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Exploring Energy Poverty in Urban and Rural Contexts in the Era of Climate Change: A Comparative Analysis of European Countries and Israel

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Abstract: This article examines the multidimensional problem of energy poverty, focusing on its connections to climate change and its manifestation at rural and urban scales across selected European countries and Israel. The study examined 31 locations in eight countries with diverse geographical and economic backgrounds: Bosnia and Herzegovina, Greece, North Macedonia, The Netherlands, Portugal, Spain, Slovakia, and Israel. The article aims to understand how winter energy vulnerability in rural and urban locations in these countries could be identified using selected energy poverty indicators and how it evolves under the influence of climate change. A set of sociodemographic, infrastructural, and economic variables, combined with climate analysis, were selected and assessed for their impact on energy poverty. We found that energy poverty in most countries depends significantly on location and regional development. Due to a combination of factors influencing energy poverty, rural households tend to be more vulnerable. Furthermore, climate change consequences will likely leave rural areas more likely to experience energy poverty in the future.

Keywords: winter energy poverty; rural–urban divide; buildings; socioeconomic factors; impacts of climate change

1. Introduction

The provision of adequate levels of energy services such as space heating and cooling continues to be a concern in Europe, as the inability to supply these essential services (i.e., energy poverty (EP)) remains a complex problem to solve. In 2021, according to the EU-SILC survey, 6.9% of the EU population—about 30 million people—could not afford to maintain a comfortable temperature in their homes in the winter [1]. Moreover, in 2020, 14.8% of EU citizens lived in deteriorating dwellings [2]. EP is a complex and multidisciplinary issue contributing to aggravating health problems and has other adverse social, economic, and political impacts on affected populations [3]. While climate change exacerbates the thermal discomfort in summer, winter EP, whose proxy is the inability to keep comfortably warm in winter, remains a severe issue, evidenced by high excess mortality [4].

EP is distributed and experienced differently at different times of the year and geographic locations due to the uneven geographies in Europe [5]. In addition to the differences observed between countries regarding the share of EP, spatial variations within each country matter, as there is considerable variation in the expression, manifestations, and magnitude of EP including the location in rural and urban settings [6,7], often highlighting rural areas as one aspect of vulnerability to EP in the EU [1,8,9]. As rural Europe faces considerable economic and demographic transformation, with regions developing along different paths [10,11], it has become increasingly important to investigate this serious social challenge across these two distinct settlement types. On top of that, climate change poses a danger to increasing these spatial discrepancies regarding vulnerability to EP, potentially widening the rural–urban divide.

Tackling EP is not a simple endeavour since it is a multidimensional problem caused by the combination of primarily three main factors—low income, high energy prices, and low household energy efficiency [12,13]. When unpacking these three leading causes, a variety of other factors emerge as relevant contributors to shaping vulnerability to EP such as climate, energy needs, energy use, building characteristics, tenure status, type of space heating and cooling equipment, and socioeconomic aspects such as age, gender, unemployment, or educational level [13,14]. Analysing complementary indicators at the regional level and accounting for the spatial differences within different countries would provide more nuanced insights on EP, allowing for policies to consider specific locations and area-based targeting when addressing the problem [14]. Following the understanding that EP is a spatial phenomenon determined by housing and the sociodemographic features of households, it is essential to explore these as determinants of EP, which are relevant for the current state of EP [5,15,16] as well as its future manifestations.

This article aims to understand the factors determining the rural–urban divide in experiencing EP vulnerability and discuss how climate change could further exacerbate this divide in winter in order to support the better targeting of measures to eradicate EP. The geographical scope includes 31 rural or urban locations in eight countries (Portugal, Spain, Slovakia, Greece, North Macedonia, The Netherlands, Bosnia and Herzegovina, and Israel) with different EP levels, presenting a diverse set of socioeconomic contexts, geographies, and climate zones. The case selection was inspired by previous studies that claim that countries on the geographical periphery of Europe, such as Mediterranean countries (Spain, Greece, and Portugal) and Central-Eastern Europe (Slovakia, North Macedonia, and Bosnia and Herzegovina), are more affected by energy poverty [8]. To represent the geographical core of Europe, we included The Netherlands, where the shares of energy poverty are lower, but energy poverty is experienced among the most vulnerable populations [17]. Israel is not exempt from energy poverty, as it also affects already vulnerable populations [18]. The diversity of households experiencing energy poverty presented through these countries aims to serve as a starting point for this baseline study to explore the links between energy poverty, climate change, and rural–urban locations. We analyse and discuss how different EP determinants impact winter energy vulnerability in rural and urban locations in selected countries and how it can evolve in the face of climate change. Our starting point was the selection of EP indicators representing the main drivers of EP on the socioeconomic, infrastructural, and technical dimensions. Furthermore, we used climate data to model the heating degree-days variation by 2050 to discuss the impact of climate change on winter energy vulnerability across rural and urban locations between 2020 and 2050. The choice to include this issue is largely justified by the literature (e.g., the last IPCC report, which related climate change to the vulnerabilities of people and territories [19]) and the lack of research on this topic.

The rest of this paper is organised as follows. Section 2 presents the literature review, where we focus on the rural and urban diversity in energy use and the impacts of climate change. Section 3 describes the methodology, while Sections 4 and 5 present the results and discussion, respectively. Section 6 presents our conclusions.

2. Literature Review

Through the literature review, we justified using specific climate, sociodemographic, and technological variables as EP determinants to study the prevalence of EP in rural and urban areas and estimate the impact of climate change on winter EP.

2.1. Factors Contributing to Energy Poverty

EP can be measured through various approaches [20,21] because there is no definite standard. The indirect or alternative indicators do not quantify this problem directly, but provide a representation of the factors or drivers that impact EP that must be used [22]. These indicators can be of various natures such as environmental, sociodemographic, economic, infrastructural, and policy, to provide a few examples. We approached the problem through EP determinants used as a proxy for indicators of EP, which were drawn from the housing and sociodemographic features of households. Additionally, we used climate indicators to explore how EP will develop in the future. Thus, we reviewed the key EP indicators that we used as EP determinants.

Inadequate housing is a key indicator of EP. While developing multidimensional approaches, some authors also consider building stock characteristics as determinants of energy vulnerabilities such as age, type of building, areas, and thermal transmittance of the envelope, spatial heating and cooling equipment, ownership, and building energy performance. Historically, climate conditions have influenced the buildings' characteristics and materials used for constructing the buildings [23]. The energy efficiency of buildings positively correlates with higher indoor temperatures and improved thermal sensations [24]. Improving the energy performance of the building envelope translates into lower energy needs for spatial heating and improved indoor air quality and thermal comfort [25–27]. On the other hand, active measures such as replacing old boilers with more efficient systems (e.g., heat pumps [28]) could also accelerate a reduction in heat consumption. However, this reduction in energy needs might not translate into a decrease in energy consumption and energy costs due to energy performance gaps [29] and high energy prices [28].

The sociodemographic features of households affect their vulnerability to the cold, their understanding of energy usage at home, and their ability to reduce energy consumption. Sociocultural factors also influence the perceptions of thermal comfort and practices of coping with the cold [30]. Households with higher education levels are more prone to invest in energy efficiency [31], whereas elderly populations are more vulnerable to EP [32]. Several authors such as [33–35] have used socioeconomic and demographic indicators to describe EP, and some of the most common include population age groups; education level; income levels; gender; unemployment rates; excess mortality rates; social support services subscription; disabilities; tenure; social housing; and unconventional dwellings.

2.2. Impacts of Climate Change on Energy Poverty

Climate change effects are bound to influence EP vulnerability across the globe. Climate indicators have been prominent variables in EP assessment studies. Multidimensional approaches such as the ones put forth for Greece [36], Italy [37], and Portugal [38] use degree-days and outside temperature data to assess space heating for indoor thermal comfort. Sanchez-Guevara, C., et al. [39] used air temperature data to calculate the cooling-degree days to evaluate the urban heat island effect and its connection to energy vulnerability in Madrid and London. Other authors, whose works were published in [16,40], developed an area-based analysis using heating degree-days to estimate a heating burden for Northern Ireland and the German city of Oberhausen. These approaches also considered the energy costs to evaluate EP. Conversely, Pérez-Fargallo, et al. [41] used a weather data forecast to develop an index to assess the potential fuel poverty risk of social housing households.

However, the literature on the impacts of climate change on EP is still scarce [42]. While some studies have found a link between climate change and energy demand [43,44], pointing out a general decrease in heating demand and increased space cooling needs in the residential sector [25,45–47], other studies have also found a nonlinear relationship between temperature and electricity demand [48,49]. This is the case of Portugal, for example, where high levels of EP translate into the social practices of avoiding the use of heating and cooling systems in order to keep the energy bills as low as possible [30].

Aside from global warming, climate change also increases the frequency of extreme weather events such as cold spells, heat waves, or storms. These events will severely affect the overall population, particularly the most vulnerable households, thus potentially causing acute energy insecurity related to power outages [42]. According to Costa-Campi et al. [50], extremely cold weather conditions significantly affect energy vulnerability more than extremely hot conditions. Other studies indicate that winter EP would become worse, especially in developing countries that would be more affected by extreme weather [51,52].

Location and climate zone contribute to shaping EP prevalence, as some regions are more vulnerable to weather changes and are more exposed to climate change. In Europe, the most substantial warming of extremely hot days is projected to occur in central and southern Europe [53].

2.3. Spatial Dimensions of Energy Poverty

EP varies geographically. Several authors have used multidimensional indices combining various sociodemographic, housing, climate, and other variables to identify locations more vulnerable to EP within a certain country or region [30,38,40,54,55].

At the core of these spatial variations, a divide between different geographical locations including urban and rural contexts within countries arises [9,15,56,57]. The EU population of 447 million inhabitants is distributed among different areas and settlement types: 39.3% of the population lives in cities, 31.6% in towns and suburbs, and 29.1% in rural areas [58]. Bouzarovski and Thomson [59] point out that low-income urban areas and marginalised rural areas are the most energy-vulnerable in the European context. Rural areas are also prone to higher energy costs due to their location, influencing the size and type of the dwelling and the heating system [30,38,60], causing the probability of being in EP to be twice as that for urban area households [61]. In fact, rural homes tend to more often be detached houses, with a bigger size, volume, and lack thermal insulation [62,63], with house renovation being less affordable to its residents [64]. Urban and rural households differ in energy use, and urban households tend to have a higher actual energy consumption [65]. On the other hand, Thomson and Snell [15] found a higher probability of being unable to adequately heat a house in rural locations compared to urban locations. Several studies have found that rural settings often lack access to heating infrastructure such as natural gas, which can imply higher costs arising by using other fuels, depending on the household context [66,67] as well as a lower security of electricity supply due to less developed infrastructure [64]. Simcock et al. [68] also highlighted that in rural areas, the availability and access to goods and services are generally poorer, potentially requiring added costs in transportation, whereas housing and service costs tend to be higher in urban settings, tenancy relations often being a barrier to implementing mitigating measures. Scholars have found that rural areas generally have the greatest likelihood of transport and EP overlap, whilst highlighting that vulnerability might not be homogenous within urban and rural territories [68]. On the other hand, from a climate perspective, urban areas are more prone to being affected by the heat island effect [35], increasing energy needs and posing added difficulties for households to maintain comfortable temperatures.

There is a higher risk of EP in rural settlements, although this can vary depending on the context, as, for instance, disadvantaged groups tend to concentrate in inner-urban areas [68]. The complex and varied combination of factors and drivers shaping EP amongst these two territorial areas calls for a deeper look into analysing EP manifestation in rural and urban contexts.

3. Methodology

This section justifies the selection of rural and urban case studies and describes the selected EP proxy indicators, data collection, and analysis process. We investigated the landscapes that led to winter energy vulnerability in rural and urban locations across eight diverse countries: Bosnia and Herzegovina, Greece, Israel, North Macedonia, The Netherlands, Portugal, Slovakia, and Spain. These countries present distinct levels of EP (based on the EEPI index [69]: Slovakia and Portugal belong to the energy poorest, and The Netherlands to the ones that are least exposed to EP) and different expressions of its drivers, covering a wide geographical spread and climate variability (Southern and Central European countries are expected to have the most significant climate change in the upcoming decades). We included EU and non-EU countries with varying living standards and other sociodemographic, economic, and infrastructural characteristics that are relevant for investigating EP. Within these countries, we focused on the territorial typology (rural and urban) as it constitutes an impactful factor in shaping EP vulnerability. Two rural and two urban case studies were selected and analysed for each country, aiming to capture the existing climatic and geographic diversity and different EP configurations while considering the weather stations' location (including opposite climatic zones within each country) and climate data availability. Regarding the EP configurations, the selection of locations also took into account the regional socioeconomic differences within each country (e.g., in the case of Spain, two locations were selected from the northern region and the other two from a southern region, thus considering the economic divide between the north and south of this country).

The rural/urban classification was defined according to the European Union regulation's Degree of Urbanisation classification [70]. The urban locations were contiguous grid cells of 1 km^2 with a density of at least 300 inhabitants per km^2 and a minimum population of 5000 inhabitants. Rural locations were grid cells outside of these urban clusters. For the non-EU countries (North Macedonia, Bosnia and Herzegovina, and Israel), national classifications set in their respective regulations defined the urban and rural areas. For Israel, urban areas have more than 2000 inhabitants per 1 km^2 [71]. In Bosnia and Herzegovina, where population density is low, urban and semi-urban locations have more than 100 people per 1 km^2 [72]. In North Macedonia, the rural–urban division follows the national legislation, which lists specific areas that should be considered rural [73].

Our study used area-based alternative indicators to investigate potential vulnerability, enabling a multidimensional approach for analysing the different aspects of the problem instead of focusing only on the economic income–expenditure aspect. To conduct a descriptive analysis of vulnerability to winter EP across the locations, we selected a variety of indicators, capturing EP drivers that portray multiple dimensions of the problem [13,74] such as housing and building energy performance and efficiency, climate, and socioeconomic characteristics of the population. We relied on publicly available data sources, Eurostat and national statistics, to gather data to identify the selected EP indicators (Table 1) detailed in their limitations and relevance in [75]. The indicators used as EP proxies and presented in Table 1 were inspired by the energy poverty literature such as those claiming that income, unemployment, presence of elderly, education level, housing tenure, age of dwellings, and fuelwood users can be factors in experiencing energy poverty [76–80]. Subsequently, aiming to assess how climate change can impact EP vulnerability, outside average temperature data, representative of standard years, were collected from the database Meteonorm for the weather stations in the analysed locations. Indeed, the initial selection of localities was conditioned on the climate data availability and subsequently made to include different climate zones in each country. We calculated and compared heating degree-days (HDDs) in the current situation and for 2050 for all of the selected areas using a fixed thermal comfort temperature threshold with the A2 scenario of the Special Report on Emission Scenarios (SRES) [81].

Table 1. Selected energy poverty proxy indicators.

Features Relevant to EP and Climate Change	EP Indicators	Description and Justification
Sociodemographic	Unemployment rate	(%)—The share of unemployed persons as a percentage of the labour force. When unemployed, households face financial limitations in their ability to afford energy, which can also impact mental well-being and ability to invest in home improvement [13].
	Average income per household	(Net per month in EUR)—Available income after income taxes and social contributions. It influences the ability of households to afford adequate levels of energy consumption and invest in energy efficiency measures [13].
	Share of elderly population and children	(%)—Number of people older than 65 years (in Greece 60 years) and younger than five years (in Greece 9 years) to the whole population. The elderly and children are more vulnerable to EP due to higher levels of dependency, while a low share of children reflects population ageing, implying future vulnerability [38,80].
	Share of inhabitants with a university degree	(%)—Number of people with tertiary education to the whole population. It is used as a proxy for the population's awareness and ability to react to thermal discomfort and search for solutions due to their higher education and knowledge. More educated people live in more energy-efficient dwellings [82].
Housing	Share of population living in an owner-occupied dwelling	(%)—Proportion of households occupied by homeowners [83]. Dwellers who own the place where they live have a higher ability to implement energy efficiency measures, while renters are more limited in their actions and tend to have poorer quality dwellings compared to other ones [84].
	Social housing	Social houses generally have poorer construction and are occupied by lower-income households, hence being potentially more vulnerable to EP [34].
	Dwellings with energy performance certificates (EPC)	(%)—Proportion of buildings with EPC in the housing stock. High energy-efficient buildings usually have lower energy requirements, which translates to lower energy bills for their occupants [85].

	Building stock age (the year of construction)	Older building typologies tend to be more energy-intensive, needing energy renovation and reconstruction to achieve energy performance standards defined in the current legislation [24].
	Type of heating equipment	Along with its energy carrier, varying efficiency rates, and infrastructure, it influences the cost of adequate heating, with impacts on air quality [86].
Climate zone	Heating degree-days (HDDs)	A difference between the outside daily temperature (if lower than 15 °C) and the value of 18 °C [81]. It is another factor also determining the amount of energy necessary to obtain appropriate indoor temperature, and it is bound to increase due to climate change [85]

Europe and its neighbouring countries display vast differences in demographics, climate, economy, and culture. This variability is shown through the selected indicators portraying significant EP determinants and consequences (Appendix A, Table A1). In this study, we covered populations from all across the economic wealth and purchasing power spectrum—from Israel and The Netherlands, with average incomes significantly above the EU average and GDP per capita, to Bosnia and Herzegovina and North Macedonia, having the lowest values for both indicators in Europe [87]. Taking the EU-SILC, we also focused on countries with different results on the EP proxy indicators—for instance, The Netherlands reported low percentages across all selected ones, and Slovakia, Greece, and Portugal recording worrying levels of reported inabilities to heat the home adequately warm. Table A1 in Appendix A displays the results for the EU-SILC selected EP proxy indicators and the EEPI indicator [69] at the national scale. The selected countries represent a range of proportions of people living in rural areas—from Israel (8.5%) and The Netherlands, with only 14.7% of inhabitants living in rural areas, to Bosnia and Herzegovina (B&H), where most of the population lives in rural areas. A total of 31 locations were analysed (Figure 1). A brief description of each country and the respective case-study locations are provided in Appendix A and Table A2.

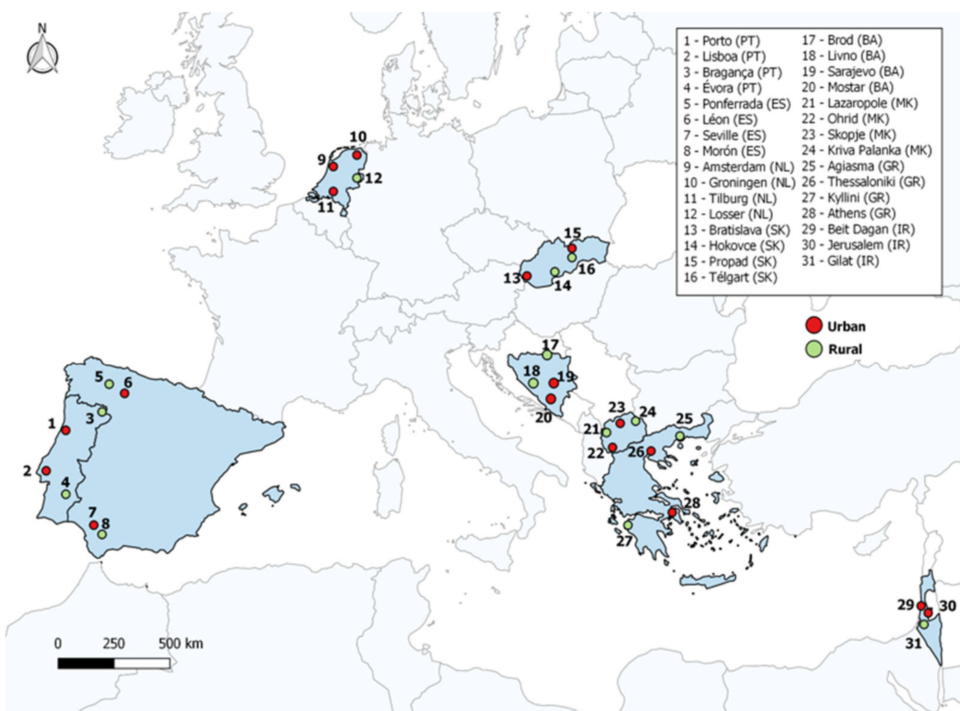


Figure 1. Map of the selected country locations and their climate zones. Source: Authors' elaboration.

4. Results

4.1. Urban–Rural Divide Informed by Sociodemographic Data

Lower-income households or groups associated with lower income such as those with an unemployed member, having achieved a lower educational level, or retired or disabled tend to be more vulnerable to EP. Although there is no clear-cut rural–urban divide regarding their location, significant socioeconomic status and demography differences have been observed in the selected countries (Table 2), and a greater proportion of the above-mentioned vulnerable groups resides in rural areas.

Table 2. Sociodemographic data for the 31 regions assessed.

Location	Urban/Rural	Unemployment Rate (%)	Average Monthly Income (€) per Household	Children under 5 Years Old (%)	Elderly Population 65+ (%)	Population with a University Degree (%)	Dwelling Ownership—Occupancy (%)	Social Housing Dwellings (%)
Sarajevo	U	28.10%	576	6.00%	16.00%	13.10%	n/a	
Mostar	U	34.60%	506.5	7.00%	18.00%	8.40%	n/a	
Brod	R	38.50%	453	4.00%	17.00%	2.60%	n/a	2.81%
Livno	R	39.60%	431.05	5.00%	13.00%	7.30%	n/a	
Athens	U	20.38%	1787	7.82%	24.47%	24.39%	56.72%	n/a
Thessaloniki	U	23.28%	1412	10.18%	22.52%	25.19%	62.68%	n/a
Kyllini	R	14.76%	1119	9.00%	28.13%	8.18%	81.53%	n/a
Agiasma	R	18.59%	1209	9.46%	28.84%	8.31%	82.88%	n/a
Jerusalem	U	5.1%	2630	12.50%	9.00%	25–5%	n/a	n/a.
Beit Dagan	U	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gilat	R	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Amsterdam	U	4.20%	2408.33	5.30%	12.70%	45.80%	29.91%	40.97%
Tilburg	U	4.00%	1966.67	4.70%	16.90%	29.10%	50.88%	33.05%
Groningen	U	5.40%	1941.67	4.20%	14.70%	38.00%	41.75%	34.20%
Losser	R	4.40%	2016.66	4.50%	25, 08%	22.70%	67.00%	25.00%
Skopje	U	29.00%	n/a	n/a	n/a	n/a	n/a	n/a
Ohrid	U	36.40%	n/a	n/a	n/a	n/a	n/a	n/a
Lazaropole	R	30.70%	n/a	n/a	n/a	n/a	n/a	n/a
Kriva Palanka	R	44.00%	n/a	n/a	n/a	n/a	n/a	n/a
Lisbon	U	5.60%	1579.20	4.40%	23.90%	26.80%	52.80%	2.10%
Porto	U	8.30%	1336.97	3.60%	23.20%	22.30%	50.70%	13.80%
Bragança	R	4.10%	951.2	2.10%	39.50%	5.90%	95.90%	1.90%
Évora	R	4.40%	1078.10	4.20%	26.90%	6.30%	70.00%	3.50%
Bratislava	U	4.50%	1348	7.70%	18.54%	27.20%	80.00%	1.00%
Poprad	U	(*) 7.08%	(*) 888	5.76%	17.05%	(*) 12.10%	91.00%	1.00%
Hokovce	R	(*) 6.82%	(*) 895	5.53%	20.29%	(*) 8.20%	99.00%	0.00%
Telgart	R	(*) 8.68%	(*) 820	8.36%	13.52%	(*) 9.97%	99.00%	0.00%
León	U	18.34%	1112.80	3.75%	23.38%	22.42%	74.85%	0.32%
Sevilla	U	24.54%	703.4	5.36%	17.10%	22.26%	82.55%	0.29%
Morón	R	24.16%	938.4	5.04%	16.71%	7.20%	87.76%	0.11%
Ponferrada	R	21.80%	945.5	4.14%	19.98%	15.03%	81.76%	0.32%

Note: * Data available only on a regional level. Data sources: B&H: [56], Greece: [88–91], Israel: [92], The Netherlands: [93] North Macedonia: [94], Portugal: [95], Slovakia: [96], Spain: [97].

The most common sociodemographic feature indicating vulnerability across countries is income. A clear pattern is observable here—income is higher in urban areas and lower in rural areas. This can be explained by urban areas having, in general, a higher living standard [98]. Similarly, the share of population with a university degree is also considerably higher in urban locations than in rural contexts. This is caused by residents in rural areas usually being employed in the agriculture sector, where university degrees for agricultural workers are not common [88,90]. However, the unemployment rate does not show a clear pattern. Southern countries (Greece and Portugal) report higher unemployment in urban areas, with higher employment in rural areas in sectors such as agriculture and tourism. Countries such as B&H and Slovakia show the opposite results, with higher unemployment in rural areas. Unemployment can be high in urban locations, which can be more detrimental than rural unemployment, as urban residents usually face higher living costs [99]. At the same time, ethnic origin is relevant in urban areas of North Macedonia and in both rural and urban locations in Israel. Therefore, for Israel, in particular, EP patterns should be observed following the Arab or Jew ethnic lines as their household incomes significantly differ, with the Jewish population being significantly wealthier [100]. Regarding the age structure, there was no uniform pattern; this varied among the countries or geographical regions. In countries like Spain, B&H, and Slovakia, the average rate of elderly people in the general population is identical in urban and rural locations. In contrast, higher percentages of people over 65 years can be found in rural locations in other countries like Portugal, Greece, and The Netherlands. The proportion of children under five years is, on average, very similar for the two territorial typologies for every country. Still, it must be noted that this proportion is changing in some countries due to the depopulation of rural areas, which is more prevalent for the younger generations [101]. Dwelling ownership is generally higher in rural areas.

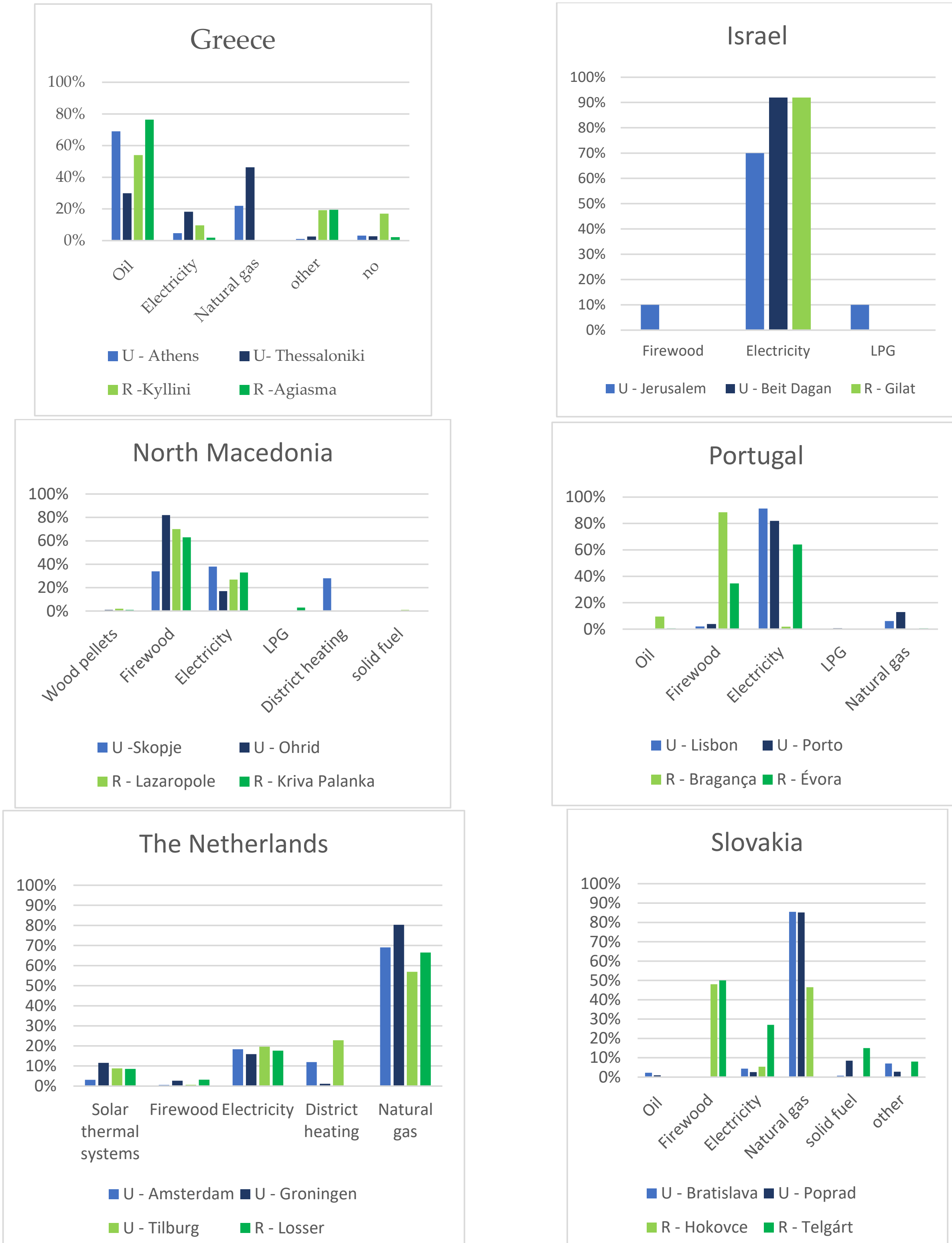
Vulnerability does not follow a clear pattern and has different expressions within the studied countries (Table 3). Nevertheless, the lower income and education levels in rural localities might comprise a more complex picture of vulnerability, with several significant EP determinants. Since data are generally scarcer in rural settings, hidden EP vulnerability situations can be more challenging to detect and should also be considered [102].

Table 3. Energy poverty vulnerability based on sociodemographic data in rural and urban locations.

Location	Sociodemographic characteristics that determine higher vulnerability (unemployment, income, elderly, children, university degree) .
Rural	Lower income (Spain, Portugal, B&H, Greece, North Macedonia, Slovakia), higher unemployment (Israel, Slovakia, B&H), higher share of elderly population (Portugal, Greece), lower education (Spain, B&H, Greece, The Netherlands, Portugal, Slovakia), lower availability of social housing (The Netherlands, Slovakia).
Urban	Higher unemployment (Greece, The Netherlands, North Macedonia, Portugal), elderly (B&H), single-parent (B&H, Portugal), single-person (North Macedonia), pensioners (North Macedonia), lower dwelling ownership (Greece, The Netherlands, Portugal, Slovakia) .

4.2. Urban-Rural Divide Informed by Housing Data

A common characteristic indicating energy vulnerability is the use of solid fuels such as fuelwood, due to their lower calorific value and a general indication of low efficient equipment. This energy carrier is predominant in rural areas in Portugal, Slovakia, and in rural and urban regions of North Macedonia (Figure 2). Fuelwood is often used as a result of poorly developed infrastructure such as missing gas pipelines or central heating [103–105]. However, despite being a cheap option for heating, fuelwood has spatial limitations, and unable to ensure fully heated spaces [106]. In some regions, even trash is utilised as fuel, which is observed in poor regions of Slovakia. The prevalence of solid fuels results in environmental harm, which is connected with worsened air quality and health problems for the inhabitants.


Greece
100%
80%
60%
40%
20%
0%
Oil
Electricity
Natural gas
other
no
U - Athens
U- Thessaloniki
R -Kyllini
R -Agiasma
Israel
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Firewood
Electricity
LPG
U - Jerusalem
U - Beit Dagan
R - Gilat
North Macedonia
100%
80%
60%
40%
20%
0%
Wood pellets
Firewood
Electricity
LPG
District heating
solid fuel
U -Skopje
U - Ohrid
R - Lazaropole
R - Kriva Palanka
Portugal
100%
80%
60%
40%
20%
0%
Oil
Firewood
Electricity
LPG
Natural gas
U - Lisbon
U - Porto
R - Bragança
R - Évora
The Netherlands
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Solar thermal systems
Firewood
Electricity
District heating
Natural gas
U - Amsterdam
U - Groningen
U - Tilburg
R - Losser
Slovakia
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
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Oil
Firewood
Electricity
Natural gas
solid fuel
other
U - Bratislava
U - Poprad
R - Hokovce
R - Telgárt

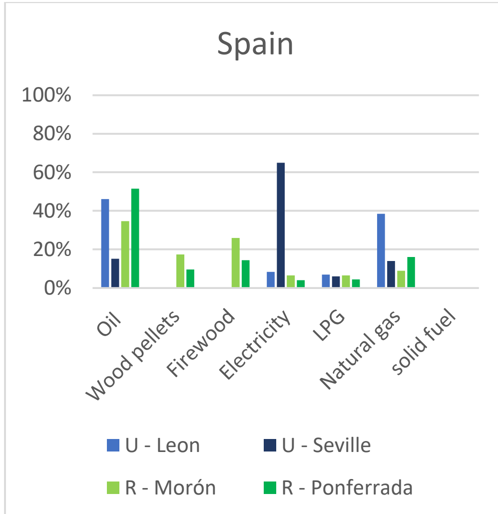

Figure 2. Sources of heating in the domestic sector. Sources: Greece: [90], Israel: [107], North Macedonia: [103], Netherlands: [108], Portugal: [109], Slovakia: [96], Spain (own elaboration from [97,110]).

Regarding the building stock, the share of buildings per age of construction varied. In rural areas (the only exception being Slovakia), there was a higher proportion of newer buildings built after 1990 and 2000 compared to urban locations. In some countries such as Spain and The Netherlands, the situation varied across the rural locations, possibly being correlated with regional localisation rather than territorial type (Figures 3 and 4). In Spain, the northern–southern 'divide' is more relevant, whereas the southern regions are more energy vulnerable because there is a higher share of dwellings with a G rating (the lowest energy efficiency), despite having a milder climate [111]. In The Netherlands, there is well-developed social housing in urban and rural communities [93] that accommodates people with lower incomes.

Single-family houses, the dwelling types with the highest heating needs, are often located in rural areas. Dwellings with old appliances and less insulation are also often found in rural locations. However, Greece's southern regions (either rural or urban) have a lower dwelling quality.

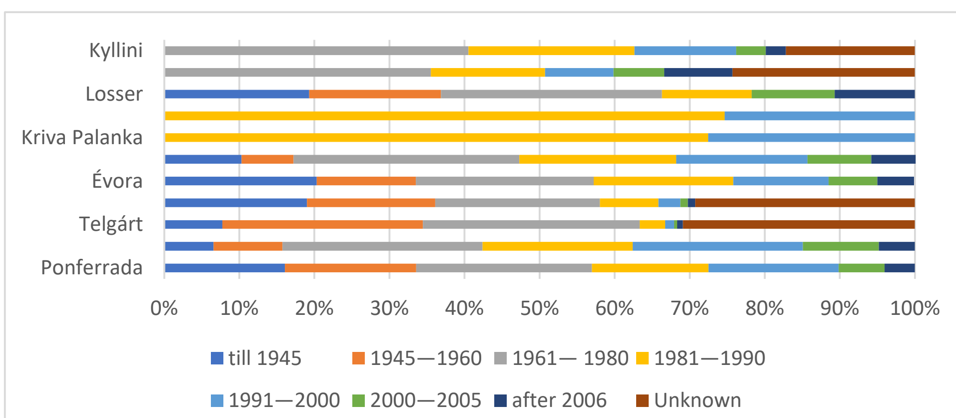

Figure 3. Share of the building stock per age of construction in each rural location.

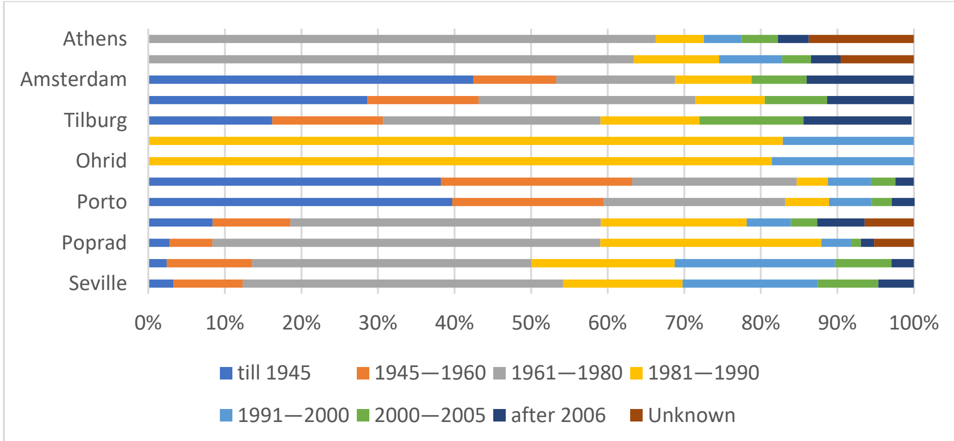

Figure 4. Share of the building stock per age of construction in each urban location. Sources for Figures 3 and 4: Greece: [90], The Netherlands: [93], North Macedonia: [103], Portugal: [95], Slovakia: [96], Spain: [97]. Note: There were slight differences among reporting when comparing the countries. In B&H and The Netherlands, the buildings mentioned as those built until 1945 were built until 1940. The breaking points in The Netherlands were 1945 and 1965. The buildings in North Macedonia were reported in two groups, with a breaking point in 1991, thus buildings reported between 1981–1990 were actually reported as built before 1991. In Portugal, Spain, and Slovakia, data "after 2006"contain data for 2006–2011.

Based on the EU Directive 2002/91/EC and its 2018 revision on the energy efficiency of buildings, EPCs are required for all retrofitted, newly built buildings or those for sale. The Netherlands is the only country where all e buildings have an EPC. In the other researched countries, there is a very high proportion of buildings without EPCs: 75–95% in rural areas, with some locations without any EPCs issued (Hokovce and Telgárt in Slovakia). Some countries in our analysis (B&H, Israel, North Macedonia) do not report EPC data. A low ratio of highly EPC-rated buildings is directly connected with a low energy efficiency of dwellings, supporting the idea that the building stock in rural locations has generally worse energy performance (Table 4).

Table 4. Residential building stock energy performance by country and location.

Country	Location		With EPC							No EPCs	Source
			A	B	C	D	E	F	G		
Greece	Athens	U	0.04%	1.40%	7.80%	13.47%	15.22%	24.69%	37.39%	49.21%	[112,113]
	Thessaloniki	U	0.05%	2.59%	13.04%	21.55%	20.26%	14.77%	27.73%	42.19%	
	Kyllini	R	0.00%	0.70%	6.96%	12.99%	16.47%	15.78%	47.10%	95.69%	
	Agiasma	R	0.20%	5.36%	10.27%	22.14%	16.73%	10.19%	35.11%	75.56%	
The Netherlands	Amsterdam	U	23.67%	16.30%	24.15%	16.95%	9.63%	5.04%	4.24%	0.00%	[114]
	Groningen	U	24.63%	15.27%	29.41%	15.60%	7.79%	3.90%	3.40%	0.00%	
	Losser	U	26.46%	17.20%	29.36%	12.25%	6.47%	3.88%	4.38%	0.00%	
	Tilburg	R	30.09%	16.21%	25.26%	13.35%	8.22%	4.31%	2.55%	0.00%	
Portugal	Lisbon	U	10.53%	18.42%	28.95%	26.32%	13.16%	5.26%	0.00%	62.00%	[115]
	Porto	U	12.20%	29.27%	24.39%	19.51%	9.76%	4.88%	0.00%	59.00%	
	Bragança	R	25.00%	25.00%	12.50%	12.50%	12.50%	12.50%	0.00%	84.00%	
	Évora	R	5.00%	15.00%	20.00%	30.00%	20.00%	10.00%	0.00%	80.00%	
Slovakia	Bratislava	U	19.57%	36.96%	32.61%	8.70%	0.00%	0.00%	2.17%	99.54%	[116]
	Poprad	U	30.88%	26.47%	20.59%	11.76%	7.35%	0.00%	2.94%	98.64%	
	Hokovce	R	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100%	
	Telgart	R	0.00%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	99.01%	

Spain	Leon	U	1.11%	1.04%	4.44%	14.07%	55.72%	11.02%	12.61%	85.57%	[97,117]
	Seville	U	0.43%	1.71%	4.09%	10.36%	53.62%	9.76%	20.03%	76.54%	
	Morón	R	0.43%	1.71%	4.09%	10.36%	53.62%	9.76%	20.03%	76.54%	
	Ponferrada	R	1.11%	1.04%	4.44%	14.07%	55.72%	11.02%	12.61%	85.57%	

Note: No EPC data were found for the Spanish localities, so the table shows the regional EPC shares as a proxy of the local ones.

Energy vulnerable households tend to more often live in social housing, older buildings, poorly insulated, larger dwellings, those equipped with old and inefficient appliances and heating technologies, not fully heated, and use oil and fuelwood (Table 5). Although there was a high variability of characteristics across the locations, a higher number of vulnerable features were located in rural areas. However, some of the housing features linked with energy vulnerability could also be found in urban areas.

Table 5. Energy poverty vulnerability in rural and urban locations based on housing data.

Housing Characteristics	Bosnia and Herzegovina	Greece	Israel	The Netherlands	North Macedonia	Portugal	Slovakia	Spain
Prevalent use of fuelwood					R + U	R	R	
Use of oil for heating		R						
Less efficient heating and appliances	R							
Poorer dwelling insulation		R			R			
Reduced heated space in dwellings					R			
Lower share of EPC							R	
Higher share of house typology					R	R	R	R
Older buildings *		R		U	U	U	R	
Lower owner occupancy		U	U	U		U	U	U
Higher amount of social housing **			U			U	U	

Note: * Age of the buildings need not indicate EP, only in combination with low energy efficiency. ** Social housing can stabilise the situation of energy poor households and is not necessarily considered as a factor determining vulnerability.

4.3. Climate Change Effects on Rural and Urban Energy Vulnerability

Figure 5 shows the variation in heating degree-days between 2020 and 2050, portraying the effect of climate change on the temperature levels and energy demand. The calculated future HDDs indicate that there can be an expected change in temperature and corresponding heating demand until 2050 in a range between −2% and −40% at our selected locations and a subsequent decrease in climate-related EP vulnerability in the winter. The mildest change is expected in the locations in The Netherlands (−2.2% in HDDs in Amsterdam—a coastal area). The most significant increase in winter temperature may occur in the southern Mediterranean countries, with the following decrease in HDDs between

2020 and 2050: −39.8% in Kyllini (rural Greece), −36.1% in Lisbon (urban Portugal), and −33.5% in Morón (urban Spain). The greatest reduction in absolute values of heating need is expected in Telgárt (rural Slovakia), where the HDDs will decrease by 14% (615 HDDs), whereas almost no change is expected to occur in Bet-Dagan (37 HDDs decrease). The decrease is connected to lower vulnerability, but it is relevant to mention that, on the other hand, these countries have significant expected increases in cooling degree-days, with an increased summer energy vulnerability of households [43].

In overview, it is anticipated that by 2050, there will be a decrease in HDDs in both the selected urban and rural areas. However, the change is forecasted to be more considerable in rural areas. On average, there is an expected decrease of 16.8% in rural areas and a 13.7% decrease in urban areas. Nevertheless, the heating demand will still be higher in rural regions, with an expected average level of HDDs of 1931 in rural locations and 1743 in urban locations in 2050. A few outliers showed that the HDD change will be minimal (lower than 5%) in urban locations in The Netherlands, while urban locations in North Macedonia will experience a higher decrease in HDDs than rural ones. In comparison, the decrease in Portugal will be higher in the southern locations of the country. Overall vulnerability related to climate and energy demand might decrease in rural locations, but it might not be enough to make them less vulnerable than urban locations, as they will still register higher HDD figures. Thus, people living in rural areas will still have higher energy needs to warm their homes and avoid cold exposure.

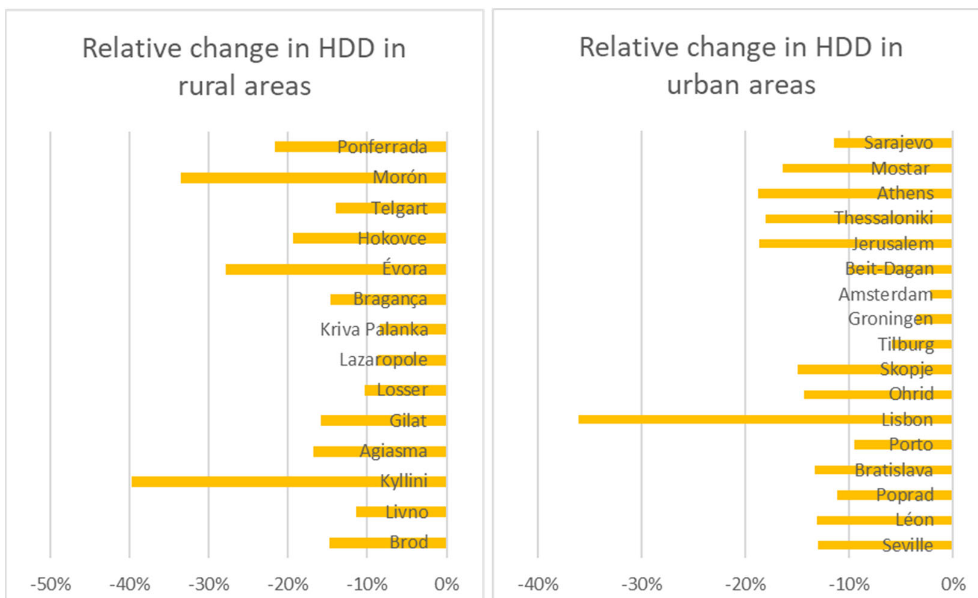

Figure 5. Relative change in HDDs between 2020 and 2050 in rural and urban areas. Source: Own computation based on Meteonorm.

5. Discussion

The results show that although there is no clear-cut conclusion to be made across all assessed locations, rural households tend to be more vulnerable to EP due to a combination of multiple factors such as lower incomes, low education levels, more widespread material deprivation, fewer options for modern heating, and lower dwelling quality. However, in a few cases, particular spatially manifested and extenuating characteristics should be taken into account such as the lower need for disposable income due to the availability of local resources, a higher ownership of dwellings, and cheaper options for heating such as fuelwood [9]. Fuelwood is indeed an important resource for poverty alleviation [79,106,118], as seen in locations in Portugal, Slovakia, and North Macedonia. However, although it can be an inexpensive fuel and a viable option to face EP, it can, on the other hand, create problems regarding air quality due to the low-efficient and polluting equipment that is frequently used in these settings, thus potentially contributing to health diseases.

The private rental sector is usually more developed in urban areas [59], with increased living costs contributing to the vulnerability of urban areas to EP, at least from an economic perspective. This effect could be alleviated through social housing, as seen in The Netherlands, where EP is less prevalent. On the other hand, in rural areas, given that income is constant but lower, and the dwellings are larger and more inefficient, an increase in energy prices could impact their vulnerability more considerably than in urban areas, as also discussed by Roberts et al. [119]. This is especially relevant for countries still undergoing the energy liberalisation process [8], or are trapped in a monopolised energy market [120]. Furthermore, higher vulnerability population segments, such as the elderly and less educated people are more present in rural areas. The results point to a potentially more persistent and long-term situation of vulnerability to EP in rural locations in contrast to the higher possibility of urban households exiting a situation of EP. This is due to the expression of multiple drivers of EP, such as population age, education level, and the lower quality of dwellings, which can be challenging to overturn. An especially crucial factor tends to be the missing heating infrastructure, leaving households in rural areas with limited (modern) options for heating, as highlighted in [121,122]. Recognising this category of vulnerable groups, such as the rural population is urgent as well as the specific targeting of measures [16,123]. However, we also point out that in some cases, there is more of a regional rather than rural–urban 'divide', for example, more southern regions in Greece and Spain have a higher energy vulnerability. On the other hand, the absence of a sharp 'divide' between regions or locations in The Netherlands can be explained by more regionally equitable housing policies such as widely distributed social housing.

It is also important to emphasise that the various expressions of EP determinants in rural and urban contexts point to different EP profiles amongst the population in these territorial typologies (i.e., population groups with different characteristics and vulnerability factors). For example, this can refer to the elderly as a common vulnerable group as well as ethnic minorities in Israel. The diversity of vulnerable groups calls for different policy approaches concerning identifying and implementing strategies for socioeconomic engagement and problem mitigation.

Climate change will impact outside temperatures, subsequently influencing the energy necessary to reach comfortable temperature levels inside homes. In the winter season, as this paper showed, the temperature is anticipated to increase, thus the heating demand is expected to decrease in almost all locations, with geographic variations. Despite a higher expected decrease in heating demand within rural areas, their heating demand will remain higher in absolute terms, and overall EP drivers might continue to make rural areas more exposed to EP, if the socioeconomic, demographic, and infrastructural landscapes remain identical in the future. On the other hand, a decreased heating energy demand is accompanied by an increased summer energy demand [43], which must be considered when assessing EP more comprehensively. Thus, the overall vulnerability levels might shift, but not decrease. Moreover, given the diverse territorial results presented in this paper, it might be inferred that geography is a key factor to consider when designing climate vulnerability mitigation policies, as it can be a determining factor for climate change impact.

Eventually, rural and urban settlements have specific characteristics that result in different EP levels. It is important to investigate them more deeply, focusing on the variation of determinants across these different types of settlements, as policy effectiveness is connected to how schemes address the most relevant causes and drivers and whom they target. Regional specificity and nuanced assessments are vital for improving the outcomes of policy instruments.

We acknowledge that due to the aim of the research, we did not go into detail when exploring all contextual factors contributing to EP, but we intended to present a crosscountry and within-country (rural–urban) comparison of EP determinants and the estimation of future climate change-caused deterioration of winter EP. The results aim to illustrate whether rural or urban regions in the studied locations will be more vulnerable, and what are their driving characteristics. Some of the limitations we had to face when preparing the study included up-to-date and available regional and local data missing. Due to these unavailable indicators, we used proxies. Additionally, the article should be considered as a baseline study as the data refer to the period before COVID-19 and the energy crises, not referring to the most current situation.

6. Conclusions

While several policies are being implemented in the EU to tackle EP, the targeting of these policies needs improvement to better address EP [13]. The current policy framework mainly covers bill support, often with scarce effectiveness [124], or the promotion of energy efficiency [125], and partly neglects other dimensions for reducing EP mitigation such as the impact of territorial and geographical settings on vulnerability-causing factors. This is partly justified by the limited understanding of the determinants of household energy consumption owning to the complex interplay of socioeconomic, cultural, and lifestyle factors (likely between urban and rural areas) that vary across countries and within a single country [30,126,127].

This article studied the EP determinants in eight countries and thirty-one locations, exploring the rural–urban divide of energy vulnerability and estimating how climate change would affect this divide in winter by 2050. The work presented herein shows spatial variations of EP determinants in different European and territorial contexts. This study confirms that those in the geographical core of Europe are less vulnerable than those on the geographical periphery, in line with previous studies [8]. Additionally, this work goes further by shedding light on the spatial variation within countries across territorial typologies. The multidimensionality of the problem of EP makes the urban vs. rural conclusion difficult to clearly distinguish. A key factor is the level of regional development manifested by the income level and technical conditions of the dwellings—the degree of thermal insulation and renovation, which are not uniform within the studied countries in the urban and rural contexts. These two characteristics have been identified as key EP determinants, thus, the paper's analysis makes it possible to identify areas in the analysed countries that are potentially more vulnerable to this issue.

Indeed, the indicators point to higher EP vulnerability levels in rural locations due to the lower income level of the local population, lower level of education, older age, and the potentially higher heating demand related to older and bigger dwellings with less efficient heating systems. These vulnerability factors are arguably not offset by a higher predicted decrease in heating demand, with the 2050 forecasted HDD values still being higher in rural areas. These findings highlight the need for tailor-made policies for tackling vulnerability in this territorial typology (such as mobile one-stop shops with technical assistance for rural areas), accounting for the specific expression of EP determinants in these locations. This does not exclude the need to focus on urban areas, which have characteristics that can be conducive to EP. In some countries, higher unemployment rates or lower levels of owner-occupied dwellings are common in urban areas. The temporal and spatial variation of determinants and different nuances across these different types of territories should be considered in policymaking at the regional level to increase the schemes' effectiveness in targeting the vulnerable population.

While this study investigated the spatial variation of all indicators, the temporal variation was limited to the climatic indicators, an identified shortcoming caused by the lack of data [20] on future socioeconomic and infrastructural development scenarios at this scale of study. Another limitation is the selection of locations, which might not have fully represented each country. It would have been preferable to guide the selection by comparing the indicators of locations to average national urban and rural country characteristics. However, these data are not available for several countries. This also unveils the need for more regular data collection to better understand regional EP diversity in different territorial contexts. As climate change affects not only temperature in the winter but also in the summer, and people are becoming exposed to higher temperatures and excess heat with an increased difficulty in cooling their houses, follow-up research could focus on the analysis of EP determinants in light of future summer cooling demand in urban and rural areas.

Author Contributions: Conceptualisation, D.D., A.S., P.P., and J.P.G.; Methodology, D.D., A.S., P.P., and J.P.G.; Validation, D.D.; Formal analysis, D.D.; Investigation, D.D. and A.S.; Resources, D.D., A.S., P.P., J.P.G., E.G.P., R.B., M.F., A.H., C.S.-G., J.K., M.T., N.S.T., and T.A.H.; Data curation, D.D. and A.S.; Writing—original draft preparation, D.D.; Writing—review and editing, D.D., A.S., P.P.; J.P.G., R.B., E.G.P., M.F., A.H., M.T. and J.K, Visualisation, D.D. and P.P.; Supervision, D.D.; Funding acquisition, D.D., J.K., J.P.G. and A.S. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: All data used in this paper are mentioned in the references and are publicly available.

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Appendix A

Table A1. Selected indicators for EP assessment.

Country	Population (Millions) (2020) [128]	Share of Population Living in Rural Areas (%) (2015) [129]	Real GDP Per Capita at Market Prices (EUR) (2019) [87]	Domestic EEPI (European Energy) Poverty Index) [69]	Arrears on Utility Bills (%) (2019) [130]	Inability to Keep Home Adequately Warm * (%) (2019) [1]	Population in Dwellings with Leaking Roofs * (%) (2019) [2]
Bosnia and Herzegovina	3.5 [131]	57.3 [131]	5217 [131]	n/a	n/a	n/a	n/a
Greece	10.7	34.5	17,750	43.69	32.5	17.9	12.5
The Netherlands	17.4	14.7	41,870	78.09	1.5	3	14.7
North Macedonia	2.1	n/a	4130 (2018)	n/a	34.4	33.1	13.9
Portugal	10.3	26.8	18,630	36.67	4.3	18.9	24.4
Slovakia	5.5	41.8	15,860	8.35	8.4	7.8	5.7
Spain	47.3	26.5	25,200	64.67	6.5	7.5	14.7
Israel	9.1[132]	8.5 [132]	36,644 [133]	n/a	40.5% [134]	38.5 [135]	n/a
European average	447.3	29	28,020	n/a	6.2	7.3	12.7

Note: Common data sources are at the heading of the table, country specific with the brackets at the cells. * Total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor.

Table A2. Basic characteristics of the selected locations.

Country	Location	Type of Location	Population (Inhabitants)	Köppen Climate Classification	Population Density (Inhabitants/km²)	Heating Degree Days (Own Elaboration from [136]
Bosnia and Herzegovina	Sarajevo	Urban	274,879	Cfb	166	2933
	Mostar	Urban	105,797	Cfb	91	1610
	Brod	Rural	17,943	Csb	76	2572
	Livno	Rural	34,133	Csb	35	3017
Greece	Athens	Urban	664,046	Csa	17,043	1422
	Thessaloniki	Urban	325,182	Bsk	18,251	1653
	Kyllini	Rural	21,581	Csa	61	1115
	Agiasma	Rural	22,331	Bsk	33	1727
Israel	Jerusalem	Urban	936,425	Bsh	7428	1194
	Beit Dagan	Urban	7285	Bsh	5131	374
	Gilat	Rural	1451	Csa	n/a *	325
The Netherlands	Amsterdam	Urban	862,965	Cfb	3935	2587
	Groningen	Urban	231,299	Cfb	2762	2903
	Tilburg	Urban	220,513	Cfb	1867	2645
	Losser	Rural	22,622	Cfb	227	2844
North Macedonia (2002)	Skopje	Urban	506,926	Cfa	over 500	2535
	Ohrid	Urban	55,749	Csa	100–499	2755
	Lazaropole	Rural	0 *	Csa	0 **	3651
	Kriva Palanka	Rural	20,820	Dwa	20–49	2705
Portugal	Lisbon	Urban	509,515	Csa	5092	905
	Porto	Urban	216,606	Csb	5230	1179
	Bragança	Rural	33,607	Csb	29	2250
	Évora	Rural	52,428	Csa	40	1307
Slovakia	Bratislava	Urban	440,948	Cfb	1199	2774
	Poprad	Urban	50,998	Dfb	808	4041
	Hokovce	Rural	495	Cfb	34	3047
	Telgárt	Rural	1519	Dfb	27	4403
Spain	Léon	Urban	131,411	Csb	3365	2364
	Seville	Urban	698,042	Csa	4956	659
	Ponferrada	Rural	68,383	Csb	241	2194
	Morón	Rural	28,389	Csa	66	900

Note: Koppen Climate Classification: Bsh—Hot semi-arid, Bsk—Cold semi-arid, Cfa—Humid subtropical, Cfb—Oceanic, Csa—Mediterranean hot summer, Csb—Mediterranean warm/cool summer, Dfb—Warm summer humid continental, Dwa—Hot summer humid continental. Sources: B&H: [131,137], Greece: [88,90] (own calculation from census 2011 population and locality's surface (km²) by census 2001), Israel: [92] (*—kibbutz–data not reported), The Netherlands: [138], North Macedonia: [139,140] (**—there are 40 houses at this location but its citizens are officially registered in other locations nearby, thus is reported as uninhabited in the statistics), Portugal: [95], Slovakia: [141], Spain: [97] (own calculation from Census 2011 and locality's surface (km²)).

Description of the case study locations.

Bosnia and Herzegovina (B&H): A country in south-east Europe located in the western part of the Balkan Peninsula. The selected locations for the country were the following: Sarajevo, the capital and largest city of B&H; Mostar, located in the south of the country, on the banks of the Neretva River, which is the cultural and economic centre of Herzegovina; Livno, a town in the southwestern part of B&H lying at 725 m above sea level, mainly on the slopes and at the foot of the hill Bašajkovac. It is widely known for dairy, horse stables, rivers rich in noble fish and crabs, and livestock production; and Brod, in the north-eastern part of the country, is known for agriculture and industries (oil refinery, furniture factories, and textiles).

Greece: Located in the south-eastern part of Europe. The four selected locations in Greece were Athens, the capital and economic centre of the country, where, according to the Hellenic Statistical Authority [88], the majority of the economically active population (66%) works in the tertiary sector; Thessaloniki, the other urban area, selected for analysis and the second-largest city in the country, where the majority of the population works in the tertiary sector (65%); Kyllini, a south-western rural coastal area, where the economically active population works mainly in the primary and tertiary sector activities (39% and 37%, respectively); and Agiasma, the other rural location in the northern part of Greece, with an economy relying mainly on primary and tertiary sector activities.

Israel: Located in the Middle East, on the coast of the Mediterranean. In Israel, a distinction is made between central and peripheral locations, considered urban and rural locations in this study. According to the Israeli Central Bureau Statistics [100], peripheral locations are distant from amenities or existing assets in all areas including the area itself. The following locations were selected as case studies: Jerusalem, the capital of Israel, the biggest city, and a major urban centre; Gilat, a rural community in southern Israel, is located in the Negev Desert, where one-third of the population works in agriculture; and Bet-Dagan is a town located in the central district of Israel and is the home of the Israel Meteorological Service.

The Netherlands: Located in Western Europe, known for its strong economy, with one of the highest GDP per capita in the EU. The four examined locations reflect the different regions in The Netherlands: Amsterdam, the capital, the largest city of the four and situated in the west of the country; Tilburg, located in the more southern part of The Netherlands and a considerably more rural surrounding compared to Amsterdam; Losser, situated in the far east on the border with Germany, a relatively small municipality with a rich history in the textile industry, similar to Tilburg; and Groningen, positioned in the north of The Netherlands, the biggest town in this more rural area.

North Macedonia: Located in south-east Europe. The following locations were selected as case studies: Skopje, an urban centre and the capital of North Macedonia, where the country's industrial, trade, and service capacities are concentrated; Ohrid, the second largest urban area located in the south-west region, known for tourism; Kriva Palanka, a rural area representing the north-east region, which offers an opportunity for work in the meat and dairy processing industry; and Lazaropole, a rural area located in the Polog region that relies heavily on agriculture.

Portugal: The westernmost country in Europe. The chosen locations were Lisbon, which is the capital city and the most relevant economic centre of Portugal; Porto, the second biggest city and also an important business centre; Bragança, a town in the north-east, located in a mountainous region with colder winters and an economy mainly based on primary sector activities and several rural civil parishes; and Évora, situated in the south-east, and is also constituted by several plain rural areas outside the city area, with agriculture and animal farming playing a major role in the region's economy and people's way of life.

Slovakia: A small central European country with significant regional socioeconomic differences (GDP, income, unemployment). The following locations were analysed: Bratislava, the capital city, the most economically developed region in the country; Poprad, situated under mountains, being the coldest town in the country and one of the most exposed to winter weather extremes; Hokovce, located in the central-southern part close to the border with Hungary, where inhabitants are employed by the local spa or agriculture; and Telgárt, a small mountain village, where most inhabitants work in forestry, agriculture, and tourism.

Spain: A southern European country characterised by a varied climate. The chosen locations were the following: Seville, the capital of Andalusia, one of the country's poorest regions located in the south; Leon, a city situated in the northern region of the Castile and Leon regions, is among the coldest towns and one of the most exposed to winter weather extremes; Morón, a village of Andalusia in the province of Seville, mainly relying on the service and agriculture sectors [142]; and Ponferrada, a small town situated in the province of Leon, a richer area whose economy is based on the service sector.

References

1. Eurostat. Inability to Keep Home Adequately Warm; Eurostat: Luxembourg, 2022.
2. Eurostat. Total Population Living in a Dwelling with a Leaking Roof, Damp Walls, Floors or Foundation, or Rot in Window Frames or Floor; Eurostat: Luxembourg, 2021.
3. Bouzarovski, S.. Energy Poverty: (Dis) Assembling Europe's Infrastructural Divide; Palgrave Macmillan: London, UK, 2018.
4. EuroMOMO. Winter Season 2016/17 Mortality Summary; EuroMOMO: Copenhagen, Denmark, 2021.
5. Stojilovska, A.; Guyet, R.; Mahoney, K.; Gouveia, J.P.; Castaño-Rosa, R.; Živčič, L.; Barbosa, R.; Tkalec, T. Energy Poverty and Emerging Debates: Beyond the Traditional Triangle of Energy Poverty Drivers. *Energy Policy* **2022**, *169*, 113181.
6. Simcock, N.; Walker, G.; Day, R. Fuel Poverty in the UK: Beyond Heating? *People Place Policy* **2016**, *10*, 25–41.
7. Bouzarovski, S.; Thomson, H. Transforming Energy Poverty Policies in The European Union; European Commission: Luxembourg, 2019.
8. Bouzarovski, S.; Tirado Herrero, S. The energy divide: Integrating energy transitions, regional inequalities and poverty trends in the European Union. *Eur. Urban Reg. Stud.* **2017**, *24*, 69–86.
9. Scarpellini, S.; Hernández, M.A.S.; Moneva, J.M.; Portillo-Tarragona, P.; Rodríguez, M.E.L. Measurement of spatial socioeconomic impact of energy poverty. *Energy Policy* **2019**, *124*, 320–331.
10. Brereton, F.; Bullock, C.; Clinch, J.P.; Scott, M. Rural change and individual well-being: The case of Ireland and rural quality of life. *Eur. Urban Reg. Stud.* **2011**, *18*, 203–227.
11. Horlings, L.G.; Marsden, T.K. Exploring the 'New Rural Paradigm' in Europe: Eco-economic strategies as a counterforce to the global competitiveness agenda. *Eur. Urban Reg. Stud.* **2014**, *21*, 4–20.
12. Dobbins, A.; Nerini, F.F.; Deane, P.; Pye, S. Strengthening the EU response to Energy Poverty. *Nat. Energy* **2019**, *4*, 2–5.
13. Pye, S.; Dobbins, A.; Baffert, C.; Brajković, J.; Grgurev, I.; De Miglio, R.; Deane, P.; Lapillone, B. Energy poverty and vulnerable consumers in the energy sector across the EU: Analysis of policies and measures, in INSIGHT_E 2015. *L'Eur. For.* **2014**, *4*, 64–89.
14. EPOV, Energy Poverty Observatory. *Guidance for Policy-Makers*; EPOV, Energy Poverty Observatory: Brussels, Belgium, 2020.
15. Thomson, H.; Snell, C. Quantifying the prevalence of fuel poverty across the European Union. *Energy Policy* **2013**, *52*, 563–572.
16. Walker, G.; Day, R. Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. *Energy Policy* **2012**, *49*, 69–75.
17. Feenstra, M.; Middlemiss, L.; Hesselman, M.; Straver, K.; Herrero, S.T. Humanising the Energy Transition: Towards a National Policy on Energy Poverty in The Netherlands. *Front. Sustain. Cities* **2021**, *3*, 645624.
18. Teschner, N.; Sinea, A.; Vornicu, A.; Abu-Hamed, T.; Negev, M. Extreme energy poverty in the urban peripheries of Romania and Israel: Policy, planning and infrastructure. *Energy Res. Soc. Sci.* **2020**, *66*, 101502.
19. IPCC. *Climate Change 2022. Impacts, Adaptation and Vulnerability*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; 3056p. https://doi.org/10.1017/9781009325844.
20. Thomson, H.; SBouzarovski; Snell, C. Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data. *Indoor Built Environ.* **2017**, *26*, 879–901.
21. Tirado-Herrero, S. Energy poverty indicators: A critical review of methods. *Indoor Built Environ.* **2017**, *26*, 1018–1031.
22. Rademaekers, K.; Yearwood, J.; Ferreira, A.; Pye, S.; Hamilton, I.; Anisimova, P.; Grover, D.; Karásek, J. *Selecting Indicators to Measure Energy Poverty*; Trinomics: Rotterdam, The Netherlands, 2016.
23. Kyprianou, I.; Serghides, D. Dealing with energy poverty in Cyprus—An overview. *Int. J. Sustain. Energy* **2020**, *39*, 308–320.
24. Santamouris, M.; Alevizos, S.; Aslanoglou, L.; Mantzios, D.; Milonas, P.; Sarelli, I.; Karatasou, S.; Cartalis, K.; Paravantis, J. Freezing the poor—Indoor environmental quality in low and very low-income households during the winter period in Athens. *Energy Build.* **2014**, *70*, 61–70.
25. Ayikoe Tettey, U.Y.; Gustavsson, L. Energy savings and overheating risk of deep energy renovation of a multi-storey residential building in a cold climate under climate change. *Energy* **2020**, *202*, 117578.
26. Pérez-Andreu, V.; Aparicio-Fernández, C.; Martínez-Ibernón, A.; Vivancos, J.L. Impact of climate change on heating and cooling energy demand in a residential building in a Mediterranean climate. *Energy* **2018**, *165*, 63–74.
27. Gouveia, J.P.; Seixas, J.; Palma, P.; Duarte, H.; Luz, H.; Cavadini, G.B. Positive Energy District: A model for Historic Districts to address Energy Poverty. *Front. Sustain. Cities* **2021**, *3*, 648473.
28. Barrella, R.; Priego, I.; Linares, J.I.; Arenas, E.; Romero, J.C. Feasibility Study of a Centralised Electrically Driven Air Source Heat Pump Water Heater to Face Energy Poverty in Block Dwellings in Madrid (Spain). *Energies* **2020**, *13*, 2723.
29. Palma, P.; Gouveia, J.P.; Simoes, S.G. Mapping the energy performance gap of dwelling stock at high-resolution scale: Implications for thermal comfort in Portuguese households. *Energy Build.* **2019**, *190*, 246–261.

30. Horta, A.; Gouveia, J.P.; Schmidt, L.; Sousa, J.C.; Palma, P.; Simões, S. Energy poverty in Portugal: Combining vulnerability mapping with household interviews. *Energy Build.* **2019**, *203*, 109423.
31. Niamir, L.; Ivanova, O.; Filatova, T.; Voinov, A.; Bressers, H. Demand-side solutions for climate mitigation: Bottom-up drivers of household energy behavior change in The Netherlands and Spain. *Energy Res. Soc. Sci.* **2020**, *62*, 101356.
32. Bouzarovski, S. Energy poverty in the European Union: Landscapes of vulnerability. *Energy Environ.* **2013**, *3*, 276–289.
33. Lin, J. Affordability and access in focus: Metrics and tools of relative energy vulnerability. *Electr. J.* **2018**, *31*, 23–32.
34. Llera-Sastresa, E.; Scarpellini, S.; Rivera-Torres, P.; Aranda, J.; Zabalza-Bribián, I.; Aranda-Usón, A. Energy vulnerability composite index in social housing, from a household energy poverty. *Sustainability* **2017**, *9*, 19–21.
35. Sánchez-Guevara, C.; Peiró, M.N.; González, J.N. Urban Heat Island and Vulnerable Population. The Case of Madrid. *Energy Build.* **2017**, *190*, 132–143.
36. Papada, L.; Kaliampakos, D. A Stochastic Model for energy poverty. *Energy Policy* **2018**, *116*, 153–164.
37. Besagni, G.; Borgarello, M. The socio-demographic and geographical dimensions of fuel poverty in Italy. *Energy Res. Soc. Sci.* **2019**, *49*, 192–203.
38. Gouveia, J.P.; Palma, P.; Simoes, S. Energy Poverty vulnerability index: A multidimensional tool to identify hotspots for local action. *Energy Rep.* **2019**, *5*, 187–201.
39. Sanchez-Guevara, C.; Peiró, M.N.; Taylor, J.; Mavrogianni, A.; González, J.N. Assessing population vulnerability towards summer energy poverty. Case studies of Madrid and London. *Energy Build.* **2019**, *190*, 132–143.
40. März, S. Assessing the fuel poverty vulnerability of urban neighborhoods using a spatial multi-criteria decision analysis for the German city of Oberhausen. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1701–1711.
41. Pérez-Fargallo, A.; Rubio-Bellido, C.; Pulido-Arcas, J.A.; Guevara-García, F.J. Fuel Poverty Potential Risk Index in the context of climate change in Chile. *Energy Policy* **2018**, *113*, 157–170.
42. Jessel, S.; Sawyer, S.; Hernández, D. Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature. *Front. Public Health* **2019**, *7*, 357.
43. Castaño-Rosa, R.; Barrella, R.; Sánchez-Guevara, C.; Barbosa, R.; Kyprianou, I.; Paschalidou, E.; Thomaidis, N.S.; Dokupilova, D.; Gouveia, J.P.; Kádár, J.; et al. Cooling Degree Models and Future Energy Demand in the Residential Sector. A Seven-Country Case Study. *Sustainability* **2021**, *13*, 2987.
44. Ramon, D.; Allacker, K.; De Troyer, F.; Wouters, H.; van Lipzig, N.P. Future heating and cooling degree days for Belgium under a high-end climate change scenario. *Energy Build.* **2020**, *216*, 109935.
45. Mancini, F.; Basso, G.L. How Climate Change Affects the Building Energy Consumptions Due to Cooling, Heating, and Electricity Demands of Italian Residential Sector. *Energies* **2020**, *13*, 410.
46. Mirasgedis, S.; Sarafidis, Y.; Georgopoulou, E.; Kotroni, V.; Lagouvardos, K.; Lalas, D.P. Modelling framework for estimating impacts of climate change on electricity demand at regional level: Case of Greece. *Conv. Manag.* **2007**, *48*, 1737–1750.
47. Vurro, G.; Santamaria, V.; Chiarantoni, C.; Fiorito, F. Climate change impact on energy poverty and energy efficiency in the public housing building stock of Bari, Italy. *Climate* **2022**, *10*, 55.
48. Silva, S.; Soares, I.; Pinho, C. Climate change impacts on electricity demand: The case of a Southern European Country. *Util. Policy* **2020**, *67*, 101115.
49. Damm, A.; Köberl, J.; Prettenthaler, F.; Rogler, N.; Töglhofer, C. Impacts of +2 °C global warming on electricity demand in Europe. *Clim. Serv.* **2017**, *7*, 12–30.
50. Costa-Campi, M.T.; Jové-Llopis, E.; Trujillo-Baute, E. La Pobreza Energética en España. Aproximación Desde una Perspectiva de Ingresos [Energy Povery in Spain. Aproximation from an Income Perspective]. Fundación Naturgy: Barcelona, Spain, 2019.
51. Hossain, B.; Sohel, M.S.; Ryakitimbo, C.M. Climate change induced extreme flood disaster in Bangladesh: Implications on people's livelihoods in the Char Village and their coping mechanisms. *Prog. Disaster Sci.* **2020**, *6*, 100079.
52. Khan, I. Drivers, enablers, and barriers to prosumerism in Bangladesh: A sustainable solution to energy poverty? *Energy Res. Soc. Sci.* **2019**, *55*, 82–92.
53. Hoegh-Guldberg, O.; Jacob, D.; Taylor, M.; Bindi, M.; Brown, S.; Camilloni, I.; Diedhiou, A.; Djalante, R.; Ebi, K.L.; Engelbrecht, F.; et al. Impacts of 1.5 °C Global Warming on Natural and Human Systems. In *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*; IPCC: Geneva, Switzerland, 2018.
54. Fabbri, K.; Gaspari, J. Mapping the energy poverty: A case study based on the energy performance certificates in the city of Bologna. *Energy Build.* **2021**, *234*, 110718.
55. Martín-Consuegra, F.; Gómez Giménez, J.M.; Alonso, C.; Córdoba Hernández, R.; Hernández Aja, A.; Oteiza, I. Multidimensional index of fuel poverty in deprived neighbourhoods. Case study of Madrid. *Energy Build.* **2020**, *224*, 110205.
56. ASBH. Agency for Statistics BH, TB10, Labor Force Survey, 2019; ASBH: Sarajevo, Bosnia and Herzegovina, 2020.
57. Bardazzi, R.; Bortolotti, L.; Pazienza, M.G. To eat and not to heat? Energy poverty and income inequality in Italian regions. *Energy Res. Soc. Sci.* **2021**, *73*, 101946.
58. Eurostat. Urban and Rural Living in the EU 2020; Eurostat: Luxembourg, 2020.
59. Bouzarovski, S.; Thomson, H. Towards an Inclusive Energy Transition in the European Union: Confronting Energy Poverty Amidst a Global Crisis; Publications Office of the European Union: Brussels, Belgium, 2020.
60. Bouzarovski, S.; Simcock, N. Spatializing energy justice. *Energy Policy* **2017**, *107*, 640–648.

61. Riva, M.; Kingunza Makasi, S.; Dufresne, P.; O'Sullivan, K.; Toth, M. Energy poverty in Canada: Prevalence, social and spatial distribution, and implications for research and policy. *Energy Res. Soc. Sci.* **2021**, *81*, 102237.
62. Owen, A.; Mitchell, G.; Unsworth, R. R Reducing carbon, tackling fuel poverty: Adoption and performance of air-source heat pumps in East Yorkshire, UK. *Local Environ.* **2013**, *18*, 817–833.
63. Mould, R.; Baker, K.J. Uncovering hidden geographies and socio-economic influences on fuel poverty using household fuel spend data: A meso-scale study in Scotland. *Indoor Build Environ.* **2017**, *26*, 914–936.
64. Golubchikov, O.; O'Sullivan, K. Energy periphery: Uneven development and the precarious geographies of low-carbon transition. *Energy Build.* **2020**, *211*, 109818.
65. Zhao, C.; Niu, S.; Zhang, X. Effects of household energy consumption on environment and its influence factors in rural and urban areas. *Energy Procedia* **2012**, *14*, 805–811.
66. Snell, C.; Bevan, M.; Thomson, T. Justice, fuel poverty and disabled people in England. *Energy Res. Soc. Sci.* **2015**, *10*, 123–132.
67. Robic, S.; Ancic, B. Exploring health impacts of living in energy poverty: Case study Sisak-Moslavina County, Croatia'. *Energy Build.* **2018**, *169*, 379–387.
68. Simcock, N.; Jenkins, K.E.; Lacey-Barnacle, M.; Martiskainen, M.; Mattioli, G.; Hopkins, D. Identifying double energy vulnerability: A systematic and narrative review of groups at-risk of energy and transport poverty in the global north. *Energy Res. Soc. Sci.* **2021**, *82*, 102351.
69. OpenEx. *European Energy Poverty Index*; OpenEx: European Commission, Brussels, Belgium, 2019.
70. European Commission. A Harmonised Definition of Cities and Rural Areas: The New Degree of Urbanisation. *WP* **2014**, *1*, 2014.
71. CBS. What is an Urban Locality? Defining "Urban Locality" in Israel and the Formation of a Statistical Model for Characterizing Localities, in WP No. 28; CBS: Tel-Aviv, Israel, 2017.
72. Goss, S. National Human Development Report for B&H; UNDP: Sarajevo, Bosnia and Herzegovina, 2013.
73. Official_Gazette_of_North_Macedonia. Список на Рурални Подрачја во Република Македонија (List of Rural Areas in the Republic of Macedonia); Official Gazette of the Republic of North Macedonia: Skopje, North Macedonia, 2008.
74. EPAH. Energy Poverty National Indicators Dashboard, in EU Energy Poverty Advisory HUB. DG Energy, European Commission. 2023. Available online: www.energypoverty.eu (accessed on 18 April 2024).
75. Gouveia, J.P.; Palma, P.; Bessa, S.; Mahoney, K.; Sequeira, M. Energy Poverty National Indicators: Insights for a more effective measurement., in EU Energy Poverty Advisory HUB. DG Energy. European Commission: 2022. Available online: www.energypoverty.eu (accessed on 18 April 2024).
76. Healy, J.D.; Clinch, J.P. Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland. *Energy Policy* **2004**, *32*, 207–220.
77. Fahmy, E.; Gordon, D.; Patsios, D. Predicting fuel poverty at a small-area level in England. *Energy Policy* **2011**, *39*, 4370–4377.
78. Brunner, K.-M.; Spitzer, M.; Christanell, A. Experiencing fuel poverty. Coping strategies of low-income households in Vienna/Austria. *Energy Policy* **2012**, *49*, 53–59.
79. Bouzarovski, S.; Herrero, S.T.; Petrova, S.; Ürge-Vorsatz, D. Unpacking the spaces and politics of energy poverty: Path-dependencies, deprivation and fuel switching in post-communist Hungary. *Local Environ.* **2016**, *21*, 1151–1170.
80. Chard, R.; Walker, G. Living with fuel poverty in older age: Coping strategies and their problematic implications. *Energy Res. Soc. Sci.* **2016**, *18*, 62–70.
81. Eurostat. *Energy Statistics—Cooling and Heating Degree Days*; Eurostat. 2020. Available online: https://ec.europa.eu/eurostat/cache/metadata/en/nrg_chdd_esms.htm (accessed on 15 June 2022).
82. Niamir, L.; Ivanova, O.; Filatova, T. Economy-wide impacts of behavioral climate change mitigation: Linking agent-based and computable general equilibrium models. *Environ. Model. Softw.* **2020**, *134*, 104839.
83. Eurostat. People in the EU—Statistics on Housing Conditions; Eurostat: Luxembourg, 2015.
84. Daniel, L.; Moore, T.; Baker, E.; Beer, A.; Willand, N.; Horne, R.; Hamilton, C. *Warm, Cool and Energy-Affordable Housing Policy Solutions for Low-Income Renters*; HURi: Melbourne, Australia, 2020.
85. Olonscheck, M.; Holsten, A.; Kropp, J.P. Heating and cooling energy demand and related emissions of the German residential building stock under climate change. *Energy Policy* **2011**, *39*, 4795–4806.
86. SIEA. *Náklady na Vykurovanie*; SIEA: Bratislava, Slovakia, 2019.
87. Eurostat. *Real GDP per Capita*; Eurostat: Luxembourg, 2020.
88. *Economic Characteristics/2011;* Hellenic Statistical Authority: Piraeus, Greece 2011. Available online: https://www.statistics.gr/el/statistics/-/publication/SAM04/2011 (accessed on 22 April 2021).
89. *Characteristics of Houses—Households/2011;* Hellenic Statistical Authority: Piraeus, Greece 2011. Available online: https://www.statistics.gr/el/statistics/-/publication/SAM05/2011 (accessed on 22 April 2021).
90. *Demographic Characteristics;* Hellenic Statistical Authority: Piraeus, Greece 2011. Available online: https://www.statistics.gr/el/statistics/-/publication/SAM03/2011 (accessed on 22 April 2021).
91. *Statistical Bulletin of Tax Data 2011*; Greek Ministry of Finance: Athens, Greece, 2011. Available online: https://www.gsis.gr/sites/default/files/2019-06/statdeltio2011.pdf (accessed on 6 June 2024).
92. Central Bureau of Statistics Israel. *Demography;* Central Bureau of Statistics Israel: Jerusalem, Israel, 2020.
93. Centraal Bureau voor de Statisriek. *Welvaart in Nederland 2019*; Centraal Bureau voor de Statisriek: The Hague, The Netherlands, 2019.

94. State Statistical Office of the Republic of Macedonia. *Labour Force Survey 2017*; State Statistical Office of the Republic of Macedonia: Skopje, Republic of Macedonia, 2018.
95. Instituto Nacional de Estadística. *Portuguese CENSUS 2011;* Instituto Nacional de Estadística: Lisbon Portugal.
96. Statistical Office of Slovak Republic. 2020. Available online: https://datacube.statistics.sk/ (accessed on 22 April 2021).
97. Instituto Nacional de Estadística. *Spanish CENSUS 2011;* Instituto Nacional de Estadística: Madrid, Spain, 2011.
98. Sabanovic E. Basic Consumption and Income Based Indicators of Economic Inequalities in Bosnia and Herzegovina: Evidence from Household Budget Surveys, Expert Meeting on Measure of Poverty and Inequality; UNECE, Budva, Montenegro, 2017.
99. State Statistical Office. *Survey on Income and Living Conditions 2017*; State Statistical Office: Sarajevo, Bosnia and Herzegovina, 2018.
100. Central Bureau of Statistics. Between Center to the Periphery: Main Findings from the Society in Israel Central Bureau of Statistics Israel; Central Bureau of Statistics: Jerusalem, Israel, 2019.
101. Camarero Rioja, L. (Ed.) The Rural Population in Spain. From Disequilibrium to Social Sustainability; Fundación La Caixa: Barcelona, Spain, 2009.
102. Barrella, R.; Romero, J.C.; Linares, J.I.; Arenas, E.M.; Asín, M.; Centeno, E. The dark side of energy poverty: Who is underconsuming in Spain and why? *Energy Res. Soc. Sci.* **2022**, *86*, 102428.
103. State Statistical Office of the Republic of Macedonia. *Energy Consumption in Households 2014*; State Statistical Office of the Republic of Macedonia: Skopje, Republic of Macedonia, 2015.
104. Žurovec, O.; Vedeld, P.O. Rural Livelihoods and Climate Change Adaptation in Laggard Transitional Economies: A Case from B&H. *Sustainability* **2019**, *11*, 6079.
105. SOSR. *Source of Heating;* SOSR: Bratislava, Slovakia, 2019.
106. Stojilovska, A.; Dokupilová, D.; Gouveia, J.P.; Bajomi, A.Z.; Tirado-Herrero, S.; Feldmár, N.; Kyprianou, I.; Feenstra, M. As essential as bread: Fuelwood use as a cultural practice to cope with energy poverty in Europe. *Energy Res. Soc. Sci.* **2023**, *97*, 102987.
107. Central Bureau of Statistics Israel. Household Income and Expenditure, Data From the 2018 Household Expenditure Survey: Central Bureau of Statistics Israel: Jerusalem, Israel, 2019.
108. Centraal Bureau voor de Statistiek. *Warmtemonitor 2019;* Centraal Bureau voor de Statistiek: The Hague, The Netherlands, 2020.
109. Directorate for Energy and Geology. *Energy. Statistics*; Directorate for Energy and Geology: Lisboa, Portugal, 2020.
110. Cuchí A.; Arcas Abella, J.; Pages, R. Estudio de la Distribución del Consumo Energético Residencial para Calefacción en España; UPCommons: Catalonia, Spain, 2017.
111. Barrella, R.; Linares, J.I.; Romero, J.C.; Arenas, E.M. Evaluating the impact of energy efficiency strategies on households' energy affordability: A Spanish case study. *Energy Build.* **2023**, *295*, 113289.
112. GGHR Government Gazette of the Hellenic Republic. *Series II 974*; GGHR: Athens, Greece, 2021.
113. Hellenic Ministry of Environment and Energy, Energy Inspection of Buildings. Statistical Analysis for the Year 2019 and 2011–2019 Time Period; Hellenic Ministry of Environment and Energy, Energy Inspection of Buildings: Athens, Greece, 2020.
114. *Regionale Klimaatmonitor*; Nederlandse Rijksoverheid: Hague, Netherlands. Available online: https://klimaatmonitor.databank.nl/Jive?sel_guid=e4d51b17-0786-4d2a-b1e6-217b54b5a0ba (accessed on 1 November 2021).
115. Adene. Certificação Energética de Edifícios [Energy Certification of Buildings]. ADENE—Portuguese Energy Agency. 2021. Available online: https://www.sce.pt/certificacao-energetica-de-edificios-3/consumidores (accessed on 1 November 2021).
116. INFOREG. Central Registry of Energy Pefrormance Certificates; INFOREG: Bratislava, Slovakia, 2021.
117. IDAE. *Estado de la Certificación Energética de los Edificios (8o Informe)*; Ministerio de Fomento, Instituto para la Diversificación y Ahorro de la Energía IDAE: Madrid, Spain, 2019.
118. Bouzarovski, S.; Petrova, S.; Sarlamanov, R. Energy poverty policies in the EU: A critical perspective. *Energy Policy* **2012**, *49*, 76–82.
119. Roberts, D.; Vera-Toscano, E.; Phimister, E. Fuel poverty in the UK: Is there a difference between rural and urban areas? *Energy Policy* **2015**, *87*, 216–223.
120. Stojilovska, A. Energy poverty and the role of institutions: Exploring procedural energy justice—Ombudsman in focus. *J. Environ. Policy Plan.* **2023**, *25*, 169–181.
121. Petrova, S.; Prodromidou, A. Everyday politics of austerity: Infrastructure and vulnerability in times of crisis. *Environ. Plan. C Politics Space* **2019**, *37*, 1380–1399.
122. Robinson, C.; Lindley, S.; Bouzarovski, S. The Spatially Varying Components of Vulnerability to Energy Poverty. *Ann. Am. Assoc. Geogr.* **2019**, *109*, 1188–1207.
123. Jenkins, K.; McCauley, D.; Heffron, R.; Stephan, H.; Rehner, R. Energy justice: A conceptual review. *Energy Res. Soc. Sci.* **2016**, *11*, 174–182.
124. Barrella, R.; Linares, J.I.; Romero, J.C.; Arenas, E.; Centeno, E. Does cash money solve energy poverty? Assessing the impact of household heating allowances in Spain. *Energy Res. Soc. Sci.* **2021**, *80*, 102216.
125. Barrella, R.; Romero, J.C.; Centeno, E. Unveiling Hidden Energy Poverty in a Time of Crisis: A Methodological Approach for National Statistics, in Living with Energy Poverty: Perspectives from the Global North and South; Routledge: London, UK, 2024.
126. Dokupilová, D.; Filčák, R. Regional disparities as roots of energy poverty in Slovakia. In *Perspectives on Energy PovertyEP in Post-Communist Europe;* Routledge: London, UK, 2021; pp. 206–221.

127. Gouveia, J.P. Residential Sector Energy Consumption at the Spotlight: From Data to Knowledge; Faculty of Sciences and Technology, Nova University of Lisbon: Lisbon, Portugal, 2017.
128. Eurostat. *Population*; Eurostat: Luxembourg, 2020.
129. Eurostat. Statistics on Rural Areas in the EU; Eurostat: Luxembourg, 2018.
130. Eurostat. Arrears on Utility Bills—EU-SILC Survey; Eurostat: Luxembourg, 2020.
131. BHAS. *Demography 2019*; BHAS: Sarajevo, Bosnia and Herzegovina, 2020.
132. Central Bureau of Statistics Israel. Population, by Population Group Religion. Age, Sex and Type of Locality (2019); Central Bureau of Statistics Israel: Jerusalem, Israel, 2019.
133. World Bank. 2018. Available online: https://data.worldbank.org/ (accessed on 1 November 2021).
134. POV. *Arrears on Utility Bills*; POV: Tel-Aviv, Israel, 2018. Available online: https://www.gov.il/BlobFolder/generalpage/dochpanatz/he/Files_Tzarchanut_doch_tzarchanut_%D7%A0bakara_2019.pdf?fbclid=IwAR26-c9qAbgCfB-qJ1bEN-8Hl-N3Ty7lvA9bGSEjTLQzX8SdYxs7FFj46ao (accessed on 1 November 2021).
135. Latet. *Alternative Poverty Report;* Latet: Tel-Aviv, Israel, 2020. Available at: https://www.latet.org.il/upload/files/16074106265fcf23c27d249266981.pdf?fbclid=IwAR0_zjhQc0H3dC-NNc1XE71iNqqc3BGIWTe4s4cMgN-OYBFCUMjL4rbb1Uo (accessed on 1 November 2021).
136. Meteonorm, M. Available online: https://meteonorm.com/en/meteonorm-features (accessed on 12 June 2022).
137. BHAS. Federal Hydrometeorological Institute of Bosnia and Herzegovina; BHAS: Sarajevo, Bosnia and Herzegovina, 2013.
138. Centraal Bureau of Statistiek. *Bevolkingsteller*; Centraal Bureau of Statistiek: Hague, The Netherlands, 2020.
139. SSO. *Census of Population 2002*; SSO: Skopje, Republic of Macedonia, 2005.
140. SSO. Statistical Yearbook 2013/Population; SSO: Skopje, Republic of Macedonia, 2013.
141. SOSR. *Demography*; SOSR: Bratislava, Slovakia, 2011.
142. Ministerio de Trabajo y Economía Social. *Informe del Mercado de Trabajo de Sevilla. Datos 2019*; Servicio Público de Empleo Estatal: Madrid, Spain, 2020. Available online: https://www.mites.gob.es/es/sec_trabajo/analisis-mercado-trabajo/index.htm (accessed on 12 June 2022).