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Local accommodation energy efficiency in Lisbon: a red flag for tourism, indoor thermal comfort, and energy renovation targets

Inês Valente[1], **Bárbara Fernandes**[2], **André César**[2], **Laura Menezes**[2] **and João Pedro Gouveia**[1,*]

[1] CENSE—Center for Environmental and Sustainability Research & CHANGE—Global Change and Sustainability Institute, NOVA School of Science and Technology, NOVA University Lisbon, Campus de Caparica, 2829-516 Caparica, Portugal
[2] NOVA School of Science and Technology, NOVA University Lisbon, Campus de Caparica, 2829-516 Caparica, Portugal
[*] Author to whom any correspondence should be addressed.

E-mail: jplg@fct.unl.pt

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Abstract

Climate change affects all sectors of society, and tourism is no exception. Adaptation in this sector is challenging because of its vulnerability to rapid change and uncertainties of an environmental and political nature. Local accommodation (LA) (short-term rentals) plays a key role in the Portuguese economy and is, thus, potentially a key driver of increased energy efficiency and promoting buildings decarbonization, thereby contributing both to climate change adaptation and mitigation of this sector. However, there is limited research on energy efficiency and climate change resilience in the LA sector. To address this research gap, this study focuses on four civil parishes situated in the historic center of Lisbon, Portugal. Using a multidimensional approach and cross-sectoral datasets, we assessed the energy efficiency of LA in Lisbon and explored the cost of renovation measures. This analysis exposed poor energy performance in LA buildings and a low frequency of buildings with thermal insulation or double-glazed windows. Despite this, energy performance in the LA sector was comparatively better than in the residential sector. Additionally, LA s are equipped with more heating and cooling systems than the broader residential sector. This knowledge is relevant for researchers and policymakers, contributing to developing sustainable tourism approaches and reaching the objectives outlined in energy renovation policies.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) 6th assessment report is clear: global greenhouse gas emissions (GHG) are at the highest recorded levels in human history. If global carbon dioxide (CO_2) emissions continue at current rates, the remaining carbon budget for keeping global warming below 1.5 degrees will likely be exhausted before 2030 (IPCC 2022). The number of extreme weather events and the intensity and duration of heating and cooling (H&C) degree days are increasing, resulting in a growing energy demand (IEA 2018, 2023). Furthermore, ecosystem services connected to human health and well-being are being impacted by climate change (IPCC 2023).

In southern Europe, the climate will undergo a shift, characterized by an increase of extreme heat events, consecutive dry and days with fire risk (EEA 2024). The Mediterranean region is identified as a 'climate change hotspot' (Ali *et al* 2022), warming 20% faster than the global average (UNEP/MAP & Plan Bleu 2020). In the Lisbon metropolitan area, the city's vulnerability to extreme heat is currently moderate but will increase significantly in the coming years (CRUD 2019). The most densely populated and urbanized areas will be the most vulnerable to extreme heat in the future. Thus, the municipality of Lisbon is a good example for assessing this risk, as its climate characteristics and high concentration of tourism make it more susceptible to the urban heat island phenomenon (CRUD 2019). Additionally, energy demand for H&C buildings is also driven by technological and infrastructural components (design and materials that determine the thermal properties of the building and its H&C efficiency) and by socioeconomic components (particularly, population density, the behavior of people, energy prices and gross domestic product) (Deroubaix *et al* 2021).

Tourism may be one of the economic activities most affected by climate change, but it also contributes to an increase in GHG (8% of total GHG emissions) (Lenzen *et al* 2018). Tourism is an expanding sector significant at both the global and European levels. Tourism contributes to the economic growth of a region, producing social benefits through job creation, improvement of infrastructures, and the development of small and medium-sized enterprises. In 2019, travel and tourism accounted for 10.3% of global GDP, with a slight decrease between 2020 and 2021 due to the pandemic (5.3% and 6.1%, respectively) (Statista 2022). Tourism is more vulnerable to climate change than the overall economy, and climate change implies a range of impacts and implications for the industry (Becken 2010, Dogru *et al* 2019), representing a need for tourism businesses and destinations to adapt (Kaján and Saarinen 2013). Climate change is set to change environmental attributes and thermal conditions, leading to higher rates of tourist dissatisfaction (Nasrollahi *et al* 2017), a decline in tourist numbers due to a loss of comfort associated with extreme weather events (Arabadzhyan *et al* 2021) and consequently losses in revenues (Pan He *et al* 2019). In fact, pleasant weather conditions are one of the main criteria for choosing a travel destination (ETC 2023a). These changes are already being observed as 2023 was characterized by extreme events, namely floods, wildfires, and heatwaves, all across Europe, impacting the length of stay in the countries and with implications for future travel choices (Salgado 2023, ETC 2023b). Given the level of economic dependence on tourism and the uncertainty surrounding how it will be impacted by climate change, there is a clear need for further research in the field of climate change and tourism, as only 0.5% of climate change studies are currently focused on tourism (Pang *et al* 2013).

Moreover, the tourism sector as a whole will need to adapt to become more sustainable principally by mitigating its impacts and promoting resilience in the sector to extreme events. Indeed, overall resource consumption in the sector is projected to grow by between 92% (water) and 189% (land use) in the period 2010–2050 (Gössling and Peeters 2015). This highlights the need to transition towards forms of tourism 'that take full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment, and host communities' (UN Tourism, n.d.). Naturally, this is especially important in regions with a high number of tourists and high vulnerability to climate change, such as the Mediterranean region (UNEP/MAP & Plan Bleu 2020). In response to these challenges, several tourist accommodations are already implementing sustainable tourism practices, particularly those related to energy efficiency. For example, according to the World Travel and Tourism Council, in 2022, almost half of tourist accommodations globally invested in insulated windows to reduce H&C practices (WTTC 2022).

Tourism in Portugal has been growing, and it is now considered one of the most competitive tourist destinations in the world. It is even considered the 12th most competitive out of 140 countries (WEF 2019). The development of Lisbon as a tourist destination has been so rapid that the city could arguably be considered to be experiencing a phase of tourism gentrification (Lopes *et al* 2019, Estevens *et al* 2023). This sector is vital for Portugal's economy, representing 8.0% of GDP in 2019 (INE 2021). Local accommodation (LA) is a popular option for tourists in Portugal. This type of tourist accommodation represents 47.2% of total tourist accommodation and provides 19.9% of the number of beds (INE 2021). In Lisbon, LA had an average annual growth higher than 85% in 2019, surpassing the number of rooms available in the hotel industry (Tourism of Portugal 2019). The rapid growth of LAs can be attributed to an increased demand for tourist accommodation in Lisbon. Furthermore, as adaptations of existent residential fractions, LAs also have the advantage of a comparatively quick rate of market entry (Ó Ramos *et al* 2022). Online platforms like Airbnb generally offer access to short-term rentals (STR) (Jover and Cocola-Gant 2022). These platforms are changing the tourism marketplace for LA, as they are a more convenient accommodation service for customers, are more affordable, and offer a wide range of services and experiences, allowing guests to 'live like a local' (Lopes *et al* 2019), encouraging them to explore non-touristic neighborhoods and to connect with residents (Roelofsen 2020). It is even argued that LA are positively impacting the renovation of buildings in cities (Balampanidis *et al* 2019, Chamusca *et al* 2019, Xu and Xu 2021). The emergence of LA in Lisbon also signifies a significant socioeconomic activity, as 49% of LA properties are owned by individuals, and 40% of households with LA obtain more than 50% of their income through these accommodations (Ó Ramos *et al* 2022). There are 20 157 LAs in the Lisbon municipality (Tourism of Portugal 2023), of which 14 052 are listed on Airbnb (Inside Airbnb 2023).

Considering that thermal comfort conditions are becoming an essential factor in choosing a tourist destination and that LA is one the main forms of tourist accommodation, thermal comfort should be a crucial focus of future measures and policies for this sector. In this sense, it is important that LAs ensure thermal conditions that enhance the resilience of these infrastructures in the face of current temperature increases and climate change–related extreme weather events such as heatwaves and cold spells. However, the Portuguese residential building stock is inefficient, and the LA sector may share characteristics which typify the existing residential dwelling stock as most of the LA units are residential units that were modified for tourism purposes. According to the (Decree-Law no. 39/2008), LA are '*Accommodation establishments are dwellings, flats, and facilities that, with proper authorization, offer temporary lodging services for a fee. However, they do not meet the criteria to be classified as tourist developments.*' and do not fall under any categories of typologies of touristic enterprises, indicating that tourist accommodation of this type is closer to residential dwellings. energy performance certificates (EPC) are an important tool to assess the energy performance of buildings, classifying them on a scale ranging from $A+$ (highest) to F (lowest). In Portugal, only 3.4% of households are very efficient (have an $A+$ rating), and 41.5% have a classification of D or below.

Additionally, 17.5% of the population expressed an inability to keep houses adequately warm (EPAH 2024). This was also concluded by Gouveia and Palma (2019) in an analysis of Portuguese EPCs, where windows and roofs were identified as the most inefficient elements in buildings. In Lisbon, 30.9% of dwellings have a C rating, and 40.4% are rated D or below ADENE (2023a) and 86% of the residential buildings were constructed before 1990 (INE 2022). The corresponding lack of indoor thermal comfort can be associated with health impacts (Middlemiss 2022), namely the increase in hospitalizations during extreme events (Alho *et al* 2024). If the characteristics of buildings in the LA sector closely resemble those in the residential sector, hypothetically, it may represent a major threat to the tourism sector, as the low energy efficiency of dwellings will reflect their inability to adapt to future climate conditions. This issue is particularly significant given the differences in thermal perceptions between tourists and locals (Lam *et al* 2018). While Portuguese citizens normalize poor thermal comfort in their homes (Horta *et al* 2019), this may not extend to tourists staying in accommodations with the same characteristics as Portuguese dwellings. Considering the current situation of the buildings, Portugal aims to renovate 100% of the residential buildings and 52% of the non-residential buildings by 2040 (compared to the existing buildings in 2018), investing, on average 165€ m^{-2} and 145 € m^{-2} on non-residential buildings (Council of Ministers Resolution no. 8-A 2021).

Despite the prevalence of LA compared to other forms of tourist accommodation, there has been limited research on the energy performance characteristics of these buildings or how they impact urban development. Taking the Portuguese context into consideration, Chamusca *et al* (2019) analyzed Airbnb's growth in Porto, arguing that one of the major effects in the city was the renovation of buildings, asserting that tourism stimulates private investment, thereby encouraging physical rehabilitation. Cocola-Gant and Gago (2021) investigated whether short-term rental platforms like Airbnb direct investment into residential real estate, and the effects on local communities in Lisbon, the results implied that the presence of these tourist accommodations leads to increased neighborhood building renovation. Rodrigues *et al* (2022) explored stakeholder perspectives on the evolution of LA in Lisbon. Based on this research, the authors suggested that to enhance sustainable practice in Las, increased regulatory oversight in the sector was required. Another recommendation was the redirection of revenue generated from LAs back into activities which enhance the quality of life of the resident community. Finally, improved communication with groups engaged in the LA sector was promoted.

Estevens *et al* (2023) analyzed the percentage of short-term rental units in civil parishes in Lisbon. They concluded tourism accommodations were present in most of the buildings that had received rehabilitation licenses, highlighting the significant influence of tourism on cities. These studies have revealed that Airbnb's presence in a region leads to waves of renovation in neighborhoods, implying that these renovated buildings have better thermal characteristics than the older dwellings, as the renovated buildings adhere to thermal comfort standards. Despite this, a deeper analysis of the comparative thermal performance of these different buildings is lacking. Vilches and Martín (2022) examined the vulnerability of LAs in Córdoba to climate change by analyzing LAs' energy performance classification/grades. The study revealed that only 13% of these accommodations had undergone rehabilitation, and among the 311 dwellings analyzed, only 101 had undertaken an energy performance assessment. 30% of the LAs were classified in the five lower ratings (*C, D, E, F, G*). Additionally, they did not compare the energy performance of the tourist accommodations with the energy performance of the residential buildings in the same region.

To contribute to the identified research gap in improving the understanding of thermal comfort in local tourist accommodation, we studied four civil parishes in Lisbon, a world tourism hotspot. These civil parishes are among those most pressured by tourism and present significant levels of social and residential energy vulnerability. Our main objectives are as follows; (1) to characterize the region in terms of building and climatization equipment, (2) to develop a comparative evaluation of the energy performance (EPC ratings) for all the dwellings in the region, and (3) to assess the cost of energy efficiency retrofit measures aligned with the Portuguese Long-term Strategy for Building Renovation 2050 to this sample of LA. Hence, due to the absence of specific data and a detailed description of these types of tourist accommodations, this study utilized multiple data sources to develop an extensive information base on LAs. This was achieved by cross-referencing data from key tourism databases (including a national database managed by the Tourism of Portugal (National Tourist Authority), with all the information regarding the LAs registered in Portugal, and the Inside Airbnb platform), the portuguese energy performance certificate buildings platform; and data sourced directly from Airbnb's platform for each LA. In this research, a departure from conventional methodologies is explored in the evaluation of thermal comfort. Studies involving thermal comfort often involve the computation of thermal comfort indices, for example, Salata *et al* (2017) mapped the mediterranean outdoor comfort index for local tourists and the Predicted Mean Vote for international tourists in Italy or Lopes *et al* (2021) that studied the perception of bioclimatic comfort of tourists in Porto, Portugal, using a quantitative index. However, the approach employed in this study includes proxy variables associated with building features and thermal characteristics, which exposes potential threats to thermal comfort. The proxy variables employed were the energy performance rating (EPC grade), the presence of insulation in the building's envelope, the type of windows installed within the building, and the existence and type of H&C systems. The EPC grade was used as a proxy of thermal comfort, calculated from the methodology set on national regulations based on energy needs, determined by accounting for reference conditions to guarantee indoor air quality, thermal comfort, and healthy spaces (ADENE & DGEG 2021). In the case of the H&C systems, the energy needs were calculated based on the ability of the dwelling to maintain an indoor temperature of 18 °C for heating and 25 °C for cooling (ADENE & DGEG 2021).

Furthermore, the building envelope is essential in determining indoor thermal comfort. Including insulation materials and double-glazed windows is also significant as they act as effective barriers against heat loss, thereby preserving desired indoor temperatures (Elghamry and Hassan 2019). Additionally, the presence of H&C equipment is paramount, given its role in regulating interior thermal conditions (Solano *et al* 2021). Considering these factors, it was considered that if a building has a high EPC performance rate, effective thermal insulation on its envelope, and is equipped with H&C systems, it is likely to provide thermal comfort to its occupants and be more resilient to extreme weather events.

This paper is structured into five sections. The subsequent section presents the case studies and outlines the methods to assess energy efficiency in the LA sector. The results and discussion sections present the findings and compare them with data from the residential sector. The conclusion section offers final remarks and addresses the necessity and significance of building renovation in both the LA and residential sectors.

2. Method

This section provides a detailed description of the research design and methods used to assess energy efficiency in the LA sector in Lisbon. The criteria for selecting the four civil parishes are outlined, and the selected parishes were those where the frequency of LA per total area coincided with high vulnerability to energy poverty according to the energy poverty vulnerability index (EPVI). The section also describes the range of databases used to gather information and carry out analyses, including two online data platforms: Turismo de Portugal and Inside Airbnb. Lastly, the process of obtaining information on the EPC performance and H&C equipment for each selected LA is explained.

2.1. Case study

We explore the case study of Lisbon, a popular tourist destination known for its amenable climate, with an average yearly temperature of 16.8 °C (Weather Sparks 2023). The warmest temperatures are typically recorded during summer, reaching 28 °C in July and August (Weather Sparks 2023). The number of heating degree days is 1071, and the duration of the heating season is 5.3 months (ADENE & DGEG 2021). According to Tourism of Portugal (2023), Lisbon has 20 157 LAs throughout the municipality. To better assess energy vulnerability in the sector, four civil parishes located in the historic area of Lisbon were chosen considering two criteria: civil parishes with the highest frequency of LA per total area (km^2); and civil parishes with the highest vulnerability ranking according to the EPVI in the city of Lisbon (Gouveia *et al* 2019, Municipality of Lisbon 2021). In addition to including socioeconomic aspects in the index, it also considers factors related to energy usage patterns, building construction attributes, and the energy efficiency of diverse building types. The index is, therefore, a highly relevant tool for application in this case. Based on the described processes, the four civil parishes chosen for this study were: Arroios, Estrela, Misericórdia, and Santa Maria Maior (figure 1).

Table 1 lists some indicators that help to describe the civil parishes under study. This information has been collected from the National Statistics Institute-CENSUS 2021 (INE 2022). The table presents a selection of the results of an energy poverty survey conducted in Lisbon (AdE Porto, Lisboa E-Nova & Porto Energy Hub 2022). The survey assessed characteristics of energy poverty in all the civil parishes of the city of Lisbon. The civil parishes in question are characterized by high population density and an aged population. A lack of

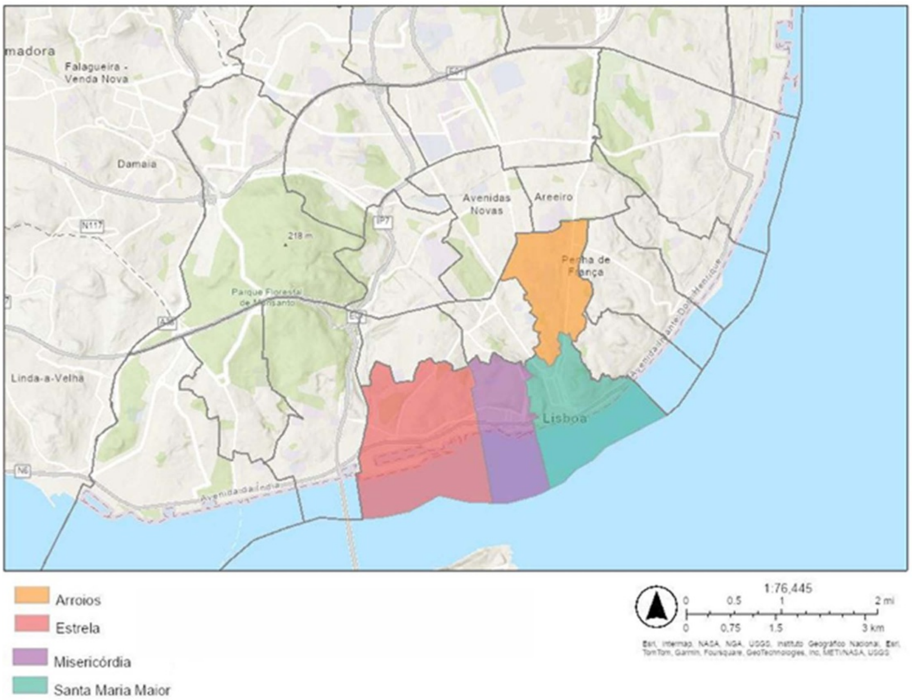

Figure 1. Civil parishes of Lisbon (outlined in grey) and study area.

Table 1. Demographic indicators by civil parishes. (Data from AdE Porto, Lisboa E-Nova & Porto Energy Hub (2022)[1] and INE (2022)[2]).

Indicator	Civil parishes			
	Arroios	Estrela	Misericórdia	Santa Maria Maior
Inhabitants (nº)[2]	33 332	20 267	9655	10 000
Population density (nº km^{-2})[2]	15 634	4405	4411	3339
Ageing index (nº)[2]	193.1	139.1	234.3	231.7
Literacy rate (%)[2]	1.9	1.2	2.1	3.2
Percentage of buildings in need of renovation (%)[2]	33	47	35	44
Percentage of dwellings for seasonal use (%)[2]	9.3	9.0	10.7	9.5
Reported having problems with damp in their dwellings (%)[1]	30	29	41	44
Temperature at home is not comfortable during summer (%)[1]	36	36	17	34
Temperature at home is not comfortable during winter (%)[1]	45	42	36	50
Sleep disturbance due to temperature (%)[1]	11	9	11	14

thermal and acoustic comfort may be experienced by the people living in these civil parishes as all survey participants report not feeling comfortable during summer and winter and report the presence of damp in their dwellings, participants also identified that poor conditions in their dwellings impacted their sleep quality, reflecting an old building stock in need of deep energy renovation. These characteristics underscore the presence of elevated energy vulnerability within civil parishes. Furthermore, given that a significant proportion of LAs are situated within these same civil parishes, it becomes apparent that this vulnerability extends beyond the confines of the residential sector and extends to the tourism sector.

2.2. Characterization of local accommodation

Several cross-sectoral databases were used to assess the energy efficiency of LA in Lisbon, as demonstrated in figure 2 and in more detail in figure 3. This made it possible to carry out the analyses.

The first step in the methodology consisted of creating a database of LA in the four civil parishes under study. Firstly, relevant publicly available datasets were identified. Two online data platforms were used to obtain data regarding the number of LAs in the four civil parishes under study: the Open database of Turismo de Portugal and the Inside Airbnb data platform. The first contains all the LAs listed in Portugal on all platforms. It has information regarding the LA (name and details about the host, location, and specifications regarding the inclusion of the LA in any Portuguese program or plan). The Inside Airbnb Platform contains all the LAs listed on Airbnb worldwide, including information regarding the location of

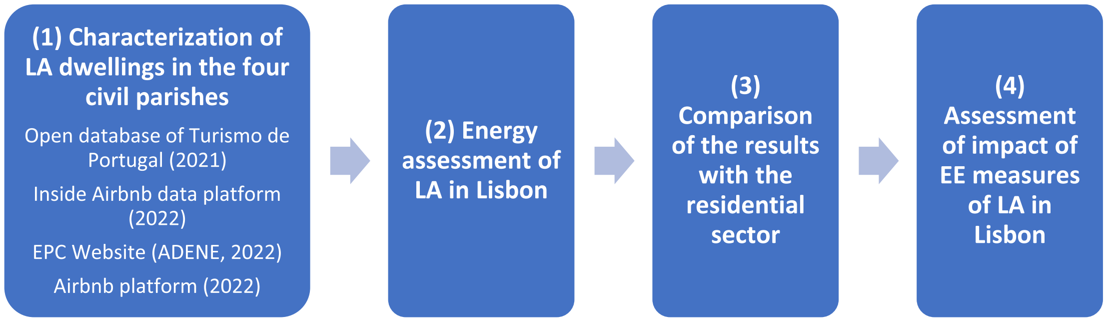

Figure 2. Methodological structure and flow of the use of different databases.

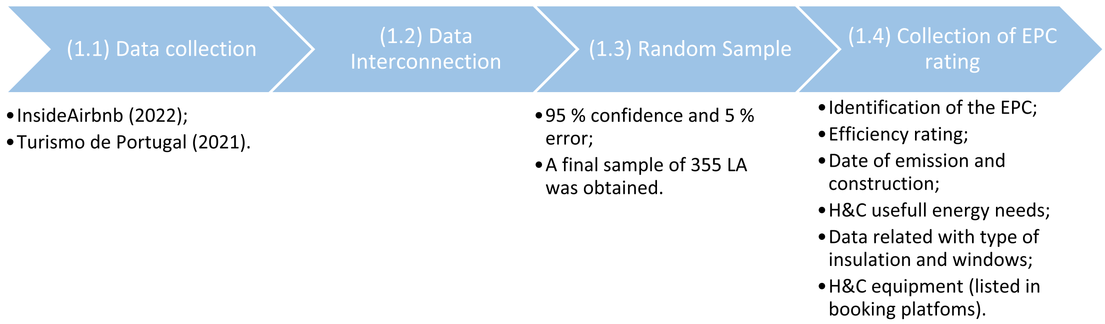

Figure 3. Methodological overview of the first step for the methodology-characterization of LA buildings in the four parishes in the study.

the LA, the host, the price per night, and the minimum number of nights required in each LA. This last parameter made it possible to discard the long-term rental accommodations since this study focuses on (STR). The Turismo de Portugal platform contained data for 11 858 LA of the four civil parishes, of which 6506 were listed on the Inside Airbnb platform. The data obtained through the two platforms had one parameter in common-the National LA Register number (nRNAL) of each accommodation—allowing the data to be crossed between the two platforms (step 1.2 from figure 3). After combining the data between the two databases and discarding the accommodations with a minimum stay of more than 20 nights, a total of 4521 LA remained, with the following information: nRNAL, name of the LA, address, and date of registration. Data with filling errors were also discarded (5%).

From the final data set, LA had the following distribution between the four civil parishes: 1894 located in Santa Maria Maior (42%), 499 located in Estrela (11%), 726 located in Arroios (16%), and 1402 located in Misericórdia (31%). After obtaining all the complete data, a representative random sample of LA was selected for each civil parish. The sample size was determined using a modified Cochran's sample size formula (equation 1). Thus, a random sample of the entire set (4521) was calculated with 95% confidence and a 5% margin of error, from which a final sample of 355 LA was obtained (step 1.3 from figure 3).

$$\text{Sample size} = \frac{\frac{Z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{Z^2 \times p(1-p)}{e^2 N}\right)}$$

N = population size; e = margin of error; Z = z-score; p = population proportion = 0.5

Equation 1. Modified Cochran's sample size formula. Used to determine the sample size with 95% confidence and 5% margin of error.

To maintain the representativeness of each civil parish, the final sample size was multiplied by the distribution percentage of LAs in each civil parish mentioned above, reaching the following results: 149 LA in Santa Maria Maior, 39 LA in Estrela, 57 LA in Arroios; and 110 LA in Misericórdia. With all the data collected, the next step was gathering information regarding the LA sample's EPC (step 1.4 from figure 3). Utilizing the address of each LA, the platform created by ADENE was used (ADENE 2023b). The relevant EPC data, including the energy performance rating, unique document identification details, date of emission, and information regarding energy consumption for heating, cooling, heating of domestic hot water, CO_2 emissions, type of insulation, and type of windows, were retrieved from the platform. To standardize the data among the civil parishes and reduce the error, all the EPCs belonging to abandoned houses and those issued under the outdated buildings' performance regulation (Decree-Law no. 78/2008) were discarded. These samples by civil parish were chosen sequentially in the complete list since most of the LAs did not present an EPC.

Using the address and name of each LA, it was possible, through the Airbnb platform, to find the relevant LAs and characterize them in terms of the H&C equipment they may have. Thus, the data obtained regarding the H&C equipment was based on the information available in each listing, namely the accommodation description and the photographs the owners provided. It is important to note that having more than one device in each dwelling is possible. Figure 3 highlights the primary steps in this first phase of the study. After organizing the data, we advanced to the subsequent stages of the methodology, namely steps three and four. These steps involved analyzing the data based on the EPC energy performance ratings and the presence of equipment for each civil parish. These steps involved analysing the data based on the EPC energy performance ratings and the presence of equipment for each civil parish. The useful energy needs for H&C were also extracted from the EPC and analyzed. These needs are calculated following the EN ISO 13790 approach which considers the heat transfer by the envelope, heat transfer by ventilation and useful heat gains (ADENE & DGEG 2021). The equation for the calculation of the heating useful energy needs is (equation 2):

$$\mathrm{EN_H} = (Q_{\mathrm{tr}} + Q_{\mathrm{ve}} - Q_{\mathrm{gu}})/A_{\mathrm{p}}$$

Equation 2. Heating useful energy needs equation.
where Q_{tr} is the heat transfer through conduction between the building and the surroundings in kWh yr^{-1}, Q_{ve} is the heat transfer through ventilation kWh yr^{-1}, Q_{gu} is the total useful heat gain in kWh yr^{-1} and A_p represents the useable floor area in the building in m^2. The equation for the calculation of the cooling useful energy needs is (equation 3):

$$\mathrm{EN_C} = (1 - n_{\mathrm{v}}) * Q_{\mathrm{g}}/A_{\mathrm{p}}$$

Equation 3. Cooling useful energy needs equation.
where n_v represents the utilisation factor of the heat gains, Q_g represents the heat gains in kWh yr^{-1} and A_p is the useable floor area in the building in m^2.

During step four of the methodology, further analysis was performed. Based on the results, a set of energy efficiency measures was simulated for the sample of LA. The measures simulated aligned with the package of measures proposed in Portugal's Long-term Strategy for Building Renovation 2050 (Council of Ministers Resolution no. 8-A 2021). Based on the measures proposed in the strategy, the study simulated the costs of replacing H&C systems and the building envelope. The suite of measures considered was the application of insulation material with a thermal conductivity coefficient of 0.037 (W/m/°C), replacing single-glazed windows with double-glazed alternatives and installing heat pumps in LA units devoid of equipment or relying solely on inefficient and commonly used portable fans or electric or gas heaters. The average investment costs were derived from a market-based generation tool (CYPE S.A. 2013), and the prices considered were 80€ m^{-2} for the insulation, 455€ m^{-2} for the windows, and €1,800 for the heat pump with two inside units. For the latter, the payback time was calculated by dividing the cost of intervention by the price per night of the LA.

3. Results

This section presents results regarding the energy performance ratings observed in LAs in the four civil parishes (section 3.1). Results regarding the number and type of space H&C equipment in LAs are also presented in subchapter 3.1. The discussion of these results (section 3.2) facilitates a general characterization of the energy efficiency of the LA sector in Lisbon and a comparison with the energy performance of the overall residential sector in Portugal. Finally, the consequences of low energy efficiency on thermal comfort in LAs are discussed, focusing on potential impacts on health and tourism (section 3.3).

3.1. Energy consumption, carbon dioxide emissions, and buildings energy performance

Among the four civil parishes, the CO_2 emissions exhibited varying levels: Santa Maria Maior recorded 1.75 t yr^{-1}, Arroios had 2.3 t yr^{-1}, Estrela emitted 1.8 t yr^{-1}, and Misericórdia accounted for 2.00 t yr^{-1}. The average price per night was €128 in Arroios, €121 in Estrela, €145 in Santa Maria Maior, and €135 in Misericórdia. Table 2 shows the heating and space cooling energy needs in each civil parish by period of construction of the LA. Small variations were noted among the four civil parishes, namely in heating needs.

Table 2. Space cooling and space heating energy needs in the four civil parishes by period of construction.

Period of Construction	Energy needs for space heating ($kWh\ m^{-2}\ yr$)				Energy needs for space cooling ($kWh\ m^{-2}\ yr$)			
	Arroios	Estrela	Santa Maria Maior	Misericórdia	Arroios	Estrela	Santa Maria Maior	Misericórdia
Before 1919	100.3	144.1	98.3	86.1	20.7	18.5	17.5	17.5
1919–1945	98.3	94.6	83.2	87.6	12.3	14.7	16.6	21.1
1946–1960	71.0	73.8	78.3	77.0	17.7	13.9	16.9	16.4
1961–1980	110.3	63.3	86.1	36.6	9.8	18.4	16.0	20.2
1981–2005	49.2	67.9	80.7	54.3	11.3	20.7	17.2	14.0
2006–2020	64.0	—	48.6	43.9	7.1	—	11.7	22.8

Legend:—no data available.

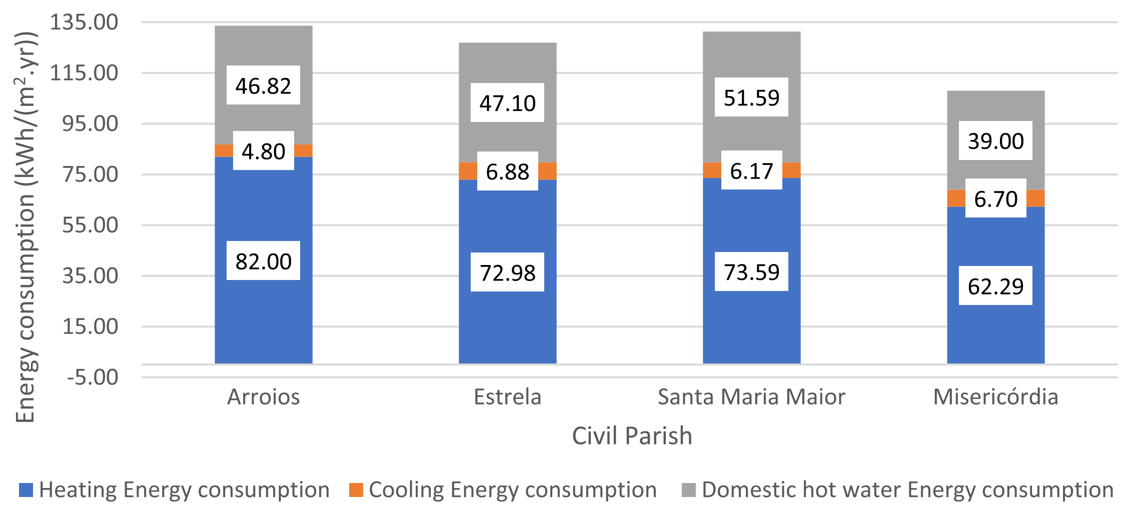

Figure 4. Energy consumption on heating, cooling and domestic hot water preparation in the civil parishes of Arroios, Estrela, Santa Maria Maior and Misericordia.

However, across all parishes, there was a trend of decreasing energy needs over construction periods, as newer buildings generally have better energy performance.

Analysis of the EPC data revealed that most of the energy consumed was used for space heating, representing 61% of the energy consumption in Arroios, 57% in Estrela, 56% In Santa Maria Maior, and 58% in Misericórdia. Cooling represents a small proportion of the energy consumption, as observed in figure 4. The total energy consumption figures for the three areas were as follows: Arroios with 133.6 kWh $(m^2\ yr)^{-1}$, Estrela with 126.96 kWh $(m^2\ yr)^{-1}$, Santa Maria Maior with 131.4 kWh $(m^2\ yr)^{-1}$, and Misericórdia with 108.0 kWh $(m^2\ yr)^{-1}$.

The results showed that LA in Lisbon is composed of an inefficient building stock that is unprepared for increasing space H&C needs and extreme weather events, as presented in figure 5. EPC grades *C* and *D* were the most prevalent, with only a few LAs presenting high energy efficiency. All four civil parishes follow similar trends in terms of EPC rating. In Arroios and Estrela, most properties had an EPC rating of *C*, representing 42% of LAs in Arroios and 44% of LAs in Estrela. In Misericórdia and Santa Maria Maior, the EPC rating of *D* was the most frequent, corresponding to 38% of LAs in Misericórdia and 35% of LAs in Santa Maria Maior. Most LAs have an EPC rating of *C* or below (98% in Arroios, 95% in Estrela, 91% in Misericórdia, and 82% in Santa Maria Maior). Highly efficient LAs (classified as *A*+, *A*, or *B*) were not identified in Estrela and Arroios. In these civil parishes, the most efficient buildings were classified as *B*- and were less common. An analysis of the price per EPC rating was conducted, revealing no correlation between higher EPC ratings and increased prices. However, despite not charging higher prices for LAs with superior EPC ratings, hosts aim to highlight the energy performance of their properties. This is evident from the frequent use of terms such as 'renovated,' 'double glazing,' 'new windows,' and 'with air conditioning' in the names and descriptions of some LA listed. All EPCs were issued between 2014 and 2022. In all four civil parishes, most EPCs were issued between 2014 and 2016. EPCs issued in 2014, 2015, and 2016 represent 79% of EPCs in Arroios, 77% in Estrela, 68% in Misericórdia, and 87% in Santa Maria Maior. Therefore, most of the EPCs will soon be due for revision; these updates may reveal changes in the energy performance of LA dwellings in the civil parishes studied.

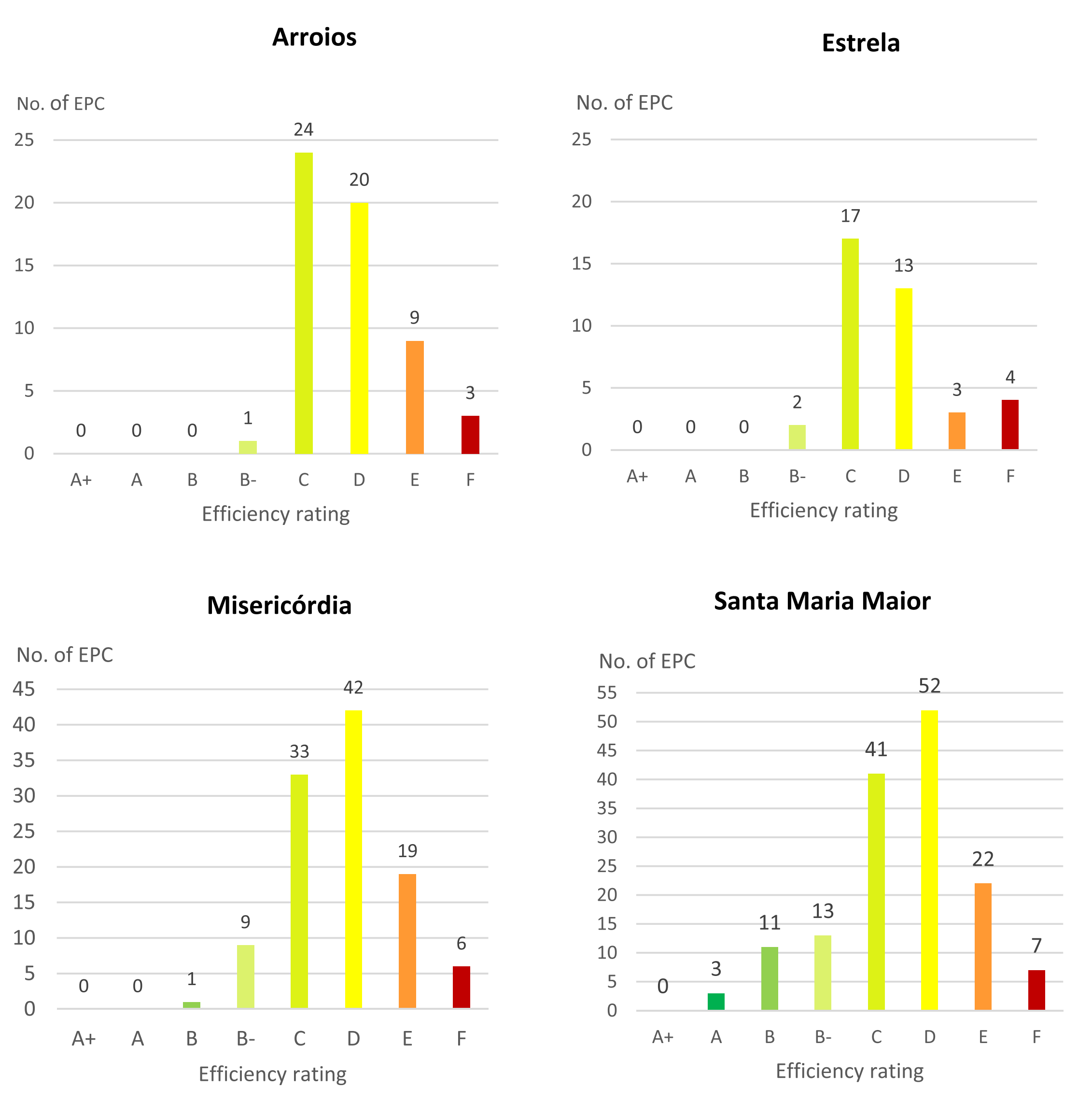

Figure 5. Number of EPCs by energy efficiency rating for LA in the civil parishes of Arroios, Estrela, Misericórdia and Santa Maria Maior.

3.2. Dwellings' envelope and equipment

Looking at the type of walls and insulation of the civil parishes' dwellings, there is a clear predominance in all four civil parishes of single walls without insulation. Simple walls without insulation are the most frequent in all civil parishes, and the type of walls (simple or cavity) with insulation represented 16% in the civil parishes of Arroios, 5% in Estrela, 24% in Santa Maria Maior, and 13% in Misericórdia, as observed in figure 6.

Overall, there was more roof insulation than any other envelope solution: 34% of the roofs had insulation in Arroios, 25% in Estrela, 39% In Santa Maria Maior, and 40% in Misericória. Nevertheless, the number of EPCs with information regarding the type of solution in the roofs was lower than the number of EPCs. Thus, conclusions should be drawn with caution. This could be because most buildings are apartment buildings; therefore, not all dwellings have a direct roof, but rather another apartment above them. All the civil parishes had mainly simple glazed windows: these types of solutions represented 96% of the windows in Arroios, Estrela, 95% in Misericórdia, and 100% in Santa Maria Maior.

Regarding H&C equipment, 355 of the properties registered having no equipment, representing 18% of the study sample. Looking at this trend by civil parish, 26% of the certificates analyzed had no equipment in Arroios, 19% in Santa Maria Maior, 15% in Estrela, and 12% in Misericórdia. For cooling proposes, the percentage of LAs with air conditioning was higher than the percentage of LAs with portable fans: 32% of LAs identified having air conditioning in Arroios, 26% in Estrela, 45% in Misericórdia and 44% in Santa Maria Maior while 19% of the LA identified having portable fans in Arroios, 18% in Estrela and Misericórdia and 23% in Santa Maria Maior. Santa Maria Maior does not present any type of equipment in the A+ rating,

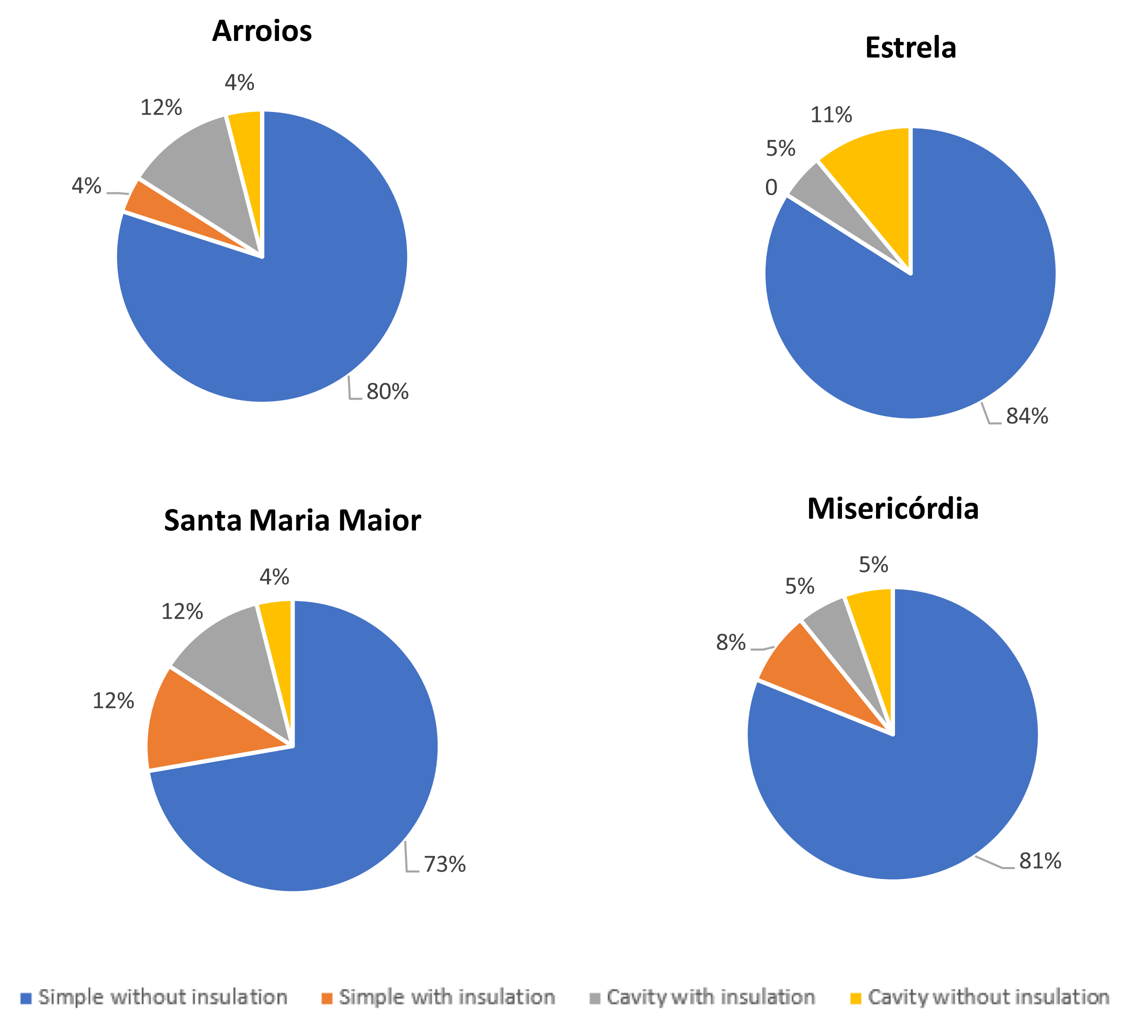

Figure 6. Percentage of dwellings with single or double walls, with or without insulation in the four civil parishes.

and the most common equipment rating is *D* (36%). In the case of the civil parish of Misericórdia, there are no dwellings rated as *A*+ or *A*, whereas properties with a *D* rating more frequently provided records of equipment (41%). In Estrela and Arroios, both civil parishes do not present dwellings rated as *A*+, *A*, and *B*; the greatest volume of equipment is registered in the *C* rating (45% at Arroios and 36% at Estrela). All these results are detailed in figure 7.

3.3. Potential energy efficiency renovation measures

The results indicate the need for deep renovation. Based on this, a series of interventions consistent with the guidelines outlined in the Portuguese Long-term Strategy for Building Renovation were simulated for this LA sample, with the results presented in figure 8. For this sample of LA, the total renovation would potentially cost €18.28 million, with the potential cost of insulation being €7.40 million, €10.7 for the window replacement and €169 thousand for the equipment replacement. The application of insulation had a potential cost of €1.24 million to the units in Arroios (48 units), € 960 thousand in Estrela (37 units), €2.23 million in Misericórdia (86 units), and €2.97 million in Santa Maria Maior (115 units). In terms of windows replacement, this would potentially represent a cost of €1.742 million in Arroios (55 units), €1.19 million in Estrela (37 units), €3.03 million in Misericórdia (95 units), and € 4.75 million Santa Maria Maior (149 units). The focus on passive measures implies a significant reduction in energy needs and indoor temperature improvements.

Consequently, these measures potentially imply better thermal comfort and reduced energy consumption for the LA occupants. Simulations of climatization systems as a complementary intervention (based on a highly efficient heat pump with two inside units and with an average price of €1 800), the associated total investment would be €30.6 thousand in Arroios, €16.2 thousand in Estrela, €30.6 thousand in Misericórdia, and €91.8 thousand in Santa Maria Maior. Improving the efficiency of space H&C systems also adds value to

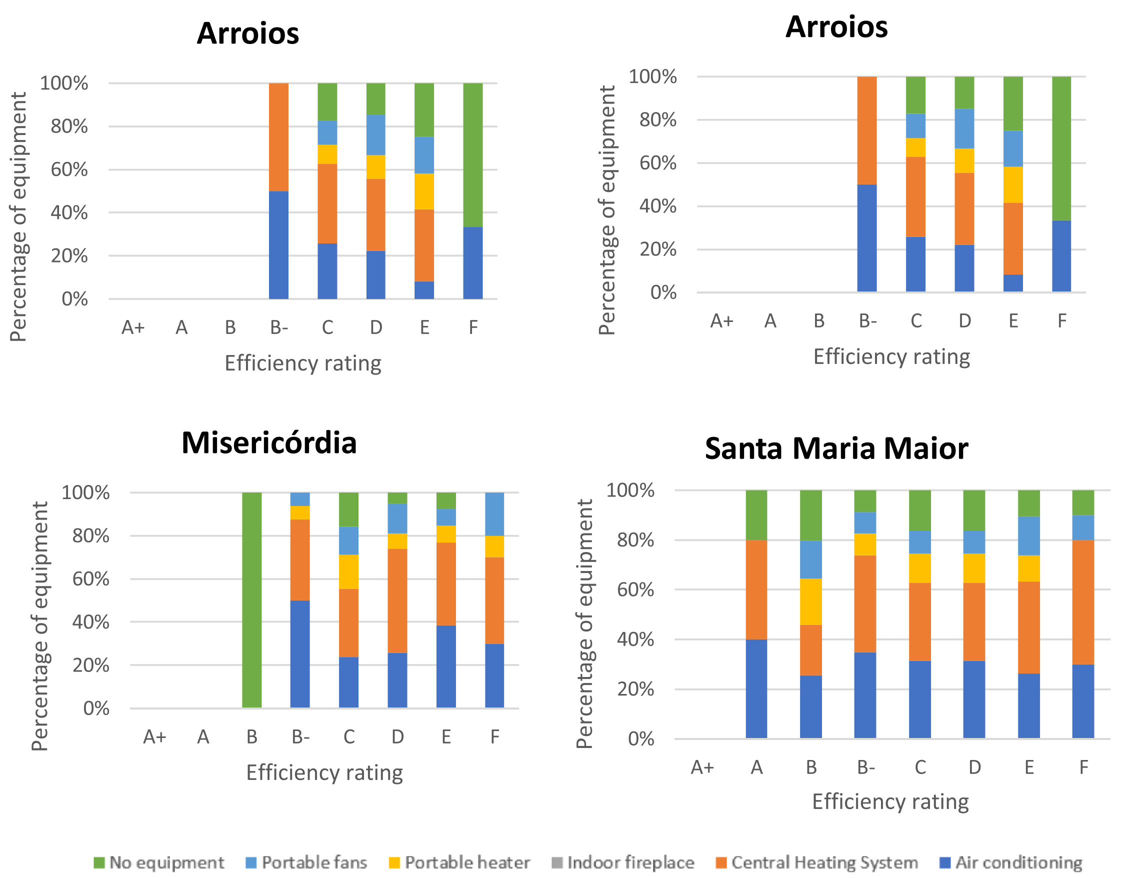

Figure 7. Percentage of equipment per EPC rating for LA in Arroios, Estrela, Misericórdia and Santa Maria Maior.

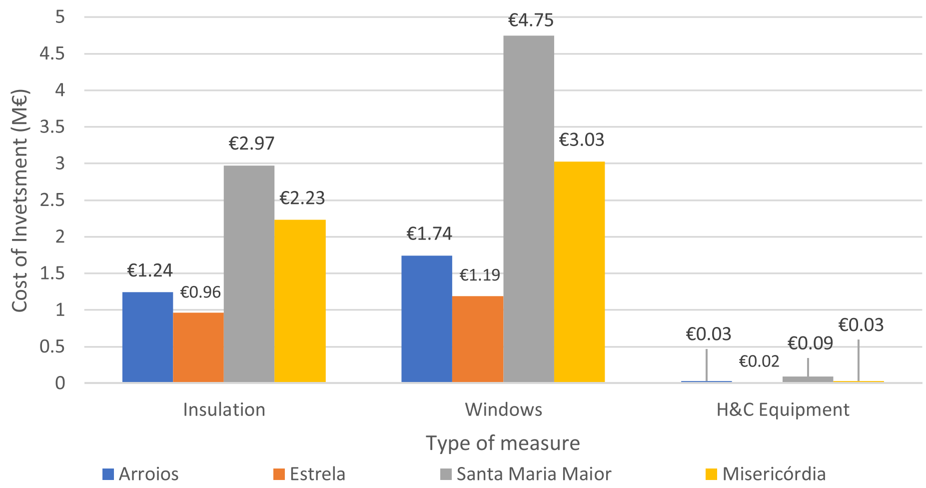

Figure 8. Cost of the different type of interventions by civil parish.

energy bills for the LA owners. The results are consistent with those of other studies, accounting for the differences in the sample size. Gouveia *et al* (2021) estimate €26 M for window retrofitting and €17 M for Wall retrofitting for residential dwellings in the Alfama district in Lisbon. Lima *et al* (2023) estimated a cost of €5.43 M for retrofitting 179 residential buildings in the Lisbon metropolitan area, including installing PV.

Despite the expected positive impacts of the suggested deep energy renovations, investment costs are still significant. One of the ways LA hosts could pay for these energy efficiency improvements would be by reflecting the costs of the interventions in the price charged in each LA. While insulation and window replacement have higher payback times due to their higher prices, the replacement of equipment in this sample of LA could be repaid within a year by an increase of 4.93€ per night. Naturally, these interventions could also enhance the EPC rating of the LA dwellings. According to Ordinance No. 6476-E (2021), all dwellings undergoing major renovations must achieve an EPC rating of C or higher post-intervention. They would also contribute to the reduction of CO_2 emissions. According to Palma *et al* (2022), for Portugal, replacing climatization equipment would reduce, on average, 80% of the CO_2 emissions, leading to the potential global reduction of the emissions to 1.57 t CO2 yr^{-1} for this sample. Namely, this would lead to a decrease of the emissions to 0.46 t CO2 yr^{-1} in Arroios, 0.36 t CO2 yr^{-1} in Estrela, 0.35 t CO2 yr^{-1} in Santa Maria Maior, and 0.4 t CO2 yr^{-1} in Misericórdia.

4. Discussion

4.1. Energy performance and vulnerability of buildings

The study unveiled a fresh and previously unexplored perspective on the energy performance of LA in Lisbon. Minor discrepancies were noted among the four civil parishes, which were the focus of this study, but a common trend of low energy performance prevailed across all four. Arroios' and Estrela's LAs are mostly rated as *C*, followed by classes *D* and below, and the energy performance classes that represent higher energy performance are less prevalent. However, Misericórdia and Santa Maria Maior seem less efficient, with most dwellings classified as *D*. Notwithstanding, they have more LAs classified as *B*- than *F*. Even though all the civil parishes presented a low-energy performance, some seem to perform better than others. Santa Maria Maior had a higher rating on the energy performance system and presented higher insulation building envelope insulation levels despite not having any double-glazed windows registered. On the other hand, Arroios had the lowest energy performance of all civil parishes and the highest number of LAs without equipment. Associated with the energy performance are also the H&C energy needs. The results indicate a reduction in these needs over successive construction periods, reflecting higher energy efficiency in newer dwellings. However, with rising temperatures, cooling demand is expected to increase. If these buildings are not renovated, energy needs, especially for cooling, are projected to rise. In fact, cooling demand could increase by up to 15 TWh per year in Portugal (Jakubcionis and Carlsson 2017). These results are slightly lower than those obtained in other studies for the residential sector. Werner (2015) reported a result of 36 kWh m^{-2}, which is higher than the average obtained for the four civil parishes. These discrepancies are likely due to differences in scale, as this study focuses primarily on multi-apartment dwellings in the civil parishes of Lisbon, whereas Werner's study includes all types of buildings at the national level. The results are more comparable to those obtained by Gouveia and Palma (2019) for multi-apartment buildings, with differences also attributable to the scale of their study, which is also at the national level.

Compared with general residential sector statistics for Lisbon and Porto all four civil parishes' LA have a below average energy efficiency performance at both the city and the national level (ADENE 2023a). In Lisbon, 31% of the buildings are rated as *C*, followed by 25% rated as D, and 71% of the dwellings are classified as *C* or below. The remaining percentages are distributed across the other ratings (with *F* and *A*+ being the least frequent grades). On average, in the sample of LA under investigation, 92% are rated as *C* or below. These results prompted two key questions: firstly, do LAs catalyze deep renovation activities within their neighborhoods? If this were the case, the EPC ratings of LAs would be expected to surpass those of a sample of residential dwellings. Secondly, it is plausible that the renovations undertaken may primarily aim to enhance LA's aesthetics rather than improve its energy efficiency. Comparing the results with the statistics for Portugal, LA in Lisbon has an even lower energy performance as, in Portugal, the most prevalent rating is *C* (25%), and 66% have a rating of *C* or below.

A similar trend of inefficiency in the LA sector was observed in another southern European city. Vilches and Martín (2022) have studied the vulnerability of LAs in Córdoba (Andalusia Region, Spain) in relation to climate change. The study's most frequently observed EPC ratings were *D* and *E*, reflecting low energy efficiency. Similar to Lisbon, the region of Andalusia has a high number of historic dwellings. Still, at the same time, it is the most reluctant to renovate them due to socio-economic and political issues. Although the comparison between LA EPC ratings in Lisbon and Córdoba is only symbolic, since the two countries have different buildings' energy performance rating systems, a pattern of low efficiency in the LA sector is observed across both regions.

Regarding insulation and windows, there is a clear need in all four civil parishes, irrespective of EPC rating, to improve the envelope of the dwellings. All four civil parishes have a predominance of single walls without insulation. The highest percentage of cavity walls with insulation is registered in Arroios and Santa Maria Maior, but it is still a reduced percentage (12%). Regarding windows, only 5% of LAs have double-glazed windows, with Santa Maria Maior having 0% of double-glazed windows registered. In this particular LA, low rates of insulation were to be expected as the civil parishes under study are part of the historic district of Lisbon, and the capacity to intervene on the building envelope may be limited by restrictions protecting historical features, a problem also referred to by Gouveia *et al* (2021). This historical limitation impacts buildings´ energy performance, given that insulation is considered one of the most cost-effective measures (Ferreira *et al* 2014, Monzón-Chavarrías *et al* 2021; Pallis *et al* 2021).

Furthermore, noise insulation measures (Khan and Bhattachaarjee 2021) are crucial in city centers. When comparing the percentage of LAs with space H&C equipment with the statistics for equipment ownership in the residential sector, LAs seem to have slightly higher rates of equipment ownership. In Portugal, 18% of dwellings do not have any space heating equipment, and 67% do not have any space cooling equipment (DGEG and INE 2021). This fact may be explained by tourists having higher thermal comfort requirements and hosts endeavoring to satisfy their guests in the pursuit of good ratings for their accommodation. Previous research in the residential sector has shown that Portuguese families tend to reduce the use of or simply do not possess H&C equipment due to low disposable incomes. Portuguese citizens can also employ alternative adaptive strategies to achieve thermal comfort (Horta *et al* 2019) and avoid high energy bills. It was also observed that the LA sector cools its buildings in a more efficient way than the residential sector: the statistics indicate a high percentage of portable fans (58.8% of the dwellings that have space cooling equipment use portable fans), while in LAs fans were not so common (only 20% of LA have a portable fan). However, a high percentage of the energy consumption in the LA of all civil parishes was attributed to heating systems, which highlights the need to improve the efficiency of this type of equipment to contribute to the decarbonization of this sector. In conclusion, tourists may observe a lack of thermal comfort during their holidays in historical civil parishes of Lisbon due to the lack of energy efficiency and H&C equipment in LAs. This can affect tourists' experience, making it unpleasant and compromising the future of the LA sector in the face of climate change since H&C needs are predicted to increase.

The results reveal numerous challenges across various aspects. The low energy efficiency of LA signifies increased energy consumption and emissions, posing a challenge in terms of mitigating climate change impacts within the sector and of the overall economy, as tourism is an important contributor to GHG emissions (Lenzen *et al* 2018). Additionally, low energy efficiency in the LA sector may necessitate higher investments in climatization systems, as they are easier to install and are more convenient for LA hosts but could lead to lower rates of deep renovation, thereby compromising targets set by the Renovation Wave and the Portuguese Long-term Strategy for Building Renovation. Moreover, low energy efficiency is linked to inadequate thermal comfort, which could have implications for health and tourism, with possible losses in revenues and the local and national economy due to the importance of this activity to the national GDP. Thus, this study also paves the way for further research on the impacts of low energy efficiency in the LAs sector.

4.2. Energy vulnerability: impact on health and tourism

As tourism can be more vulnerable to climate change than other economic activities in the case of extreme events, a drop in the flow of tourists may be observed. Portugal is in a particularly vulnerable position due to tourism's significant contribution to GDP; therefore, there must be a strategy to prevent reductions in visitor numbers. Consequently, LA should be included in this strategy as it constitutes a significant proportion of the overall tourism sector in Portugal. LAs with high EPC ratings could be a good indicator that the sector is prepared to face extreme events such as heat waves and cold spells. However, we found a low prevalence of efficient buildings in the analyzed civil parishes. Efficient equipment could satisfy energy needs, but we found a high prevalence of dwellings without H&C equipment, which can significantly compromise thermal comfort, particularly during extreme weather events. Efficiency is so critical that it mitigates the need for exponential increases in energy consumption and consequent expenses.

It is important to consider the vulnerability of LA in Lisbon to extreme weather events, namely heat waves, since the frequency, duration, and magnitude of severe heat stress events are likely to increase, mainly in highly populated urban areas (Carvalho *et al* 2017). Although most studies on heat-related mortality have focused on outdoor ambient temperature increases, most fatal heat exposures in developed countries occur indoors (Quinn *et al* 2014). Looking into the results obtained for the four civil parishes under study, only 40% of the analyzed LAs were equipped with air conditioning, and the largest share of energy consumption was attributed to heating. This, along with the lack of thermal insulation and low prevalence of double-glazed windows observed in the general residential buildings in the same civil parishes, shows that LA dwellings may not have the adaptive capacity to provide thermal comfort during extreme weather events such as heat waves. Barbosa *et al* (2015) highlighted that installing air conditioning in dwellings is likely to increase in response to climate change, particularly in Southern Europe, where most residential buildings still rely on natural ventilation for cooling. In the same study, results relating to a 1960s typical building case study in Lisbon showed that optimal ventilation and insulation measures lead to decreased internal temperatures, reducing vulnerability significantly, although not totally under extreme heat events. Therefore, insulation options are critical as a measure to enhance LA adaptive capacity, as well as for the potential energy savings they may represent.

5. Conclusions

The climate and energy crisis are putting pressure on all social, economic, and environmental sectors, pushing them to adapt. The tourism sector is no exception, and while it is influenced by climate change, it is also a driver of it. Thus, the sector has ample opportunity to promote sustainability principles, starting with its energy needs. The tourism sector is vital for the Portuguese economy, and LA represents almost half of the total tourist accommodation in the country. Therefore, investing in increasing the energy efficiency and decarbonization of the sector will contribute significantly to decoupling economic growth from increasing energy consumption and carbon emissions. The LA sector can notably drive deep energy renovation in neighborhoods and cities. Despite the large initial investment, renovation actions should be seen as long-term investments and as savings measures since they may provide a sound return on investment for property owners in the long run, as the investment will be compensated in lower energy bills, increased thermal comfort, and improved guest ratings, potentially even attracting greater numbers of tourists to the LA in question. LAs have been overlooked in previous studies, therefore presenting a gap in the literature regarding this particular sector and corresponding knowledge of building quality and the vulnerability of these buildings to providing indoor thermal comfort. Aiming to develop insights on this underexplored area, we examined four civil parishes in Lisbon that are already facing climate change effects, such as heatwaves and abrupt temperature changes, and contain a large number of LA dwellings. Additionally, the insights gained are relevant to the broader built environment sector, promoting improved energy efficiency and thermal comfort across various building types.

To carry out this analysis, the EPCs in a selected sample of LAs were analyzed to collect information on their issue date, energy rating, window types, building envelope, and energy equipment. From this information, it was possible to identify that most of the dwellings have an EPC rating of *D*, with most EPCs issued in 2014. It was also found that many of the existing dwellings in the four civil parishes do not have an EPC. The results obtained regarding energy efficiency ratings and the type of windows and building envelopes were as expected, given their consistency with previous research on the Lisbon and Portuguese cases. Nonetheless, numbers concerning equipment ownership and dwelling structures (lack of insulation and poor windows) were surprisingly low, as almost one-third of LA does not possess any H&C equipment. Regardless, our study shows that LA sector is better equipped than residential dwellings; however, this difference is insufficient to provide thermal comfort and promote greater efficiency in the sector.

Considering these results, substantial energy renovations are imperative to secure a sustainable and more resilient future, guarantee the thermal comfort of tourists, and safeguard tourism revenue. These energy renovations should focus on the building's passive components (e.g., insulation and windows), not only on the climatization equipment. Consequently, our results underscore the pressing need for policies to improve energy efficiency in both the residential and tourism sectors. The Portuguese More Sustainable Tourism Strategy 2020–2023 (Tourism of Portugal 2021) sets targets specific to the LA sector by implementing a best practice guide for LAs and revising the ordinances/requirements for LAs to include energy requirements. One of the ways to contribute to the best practices guide, and the energy requirements could be to set specific targets for LA in terms of EPC and provide guidelines for best practices for insulation and H&C equipment installation. Given the slight disparities observed at the civil parish level, these policies should be formulated locally, and passive measures such as installing double-glazed windows and increasing thermal insulation on walls and roofs should be prioritized. Additionally, incentives should be provided to encourage the installation of more efficient climatization systems. Such measures would not only directly enhance indoor thermal comfort in these regions but also facilitate the attainment of targets outlined in the long-term buildings renovation strategy and the roadmap for carbon neutrality 2050. For these policies and strategies to be effective, it is essential to involve all stakeholders in the process. The LA sector is multifaceted, involving various participants, including hosts, tourists, LA associations, and local entities. Incorporating perspectives from all these stakeholders is crucial to ensure the resilience of this sector.

Data availability statement

The data cannot be made publicly available upon publication because they are owned by a third party and the terms of use prevent public distribution. The data that support the findings of this study are available upon reasonable request from the authors.

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ORCID iDs

Inês Valente https://orcid.org/0009-0001-9621-047X
João Pedro Gouveia https://orcid.org/0000-0002-7360-1363

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