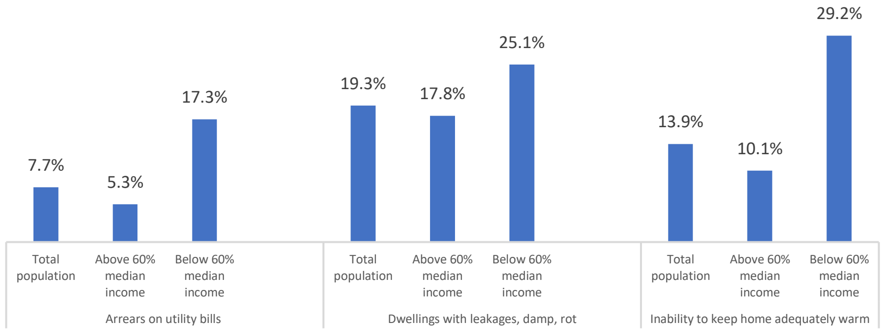
Figure 43: EU-SILC energy poverty indicators for Italy (2012-2023).



Source: Eurostat 2024

Concerning the occurrence of energy poverty in the total population, as revealed in Figure 44, people below and people above the national poverty threshold, it is observed in all three indicators that the percentages concerning the total population are relatively close to the ratios referring to people above 60% (although they are higher). On the other hand, the percentages concerning the population below the poverty line are far higher.

Figure 44: Average values of energy poverty EU-SILC indicators for Italy (2012-2023), by energy poverty threshold.



Source: Eurostat 2024

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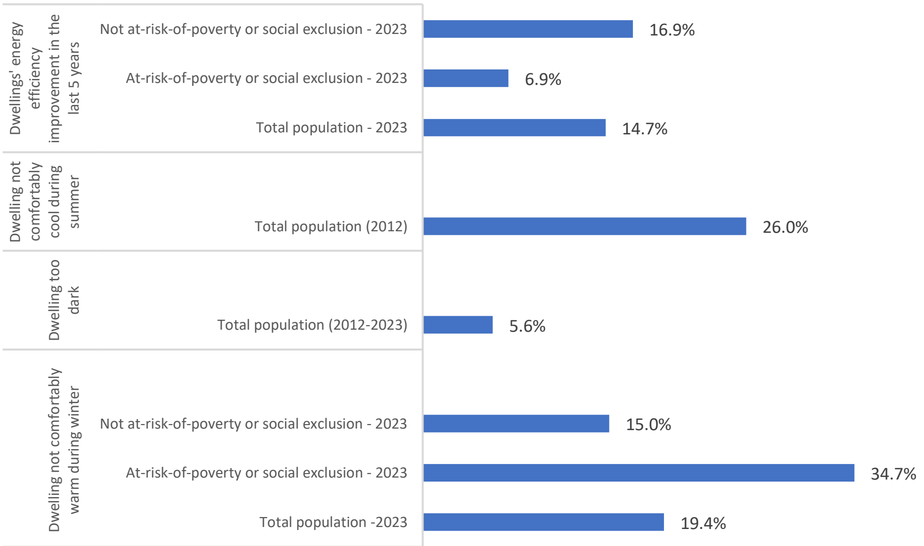
Similar concerns are revealed in Figure 45. Approximately 35% of the population at risk of poverty or social exclusion live in buildings that are not comfortably warm during winter; only 7% have improved their residence's energy efficiency during the last 5 years. As far as households are concerned at risk of poverty or social exclusion, the rates of dwellings that are not comfortably warm are significantly lower (15%), and 17% of them have upgraded their homes' energy efficiency during the last 5 years. Concerning the total population, 19.5% of households do not dwell in comfortably warm homes, 15% have accomplished energy efficiency upgrades during the last five years, 26% are not comfortably cold in summer, and more than 5.5% live in dwellings too dark.

Figure 45: Dwellings characteristics affiliated with energy poverty in Italy.



Source: Eurostat 2024

Moving to recent findings from the Energy Poverty Observatory (ENPO) - IPSOS November 2024 report, Italian households, while perceiving an improvement in their economic situation, continue to exercise caution regarding potential unexpected expenses—a reflection of deep-rooted prudence that endures despite more optimistic prospects. Meanwhile, in-depth awareness of fuel poverty is limited to a minority of the population (21%), although the issue is

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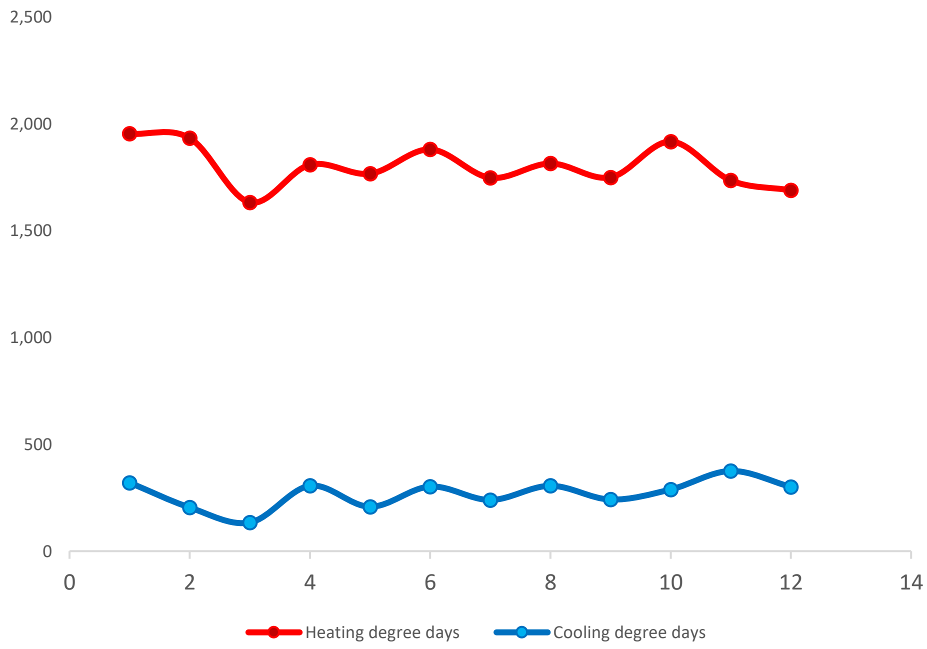
generally acknowledged as significant, albeit gradually diminishing. In this context, interest in Renewable Energy Communities increases. Indeed, Italy is investing in developing renewable energy communities, which allow citizens to collectively manage and benefit from renewable energy sources (Tatti et al., 2023). Nevertheless, concerns about initial costs and bureaucratic hurdles persist, underscoring the crucial role of institutions, especially local government, in tailoring effective policies.

Figure 46 presents the Cooling and Heating degree days, with an average number of 269 cooling degree days and 1,802 heating degree days.

Figure 46: Cooling and Heating degree days for Italy (2012-2023).



Source: Eurostat 2024

5.3.2. Results Derived From Previous Quantitative Analysis For Italy

Due to the economic crisis, Italian households have suffered more from poverty in recent years. More specifically, according to the Italian National Institute of Statistics, absolute poverty rose from 4% to 6.9% between 2009 and

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2017, making energy poverty an increasingly pressing issue for Italian governmental and non-governmental organizations (Betto et al., 2020). In 2012, the proportion of households experiencing energy poverty in Italy varied considerably depending on which indicator was employed, ranging from 5% to 20%. The official indicator adopted in 2017 in Italy depends on expenditure data and involves the vulnerable population with no consumption, therefore shedding light on the hidden energy poverty dimension. According to this measure, energy-poor households had remained relatively stable between 2005 and 2016, at 8% approximately (around 2 million households), significantly lower than other well-established indicators (i.e., 10% rule, LIHC approach, or subjective evaluations). Aiming to overcome the limitations deriving from households' preferences and calculating the required heating to achieve a minimum thermal level, a new indicator was introduced, demonstrating that approximately 11.7% of households (around 3 million households) were identified as energy poor during the period 2014-2016 (Faiella & Lavecchia, 2021).

Furthermore, residential energy expenditure in Italy has increased significantly in previous decades, mainly because of higher energy costs. From 2000 to 2013, residential energy metrics increased significantly: electricity consumption by 10%, electricity costs by 30%, natural gas consumption by 31%, and natural gas costs by 37%. The share of energy expenses in total household expenditure increased by 1%, reaching 5.8%. Especially for the cases in the lowest part of the distribution, the ratio was significantly higher (8.6%), indicating the inelastic relationship between price changes and energy consumption in the short run. This leads to a more significant portion of household budgets, deteriorating the risk of poverty for vulnerable populations with limited resources. Aiming to mitigate the negative impact of the 2008 surge in oil prices, the Italian government implemented 2009 income-based assistance for electricity and gas bills. However, it was considered that these measures had not been entirely effective (Faiella & Lavecchia, 2021).

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Italian households experiencing energy poverty encounter two distinct challenges: the inability to cover higher energy bills (Faiella et al., 2017; Miniaci et al., 2014), and the self-imposed reduction in energy consumption aiming to avoid the former condition. The latter describes hidden energy poverty, which was thoroughly investigated in the work of Betto et al. (2020), which introduced a new indicator intending to include this dimension of energy poverty. Their work reveals that to identify the key factors that act as determinants, policymakers should focus on household size, climatic zone, building energy efficiency, and poverty status.

Shedding further sheds light on the disparities within the Italian context (Bardazzi et al., 2021) and highlights the need to investigate the impact of various inequalities observed in the country. The economic differences between North and South Italy and the disparities in climatic conditions offer valuable insights for evaluating whether the geographical differences in energy poverty are connected to income inequality. Their work used both subjective and expenditure-based measuring techniques and a combination of them, having as general controls the climatic conditions and a south dummy. The study demonstrates that income inequality significantly determines energy poverty in Italy. Additionally, it was confirmed that income level, vulnerable populations (like single-parent households), and energy system (i.e., absence of central heating systems) increase energy poverty. However, when employing the 10% rule and the LIHC indicator, the outcomes were not satisfactory, as they failed to recognize low-bottom households that struggle with the dilemma of "eat or heat?".

Inspired by the impacts of climate change on energy poverty due to the transformation of the built environment it will bring and the deficiencies it will reveal, Berti et al. (2023) highlighted the need to investigate the phenomenon in regions with different climatic conditions, like Italy. The study demonstrated that buildings' energy efficiency is associated with energy poverty. Many households dwell in buildings constructed before 1976 (when the first energy-saving law was imposed). Although tax incentives for renovations and energy retrofit during the previous decades benefited more than 21 million renovations, it was found that Southern Italy was less affected compared to the Northern parts of the country. Furthermore, taking into consideration the presence of fragile conditions within the households (like being single and over 65 years old, households with at least one immigrant, single parents, and household size of more than five members), it was concluded that the region of Lombardy has the highest share of vulnerable population for all the aforementioned categories, except large household size (where the region of Campania had the highest record).

Additionally, for all the categories analyzed, a distinction exists between the northern and southern parts: the southern regions and Islands report the lowest incomes, whereas the northern regions are associated with the highest incomes. Although Lombardy is a high-density and high-income region, it has an old building stock. Furthermore, Campania and Sicily are low-income regions with low-efficiency buildings. Finally, the study highlights the need to enforce climate and climate change-related measures. Policy implications should account for the effect of different climatic conditions between and within regions. Additionally, the impact of climate change on building performance and the nationwide trend concerning less heating demand and more cooling needs were revealed.

Similarly, Vurro et al. (2022) studied a neighborhood in Bari (South Italy). According to future weather simulations, it was concluded that current energy consumption is relatively evenly distributed between heating in the winter and cooling in the summer. Furthermore, starting in 2020, a shift will result in higher cooling consumption due to rising temperatures and a corresponding decrease in heating energy consumption. In the extreme scenario, almost all energy consumption will be driven by cooling. By 2050, energy consumption is expected to rise by 8.9% compared to 2020, and by 2080, it will have increased by 15.7% compared to 2050. Furthermore, the study revealed a medium to strong association between age and energy consumption and no association between tenants' numbers, despite the finding concerning low energy consumption in apartments with more than five people.

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Since 2022, households have experienced an increase in the share of energy expenses relative to their total expenditures. However, poorer households, which benefited from targeted transfers and generalized price containment measures, faced a minor increase in energy spending compared to households with overall expenditures around the median. According to the Observatory on Energy Poverty, 2 million households—7.7% of the total population—are in energy poverty; -0.8% compared to 2021 (-189,000 households). From the perspective of public finances, policies to support households continued, with an allocation of €16.8 billion annually in 2022. Thus, the rise in energy prices did not affect all households equally. Households benefited from a variety of interventions, which can be grouped into two categories: generalized price measures or tariff adjustments (such as the reduction of VAT on gas from 22% to 5% and the elimination of general system charges for electricity and gas) and targeted transfers (including an increase in beneficiaries and amounts of the electricity and gas bonuses, as well as one-off bonuses of €150 and €200 in July and November 2022, respectively).

Furthermore, the pool of beneficiaries was expanded following an increase in the ISEE threshold from €8,265 to €12,000 annually for accessing the bonus (OIPE). Since the pandemic and geopolitical tension due to the Russian-Ukrainian war, energy poverty has been confirmed to be a significant issue in Italy because of the dependence on energy imports and price volatility. Provided that since mid-2021, Italy has experienced sharp increases in energy prices, which have significantly impacted household expenditures, the Italian government has implemented measures such as social bonuses and one-off allowances to mitigate these effects (Bonfatti & Giarda, 2024).

5.4. The Portuguese case

5.4.1. Socioeconomic profile of Portugal

Portugal has an average population of around 10 million, with a population density of approximately 113.25 persons per square kilometer, comparable to the

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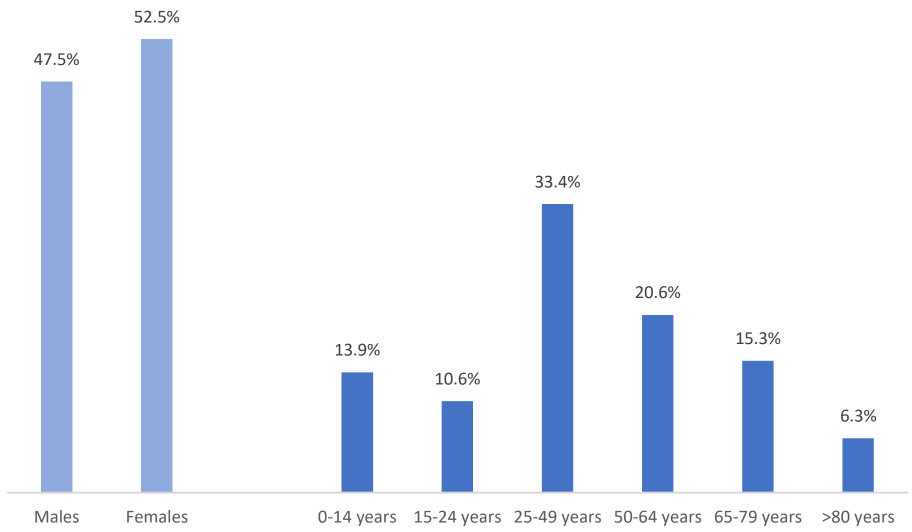
EU-27 average. As shown in Figure 47, the population is composed of roughly 48% males and 52% females. Regarding age distribution, about 14% are infants and children (0-14 years), 10.5% are young people aged 15-24, 33% are middle-aged adults (25-49 years), 20.5% are aged 50-64, 15% are 65-79 years old, and 6% are 80 years or older.

Figure 47: Average demographic statistics for Portugal (2012-2023).



Source: Eurostat 2024

After that, Figure 48 presents the household type distribution. Almost 22% are singles (15% are males and 18% are females). Concerning the age profile of singles, 9% are younger than 65 years old, and 13% are 65 or above. 65% of households do not have dependent children, while 35% are households with dependent children. 13% are households with two adults younger than 65 years old, and 17% with at least one adult aged 65 years or over. Concerning two-adult households, more than 12.5% have one dependent child, 9% have two children and almost 2% have three or more children. Approximately 13% of households have three or more adults, and almost 7% have dependent children.

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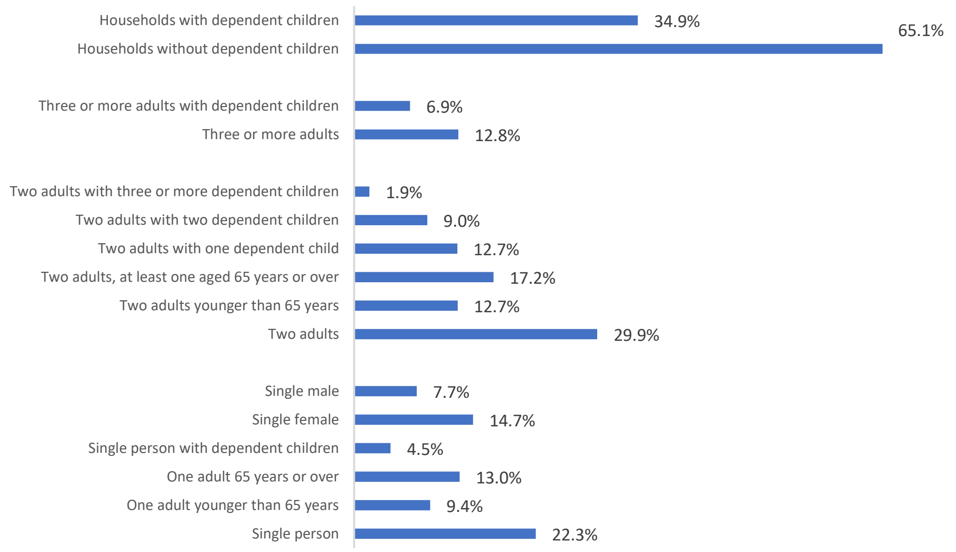
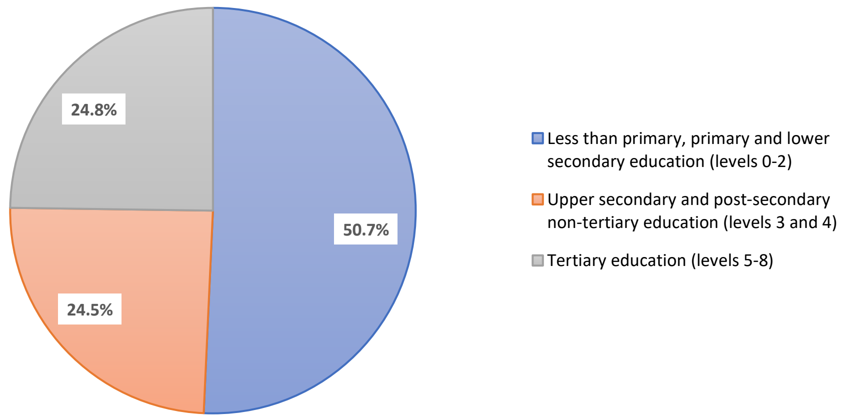
Figure 48: Household types distribution in Portugal (2012-2023).



Source: Eurostat 2024

As observed in Figure 49, the educational data reveal that half of the population (50.7%) has completed less than primary, primary and lower secondary education, significantly higher than EU-27 and South European groups. The incidence of upper secondary or post-secondary non-tertiary and tertiary education is equally shared (24.5% and 24.8%, respectively).

Figure 49: Average educational attainment level in Portugal, 2012-2023.



Source: Eurostat 2024

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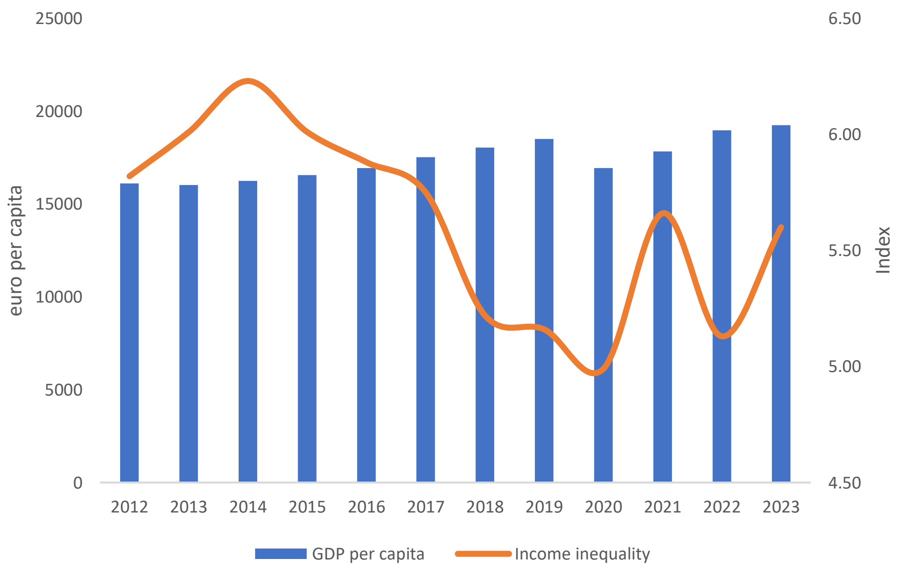
The observations concerning the GDP per capita in Figure 50 reveal an increasing trend during the studied period, with a mean value of 17,410€ and an exception in 2020, which dropped significantly. Income inequality increased up to 2014 and dropped noticeably up to 2020. In 2021 and 2023, high values were marked (approximately 5.6, also the mean value for 2012-2023). Both parameters (GDP per capita and income inequality) perform worse than in the EU-27 and South Europe.

Figure 50: Real GDP per capita and inequality of income distribution in Portugal (2012-2023).



Source: Eurostat 2024

Analyzing poverty in Portugal, it is observed in Figure 51 that around one-third of the population perceived themselves to suffer from poverty (specifically, the average value for subjective poverty is 32%, as shown in Figure 51). Furthermore, 22% are under the national poverty line. Both indicators are lower than the group for southern countries and similar to EU-27. The proportion of people who face difficulties making ends meet is severely high (68%), similar to the South European average and higher than the EU-27. As for the population at persistent risk of poverty, the trend is unclear; the percentage is 26%, which is

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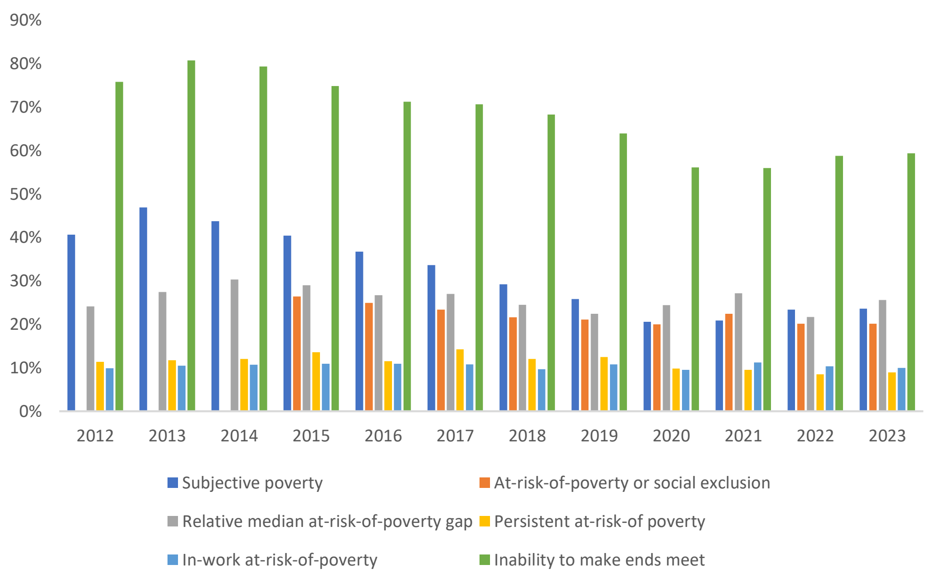
higher than both subcategories. The share of people with persistent poverty is 11%, higher than in the EU-27 and lower than in South Europe.

Figure 51: Subjective poverty, at-risk-of-poverty or social exclusion, relative poverty gap, inability to make ends meet, persistent at-risk-of-poverty, in-work at-risk-of-poverty, for Portugal (2012-2023).



Source: Eurostat 2024

Figure 52 presents significant information concerning the labor sector in Portugal. The unemployment rate in Portugal (average 6.5%) has decreased over the years; it is one unit higher than the EU-27 and one unit lower than the group of southern countries. Jobless households (average 7.3%), part-time employment (7.8%), and short-term contracts (17%) show a similar evolution during that period. However, the only exception for all indicators is observed in 2023, when all observations present deterioration.

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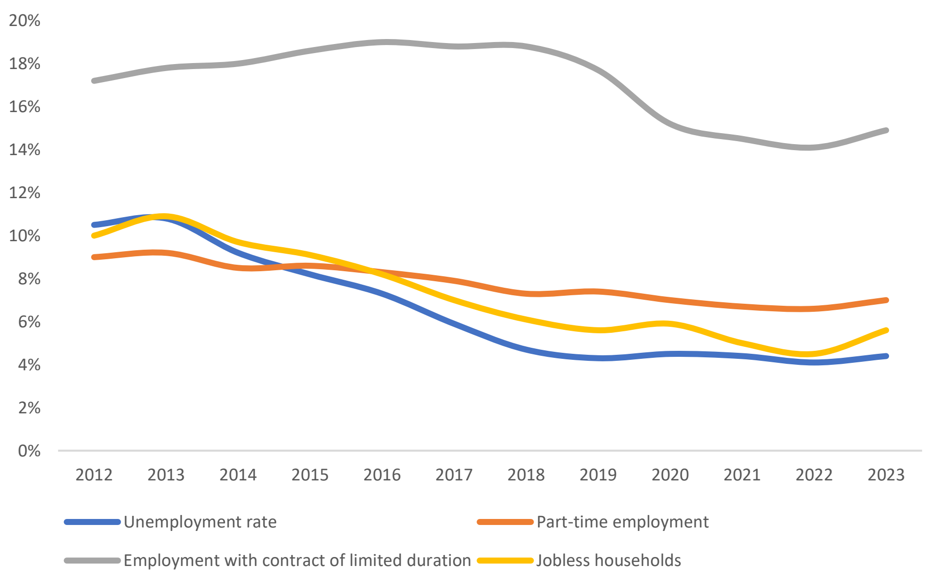
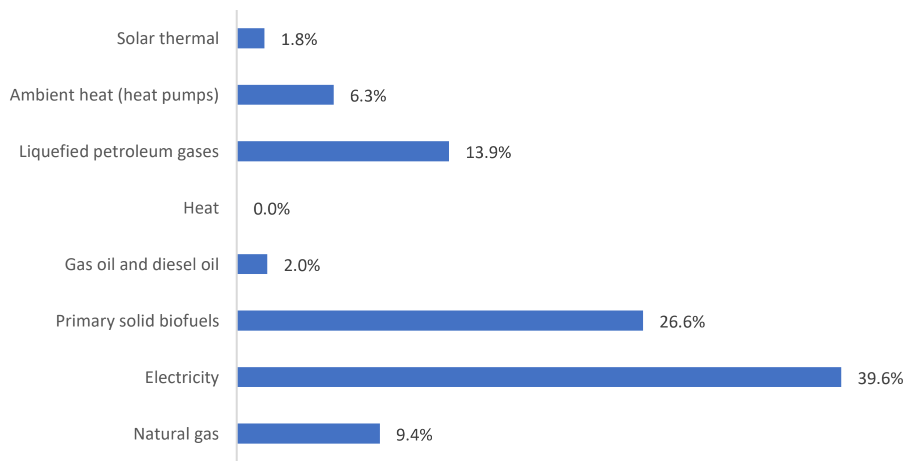
Figure 52: Employment statistics for Portugal (2012-2023).



Source: Eurostat 2024

The average percentage of energy product type consumed by households for 2012-2022 is presented in Figure 53 and is defined as follows: 40% electricity, 26% primary solid fuels, 14% liquefied petroleum gases, and 6% ambient heat (heat bumps).

Figure 53: Average energy consumption of Portuguese households by energy type (2012-2022).



Source: Eurostat 2024

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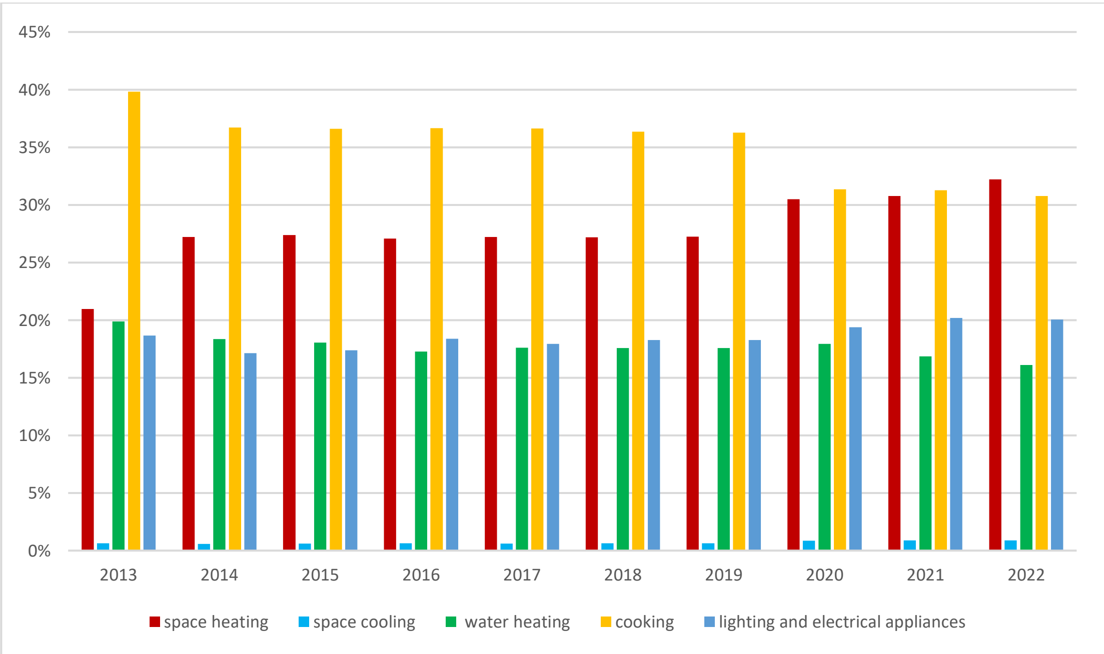
Analyzing the Portuguese household energy use trends (Figure 54), it is observed that "cooking" is constantly the dominant end-use, although it declined from almost 40% in 2013 to 31% in 2022. The second highest category is "space heating" presenting a gradual increase from 21% in 2013 to 32% in 2022. Then, "lighting and electrical appliances" at around 19% and "water heating" at 18% follow. "Space cooling" demonstrates minor percentages, below 1%.

Figure 54 Portuguese households' energy use (2013-2022)



Source: Eurostat 2024

Figure 55 provides key insights into Portugal's energy sector. Electricity prices increased between 2012 and 2016, peaking at 0.235 €/kilowatt-hour, then declined steadily until 2021, reaching 0.21 €/kilowatt-hour. In 2022, prices rose slightly to 0.22 €/kilowatt-hour, although not as sharply as in the EU-27 and other South European countries. Natural gas prices followed a similar pattern, rising between 2013 and 2015 before decreasing from 2016 to 2021, with a minimum value of 0.078 €/kilowatt-hour. However, in 2022, natural gas prices reached their highest value at 0.127 €/kilowatt-hour. Energy expenditure remained relatively stable until 2022, when it increased significantly. Final energy consumption

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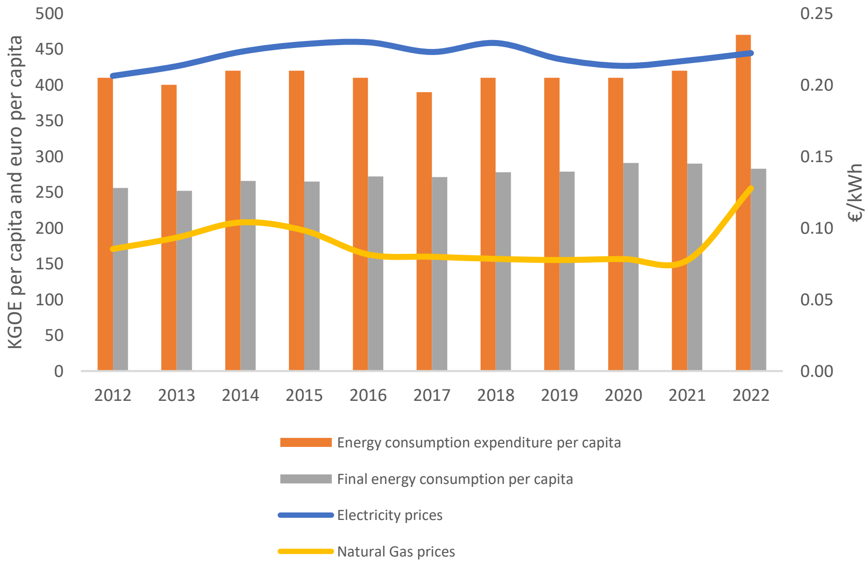
showed a steady upward trend from 2012 to 2021, averaging 272 KGOE/capita, with the only decline observed in 2022, likely due to rising energy prices.

Figure 55: Final energy consumption, energy expenditure, electricity and natural gas prices for Portuguese households (2012-2022).



Source: Eurostat 2024

Several analysis points emerge when examining the energy poverty indicators included in the EU-SILC survey, as depicted in Figure 56. First, arrears on utility bills increased up to 2014 but started decreasing after, with a mean value of 5.8%, which is lower than EU-27 and southern countries. However, in 2021 and 2022, the indicator increased. The average value of the indicator referring to the presence of leakages, damp, or rot in the house is 27.5%, significantly higher than EU-27 and South Europe. This metric had the lowest observation in 2012 (22%), and after, it presents several ups and downs during the studied period, with maximum values in 2013, 2014, 2016, and 2023 (close to 30%) and minimum in 2012 (22%). Concerning the inability to keep homes adequately warm, the indicator was increasing until 2014, then it presented a decreasing trend up to 2021, and in 2022 it started increasing again. The average value (21.7%) exceeds the EU-27 and South Europe.

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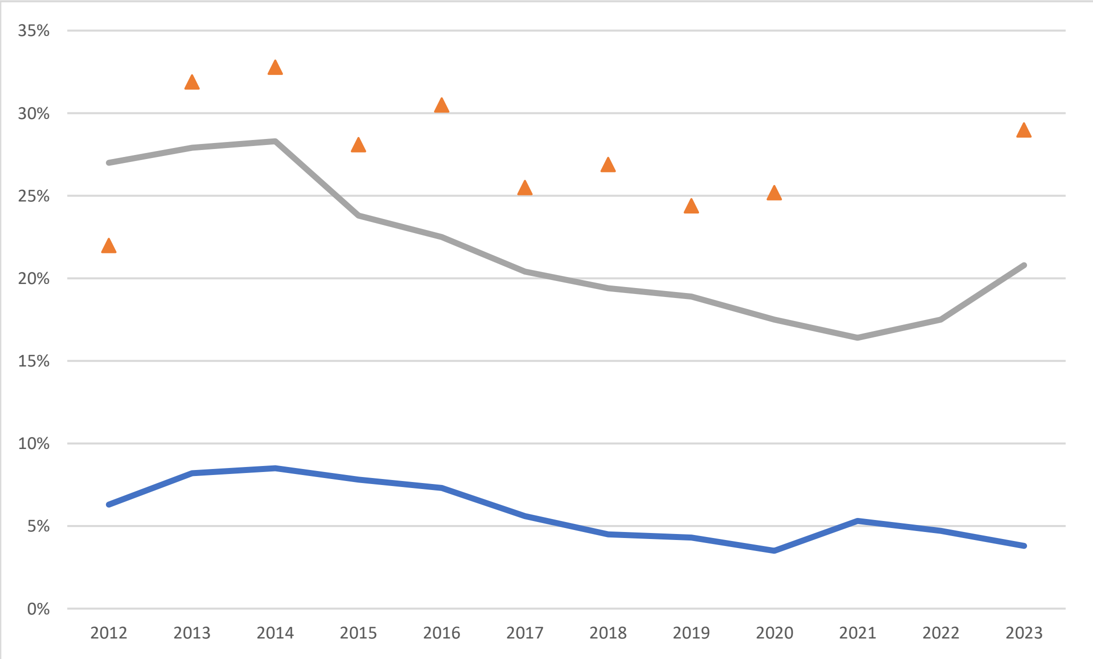
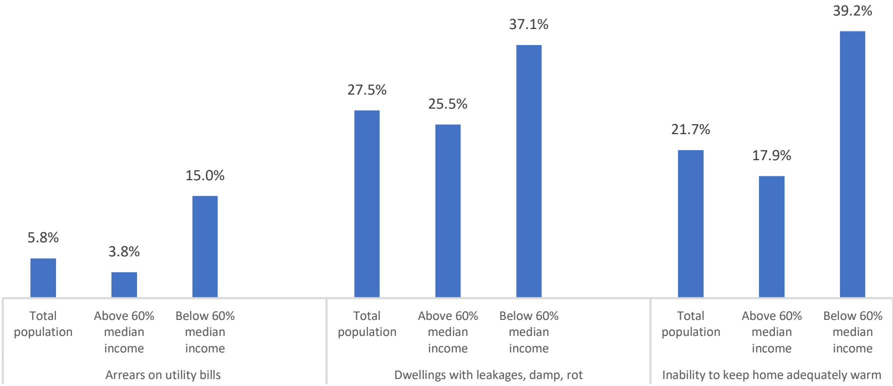
Figure 56: EU-SILC energy poverty indicators for Portugal (2012-2023).



Source: Eurostat 2024

Figure 57 analyzes the prevalence of energy poverty across the population and among individuals above and below the national poverty line, revealing a trend consistent with other countries. Energy poverty rates for the total population and those above the poverty line are relatively similar, whereas the rates are significantly higher for individuals below the poverty line.

Figure 57: Average values of energy poverty EU-SILC indicators for Portugal (2012-2023), by energy poverty threshold.



Source: Eurostat 2024

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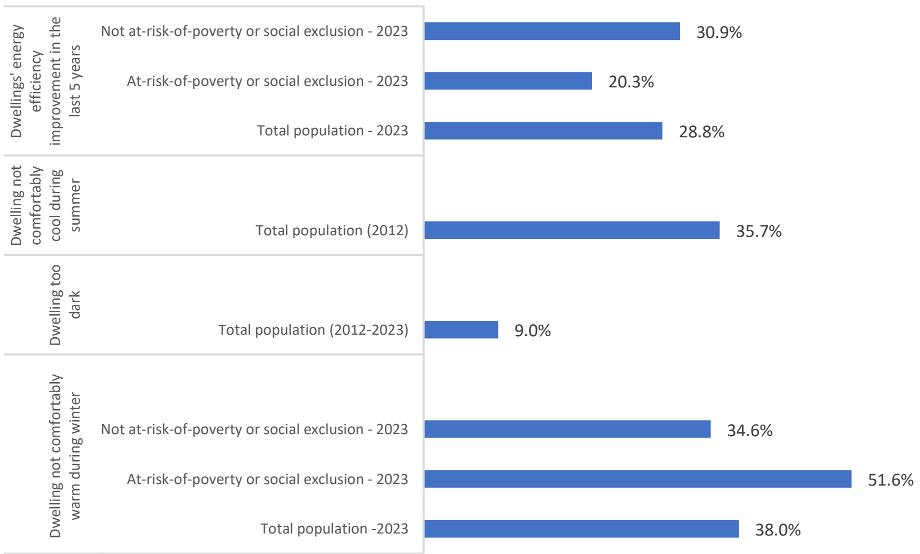
Figure 58 confirms that people at risk of poverty are severely affected by energy poverty. Approximately 52% of the population at risk of poverty or social exclusion live in buildings that are not comfortably warm during winter, and 20% have improved their residence's energy efficiency during the last 5 years. At lower rates (35%), households not at risk of poverty or social exclusion report their dwellings are not comfortably warm, and almost one-third have upgraded their homes' energy efficiency during the last 5 years. Concerning the total population, 38% of households do not dwell in comfortably warm homes, 29% have accomplished energy efficiency upgrades during the last five years, 36% are not comfortably cold in summer, and 9% live in dwellings too dark.

Figure 58: Dwellings characteristics affiliated with energy poverty in Portugal.



Source: Eurostat 2024

Figure 59 presents the Cooling and Heating degree days, with an average number of 213 cooling degree days and 1,141 heating degree days.

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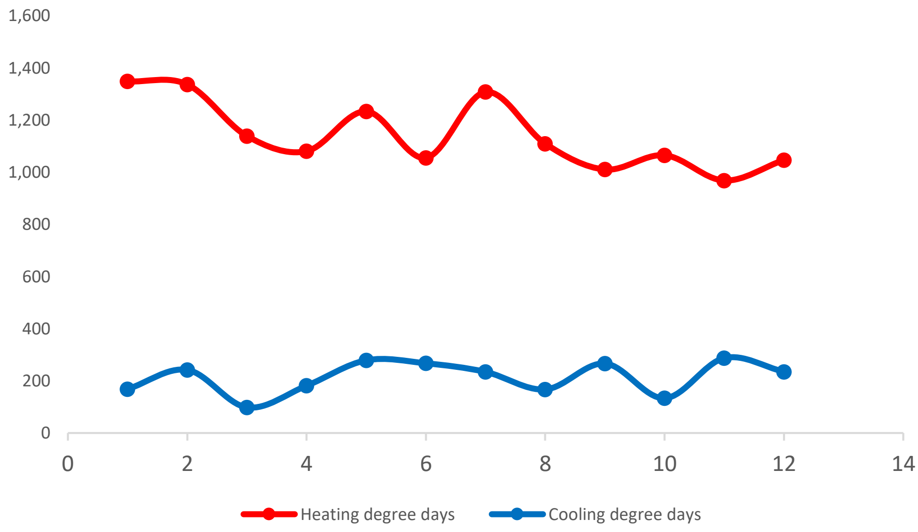
Figure 59: Cooling and Heating degree days for Portugal (2012-2023).



Source: Eurostat 2024

5.4.2. Results Derived From Previous Quantitative Analysis For Portugal

There is a relatively recent history of research studies focusing on EP measurement in Portugal. The existing work examined energy poverty through thermal comfort, performance, and efficiency analysis. Building on previous research assessing energy consumption patterns using electricity smart meters and socioeconomic data (Gouveia et al., 2012; Gouveia & Seixas, 2016). Gouveia et al. (2018) set out to identify energy-poor consumers by combining daily smart meter data for 265 houses from 2011 to 2014 with household door-to-door surveys and energy simulations of building typologies. The authors conducted a clustering analysis to detect different yearly electricity consumption profiles, daily consumption levels, and distinct groups of electricity consumers. The authors defined building typologies where the identified groups of people were living and used a building energy model to predict space heating and cooling energy needs, cross-referencing them with the electricity consumption.

In a different approach, (Simoes et al., 2016) developed a methodology to estimate the potential EP of residential dwellings at a regional level. The method

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is a weighted vulnerability index combining data on income, level of education, unemployment rate, and number of inhabitants above 65 years old, and a space heating and cooling gap estimated per household typology. The study was conducted for 29 municipalities across the country. Results show that an average of 22% of the inhabitants are potentially energy-poor regarding their dwellings' space heating and 29% regarding space cooling.

Building on the work of Simoes et al. (2016) and Palma et al. (2019), Gouveia et al. (2019) introduced the Energy Poverty Vulnerability Index (EPVI), a comprehensive composite index designed to map and assess energy poverty across all 3,092 Portuguese civil parishes. The EPVI integrates various socio-economic indicators (e.g., proportions of elderly and young people, unemployment rates, income levels, and education levels), climate variables (such as Heating Degree Days, Cooling Degree Days, and the duration of heating and cooling seasons), energy consumption patterns (e.g., electricity, natural gas, and biomass usage), energy needs for heating and cooling (per square meter and per household), data on climatization technologies (efficiency and ownership), and construction characteristics of 187 building typologies (e.g., building height, area, structural materials, wall and window types, and roof types) by region. The analysis reveals that civil parishes in Portugal's northern and inland central regions face higher energy poverty vulnerability for heating and cooling. This is attributed to harsher climate conditions, lower energy efficiency of the building stock, reduced energy consumption for thermal comfort, and the limited capacity of the local population to implement energy efficiency measures to improve thermal comfort.

Horta et al. (2019) used the index to delve deeper into local EP analysis, selecting ten hotspot areas nationwide to interview 100 households. Collecting direct feedback from the inhabitants in vulnerable regions adds a more participatory qualitative dimension to the study, enabling a deeper understanding of EP effects in the population. This research shows that households often accept feeling cold or hot in winter or summer, also uncovering a lack of social

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recognition of the EP issue, which can exacerbate adverse effects on the quality of life and health.

Palma et al. (2022) used the EPVI to estimate future energy poverty vulnerability levels and carbon dioxide emissions, assessing different scenarios of HVAC equipment ownership while considering energy justice issues. Increasing equipment efficiency to regulation levels without changes in the current equipment stock proves only effective in reducing winter energy poverty, with a decrease in municipal vulnerability levels of about 18 percent. A comprehensive replacement and transformation of the current stock effectively reduces winter and summer energy poverty, respectively, 47.8 percent and 26.3 percent in average municipal levels, also reducing potential carbon emissions by 3554 kilotons. Equipment replacement should be coupled with building energy performance while addressing fuel and equipment access inequalities. This study shows the relevance of exploring the impact of space heating and cooling equipment replacement measures on energy poverty at the regional level and can help predict evolving vulnerabilities to inform long-term strategies.

Oliveira Panão (2021) explored Portuguese HBS microdata to assess various energy poverty expenditure-based indicators (the 2 M, LIHC, and MIS), aiming to analyze their performance. It demonstrates that existing data offers several possibilities to calculate a more diverse set of expenditure-based indicators at NUTS 3 level. The author proposes a moderate heating cost and defends that an energy poverty indicator should integrate the capacity to evaluate net-income elasticity to pay for expected (estimated) energy expenditure.

With a focus on policy analysis at the national level, Palma et al. (2024) critically analyze and compare the EP definition and measurement framework proposed in the national energy poverty mitigation strategies of Portugal and Spain, aiming to identify similarities, shortcomings, and best practices and contribute to the enhancement of the diagnosis framework of both strategies. It draws on state-of-art literature, policy on definitions and measurement

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approaches, and a specific review of alternative measurement approaches and data sources in both countries. Findings point to a need to broaden the scope and increase the representativeness of energy services and the types of vulnerability in the definitions. Available data and indicators can be used to widen comprehensiveness, reduce redundancy, and integrate analysis of depth and persistence in the current measurement framework in the short term. More profound improvements require increased indicator intersectionality and alternative data and indicators.

6. Empirical tools to address the research questions

The first step of the research involves descriptive statistical analysis for all four partner countries as a group and for each separately. The descriptive and inferential statistical analyses involve the progress of:

- Sociodemographic, climatic, and economic variables at macro-level analysis
- Official objective and subjective energy poverty indicators at the micro-level (obtained from national statistical authorities – EU SILC)
- Variables (microdata) affecting energy poverty occurrence (i.e. income, education etc. obtained from national statistical authorities – EU SILC)
- General demographic characteristics (obtained from national statistical authorities – EU SILC)
- National progress of affiliated SDGs

After the statistical research, which provides valuable insights concerning energy poverty, specialized empirical analysis involving thorough econometric approaches, the econometric analysis will be employed. This section concerns the econometric test hypothesis for all four partner countries as a group and each country separately, employing regression models. The dynamic relationships between energy poverty and the related independent variables will be investigated at the beginning of the empirical analysis. Apart from revealing the nexus of several factors with energy poverty, the analysis will provide valued considerations concerning the period before, during, and after the pandemic. Since

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the literature argues that the impacts of energy poverty on social and individual prosperity worsen the possibilities of overcoming it, the research will incorporate econometric causality tests to recognize potential bi-directional relationships. This will shed light on permanent energy poverty issues.

7. Conclusions

The investigation and study of existing official indicators revealed that all approaches to identifying and measuring energy poverty have advantages and disadvantages. The multidimensionality of the phenomenon sets the need for a thorough and holistic approach, embracing interdisciplinarity and collaboration of multiple academic fields, policymakers, and civic organizations. This will lead to valuable and inclusive findings and considerations for hidden and persistent energy poverty.

The descriptive statistical analysis revealed that despite the unity and cohesion efforts of the EU among its member states, significant disparities are observed primarily in government mitigation policies and tools. The analysis between the EU-27 and the group of Southern European countries demonstrated differences in socioeconomic and energy poverty metrics. Findings showed that economic growth is higher for the EU-27, while South Europe has faced more significant difficulties, even if with less intensity recently. Similarly, EU-27 performs better in most poverty-affiliated indicators, showing a social and economic disparity across countries. According to all energy poverty indicators, Southern European countries struggle deeper with energy poverty despite milder winter conditions, consistent with socioeconomic indicators.

The analysis in the group of four South European countries involved in the project also detected quantifiable changes between them, revealing that societies with similar climatic conditions but different geographic and climate zones and socioeconomic and political conditions experience energy poverty differently. Greece and Portugal have the lowest economic growth, while Italy has the highest amongst the group, almost as the average of the EU-27. Greece has the highest income inequality and Italy the lowest. Furthermore, Greece presented the most worrying facts concerning poverty, especially for "Subjective poverty" and "ability to make ends meet". The values were far higher than those of the EU-27 and the group of South European countries. Regarding energy poverty, Portugal seems to be more affected by the indicator examining the building's characteristics, and Greece by the indicators referring to arrears and ability to keep home adequately warm.

The literature review of each country also indicated that socioeconomic, demographic, and energy sector characteristics shape energy poverty. Furthermore, it is concluded that all countries have significant geographical differences and several climatic zones between and within them, urging for detailed spatial analysis and temperature involvement. In addition to geographic and climatic conditions, it is important to analyze public policies to mitigate energy poverty, e.g. incentives for building renovations, targeted support for vulnerable families, and the promotion of energy-efficient appliances.

Consequently, Deliverable D2.3 has recognized the synergies of energy poverty in South Europe. It also sets the foundation for the empirical analysis in the following steps, which will lead to valuable identification of the vulnerable population in the group of countries and for each country separately. Furthermore, it will provide significant insights concerning targeted policy implications. Building on these findings, our subsequent research phase will involve two critical deliverables. Deliverable 3.1 will conduct a comprehensive statistical analysis within each country, leveraging the NUTS 1 and NUTS 2 classifications provided by Eurostat. This analysis will incorporate unbalanced panel data to perform regression modeling, aiming to confirm or reject the significance of various factors that may serve as drivers or determinants of energy poverty at an aggregate level. This approach will enable a nuanced understanding of energy poverty between and within the selected countries at a regional level. Deliverable 3.2 will delve deeper into the issue by employing a more advanced panel analysis (pseudo-panel analysis). This method will focus exclusively on

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households with similar demographic characteristics, allowing us to assess the impact of these consistent traits on energy poverty within each country. By isolating these factors, we aim to uncover more detailed and country-specific insights into the dynamics of energy poverty.

These steps are essential for refining our understanding and providing robust, targeted recommendations for policy interventions that address the specific challenges faced by vulnerable populations across South Europe.

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