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Chilling and sweltering at home: Surveying energy poverty and thermal vulnerability among Portuguese higher education students

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ABSTRACT

Portugal faces substantial energy poverty challenges compared to its EU counterparts, mainly stemming from aged buildings with poor thermal performance. This situation is especially critical for higher education students, who exhibit increased vulnerability to energy poverty due to unstable housing conditions within the private rental sector. Among these students, displaced individuals are notably vulnerable and heavily reliant on the private rental sector. Thus, this study delves into the thermal comfort and potential energy poverty vulnerability of higher education students, both displaced and local, across four Portuguese regions: North region, Centre region, Lisbon Metropolitan Area (AML), and Alentejo. Surveying 848 students via a 32-question online survey reveals that discomfort prevails in both summer and winter for most populations. Displaced students experienced greater discomfort than local students, potentially attributable to their reliance on the private rental sector, which often entails precarious housing. Although regional disparities in thermal comfort were not significant, the causes of discomfort varied significantly between regions. Notably, displaced students from Alentejo emerged as the most potentially vulnerable population to energy poverty within the study cohort. This study underscores the imperative for policymakers, higher education institutions, and researchers to redirect their focus towards enhancing student housing, particularly within the private rental sector and older buildings, while addressing the energy poverty vulnerability of displaced students.

1. Introduction

Energy poverty (EP) is defined as a situation wherein an individual cannot secure materially and socially necessitated energy services in their home, encompassing aspects of security of supply, affordability, and access [1]. While the causes of EP are complex and multifaceted, three primary factors are commonly identified: low-income levels, poor household energy efficiency and building performance, and high energy prices [2]. Vulnerability to EP varies among households and individuals and can be influenced by sociodemographic factors, household composition, health, energy literacy, cultural factors, and climate change [2].

Identifying and measuring EP at the local level can be challenging, as EP is a private issue that fluctuates over time and across regions, often dependent on cultural factors [3]. Two main types of information contribute to this assessment: measurable EP, relying on objective data such as energy consumption, income, and building efficiency, and perceived EP, which relies on subjective judgments like thermal comfort, assessed through qualitative methods like observations and interviews, capturing the lived experiences of households [2].

EP can be measured using multiple indicators of both types. The EU (European Union) Energy Poverty Advisory Hub (EPAH) depicts multiple indicators organised by various topics, such as climate, building stock, energy consumption and equipment, and socio-economic and living conditions [4]. These indicators help to understand the EP problem, its drivers, and its consequences, providing valuable insights for member states and other agency levels in formulating national strategies and policies [4]. Key indicators regarding the building stock are: "Pop. Liv. dwelling with presence of leak, damp and rot", "Pop. Liv. Dwelling equipped with heating", and "Pop. Liv. Dwelling equipped with air conditioning" [4]. Socio-economic and living condition indicators include: "Inability to keep home adequately warm", "Arrears on utility bills"; "Pop. Liv. dwellings comfortably warm in wintertime", "Pop. Liv. dwelling comfortably cool during summertime", "At risk of poverty or social exclusion" [4].

EP in Portugal might be considered problematic compared to other EU countries. In fact, according to INE [5], in 2023, 20.8 % of the

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Portuguese population couldn't afford to keep their home adequately warm, and the percentage of the population living with a leak, damp, or rot in their dwelling was 29 %. Moreover, in 2022, 4.7 % of the population were unable to pay for utility bills (heating, electricity, gas, water, etc.) on time due to financial difficulties [6], and 20.1 % were "At risk of poverty or social exclusion" [7]. Although the concern about EP is mainly centred on winter, a large percentage of the Portuguese population also finds it challenging to maintain a comfortable temperature in their homes in summer, given that, in 2023, 38.3 % of the population lived in a dwelling not comfortably cool during summertime [5].

In 2020, Portugal ranked twenty-fourth in the Composite Energy Poverty Index (CEPI) and effects-based scores among the 27 EU Member States, indicating relatively higher levels of EP and its effects [8]. The effects-based scores focus solely on the consequences of EP, including insufficient warmth, energy arrears, and dwelling quality issues, while the CEPI considers both causative and consequential factors. The identified causes are high energy costs, poor energy efficiency, and low income [8].

One of the leading causes of the EP situation in Portugal is the prevalence of old and inadequately prepared buildings with low thermal performance, which increases vulnerability to EP [9] since 65 % of energy-performance certified residential buildings in the country fall within energy class C or lower [10], and that 50.2 % of the classic buildings existing in 2021 had been built before 1980 [11].

Housing conditions are particularly relevant for one of the populations considered vulnerable to EP, the higher education student population (e.g., [12]). Studies focused on this demographic group have highlighted their increased vulnerability, primarily stemming from precarious housing conditions in the Private Rental Sector (PRS) ([12–14]). Higher education students represent a significant portion of the demand within the PRS in various regions. They form a specialised market niche characterised by housing supply tailored to their distinct requirements [15]. However, residing in the PRS can contribute to EP, as vulnerability to EP often relates to rental conditions and terms, such as housing quality and tenancy stability [16].

Displaced students may be considered a particularly vulnerable group within the higher education student population since they are very dependent on the PRS. In Portugal, the living conditions of this group, particularly for those facing financial constraints, have become increasingly critical due to rising property market pressures [17]. The 2021/2022 academic year witnessed 119,818 displaced students, constituting 35.5 % of the total student population in public higher education in Portugal [17].

While some studies have explored the vulnerability of higher education students in terms of EP, they have not explicitly focused on displaced students. Previous research has investigated the impact of PRS housing characteristics on students' energy expenses, thermal comfort, and overall well-being [13]. Additionally, some studies have examined factors influencing students' EP levels, such as the type of accommodation (Subdivided Units, which have a floor area of between 9 and 18 m^2, which equates to around 10 m^2 per person) [14], private or shared accommodation [18]; the shifts in attitudes and behaviours due to the COVID-19 pandemic [19]; or the student type (local or exchange) [20].

In certain studies, regional differences have been important factors when analysing the EP situation among students. For instance, Kousis et al. [13] conducted a comprehensive study involving students across various countries, including Bulgaria, Cyprus, Greece, Lithuania, Romania, the UK, and Ireland; Nazarahari et al. [18] conducted a comparative analysis between Japanese and non-Japanese college students; and Castro and Gouveia [20] examined variations in students' EP perception and vulnerability based on diverse geographical, social, and building-related contexts in Montevideo, Lisbon, and Padua.

The present study aims to investigate the perception and vulnerability to EP of higher education students of two profiles (displaced or local) residing in mainland Portugal, comparing the situation among its four NUTS II regions and considering two seasons (winter or summer). We aim to identify common challenges and impacts while discussing students' vulnerability to unstable housing conditions in the PRS and their potential EP situation. In addition, we explore potential drivers of EP vulnerability, particularly heating and cooling equipment ownership, challenges related to energy bill payments, and the condition of the students' housing, seeking to understand the lived experiences, behaviours, and attitudes of these students towards their thermal comfort and energy use. In doing so, we aim to raise awareness of this issue and contribute to the broader discourse on EP and potentially vulnerable groups by highlighting the particular vulnerabilities faced by higher education students, thereby informing future research and policy interventions.

2. Methodology

We employed a comprehensive approach to examine the dynamics of EP among higher education students living in mainland Portugal to assess their potential vulnerability to this issue. The methodology comprises five distinct subsections designed to facilitate a clear understanding of the regions under study and the procedural framework. The first subsection provides the method of crafting the survey, while the second indicates the selected case study regions. Additionally, to provide a context that encompasses essential facets of household energy needs and consumption patterns, the third and fourth subsections offer an insight into each region's climate and socio-economic characteristics, respectively. Lastly, the fifth subsection is dedicated to elucidating the procedures employed in data analysis.

2.1. Survey

An online survey consisting of thirty-two questions was developed in English and Portuguese (considered a single survey), based on Castro and Gouveia's [20] forty-four questions survey. Our version made several modifications to focus specifically on factors explaining EP vulnerability, excluding sections related to "House hunting choices," "EP concept and perception," and "Solutions and policies" (see Appendix A for details). This survey was opened for responses between September 2022 and April 2023, focusing on the Portuguese high-education student community. To support the open online dissemination of the survey, 115 Portuguese high education institutions (public and private institutions of Portuguese polytechnic and university education) were listed and contacted based on the A3ES database [21] from all regions of Portugal, including the islands. Ultimately, 17 institutions agreed to disseminate the survey to their students.

Out of 894 initially collected surveys for mainland Portugal and islands, 46 responses were incomplete and were thus excluded from the analysis. Additionally, the responses from the Azores (11) and the Algarve (13) were considered too low to represent each student population reliably and were excluded. Consequently, we focused on 848 valid responses (where respondents answered most of the questions) from the four remaining regions, which had sufficient response rates. Despite these efforts, we acknowledge the limitation that there is no available data on the distribution of local and displaced students by region to fully assess the representativeness of each population studied.

The survey questions were designed to characterise each population of students and to describe their energy consumption habits, energy-related equipment, perception of EP, and their lived experience in maintaining comfortable internal temperatures. Two types of populations of high education students (one of Displaced Students, DS, and another of Local Students, LS) were considered in four Portuguese regions: North region (Norte), Centre region (Centro), Lisbon Metropolitan Area (AML), and Alentejo. Regarding the residence of the DS, the analysis only considered the residence where the DS currently lived and not their residence of origin.

2.2. The four Portuguese regions

To unify the responses across different populations, we merged the responses for each NUTS II region (Norte, Centro, AML, and Alentejo), corresponding to the region where each respondent's higher education institution is located. Fig. 1 shows all the respondents' higher education institutions according to the corresponding region.

2.3. Climate characterisation of the Portuguese regions

Recognising the climatic nuances inherent to each Portuguese region becomes pivotal as it can affect the perceived thermal comfort experienced by its inhabitants. This crucial aspect was considered to facilitate a more profound comprehension of the susceptibility to EP and the intricate energy consumption behaviours exhibited within the populations under examination.

Table 1 presents the weather description of each Portuguese region (Norte in blue, Centro in green, AML in yellow, and Alentejo in orange) based on three variables: Average Maximum and Minimum Temperatures and Average Relative Humidity for winter and summer (data from IPMA [22]). These climatic features of each Portuguese region were based on the climatic characterisation of the NUTS III (sub-regions), where most of the respondents' higher education institutions are located in each region (for Norte: Cávado; for Centro: Região de Aveiro and

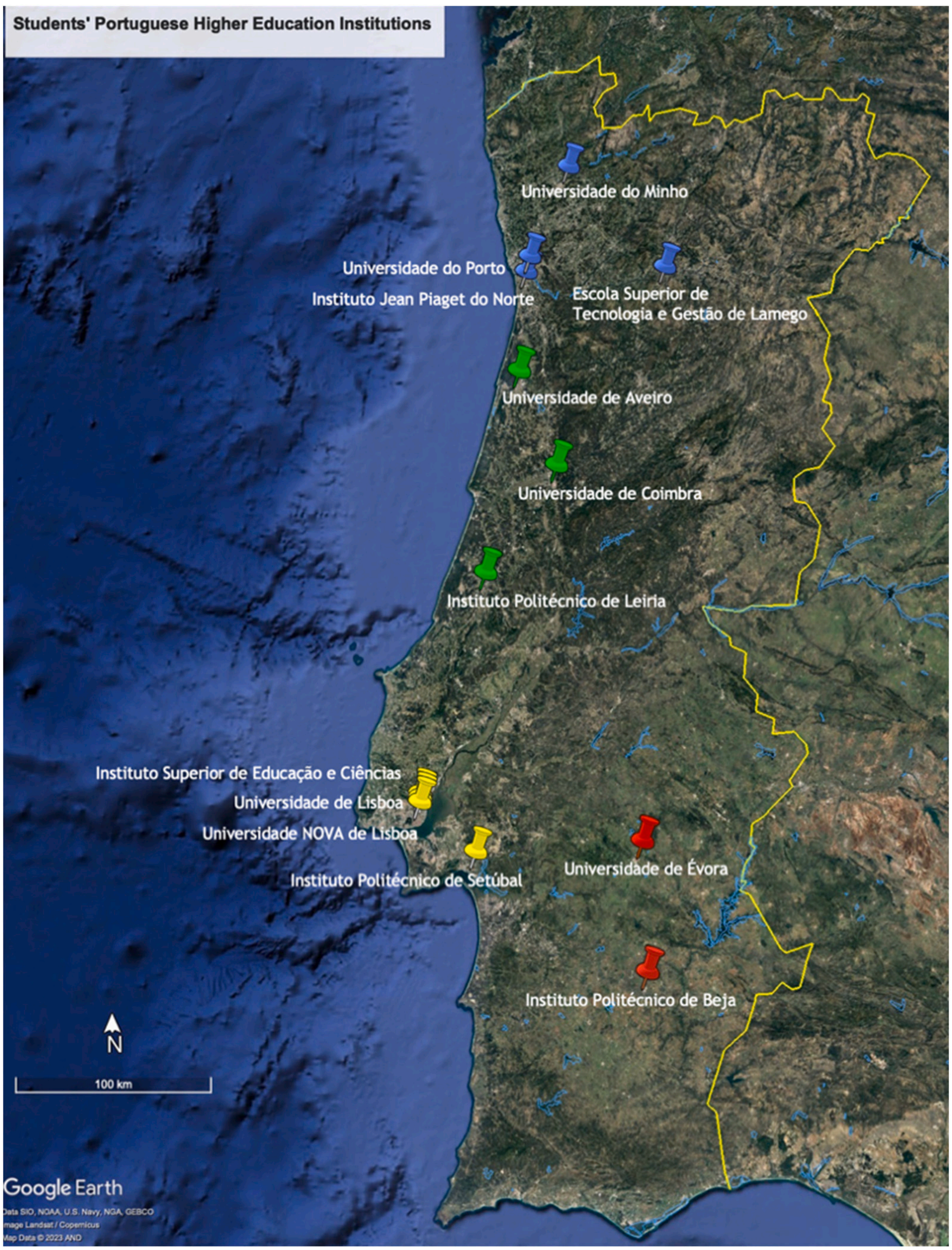

Fig. 1. Location of respondents' Portuguese higher education institutions (in blue are those from the Norte region, in green are those from the Centro region, in yellow are those from the AML region, and in red are those from the Alentejo region), adapted from Google Earth. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Weather description of each Portuguese region (Norte, Centro, AML, and Alentejo) based on three variables (Average Maximum and Minimum Temperatures and Average Relative Humidity) for winter and summer, according to IPMA [22].

Season	Variable	Portuguese Regions - Simulated history - 1971-2000			
		Norte (Cávado)	Centro (Aveiro/Leiria)	AML	Alentejo (Alentejo Central)
Winter	Average maximum temperature (ºC)	8.1	9.5/9.2	10.8	9.3
	Average minimum temperature (ºC)	6.8	8.2/7.9	9.4	7.9
	Average relative humidity (%)	85	83/84	83	84
Summer	Average maximum temperature (ºC)	19.3	20.1/20.3	22.1	23.7
	Average minimum temperature (ºC)	16.9	17.8/18.0	20.2	21.6
	Average relative humidity (%)	70	72/71	64	51

Norte region is represented in blue, Centro region in green, AML region in yellow, and Alentejo region in orange.

Região de Leiria; for the AML: AML; for Alentejo: Alentejo Central) (see Table 3 in Results). There is an influence from the southern and coastal factors in the easing of temperatures (Table 1). In winter, temperatures are lower in the Norte region and higher in the AML, and relative humidity is similar among regions (Table 1). In summer, temperatures are lower in the Norte region and higher in the Alentejo region, with a lower relative humidity than the other regions (Table 1).

2.4. *Socio-economic characterisation of the Portuguese regions*

The socio-economic profiles of the four Portuguese regions were constructed by considering seven key indicators: poverty, labour market, disposable income, economic growth, human capital, electrical energy consumption, and Air Conditioning (AC) ownership (Table 2). These comprehensive indicators collectively offer a holistic perspective on each region's socio-economic landscape, enabling a nuanced analysis of its unique characteristics and vulnerabilities related to EP.

The choice of these indicators is linked to indicators of EPAH such as

Table 2
Socio-economic description of each Portuguese region (Norte, Centro, AML, and Alentejo) based on seven indicators [24–29].

Indicator	Source	Portuguese Regions			
		Norte	Centro	AML	Alentejo
Poverty Risk Rate (% of total population) in 2021, based on the national threshold	INE [23]	20.0	15.6	10.4	14.9
Unemployment Rate (%) in the 1st Quarter of 2023	INE [24]	7.6	5.6	8.0	7.2
Gross Household Disposable Income per capita (€)	INE [25]	10595	11279	14518	11533
Gross Domestic Product (GDP) per capita	INE [26]	19450	19983	30109	21670
Higher education attainment rate of the resident population aged 25-64 (%)	INE [27]	28.7	29.7	40.9	25.2
Electrical energy consumption per inhabitant (kWh/inhab.) in 2021	INE [28]	4097	5727	4038	7087
Private households with AC (%) in 2015	PORDATA [29]	13.2	10.2	18.7	30.3

Norte region is represented in blue, Centro region in green, AML region in yellow, and Alentejo region in orange.

"At risk of poverty or social exclusion" and "Disposable annual household income" (socio economic and living conditions), "Final consumption expenditure of households" (energy consumption and equipment) and "Pop. Liv. dwelling equipped with air conditioning" (building stock) [4].

Of all four regions, AML has the lowest poverty risk rate despite having the highest unemployment rate (Table 2). In addition, AML is the region with the highest disposable income, GDP, and higher education attainment rate (Table 2). Despite this, the Alentejo region has the highest electricity consumption per inhabitant and the highest AC ownership (Table 2). The highlight of the Norte region is that it has the highest poverty risk rate, while the Centro has the lowest unemployment rate and the lowest ownership of AC (Table 2).

2.5. Data analysis

Initially, the 838 valid responses in Portuguese or English were unified into English terms and merged into a single data sheet to enable consolidated analysis and comparison of responses. Afterwards, the answers of the following eight populations were analysed: Norte DS, Norte LS, Centro DS, Centro LS, AML DS, AML LS, Alentejo DS, and Alentejo LS.

All questions were answered by all the 838 students, except 12 respondents (9 DS and 3 LS from AML) who did not respond to the following questions: "Is this a full-time residence, or do you spend time in another residence at the weekends?"; "I find the thermal comfort conditions most comfortable in..."; "Year in which the building you inhabit was built"; "My building has draughts, cracks, humidity or mould"; and "How do you heat/cool your residence?"

Nine distinct subsections of the results were created to enhance comprehension regarding various influencing factors. These sections serve to fully grasp the profound scope of EP among highly educated Portuguese students. The initial two subsections provide a comprehensive portrait of each population, achieved by characterising the sample and giving a general description of the accommodations. Subsequently, the following two subsections delve into the students' perception of thermal comfort during winter and summer and the heating and cooling equipment they use. The following subsection is dedicated to exploring energy expenditures, the challenges posed by energy costs, and the extent of adopting energy-saving measures. Ultimately, the final two subsections examine building conditions and the impacts of thermal discomfort and poor building conditions.

Broadly, the responses were structured based on the percentage of students within each population and graphs and tables were employed to illustrate this variation across all subsections. For some questions (see Table B), the original survey categories were restructured into fewer categories to streamline the analysis. The revised categories and the corresponding revised title of the question are detailed in Table B.

These indicators are important for Member-States and other agency levels in defining national strategies and policies, as they offer a deeper understanding of the EP issue, its root causes and its impacts [4]. Key indicators regarding the building stock are: "Pop. Liv. dwelling with presence of leak, damp and rot", "Pop. Liv. Dwelling equipped with heating", and "Pop. Liv. Dwelling equipped with air conditioning" [4]. Socio-economic and living condition indicators include: "Inability to keep home adequately warm", "Arrears on utility bills"; "Pop. Liv. dwellings comfortably warm in wintertime", "Pop. Liv. dwelling comfortably cool during summertime", "At risk of poverty or social exclusion" [4].

Specific subsections and the respective questions, identified in Table 3, underwent a multivariate analysis in which each question was treated as a response variable. The subsections were organised according to the indicators to which they related. While subsection 3.3 relates to subjective thermal comfort (perceived EP), subsection 3.6 refers to building efficiency (measurable EP) [2]. Subsection 3.5 is related to the EPAH's socio-economic indicator, "Arrears on utility bills" [4]. The contextual factors of dwelling types and available heating/cooling equipment [2] are represented in subsections 3.7 and 3.4 respectively, which are also related to the EPAH's indicators regarding the building stock: "Pop. Liv. Dwelling equipped with heating", "Pop. Liv. Dwelling equipped with air conditioning", and "Pop. Liv. dwelling with presence of leak, damp and rot" [4]. Finally, subsection 3.7 aims to represent the impacts of thermal discomfort and poor building conditions from the other subsections, where the intervals of year of construction of buildings are aligned with statistical reporting conventions of the Portuguese National Statistics Institute (INE), which categorises buildings based on significant periods that reflect changes in construction practices and thermal regulations (i.e.1990 and 2006).

Table 3
Identification of the subsections where a multivariate analysis was carried out and the respective questions treated as response variables. Information on categories of the variables not shown in this table is given in Table B.

Subsection	Questions/response variables
3.3. Students' perception of thermal comfort during winter and during summer	Level of thermal comfort during winter Level of thermal comfort during summer
3.4. Heating and cooling equipment	Heating and cooling equipment (10 variables with two categories each corresponding to the existence or absence of a particular device)
3.5. Energy expenditures and coping strategies	Level of difficulty in paying their energy bills Level of cuts in energy use to reduce energy bills "Did you cut or reduce energy consumption for heating your residence during the winter due to energy costs?" "Did you cut or reduce energy consumption for cooling your residence during the summer due to energy costs?"
3.6. Building conditions	Year of construction of the building they live in Presence of problems in students' accommodation (draughts, cracks, humidity, or mould) Did the poor building conditions of your house affect you?
3.7. Impacts of thermal discomfort and poor building conditions	Level of impact of thermal discomfort on students' capacity to concentrate and/or educational attainment Level of impact of thermal discomfort on students' health (e.g., frequent colds in winter, respiratory problems) Level of limitation on ability to purchase other goods and services when paying energy bills

Five multivariate analyses were carried out corresponding to the five subsections shown in Table 3. Each analysis included a PERMANOVA [30] with two fixed and orthogonal factors: type of student (two levels—DS and LS) and region (four levels— Norte, Centro, AML, and Alentejo). The categories of each response variable are listed in Table B (new categories) or, in the case of subsection 3.4, correspond to the original variables described in Appendix A. For the "Level of difficulty in paying their energy bills," a response of 0 was assigned to students who did not answer the question and, therefore, were not responsible for paying these energy bills. Regarding the question about the "Year of construction of the building they live in," the response "Don't know" was incorporated into the analysis using the value "3", which corresponded to the average of the answers.

Each survey was an independent replicate. The sample size varied from 19 (Norte DS and Centro LS) to 391 (AML LS) (see Table 4), except for subsection "3.4. Heating and cooling equipment" where the sample size was slightly lower in Norte LS (n = 50), AML LS (n = 386), AML DS (n = 216). The homogeneity of the multivariate dispersions based on the Bray-Curtis similarity was tested by the PERMDISP routine applied to

Table 4
Characterisation of the survey sample: sample size, sex, age (2 most common), nationality, having a chronic/long-term illness, employment status (the majority), possession of social support/scholarship, education (2 most common), field of study (2 most common), higher education institution, and type of higher education institution (A/E/T, Architecture/Engineering/Technology).

Population	Norte (DS)	Norte (LS)	Centro (DS)	Centro (LS)	AML (DS)	AML (LS)	Alentejo (DS)	Alentejo (LS)
Sample size	19	51	44	19	226	391	54	34
Sex	Female (74 %); Male (26 %)	Female (57 %); Male (43 %)	Female (68 %); Male (32 %)	Female (68 %); Male (26 %); Non binary (5 %)	Female (58 %); Male (41 %); Non binary (1 %)	Female (60 %); Male (40 %)	Female (78 %); Male (22 %)	Female (59 %); Male (38 %); Non binary (3 %)
Age	21–24 (53 %); 18–20 (26 %)	21–24 (39 %); 18–20 (20 %)	18–20 (45 %); 21–24 (36 %)	18–20 (32 %)	21–24 (38 %); 18–20 (35 %)	18–20 (41 %); 21–24 (33 %)	21–24 (39 %); 18–20 (35 %)	21–24 (24 %); 18–20 (21 %)
Nationality	Portuguese (89 %); Other (11 %)	Portuguese (100 %)	Portuguese (93 %); Other (7 %)	Portuguese (95 %); Other (5 %)	Portuguese (73 %); Other (27 %)	Portuguese (94 %); Other (6 %)	Portuguese (94 %); Other (6 %)	Portuguese (94 %); Other (6 %)
Have a chronic/ long-term illness	0 %	25 %	30 %	21 %	15 %	21 %	26 %	29 %
Employment status	Full time student (74 %)	Full time student (55 %)	Full time student (89 %)	Full time student (68 %)	Full time student (76 %)	Full time student (70 %)	Full time student (81 %)	Full time student (53 %)
Possession of social support/ scholarship	68 %	53 %	66 %	47 %	38 %	24 %	48 %	32 %
Education	12th year (37 %); Master's degree (37 %)	Bachelor's degree (43 %)	Bachelor's degree (43 %); 12th year (36 %)	12th year (42 %); Master's degree (37 %)	12th year (40 %); Bachelor's degree (32 %)	12th year (46 %); Bachelor's degree (32 %)	12th year (44 %); Bachelor's degree (35 %)	12th year (38 %); Master's degree (32 %)
Field of study	Social Sciences (47 %); Mathematics/ Exact sciences (26 %)	A/E/T (39 %); Life sciences/ Medicine (24 %); Social Sciences (24 %)	Life sciences/ Medicine (68 %)	Life sciences/ Medicine (74 %)	A/E/T (45 %); Social Sciences (23 %)	A/E/T (51 %); Life sciences/Medicine (22 %)	Life sciences/ Medicine (41 %); A/E/T (22 %); Social Sciences (22 %)	Social Sciences (47 %)
Higher Education Institution	Universidade do Minho (74 %); Universidade do Porto (21 %); Escola Superior de Tecnologia e Gestão de Lamego (5 %)	Universidade do Minho (69 %); Universidade do Porto (16 %); Universidade Aberta (12 %); Instituto Jean Piaget do Norte (4 %)	Universidade do Aveiro (43 %); Instituto Politécnico de Leiria (41 %); Universidade de Coimbra (16 %)	Universidade do Aveiro (53 %); Instituto Politécnico de Leiria (21 %); Universidade Aberta (21 %); Universidade de Coimbra (5 %)	Universidade NOVA de Lisboa (75 %); Universidade de Lisboa (23 %); Instituto Politécnico de Setúbal (2 %)	Universidade NOVA de Lisboa (70 %); Universidade de Lisboa (20 %); Universidade Aberta (4 %); Instituto Superior de Educação e Ciências (3 %); Instituto Politécnico de Setúbal (2 %)	Universidade de Évora (98 %); Instituto Politécnico de Beja (2 %)	Universidade de Évora (97 %); Universidade Aberta (3 %)
Type of Higher Education Institution	Public (100 %)	Public (96 %); Private (4 %)	Public (100 %)	Public (100 %)	Public (95 %); Private (5 %)	Public (96 %); Private (4 %)	Public (100 %)	Public (100 %)

the factor location and the factor type of student [31]. Pair-wise tests were carried out when variation among regions was detected. The SIMPER procedure [32] was used to identify which variables contributed most to the dissimilarity among regions or between both types of students. The variables that explained most differences (>70 % of cumulative dissimilarity) were selected. All analyses were based on Bray-Curtis similarity of untransformed data and unrestricted permutations of raw data, Type III sums of squares, and 999 permutations (see Anderson et al. [33]). All analyses were performed using PRIMER 7 [34] with the PERMANOVA + add-on [33]. The choice of PERMANOVA in this study is due to its robustness and flexibility, allowing the partitioning of multivariate variation based on a chosen dissimilarity measure without assuming multivariate normality [35]. This method's versatility makes it ideal for analysing high-dimensional systems [35], such as those involving EP, providing nuanced insights crucial for effective policy and intervention strategies.

3. Results

The results are presented in nine sections. The first two sections provide an overview of each population and describe their accommodations. The following two sections focus on how students perceive thermal comfort in winter and summer and the heating and cooling equipment they use. Following that, one section explores energy expenses, the challenges related to energy costs, and the use of energy-saving measures (coping strategies). Lastly, two sections examine building conditions and the impacts of thermal discomfort and poor building conditions.

3.1. Sample characterisation

Table 4 presents a comprehensive characterisation of each population subset within the present study, detailing their size and general respondent attributes. These attributes encompass sex, age, nationality, presence of chronic/long-term illnesses, employment status, possession of social support/scholarships, education, field of study, higher education institution, and type of higher education institution.

The sample sizes ranged from 19 individuals in Norte DS and Centro LS to 391 individuals in AML LS. Most respondents were females aged 18–24, categorised as 18–20 or 21–24. Most respondents were

Portuguese (>89 % of all populations, except for AML DS, where 27 % were of other nationalities). >70 % did not report chronic/long-term illnesses (Table 4).

Most respondents (>53 % of all populations) were engaged as full-time students, with respondents from the Norte (both DS and LS) and Centro DS having social support or scholarships. The same is not valid for students in the AML and Alentejo regions (Table 4).

In terms of geographic distribution, most of the respondents' higher education institutions are located in Braga (Cávado) for Norte; Aveiro and Leiria for Centro; Lisbon for AML; and Évora (Alentejo Central) for Alentejo (Table 4).

3.2. General description of accommodation

Regarding LS, Fig. 2 shows that most of the LS from Norte and AML were relatives of the owner of the building. Centro LS were distributed mainly between the categories "Owner of building" and "Relative of building owner" (37 % in both categories). Alentejo LS were distributed primarily between the categories "Owner of building", "Relative of building owner", and "Long-term renter" (26 %, 35 %, and 26 %, respectively). With regard to DS, most students from all populations were distributed in the "Long term renter" and "Short term renter" categories (63 % from Norte, 73 % from Centro, 70 % from AML, and 80 % from Alentejo, adding the percentages of these two categories together) (Fig. 2).

As might be expected from the results in Fig. 2, the majority of LS from all regions lived in a residence that they owned or that was owned by family or friends (between 56 % of Alentejo LS and 86 % of Norte LS) (Fig. C.1). Regarding the DS, most students from all populations fell into the "House/apartment rented directly from owner" or "Room rented directly from owner" categories (53 % in Norte, 59 % in Centro, 60 % in AML, and 78 % in Alentejo, adding the percentages of these two categories together), which is in line with the two most frequent types of tenure in these four populations (Figs. 2 and C.1).

About the question "Is this a full-time residence or do you spend time in another residence at the weekends?", the vast majority of the LS in all regions answered "it's a full-time residence" (between 68 % of Centro LS and 96 % of Norte LS) (Fig. C.2). In the case of Norte DS, the answer with the highest values was also "it's a full-time residence", while in the case of Centro DS, the answer with the highest values was "sometimes I spend time in another residence on weekends". Between these two response categories, the DS from AML and Alentejo were similarly distributed (between 41 % and 46 %) (Fig. C.2).

In terms of the residence where students felt the most comfortable thermal comfort conditions across all regions, the DS responses primarily leaned towards the option "Another residence where I frequently spend time in Portugal (at the weekend with family or similar)", with percentages ranging from 40 % in AML to 57 % in Alentejo (Fig. C.3). In the case of Norte DS, this percentage was 42 %, a figure closely aligned with the 37 % attributed to the response "The residence I rent to facilitate my studies" (Fig. C.3). On the other hand, LS in all regions predominantly selected the " doesn't apply" option (Fig. C.3), potentially due to the absence of an alternative residence in their circumstances.

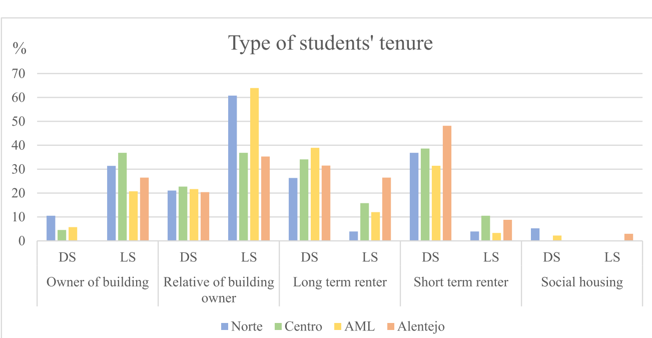

Fig. 2. Type of student's tenure of each population.

3.3. Student's perception of thermal comfort during winter and during summer

The perception of thermal comfort during winter and summer among DS and LS across the Norte, Centro, AML, and Alentejo regions is depicted in Figs. 3 and 4. In general terms, most students fell into the "Comfort" or "High Discomfort" categories, with "Mild Discomfort" generally being less prevalent. According to the results of the PERMANOVA analysis (shown in Table 5), there were significant differences between DS and LS. At the same time, there were no significant differences among regions, and the interaction between the two factors was not significant. The SIMPER analysis of variation between DS and LS showed that both winter and summer discomfort were higher in the DS group than in the LS group. This is particularly relevant in the Alentejo region during winter, where 59 % of DS students feel highly uncomfortable, while the percentage of LS who feel the same is lower (38 %) (Fig. 3), and in the Norte during summer, where around twice as many DS students (63 %) feel highly uncomfortable compared to LS (33 %) (Fig. 4).

3.4. Space heating and cooling equipment

All population groups indicated that they possessed a diverse array of heating and cooling equipment in their residences, with up to ten different types of equipment. However, some students stated they had no equipment (Fig. 5).

The PERMANOVA analysis revealed significant differences between

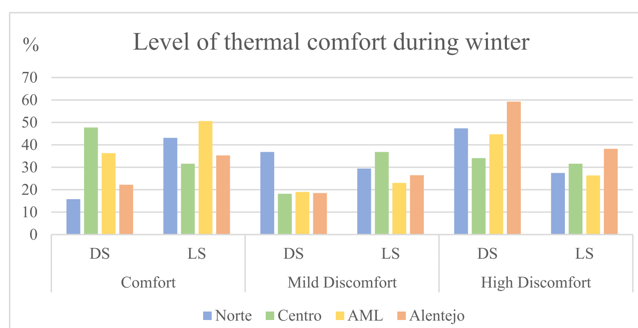

Fig. 3. Perception of thermal comfort during winter of each population (from comfort to high discomfort).

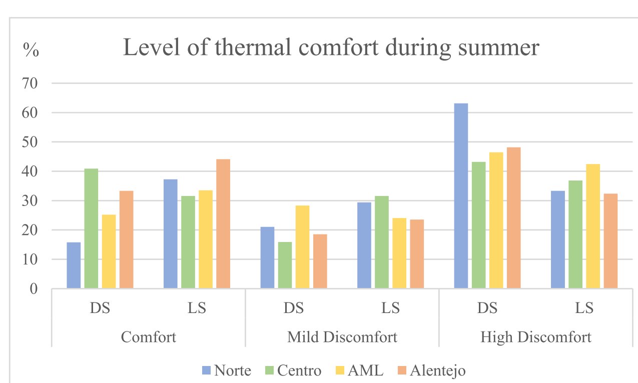

Fig. 4. Perception of thermal comfort during summer of each population (from comfort to high discomfort).

Table 5
PERMANOVA analyses of factors region (Norte, Centro, AML, and Alentejo) and type of student [Displaced Students (DS) and Local Students (LS)] on the answers to questions addressed in subsections 3.3, 3.4, 3.5, 3.6, and 3.7. Pair-wise test results and corresponding SIMPER analyses are included whenever the factors were significant. Bold—significant p-values ($p \leq 0.05$).

Effect	df	MS	Pseudo-F	p-value
3.3. Students' perception of thermal comfort during winter and during summer				
Region	3	358.44	0.91403	0.4755
Type of student	1	2614.5	6.6669	**0.0031**
Region × Type of student	3	387.51	0.98815	0.4363
Res	830	392.16		
SIMPER analysis to factor type of student				
DS vs. LS	SIMPER analysis to variation between DS and LS showed that both winter and summer discomfort were higher in the DS group than in the LS group.			
3.4. Heating and cooling equipment				
Region	3	14,802	3.8399	**0.0001**
Type of student	1	9287.3	2.4093	**0.0299**
Region × Type of student	3	4563.6	1.1839	0.2723
Res	813	3854.7		
Pair-wise tests to factor region: Norte = Centro ≠ AML ≠ Alentejo (significant at the 5 % level)				
SIMPER analysis to factors type of student and region (variables that explained >67 % of cumulative dissimilarity)				
DS vs. LS	The variables that contributed the most (67 %, in descending order) are: electric radiator (more important for DS); oil heater (more important for DS); heat pump/air conditioning (more important for LS); thermoventilator (more important for DS); I don't have heating equipment (more important for DS).			
Norte-Centro vs. AML-Alentejo	Norte-Centro students reported less use of heating and cooling equipment and specific use of wood burning fire compared to the other regions.			
AML vs. Alentejo	The main explanation for the differences between the Alentejo and AML regions is the greater use of oil heater, thermoventilator and heat pump/air conditioning in Alentejo and electric radiator and fan in AML.			
3.5. Energy expenditures and coping strategies				
Region	3	1649.5	3.9776	**0.003**
Type of student	1	58.353	0.14071	0.845
Region × Type of student	3	385.14	0.92872	0.5
Res	813	414.7		
Pair-wise tests to factor region: AML ≠ Alentejo = Norte (significant at the 5 % level), no defined pattern for Centro				
SIMPER analysis to factor region (variables that explained >77 % of cumulative dissimilarity)				
AML vs. Norte-Alentejo	The variables that contributed the most (77 %, in descending order) are: Level of difficulty in paying their energy bills (more important for Norte-Alentejo); Level of cuts in energy use to reduce energy bills (more important for Norte-Alentejo); Did you cut or reduce energy consumption for heating your residence during the winter due to energy costs? (more important for Norte-Alentejo).			
3.6. Building conditions				
Region	3	1231.6	4.3592	**0.0009**
Type of student	1	1466.5	5.1906	**0.0118**
Region × Type of student	3	579.46	2.051	0.0791
Res	830	282.53		
Pair-wise tests to factor region: AML ≠ Alentejo (significant at the 5 % level), no defined pattern for Centro and Norte				
SIMPER analysis to factors type of student and region (variables that explained >81 % of cumulative dissimilarity)				
DS vs. LS	The variables that contributed the most (81 %, in descending order) are: Year of construction of the building they live in (older buildings for DS); Presence of problems in students' accommodation (draughts, cracks, humidity, or mould) (more important for DS).			
AML vs. Alentejo	The variables that contributed the most (81 %, in descending order) are: Year of construction of the building they live in (older buildings for Alentejo); Presence of problems in students' accommodation (draughts, cracks, humidity, or mould) (more important for Alentejo).			
3.7. Impacts of thermal discomfort and poor building conditions				
Region	3	2798.3	4.6831	**0.0004**
Type of student	1	863.07	1.4444	0.2399
Region × Type of student	3	476.72	0.79782	0.5614
Res	830	597.53		
Pair-wise tests to factor region: AML ≠ Alentejo = Centro (significant at the 5 % level), no defined pattern for Norte				
SIMPER analysis to factor region (variables that explained >70 % of cumulative dissimilarity)				
AML vs. Centro-Alentejo	The variables that contributed the most (70 %, in descending order) are: Level of limitation on ability to purchase other goods and services when paying energy bills (more important for Centro-Alentejo); Level of impact of thermal discomfort on students' capacity to concentrate and/or educational attainment (more important for Centro-Alentejo).			

the types of students (DS versus LS) and among regions, while the interaction between the two factors was not significant (Table 5). Pair-wise tests applied to differences among regions revealed the following pattern: the Norte region is statistically equivalent to the Centro region, forming the Norte-Centro group, which is significantly different from AML and Alentejo. Furthermore, AML is substantially different from Alentejo.

SIMPER analysis applied to the dissimilarity between the types of students showed that the following devices explained 67 % of this dissimilarity: electric radiator, oil heater, and thermoventilator were more used by DS, while LS used more heat pump/air conditioning. Results from SIMPER analysis among Norte-Centro, AML, and Alentejo are shown in Table 6. In general, Norte-Centro students reported less heating and cooling equipment use and more specific use of wood-burning fire than other regions. The main explanation for the differences between the Alentejo and AML regions is the greater use of oil heaters, thermoventilators, and heat pumps/air conditioning in Alentejo and electric radiators and fans in AML.

3.5. *Energy expenditures and coping strategies*

The majority of students of both types, with the exception of LS students in the AML region (48 %), paid their energy-related household bills, with the values in the Centro (LS, 79 %), Alentejo (LS, 71 %; DS,76

%) and Norte (DS, 76 %) regions standing out (Fig. C.4).

Most students from all populations who answered that they paid their energy-related household bills had a low level of difficulty in paying them (Fig. C.5). The following results relate to the entire sample of students, not just those who paid their energy bills. Most students from all populations (except for DS from AML, with 47 %) highly avoided using heating and/or cooling equipment to reduce energy bills (Fig. 6).

These notable reductions can be primarily attributed to the fact that most populations have reduced their energy consumption for home heating during the winter due to cost considerations (Fig. C.6).

Regarding whether individuals had curtailed their energy usage to cool their homes during the summer due to cost considerations, the prevailing response in the Norte and Centro regions was "not applicable" for the majority, ranging between 53 % and 61 % (Fig. C.7).

Following the PERMANOVA analysis, differences were observed among the regions; there were no significant differences between DS and LS, and the interaction between the two factors was not significant (Table 5). Pair-wise tests applied to differences among regions revealed that the Norte region is statistically equivalent to the Alentejo region, forming the Norte-Alentejo group, which is significantly different from AML. Moreover, there were no defined patterns for Centro.

Concerning the SIMPER analysis, Norte-Alentejo exhibits higher values than AML for the "level of difficulty in paying their energy bills", the "level of cuts in energy use to reduce energy bills", the answer to "Did you cut or reduce energy consumption for heating your residence during the winter due to energy costs?"

In summary, it can be inferred that AML is more favourable (students face fewer difficulties) than the Alentejo and Norte regions, where students experience greater difficulty paying their energy bills and greater energy consumption cuts.

Besides the coping strategy of reducing energy consumption due to cost considerations, the vast majority (>60 %) of students across all populations exhibited a high level of adoption of measures to endure heat or cold conditions instead of using heating or cooling equipment (Fig. C.8), such as using blankets or leaving the house. The Centro region stands out with the highest values, recording 84 % of DS and 95 % of LS adhering to this practice (Fig. C.8). Among DS, values are relatively consistent across regions, with 84 % in the Norte and Centro regions, 76 % in AML, and 83 % in Alentejo (Fig. C.8).

3.6. Building conditions

Regarding the construction year of the student's residence buildings, Fig. 7 shows the population distribution in five categories: "Pre 1920", "1920–1990", "1991–2006", "Post 2006", and "Don't know."

Most of the populations (except the Norte DS) stated that problems existed in their homes, such as draughts, cracks, humidity, or mould (Fig. 8).

Moreover, the vast majority of students from all populations felt that the poor building conditions of their homes affected them (Fig. C.9).

The PERMANOVA analysis revealed differences between the regions' housing conditions and the types of students (LS and DS). The interaction between the two factors was not significant (Table 5). Pair-wise tests applied to differences among regions revealed that the AML is statistically different from the Alentejo region. There was no defined pattern for Centro and Norte.

SIMPER analysis applied to the dissimilarity between the types of students showed that DS exhibits higher values than LS for the "year of construction of the building they live in" (older buildings for DS) and for the "presence of problems in students' accommodation (draughts, cracks, humidity, or mould)".

About the SIMPER analysis among AML and Alentejo, Alentejo exhibits higher values than AML for the "year of construction of the building they live in" (older buildings for Alentejo) and for the "presence of problems in students' accommodation (draughts, cracks, humidity, or mould)".

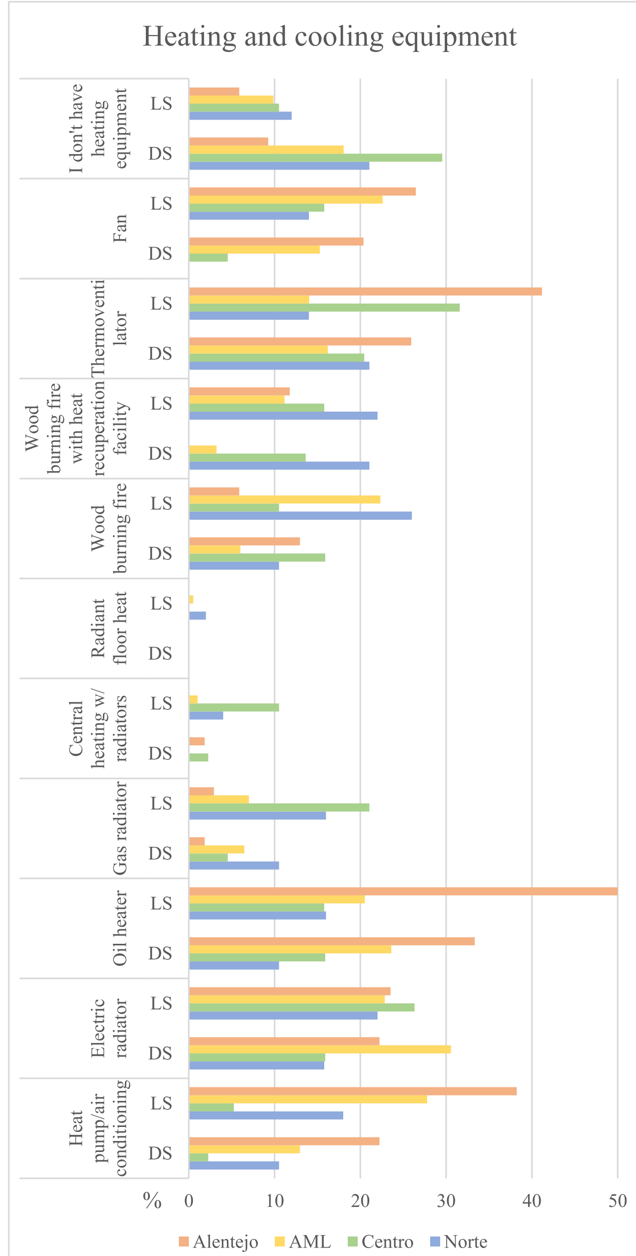

Fig. 5. Heating and cooling equipment in each population.

Table 6
Significantly higher values of equipment ownership in each pair of regions, according to the Simper analysis.

Devices/regions	Norte-Centro vs AML	Norte-Centro vs Alentejo	AML vs Alentejo
Heat pump/air conditioning	AML	Alentejo	Alentejo
Electric radiator	AML	Alentejo	AML
Oil heater	AML	Alentejo	Alentejo
Thermoventilator	Norte-Centro	Alentejo	Alentejo
Fan	–	–	AML
Wood burning fire	Norte-Centro	Norte-Centro	–
No heating equipment	Norte-Centro	Norte-Centro	–

In conclusion, it can be inferred that the Alentejo and DS share the common characteristics of older buildings and a higher incidence of

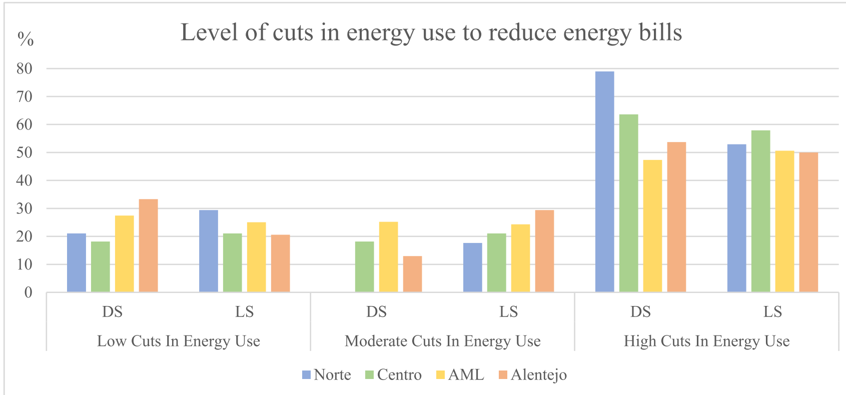

Fig. 6. Level of cuts in energy use by each population to reduce their energy bills (from low to high reductions in energy use).

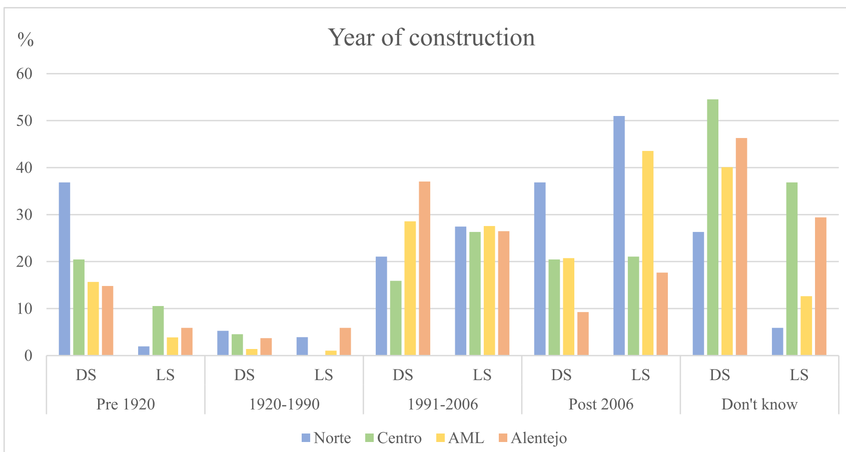

Fig. 7. Year of construction of the building where students from each population lived.

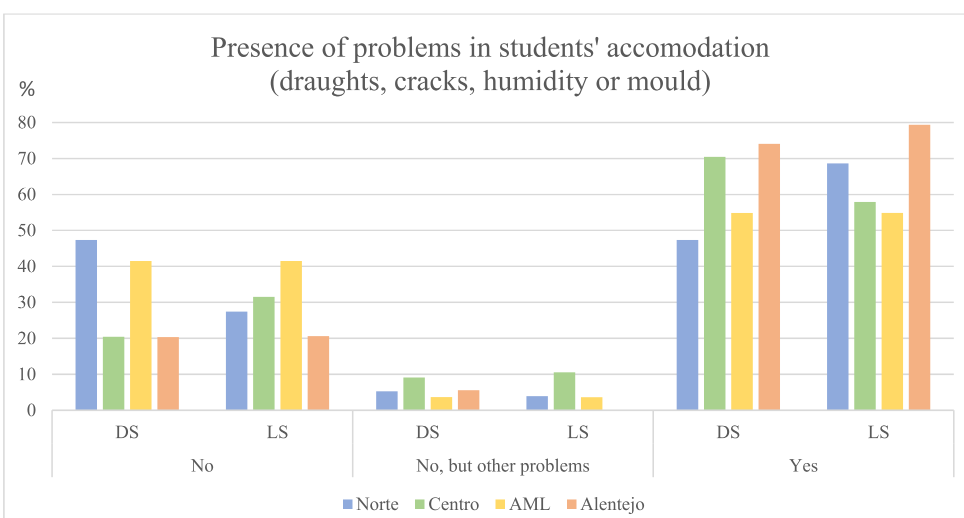

Fig. 8. Presence of problems (draughts, cracks, damp, or mould) in the accommodations of each population.

housing problems, and these distinctions are statistically significant.

3.7. Impacts of thermal discomfort and poor building conditions

Across all populations, the levels of impact resulting from thermal discomfort on education and health predominantly exhibit higher values within the low-impact range (Figs. C.10 and C.11). Moreover, the majority of students from all populations experienced a low level of limitation on their ability to purchase other goods and services, including items like medicines or internet access (Fig. C.12), when paying energy-related household bills.

According to the PERMANOVA analysis, differences were observed among the regions. Still, there were no significant differences between DS and LS, and the interaction between the two factors was not significant (Table 5). Pair-wise tests applied to differences among regions revealed that the Centro region is statistically equivalent to the Alentejo region, forming the Centro-Alentejo group, which is significantly different from AML. Moreover, Norte did not have defined patterns.

Regarding the Simper analysis, Centro-Alentejo exhibits higher values than AML for the "level of limitation on the ability to purchase other goods and services when paying energy bills" and the "level of impact of thermal discomfort on students' capacity to concentrate and/or educational attainment."

In summary, it can be inferred that AML is more favourable (students face fewer impacts) than Alentejo and Centro regions, where students experience higher limitations and impacts.

Finally, among students who perceived the poor building conditions of their homes as impactful, the primary effect across all populations was feeling uncomfortable, and the secondary effect, ranking second highest, was a reduction in their capacity to concentrate on their work or studies (Fig. C.13).

4. Discussion

Most displaced students (DS) or local students (LS) from the four mainland Portuguese regions studied (Norte, Centro, AML, and Alentejo) felt uncomfortable (mild or high discomfort) in summer and winter, except for LS in AML in winter, where the majority felt comfortable. No differences in the perceived thermal comfort were found among regions, but differences in this perception were observed between DS and LS. Winter and summer discomfort were higher in the DS than in the LS groups. In particular, the highest values for the percentage of DS with discomfort in winter were observed in the Alentejo region. In contrast, the highest values for discomfort in summer were recorded for DS in the Norte region.

The analysis of the causes of this variation in perceived thermal comfort was organised into three possible causes: heating and cooling equipment ownership, challenges with energy bill payments, and the building conditions in which they lived. However, only two sets showed differences between DS and LS: building conditions and ownership of heating and cooling equipment. DS tend to live in older buildings with more problems (draughts, cracks, damp, or mould), whereas LS have better building conditions. The rental status of DS might explain these differences compared to the homeownership status of most LS, which is in accordance with the highlighted students' EP vulnerability stemming from precarious housing conditions in the Private Rental Sector (PRS) [12–14,36] as vulnerability to EP often relates to rental conditions and terms, such as housing quality and tenancy stability [16]. LS also tend to have more heat pumps/air conditioners, which contribute to their greater thermal comfort, while DS tend to own less efficient devices like electric radiators, oil heaters, and thermoventilators, which may explain their increased thermal discomfort compared to LS.

Although no differences were found in the perception of thermal comfort between regions, analysing the potential causes of discomfort revealed significant differences between regions. In other words, the similar discomfort perceived in the different regions seems to have had various reasons. Equipment ownership differed significantly among regions, with students in the Alentejo region having more heat pumps/air conditioners than those in AML, potentially due to Alentejo's higher extreme temperature values and older buildings. This aligns with southern Portugal's higher ownership rates of cooling systems, leading to greater use of cooling equipment, higher consumption, and lower energy performance gaps [37]. Conversely, students in Norte-Centro regions reported less use of cooling and heating equipment, relying more on wood-burning fires. This correlates with higher cooling energy performance gaps in these regions due to low ownership and consumption of cooling equipment despite milder summer temperatures and higher heating energy performance gaps due to colder outside temperatures [37]. These differences reflect the geographic variations in Portugal's heating and cooling equipment ownership [37], influenced by cultural factors, energy infrastructure, and fuel accessibility [9,38].

Regarding building conditions, the Alentejo had significantly older buildings and a higher incidence of housing problems than the AML. In fact, in terms of Portuguese NUTS III (sub-regions), there is an uneven distribution of the index of buildings, with three sub-regions in the Alentejo having the oldest housing stock (Alto Alentejo, Baixo Alentejo and Alentejo Central) [11]. In addition, based on the study by Costa-Carrapiço et al. [39], the problems of EP in Alentejo may be exacerbated during winter in vernacular dwellings.

Similarly, Alentejo recorded significantly worse figures for the last set of causes analysed, challenges with energy bill payments, compared to the other regions. Students in the Alentejo and Norte regions experienced greater difficulties in paying their energy bills and made greater cuts in energy consumption than those in AML. Some additional factors that may contribute to these difficulties in the Norte region are its high at-risk-of-poverty rate [23] and the presence of social support or scholarships for many respondents from this region. These same factors and the greater difficulties with paying energy bills in the Norte region may explain the high share of DS feeling thermal discomfort in winter and summer.

Despite the generalised thermal discomfort and widespread adoption of coping strategies to endure heat or cold conditions instead of using heating or cooling equipment, as well as the potential vulnerability to EP of all populations, when students were asked about the impact resulting from thermal discomfort on their education and health, as well as their limitations in purchasing goods and services when paying energy-related household bills, the most frequent response category was "low impact" or "low limitation". This fact may be explained by a lack of knowledge and/or awareness of this issue or the tendency to consider it normal and acceptable to feel thermal discomfort at home, as suggested by Horta et al. [38]. This explanation can be applied across DS and LS since the patterns of the impacts of thermal discomfort and poor building conditions were similar between the two student groups. However, there were regional differences in these responses. Students in the Alentejo and Centro regions felt greater limitations and impacts from the EP than AML. A factor that may contribute to these limitations in the Centro region is the presence of social support or scholarships for many respondents from this region.

As a result, AML seems to be the most favourable region of all, with students having newer buildings and a lower incidence of housing problems, facing fewer challenges with energy bill payments, and, as would be expected, fewer impacts from EP. This result may explain the comfort in winter for LS from AML but not the discomfort in winter for DS and in summer for both LS and DS in this region. Castro and Gouveia [20] showed the vulnerability of university students in Lisbon to EP, which was exacerbated by housing problems, particularly during the winter, with 66 % of local students (including the national displaced students) and 77 % of international exchange students reporting discomfort. Both studies show worse figures than the 15 % of young people aged 15 to 18 in Lisbon experiencing winter thermal discomfort in their homes [40], which can negatively impact their school performance and lead to social isolation [41].

Regardless of the higher levels of discomfort among displaced students, >48 % of all students reported winter thermal discomfort, worse than the national average of 20.8 % of the population unable to keep their homes adequately warm in 2023 [5]. In summer, >56 % of all students reported thermal discomfort, worse than the 38.3 % of the Portuguese population living in a dwelling not comfortably cool during summertime in 2023 [5]. Additionally, >47 % of all students reported problems in their buildings, such as draughts, cracks, humidity, or mould, worse than the 29 % of the Portuguese population living with such housing problems in 2023 [5].

In summary, the Alentejo region and DS populations were confronted with older buildings and a higher prevalence of housing problems, suggesting they represent potentially more vulnerable populations to EP. Thus, the DS from Alentejo seems to be the most potentially vulnerable to EP among the studied populations and one of the two populations that perceived the most significant discomfort in winter.

Notably, the Alentejo students, a key focus of our study, were well-represented in the sample. At the same time, AML had the largest sample, which is consistent with its higher number of students and institutions. Although specific regional data on local and displaced students is unavailable, we ensured balanced representation across the four regions. Since private institution students constituted <5 % of our sample, a detailed analysis of this group was not feasible. This reflects the overall higher education landscape in Portugal, where public education predominates, with only 19.5 % of students enrolled in private institutions in 2022/23 [42]. Our study's limitations include the need for a more representative sample covering all seven Portuguese regions and private institutions to avoid overemphasising AML and public education. Despite these limitations, our random and unbiased sampling approach strengthens the reliability of our findings.

5. Policy recommendations

Given that students are neglected by policymakers and that students often do not identify themselves as a vulnerable group to EP [12,20], and since they may not be aware of the consequences of experiencing thermal discomfort at home, there is a critical need to shift research and policy focus to raise awareness of the poor quality of student housing. Young adults aged 18–34 living independently, including students and those in the PRS, are recognised as hard-to-reach energy users [43], meaning they are difficult to reach, motivate or engage with traditional interventions, programmes or services, typically top-down [44]. They face heightened vulnerability to EP due to prevalent poor housing conditions and limited control over energy services [43]. Petrova [36] underscores the normalisation of inadequate energy services in young adults' housing, influenced by socio-political norms that tolerate low-quality housing during the transitional period of youth. This demographic also exhibits specific energy demand dynamics, such as shared bill management and high non-heating energy use, alongside spatial clustering in PRS and low engagement in local politics [36]. To tackle these challenges, it is essential to develop new practices, resources, and engagement strategies and enhance the collaborative design and execution of interventions, incorporating support networks that extend beyond energy-related contexts [45].

Therefore, policymakers should adapt and formulate policies based on the findings of this study, with particular attention to students in Alentejo and DS at a national level. This should be addressed within the framework of the Portuguese National Long-Term Strategy to Combat Energy Poverty 2023–2050 (ELPPE) [46], alongside its periodic ten-year Action Plans to Combat Energy Poverty (PACPE) and the National Plan for Higher Education Accommodation (PNAES) [17].

Firstly, implementing the ELPPE should aim to enhance the energy performance of accommodation for these student populations, broaden access to energy services, reduce energy costs, and improve energy literacy. Secondly, DS face increasingly challenging living conditions due to escalating property market pressures in Portugal [17], with the price of rooms and flats for students rising by 10.5 % from 2022 to 2023 [47]. Addressing this issue necessitates more than just the construction of new student residences or building adaptations. The PNAES aims to increase the bed capacity from 15,073 to 26,772 until 2026 in a universe of 119,818 DS in public higher education [17]. Thirdly, collaborative efforts among ELPPE, PACPE, and PNAES are essential, as this issue intersects both domains and requires urgent attention and action from all sides. For instance, actions should be taken directly within the PRS, potentially including incentives for private landlords who rent to DS and projects that enhance energy efficiency within the PRS. Additionally, minimum efficiency standards should be mandated when renting to higher education students, as proposed by Morris and Genovese [12]. Higher education institutions could play a pivotal role by engaging with energy providers, landlords, local authorities, and student unions to improve energy access, address housing inefficiencies, and raise EP awareness.

Addressing the urgent need for building renovation in Portugal, especially within the PRS and older buildings, should be a priority. Palma et al. [48] suggest focusing on renovating older house archetypes, primarily to reduce space heating needs. To achieve this, there is a requirement for more attention to be given to improving overall energy efficiency in buildings, and traditional top-down approaches to building renovation policies have often fallen short of delivering desired outcomes [48]. Palma et al. [48] propose a more effective bottom-up approach, utilising archetype-based methods to estimate energy needs reduction and a retrofit measures database to calculate investment costs. Their findings emphasise the significance of prioritising roof renovations when designing support schemes and the combination of internal and external wall insulation as a promising strategy to reduce energy needs during the heating season [48].

Finally, higher education institutions should be empowered to certify suitable accommodations, ensuring they meet the required energy efficiency standards and minimise the risks of EP among higher education student populations. Collaborative efforts involving student groups, higher education institutions, landlords, and local and national governments are essential for meaningful progress in this field. These stakeholders must work together to enhance the quality of accommodations for higher education students and reduce their vulnerability to EP. This multi-level approach can ensure that policies are inclusive and reflect the diverse needs of students across different regions.

6. Conclusion

The state of energy poverty (EP) in Portugal presents high challenges compared to other EU member states, primarily attributed to the prevalence of aging buildings with poor thermal performance. These housing conditions are especially pertinent for the higher education student population, who are increasingly vulnerable to EP, mainly due to unstable and poor housing situations within the Private Rental Sector (PRS). Within this population, displaced students stand out as an exceptionally vulnerable group, heavily reliant on the PRS with limited control over energy services and categorised as hard-to-reach energy users. Notably, in Portugal, the living conditions of displaced students, particularly those with financial limitations, have become increasingly precarious due to the surging pressures within the property market.

Our study compared thermal comfort and vulnerability to EP between displaced (DS) and local (LS) higher education students in Portugal. Surveying 848 respondents across four mainland Portuguese regions (Norte, Centro, AML, and Alentejo), the research found widespread discomfort in both summer and winter, with DS reporting higher levels compared to LS. While regional differences in thermal comfort were not significant, the causes of discomfort varied significantly across regions.

The analysis revealed significant differences between DS and LS in two factors contributing to perceived thermal discomfort: building conditions and ownership of heating and cooling equipment. DS tended to reside in older buildings with more structural problems, whereas LS had better building conditions. LS also possessed more energy-efficient equipment, contributing to their enhanced thermal comfort. These differences might be explained by the rental status of DS compared to the homeownership status of most LS since the vulnerability of DS to EP may be due to the precarious housing conditions in the PRS.

These findings highlight potentially vulnerable populations, particularly DS from the Alentejo region, who faced older building conditions and more structural problems. Despite widespread discomfort and potential vulnerability to EP, students generally reported a low impact on their education and health, as well as limitations on purchasing goods and services when paying energy-related household bills. This could be attributed to a lack of awareness of the consequences of such discomfort or a normalisation of it.

Recognising the negligence of students by policymakers and their lack of self-identification as a vulnerable group to EP, this study underscores the urgency of refocusing research and policy attention on the substandard quality of student housing. Policymakers should use this research to tailor policies, particularly considering Alentejo students and DS at the national level. This realignment should occur within the framework of the National Plan for Higher Education Accommodation (PNAES) and the implementation of the National Long-Term Strategy to Combat Energy Poverty 2023–2050 (ELPPE) and its recurring ten-year Action Plans to Combat Energy Poverty (PACPE).

Collaboration among ELPPE, PACPE, and PNAES is essential, particularly within the PRS, with potential incentives for landlords and the enforcement of minimum efficiency standards for student rentals. To address Portugal's urgent need for building renovations, with a specific focus on the PRS and older buildings, an approach similar to the one proposed by Palma et al. [48] should be adopted, prioritising older house archetypes and utilising a bottom-up methodology.

Lastly, higher education institutions should be empowered to certify suitable accommodations that meet energy efficiency standards, minimising EP risks among students. Collaboration among student groups, higher education institutions, landlords, and local and national governments is essential to enhancing accommodation quality and reducing student vulnerability to EP. Such collaboration could facilitate access to affordable energy, address housing inefficiencies, and raise EP awareness. This collective effort is pivotal for achieving meaningful progress in this critical area and should be at the centre of future research into collaborative processes in this field.

Regarding the study's limitations, the responses from DS relating to the summer should be interpreted with caution, as they may be affected by the fact that DS may spend part of the season in their hometowns, outside the region of their higher education institution. Moreover, we acknowledge that a more comprehensive analysis would necessitate a more representative sample encompassing all seven Portuguese regions, including private institutions, to avoid an emphasis on the AML in the overall sample or of the public higher education. Despite these limitations, our efforts to ensure a random and unbiased sample enhance the reliability of our findings. The study aimed to raise awareness of the problem, and as it was seen to be a significant issue, we recommend a solution by suggesting an expansion of the analysis by including EP-related questions in the usual annual surveys conducted by higher education institutions. Such questions should consider students' housing situations, whether they reside in public institutional housing, private residences, or the PRS, as these distinctions can significantly affect their vulnerability to EP. In addition to the student's housing situation, future research should explore other dimensions, such as sex and country of origin, to gain a deeper understanding of the factors influencing EP. By analysing the results from these regular surveys, each institution can tailor its actions to address the specific vulnerabilities of its student population to EP, involving all relevant stakeholders, including the students themselves. While our study focuses on Portuguese higher education students, its findings on EP are pertinent globally, especially in regions with comparable climates and housing challenges. Future studies should explore EP among higher education students in varied socio-economic contexts to validate and extend our insights on effective intervention strategies.

CRediT authorship contribution statement

Carolina Cruz Castro: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **João Pedro Gouveia:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103842.

Data availability

Data will be made available on request.

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