Life ReHABITA

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Building Assessment Report based on energy studies

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Content

Introduction

The LIFE ReHABITA Project aims to tackle energy poverty and promote the renovation of homes in vulnerable situations across several European cities. This report is part of a series of energy studies conducted under the project, specifically for the city of Lorca (Region of Murcia, Spain), which is one of the main participating cities, along with Gospić (Croatia), Plovdiv (Bulgaria), Ploiești (Romania), and Saldus (Latvia).

Energy poverty refers to a situation where households cannot access the energy services needed to maintain a decent, safe, and healthy living standard. It is usually linked to three main factors: low incomes, high energy costs, and poor energy efficiency in residential buildings.

The recent energy crisis in Europe, combined with the rising electricity prices and the deterioration of old buildings, has worsened the vulnerability of many households. Improving energy efficiency in buildings is therefore a key priority to ensure that everyone can access affordable, safe, and sustainable energy, as outlined in Sustainable Development Goal 7.

This study was conducted to identify the level of energy vulnerability in households and to create a technical basis for determining which renovation actions should be prioritized. Information was collected on buildings, heating and hot water systems, lighting, energy supplies, and consumption. This data was used to evaluate the efficiency of homes and their impact on the comfort levels and energy costs for the families living there.

The data collected is essential for the LIFE ReHABITA project, which aims to improve energy efficiency in vulnerable households, encourage responsible energy use, and ensure access to comfortable and sustainable homes. This energy analysis will also help identify the vulnerability of the pilot buildings where renovation actions will take place.

Methodology

The building analysis was conducted following the criteria outlined in the methodological guide "Guidelines on How to Approach Energy Studies in Vulnerable Homes" developed within the framework of the LIFE ReHABITA project.

This methodology focuses on the quick and effective assessment of the energy conditions in homes, with particular attention to the factors influencing energy poverty, while avoiding complex or invasive audit processes for residents.

The study is based on data collected during visits to the homes, supplemented with available prior information about the buildings and their surroundings. All relevant data is broken down and explained in Section 3 of the energy analysis results. The results are then analysed based on six main criteria, each of which contributes to determining the building's Global Score. Each of the criteria established in the methodology is assessed and scored based on its performance. The total score, known as the Global Score, is calculated out of a maximum of 50 points, allowing for the determination of the energy vulnerability level of each building. The criteria for calculating the global score are as follows:

- **Energy consumption** *(kWh/m^2 per dwelling)***:** This criterion measures the amount of energy consumed by the homes. An energy efficiency threshold is set based on the average consumption of homes with similar conditions in the same region or climate zone. The goal is to identify whether energy consumption is below this threshold or if it presents excessive levels that could indicate energy inefficiencies.
- **Energy expenditure** *(€/m^2 per dwelling)***:** This criterion evaluates the cost associated with the households' energy consumption. A minimum expenditure threshold is set based on typical values for homes with similar conditions. This threshold helps to identify potential problems if the expenditure is either significantly high or low in comparison to the threshold. The threshold is adjusted based on the specific characteristics of each region or country, enabling a more accurate assessment of costs and potential inefficiencies.
- **Building envelope quality:** This criterion evaluates the building's ability to maintain internal thermal conditions and prevent energy losses. The global score is obtained by averaging the individual scores for external walls, windows, and airtightness, considering their quality in terms of thermal insulation, airtightness, and efficiency. Higher scores correspond to poorer quality in these factors, while lower scores reflect better quality.

- **HVAC System efficiency:** This criterion assesses the efficiency of the heating, ventilation, and air conditioning (HVAC) systems based on their performance. The HVAC score is calculated as the average of the heating and cooling performance, assigning a higher score to less efficient systems and a lower score to more efficient systems.
- **DHW System efficiency:** This criterion evaluates the energy performance of the domestic hot water (DHW) systems based on their performance. The score is assigned based on the efficiency of the systems, giving higher values to less efficient systems and lower values to more efficient ones, with a particular penalty for systems based on Joule heating.
- **Number of occupants:** The number of inhabitants in each home is the factor that determines the score, with no distinction between different types of people.

Each criterion is rated on a scale of 1 to 10 (except for SHW and energy cost, which have a maximum of 5 points), resulting in a maximum score of 50 points. Based on the final result of the energy studies, the buildings are classified into three levels of energy vulnerability:

- High vulnerability: Homes with a very low energy efficiency level, indicating an urgent need for intervention.
- Medium vulnerability: Homes with significant energy deficiencies, but not critical.
- Low vulnerability: Homes with acceptable energy conditions.

The consistent application of this methodology across all participating cities ensures the ability to compare the results later on and allows for a joint diagnosis of the energy situation in vulnerable homes across Europe.

Results of the energy analysis at local level

Below are the results obtained from the energy analysis of the buildings in the different cities, organized into six key sections to facilitate understanding of the main characteristics and energy consumption of the homes.

1. LORCA

Lorca is a city located in the southeast of Spain, in the Region of Murcia. Its semi-arid Mediterranean climate is characterized by very hot summers, with temperatures exceeding 40°C, and mild winters. This thermal variability creates high energy demand in homes, especially during the summer months when the need for cooling significantly increases. Moreover, the architectural design of many homes, particularly the older ones, is often not aligned with current energy efficiency standards.

A total of 129 vulnerable homes has been analysed in Lorca to assess the energy situation of the households. The aim of this study is to identify potential deficiencies in the energy efficiency of homes, especially those built before the implementation of regulations such as the CTE and NBE CT 79.

1.1. Building characteristics and their surroundings

This section analyses the main characteristics of the homes, highlighting their type, construction year, average size, number of occupants and other relevant information of the surroundings.

- **Types of dwellings**

  The majority of homes analysed in Lorca are apartments in buildings (95 homes, 73.6%), while the remaining (34 homes, 26.4%) are single-family homes.

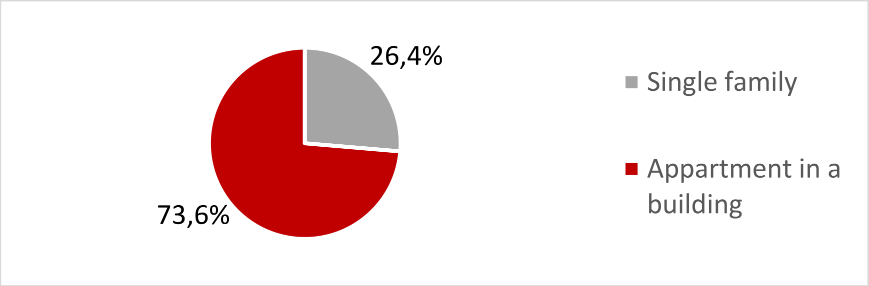

Figure 1. Type of dwellings in Lorca

It is interesting to note the distinction between single-family homes and apartments from an energy perspective. On one hand, single-family homes usually have more surfaces exposed to the outside, such as exterior walls, roofs, and floors, which leads to greater energy losses. This means they require more energy to maintain an adequate internal temperature. In contrast, apartments, by sharing walls, roofs, and floors with other homes, have fewer surfaces in contact with the outside, allowing them to take advantage of the heat from adjacent homes and experience lower energy losses.

- **Year of construction:**

Of the 129 homes analysed in Lorca, 125 were built before the Technical Building Code (CTE, 2007) came into force, and 61 of them were constructed before the implementation of the NBE-CT-79 (1979). This has a significant impact on the energy efficiency of homes, as they lack thermal insulation, efficient climate control, and other modern building requirements introduced by the CTE in 2006. Homes built before the NBE-CT 79 have even greater deficiencies in regulating thermal conditions, leading to much higher energy consumption, especially in winter and summer. The absence of adequate insulation and the obsolescence of heating and cooling systems contribute to higher energy costs and increase the risk of energy poverty, particularly in low-income households.

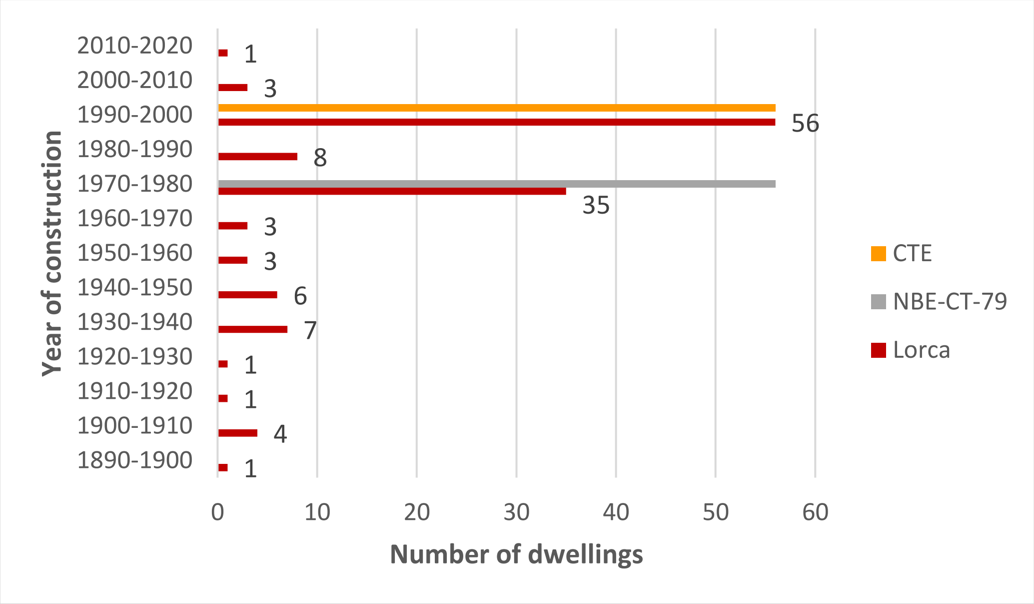

Figure 2.Number of dwellings by year of construction in Lorca.

- **Housing size**

The size of the homes in Lorca shows that the average size of the homes is above the national average. According to the 2024 annual report published by the College of Registrars of Spain, the average size of used homes in Spain is

98.6 m²[1], while the average size of the analyzed homes is 120.6 m². Specifically, 85.2% of the homes analyzed in Lorca exceed the average size of homes in Spain. Due to this characteristic, the homes in Lorca, especially those exceeding 150 m², present a challenge in terms of energy efficiency due to their size. The larger the space, the higher the energy consumption, especially if the home lacks proper insulation or efficient climate control systems.

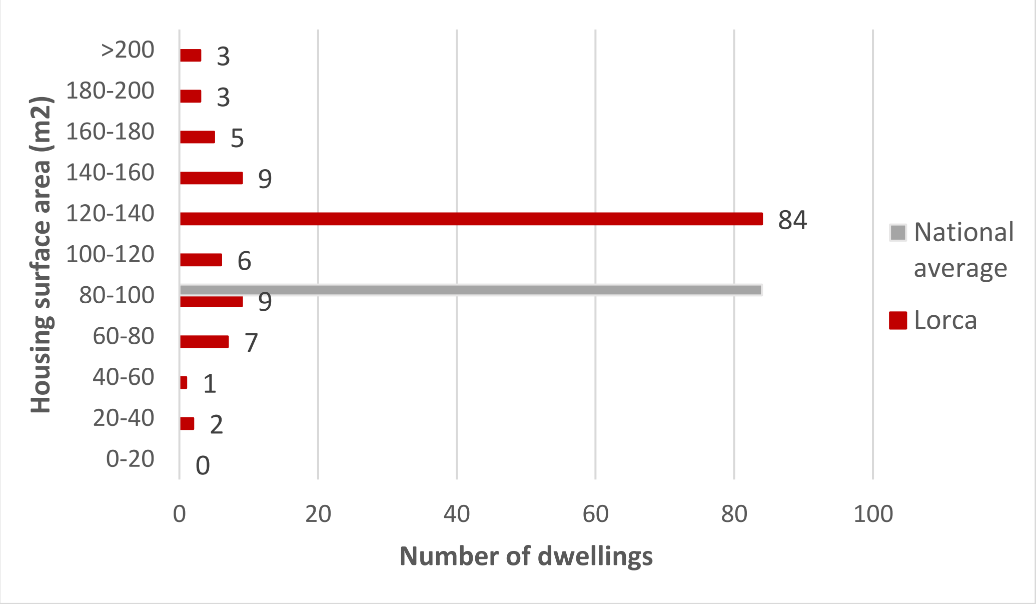

Figure 3. Number of dwellings by housing surface area in Lorca.

- **Number of occupants per home**

The average number of occupants per home in Lorca is 2,92 people, significantly higher than the national average, which stands at 2,54[2]. his means that many households in the city have high energy needs, as the more occupants there are, the higher the demand for heating, cooling, and hot water, which increases energy consumption. Additionally, many of these households may struggle to cover these costs due to the lack of appropriate energy efficiency measures in their homes, which could lead to situations of energy poverty.

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[1] Colegio de Registradores de la Propiedad, Bienes Muebles y Mercantiles de España. (2024). Estadística Registral Inmobiliaria – Anuario 2024. https://www.registradores.org/documents/33383/148210/ERI+Anuario+2024.pdf

[2] Instituto Nacional de Estadística (INE). (2021). *Censos de Población y Viviendas 2021. Resultados sobre Hogares y Viviendas*.

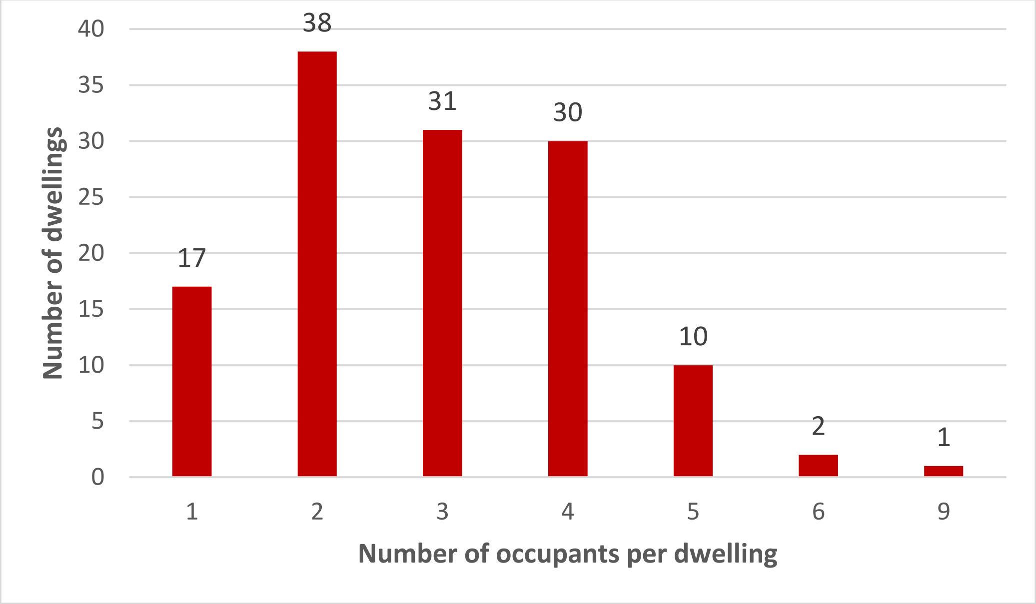

Figure 4. Occupants per dwelling in Lorca

Energy studies also analyzed the profile of the occupants, as factors such as age or health conditions can increase their energy vulnerability. A total of 377 people live in the analyzed homes, of which 106 are minors, 54 are elderly, and 7 have a chronic illness or some form of adverse health condition. This means that 44% of the residents of homes are at a higher risk of energy vulnerability.

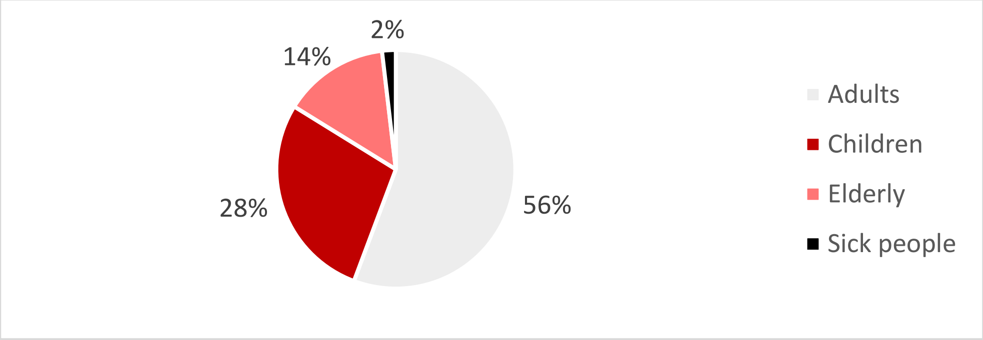

Figure 5.Vulnerable groups in households in Lorca.

Children and the elderly are especially vulnerable to health problems related to cold or heat, as they have a lower ability to regulate their body temperature. People with chronic illnesses also face risks, as some health conditions require controlled environments to prevent complications. Additionally, these groups often have lower incomes, which can limit their access to adequate heating and lead to energy poverty. The lack of resources to maintain an optimal temperature in the home can exacerbate pre-existing health problems and increase vulnerability to extreme conditions.

- **Access to green areas**

In Lorca, 59 out of 129 homes have access to green spaces, while 70 do not.

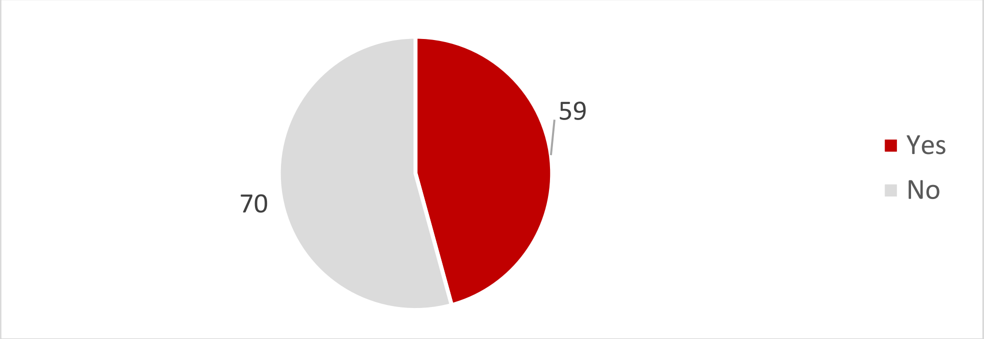

Figure 6. Number of dwellings in Lorca with and without access to green areas

Access to green areas is linked to a better quality of life, as they help regulate temperatures, reducing the need for artificial heating and cooling, which in turn can lead to lower energy consumption. Additionally, green spaces provide recreational areas and improve mental well-being, reducing the financial and emotional stress associated with high energy costs.

The lack of green spaces in some areas exacerbates energy poverty, as residents without these spaces often rely more on energy-intensive heating and cooling systems. This leads to higher energy bills, increasing the risk of energy poverty. Therefore, improving access to green spaces could play a crucial role in addressing energy poverty and promoting more sustainable urban development in Lorca.

1.2. Comfort at home

In addition to analysing the characteristics and composition of the homes, we have also assessed the level of comfort within them, considering three key aspects: thermal, acoustic, and lighting comfort. These factors are essential for understanding the quality of life of the residents and their energy vulnerability, as a comfortable environment directly contributes to the physical and emotional well-being of individuals.

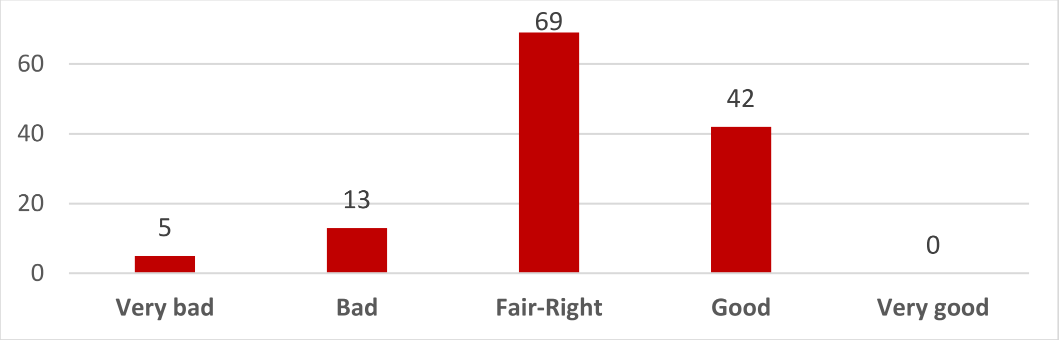

Figure 7.Thermal comfort in Lorca households.

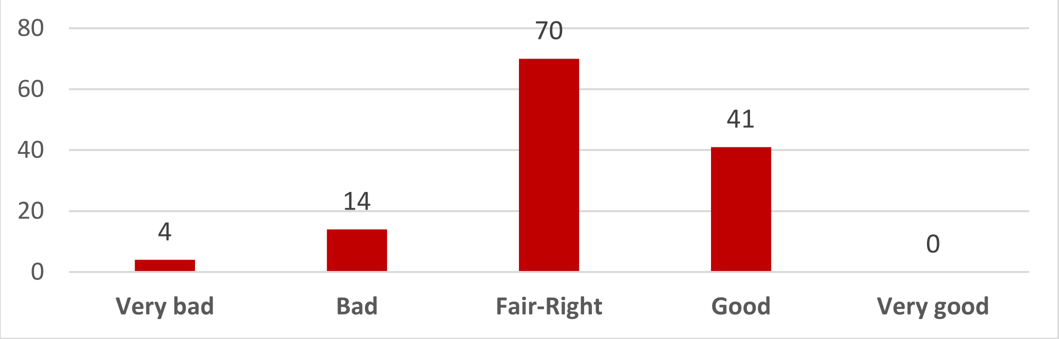

Figure 8. Acoustic comfort in Lorca households

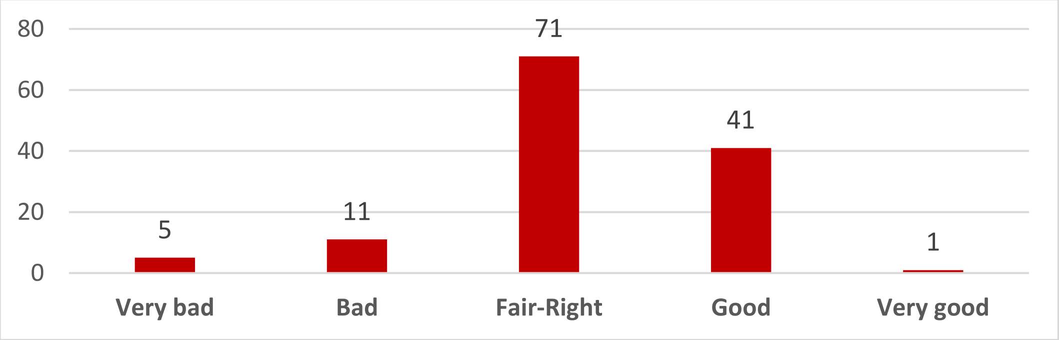

Figure 9. Lightning comfort in Lorca households.

In Figures 7-9, we can observe that homes with poor thermal comfort, such as those reporting "very poor" (5 homes) or "poor" (13 homes), are particularly vulnerable. These homes often have insulation problems or inefficient heating systems, which results in higher energy consumption to maintain an adequate temperature, increasing the risk of energy poverty. Similarly, homes with low acoustic comfort, such as those reporting "very poor" (4 homes) or "poor" (14 homes), may also have higher energy consumption, as they may require additional insulation solutions, impacting their energy bills. Furthermore, homes with deficiencies in lighting comfort, particularly those reporting "very poor" (5 homes) or "poor" (11 homes), could be using more energy for artificial lighting, which also increases consumption.

Additionally, the deficiencies in thermal, acoustic, and lighting comfort observed in the homes of Lorca have a direct impact on the health and well-being of their residents, particularly in the most vulnerable groups. The lack of proper thermal insulation and reliance on inefficient heating systems increase the risk of cold- or heat-related illnesses, such as respiratory or cardiovascular problems. Children, the elderly, and those with chronic illnesses are especially susceptible to these conditions. Moreover, the inability to maintain comfortable temperatures in the home can exacerbate pre-existing health conditions, worsening quality of life and increasing the economic burden on affected families, who are already facing financial difficulties.

This analysis also sought to examine the impact of the current regulations on the perception of comfort in the homes studied.

Table 1: Thermal comfort distribution in dwellings before and after the NBE-CT-79 and CTE regulations

Thermal comfort	Number of dwellings	Before NBE CT 79		Before CTE		After CTE	
Very bad	5	4	7%	5	4%	0	0%
Bad	13	11	18%	13	10%	0	0%
Fair-Right	69	30	49%	66	53%	3	75%
Good	42	16	26%	41	33%	1	25%
Very good	0	0	0%	0	0%	0	0%

Table 2: Acoustic comfort distribution in dwellings before and after the NBE-CT-79 and CTE regulations

Acoustic comfort	Number of dwellings	Before NBE CT 79		Before CTE		After CTE	
Very bad	4	3	5%	4	3%	0	0%
Bad	14	13	21%	14	11%	0	0%
Fair-Right	70	30	49%	67	54%	3	75%
Good	41	15	25%	40	32%	1	25%
Very good	0	0	0%	0	0%	0	0%

Table 3: Lightning comfort distribution in dwellings before and after the NBE-CT-79 and CTE regulations

Lightning comfort	Number of dwellings	Before NBE CT 79		Before CTE		After CTE	
Very bad	5	4	7%	5	4%	0	0%
Bad	11	10	16%	11	9%	0	0%
Fair-Right	71	32	52%	68	54%	3	75%
Good	41	15	25%	40	32%	1	25%
Very good	1	0	0%	1	1%	0	0%

Of the 61 homes built before the NBE CT 79 that were analyzed, the data shows that 7% of the homes were classified as "very poor" in thermal comfort, 5% in acoustic comfort, and 7% in lighting comfort. Additionally, 18% of the homes were rated as "poor" in thermal comfort, 21% in acoustic comfort, and 16% in lighting comfort. This indicates that 25% of homes had deficient comfort conditions in at least one of the three aspects, which affected both their quality of life and energy efficiency. On the other hand, 49% of the homes showed "fair-regular" conditions in thermal comfort, 49% in acoustic comfort, and 52% in lighting comfort, suggesting that a significant proportion of homes already met basic standards but still had considerable room for improvement.

From 1979, when the NBE CT 79 came into force, to 2006, the homes showed significant improvements, although still far from optimal comfort levels. In this group, 125 homes were analyzed, with the percentage of those reporting "very poor" levels reduced to 4% in thermal comfort, 3% in acoustic comfort, and 4% in lighting comfort. Homes rated as "poor" decreased to 10% in thermal comfort, 11% in acoustic comfort, and 9% in lighting comfort. However, no home analyzed reported "very good" levels in thermal or acoustic comfort, and only one did so in lighting comfort. This indicates that the NBE CT 79 was an important step, but it still did not achieve optimal comfort in all homes.

Finally, after the implementation of the CTE, the improvement was notable, as 100% of the homes reached "regular" or "good" levels, demonstrating the positive impact of this regulation on overall comfort. However, it is noteworthy that a small percentage of homes were rated as "good" and that no homes were rated as "very good" in comfort levels. This could be due, on one hand, to the small number of homes included in the study, as only four of them were built after the implementation of the CTE, or it could be due to deficiencies in construction, maintenance, or subjective factors related to the perception of comfort.

1.3. Heating

Of the 129 homes analyzed in Lorca, 84% (109 homes) have some type of heating system, while 16% (20 homes) do not have this service.

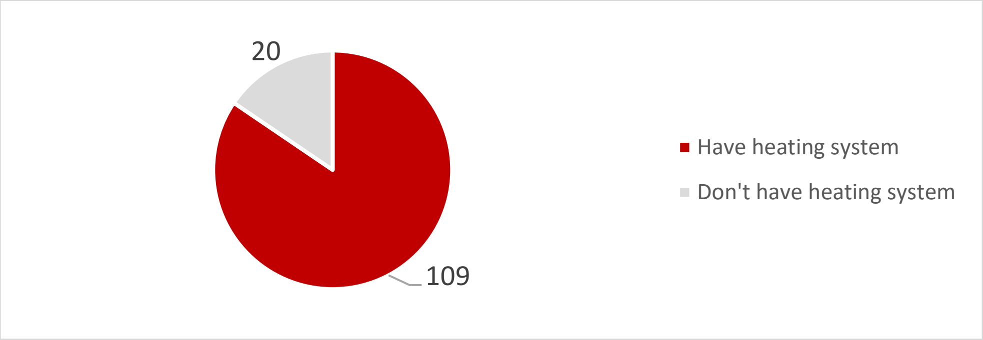

Figure 10. Number of dwellings with or without heating systems in Lorca.

- **Types of heating system**.

  As shown in Figure 11, the most common heating system in the homes of Lorca is the heat pump, present in 102 homes (79% of the total). In second place are wood stoves or other types of biomass, used in 6 homes (5%). Finally, a single home uses an electric heater as its heating system.

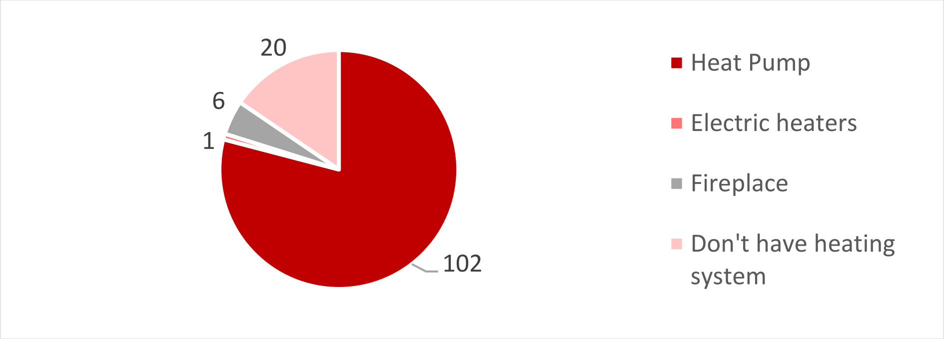

Figure 11. Type of heating system in the dwellings in Lorca.

- **Energy sources**.

  In terms of energy sources, a total of 103 homes (80%) use electricity as their heating source, reflecting a strong reliance on electricity for heating in Lorca. On the other hand, 6 homes (5%) use biomass in the form of firewood, indicating a minority presence of these more traditional systems.

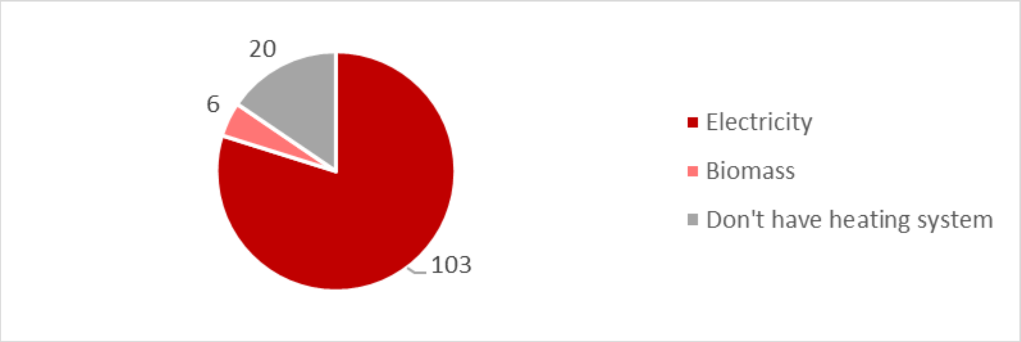

Figure 12. Type of energy source in heating systems in Lorca.

- **Heating energy consumption**.

  With the available data, it is not possible to conduct a detailed analysis of the specific energy consumption for heating. The surveyed households that use fireplaces for heating did not provide data on biomass consumption, making it difficult to conduct a specific energy study in this regard. Additionally, in households using Joule effect stoves or heat pumps, the electricity consumption includes both heating and cooling as well as general electrical usage. For this reason, the energy consumption analysis will focus on the electricity section (3.1.7).

1.4. Cooling

Of the 129 homes analyzed in Lorca, 108 have cooling systems, representing 84% of the total. On the other hand, 19 homes (15%) do not have cooling systems, and 2 homes did not specify in their responses whether they have this type of system.

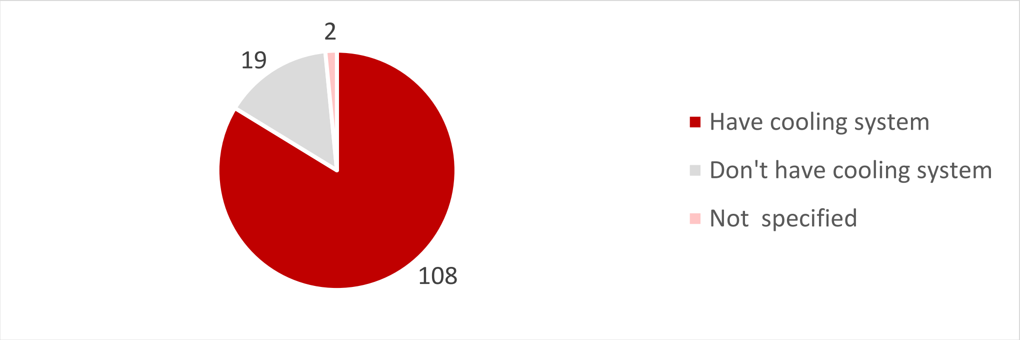

Figure 13. Number of dwellings with or without cooling systems in Lorca.

- **Types of cooling systems**.

  All the cooling systems present in the homes analysed are heat pumps. This type of system is the most affordable and effective option for maintaining a climatized home in Lorca, especially considering the high temperatures the city experiences during the summer months.

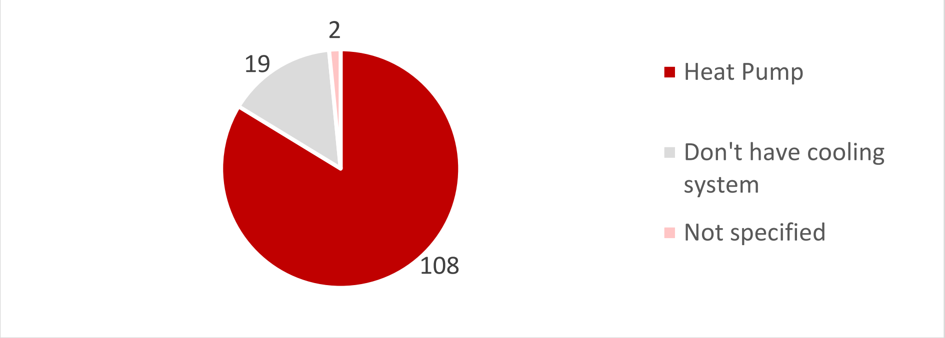

Figure 14. Type of cooling system in the dwellings in Lorca.

- **Energy sources**.

  All the heat pumps used in the homes analysed work exclusively with electricity.

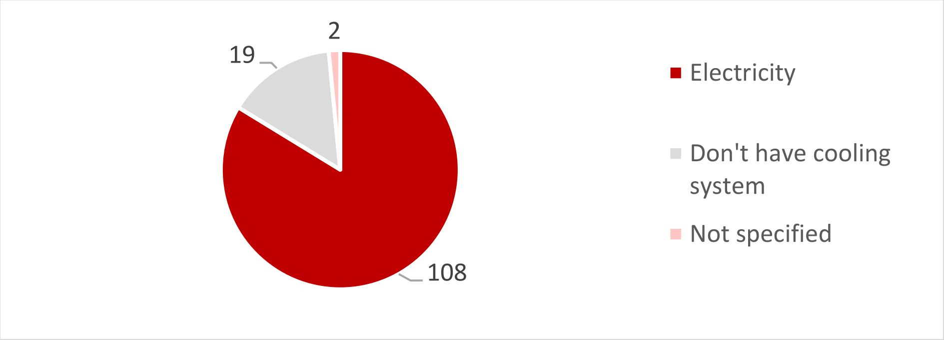

Figure 15. Type of energy source in cooling systems in Lorca.

- **Cooling energy consumption**.

  With the available data, it is not possible to conduct a detailed analysis of the specific energy consumption for cooling. In homes that use heat pumps for cooling, the electricity consumption includes both cooling and heating, as well as the general electrical consumption of the home, and there is no separate data available to distinguish the consumption exclusively for cooling. Therefore, the energy consumption analysis will be conducted under the electricity section (3.1.7) in its entirety, without breaking down the consumption associated with cooling separately.

1.5. Domestic hot water

According to the data collected, of the 129 homes analysed in Lorca, 122 (95%) have domestic hot water systems (DHW), while 7 (5%) indicate that they do not have this system.

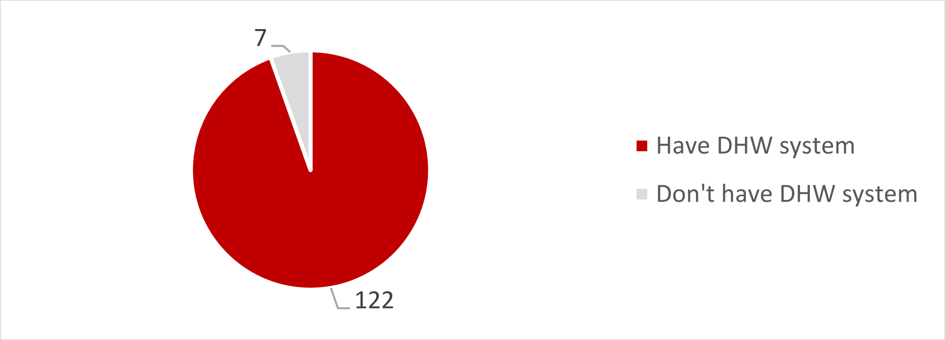

Figure 16. Number of dwellings with or without DHW systems in Lorca.

Although at first glance the number of homes without this system may seem small, not having a DHW system at home has significant social and energy-related consequences. These households rely exclusively on cold water, which severely limits their ability to perform essential daily tasks, such as showering, washing, or cooking properly during the colder months of the year. The lack of a DHW system affects both the physical and emotional well-being of the residents, increasing the risk of energy poverty in a context where access to quality basic services is essential to ensure a dignified life.

- **Types of DHW systems.**

  Of the 122 homes with a hot water system, 81 use electric water heaters, while 41 have water heaters powered by fuel (gas, LPG, or biomass).

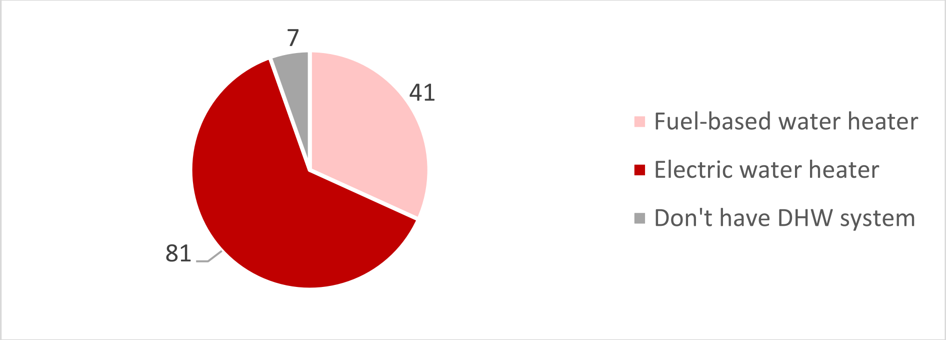

Figure 17. Type of DHW system in the dwellings in Lorca.

- **Energy sources.**

  When analysing the energy sources used for the hot water system in the homes with this system in Lorca, we find different energy sources:

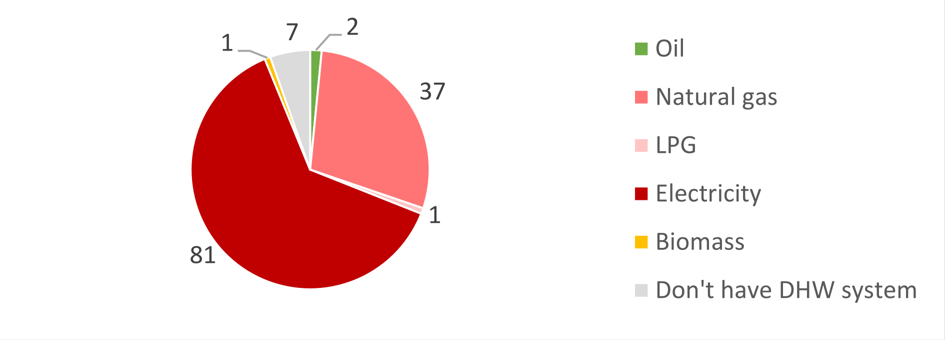

Figure 18. Distribution of DHW system energy sources in dwellings in Lorca.

  Of the 122 homes with domestic hot water systems, 81 use electric water heaters that heat the water through the Joule effect. This system has advantages such as ease of installation; however, using electricity for DHW is usually more expensive than other energy sources, which can lead to higher energy costs and exacerbate energy poverty in households with fewer resources. 37 homes use natural gas, which is a more economical option than electricity. Finally, sources like LPG and biomass are uncommon, with only one home using each type. Lastly, 2 homes use oil boilers, an option in decline due to its high cost and environmental impact. Although their representation is minimal, these sources reflect the diversity of energy options, many of which are less efficient and more expensive for low-income households.

- **Energy consumption.**

  We cannot analyse the specific energy consumption for DHW, as in the case of homes with electricity, this consumption is included within the total electricity consumption. For homes using natural gas, LPG, or biomass, we have not received detailed data on DHW consumption, as some homes do not have a DHW system or are unaware of this information.

1.6. Lightning

Of the 129 homes analysed, 64 use incandescent bulbs, 64 use LED bulbs, and 1 uses compact fluorescent bulbs.

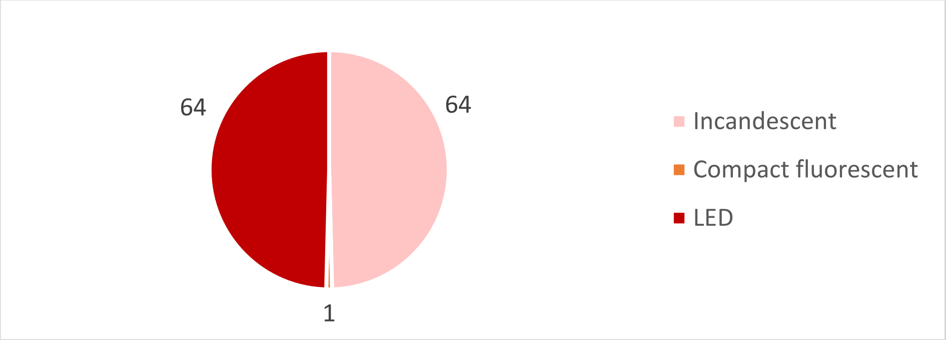

Figure 19. Type of lightning system in the dwellings in Lorca.

Incandescent bulbs are much less efficient compared to LED bulbs. An incandescent bulb consumes approximately 60 W to produce the same amount of light as an 8-10 W LED bulb. This means that LED bulbs use between 80% and 90% less energy to provide the same brightness. If we extrapolate this to total consumption, households using incandescent bulbs face significantly higher energy costs, which can exacerbate energy poverty in families with limited resources, as their electricity bills will be higher.

1.7. Electricity

In the specific case of Lorca, electricity consumption includes not only general electricity use but also the use of heating, cooling, and, in many cases, hot water (ACS) systems. For this reason, electricity consumption in Lorca directly correlates with the total energy consumption of the home.

- **Connection to the grid.**

  Of the 129 homes analysed in Lorca, 11 have not provided data on their electricity consumption. Among these 11 homes, 4 do not have an electricity contract and are connected to the grid irregularly.

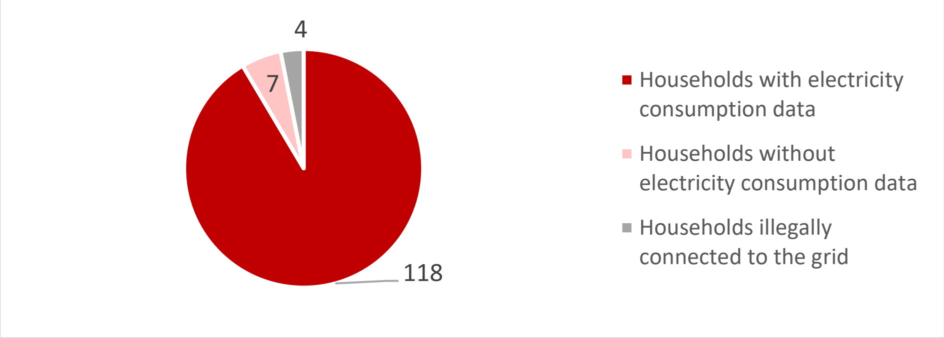

Figure 20. Electricity connection of households in Lorca.

- **Energy consumption.**

  The average consumption of 118 homes in Lorca, for which data is available, is 4.458,6 kWh/year. To contextualise this data, the average annual electricity consumption per household in Spain has been taken as a reference, which according to IDAE is 3.222 kWh/year.

  It is important to note that this national figure only corresponds to domestic electricity consumption, whereas the analysis conducted in Lorca includes total electricity consumption, including heating and cooling, as in most of the homes these services are covered by electric systems (especially heat pumps). Therefore, the comparison should be interpreted with the understanding that the national consumption does not include energy from other fuels used for heating, such as natural gas, oil, or biomass, which are present in many Spanish homes.

  Even so, even considering this difference in scope, the average electricity consumption in Lorca is approximately 38% higher than the national average. This higher consumption may be due to local climate conditions –which require intensive use of air conditioning in summer–, reliance on electric systems for heating, as well as potential situations of energy vulnerability that may affect habits and efficiency in the use of equipment.

- **Energy price**

  The average annual cost of the electricity bill in the homes analysed in Lorca is 663,41€, a figure notably lower than the national average expenditure. According to INE data, the average electricity expenditure per household in Spain is approximately 992€ per year.

  When comparing both figures, we observe that, although homes in Lorca have an electricity consumption 38% higher than the national average, their electricity expenditure is 33% lower.

  This difference is primarily explained by the socio-economic profile of the homes studied. The households analysed are in a state of energy vulnerability and, therefore, meet the requirements to qualify for the Electric Social Bonus, a protective measure offering discounts ranging from 40% to 80%. The Electric Social Bonus helps explain why, despite consuming more energy –due to intensive use of electric systems for heating and cooling– the final expenditure is significantly lower than the national average.

  Moreover, in municipalities like Lorca, where there is a high dependence on electric systems for climate control needs, access to the Electric Social Bonus becomes a key element in mitigating the risk of energy poverty and ensuring the affordability of the electricity supply.

- **Energy consumption per household**

  Of the 118 homes that have reported electricity consumption, 85 of them (72%) have an annual electricity consumption higher than the national average.

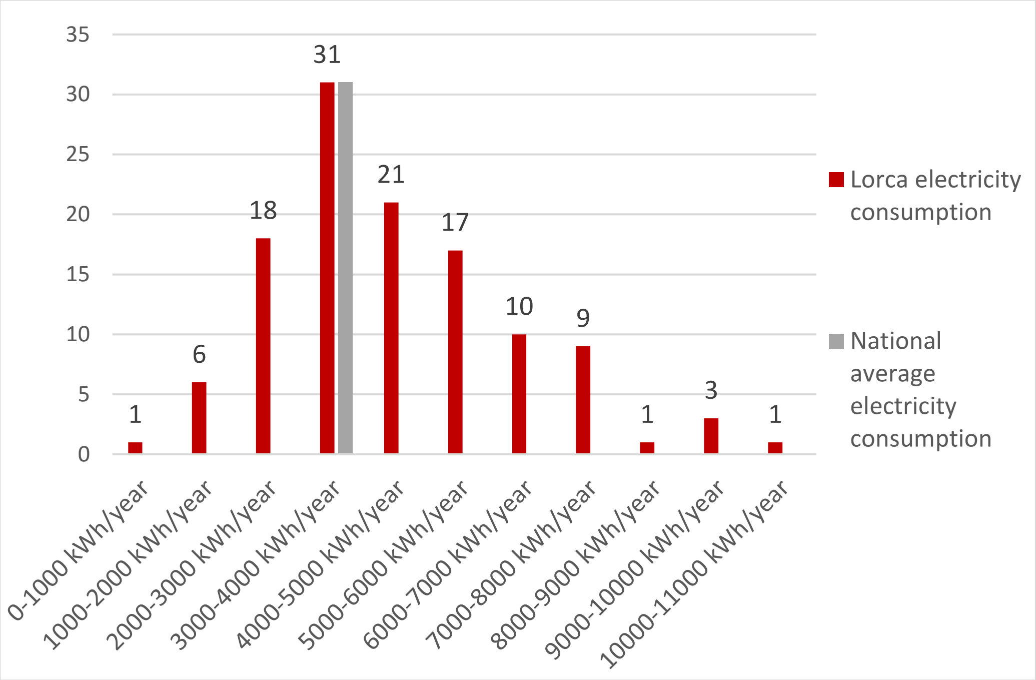

Figure 21. Electricity consumption per dwelling in Lorca.

For this analysis, the national indicator of average annual electricity consumption per household is used as a reference, as the recorded consumption in Lorca refers exclusively to electricity. It is important to note that this electricity consumption includes, in addition to usual domestic use, consumption associated with electric heating and cooling (heat pumps) and, in many cases, hot water (ACS) via electric water heaters (Joule effect). This may be the reason why the observed values are higher than the national average.

1.8. Data analysis

- **Electricity consumption vs. housing area**

  Figure 22 represents the electricity consumption of the homes in Lorca against the housing area.

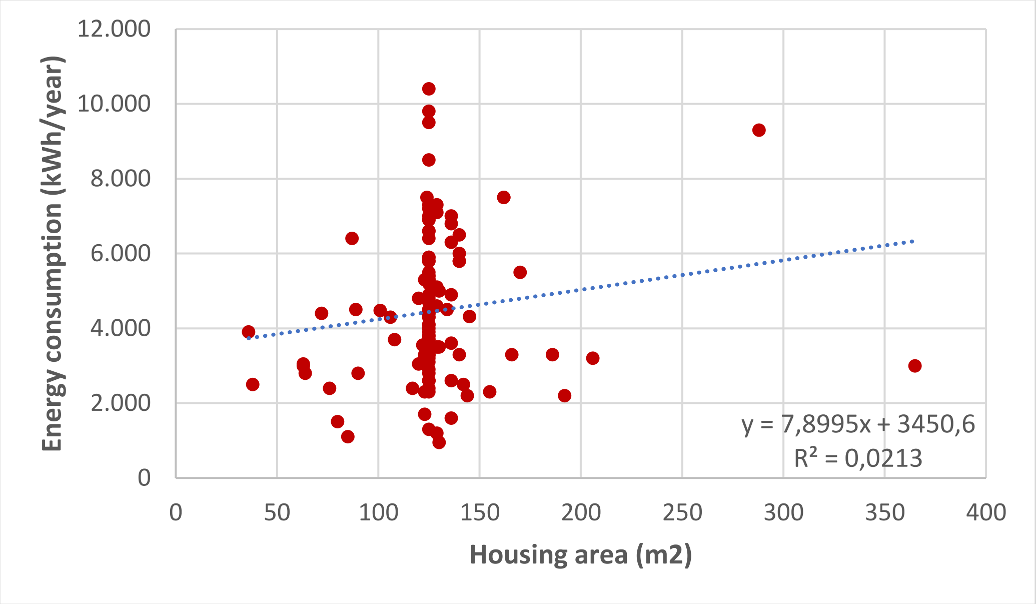

Figure 22. Electricity consumption per housing area.

The statistical analysis of the relationship between housing area and energy consumption shows a very low coefficient of determination ($R^2 = 0,0213$). This indicates that only 2,13% of the energy consumption in homes is directly correlated with their size.

Under normal conditions, energy consumption should be clearly related to the area to be climatized, as larger homes require more energy to maintain appropriate comfort conditions. However, in the homes analysed in Lorca, this relationship is almost non-existent.

This result shows that energy consumption is not determined by the size of the home but by factors such as the low thermal efficiency of the buildings, the use of inefficient electric systems for heating and hot water, and the partial use of the home by households to reduce energy costs.

- **Energy consumption vs. number of occupants**

The following analysis examines the relationship between the annual electricity consumption of the homes and the number of occupants residing in them, with the aim of identifying whether there is a direct relationship between the needs of the people and energy use in the homes of Lorca.

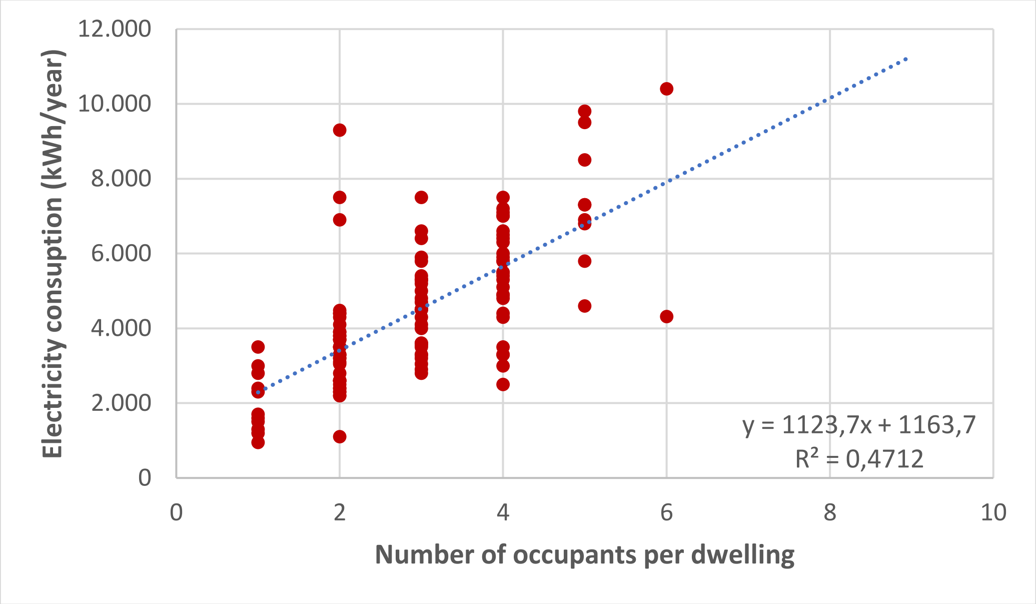

Figure 23. Electricity consumption per number of occupants in Lorca.

The analysis of the relationship between annual electricity consumption and the number of occupants in the household shows a significant correlation ($R^2 = 0,4712$). This indicates that nearly half of the energy consumption in homes can be explained by the number of people residing in them.

The slope of the regression line shows that each additional occupant leads to an approximate increase of 1.124 kWh per year. This increase is mainly associated with a higher use of hot water, electric heating, and cooling, i.e., basic domestic comfort needs.

This result contrasts with the lack of relationship between consumption and housing area and highlights that, in these homes, energy consumption is mainly conditioned by the needs of the people and not by the size of the household, a characteristic behaviour of energy poverty situations.

- **Energy consumption vs. year of construction**

In Figure 24 it is examined the relationship between the annual electricity consumption of the homes and their year of construction, to check if the age of the building significantly influences energy use in the home. This analysis helps to assess to what extent the construction conditions associated with different thermal regulations can explain the consumption levels observed in the studied homes.

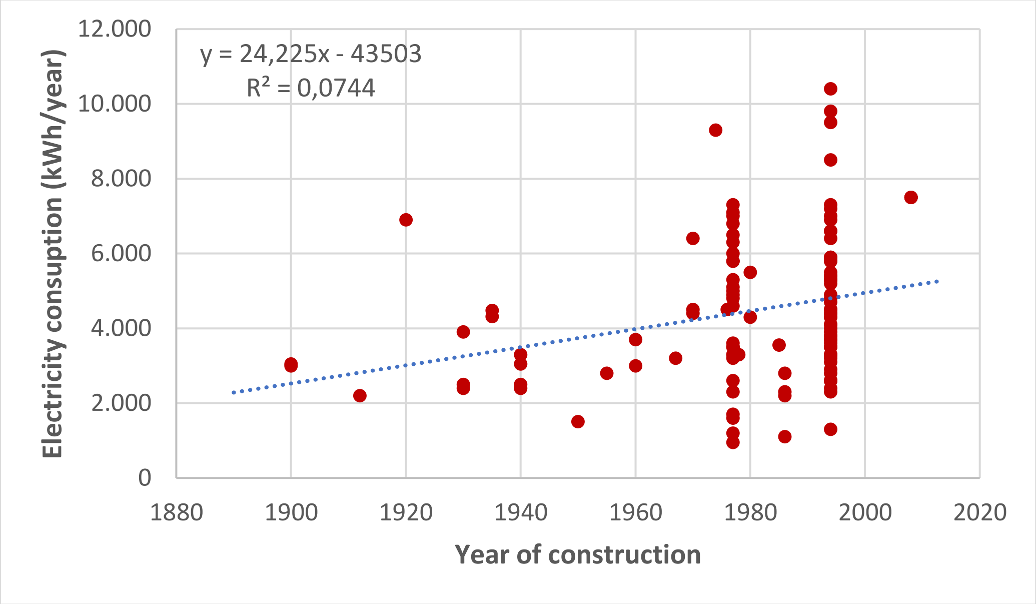

Figure 24. Electricity consumption in Lorca dwellings per year of construction.

The analysis of the relationship between annual electricity consumption and the year of construction of the homes shows a very weak correlation (R^2 = 0,0744). This indicates that the age of the home hardly explains the level of energy consumption observed.

Under normal conditions, older homes should have significantly higher consumption than newer ones due to the lack of thermal insulation requirements. However, in the homes analysed in Lorca, this pattern is not observed. High consumption is found in relatively recent homes, and low consumption is found in very old homes.

This behaviour highlights that energy consumption is not primarily conditioned by the year of construction of the building, but by factors such as the use of inefficient electrical equipment, the lack of energy rehabilitation, and the partial use of the home by households to reduce costs

- **Energy consumption vs. thermal comfort**

In Figure 25, the relationship between annual electricity consumption and perceived thermal comfort is analysed, to verify whether higher energy expenditure translates into better living conditions.

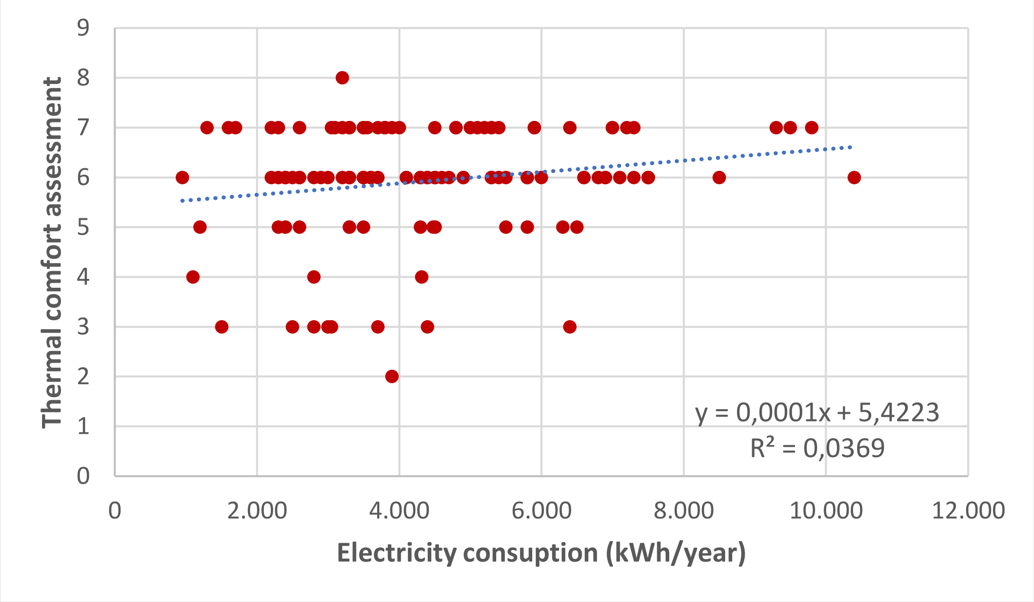

Figure 25. Thermal comfort assessment per electricity consumption.

The analysis of the relationship between annual electricity consumption and the level of thermal comfort declared by the residents shows no direct relationship between the two variables. The data dispersion reveals that homes with high consumption levels have similar comfort levels to homes with much lower consumption.

Under normal conditions, higher energy consumption should result in better thermal comfort. However, in the homes analysed in Lorca, increased consumption does not lead to an improvement in comfort, indicating that much of the consumed energy is wasted due to the low thermal efficiency of the building envelope and the use of inefficient equipment.

- **Housing area vs. thermal comfort**

Figure 26 analyses the relationship between the housing area and perceived thermal comfort, to check if the size of the home influences the living conditions and thermal wellbeing of its residents.

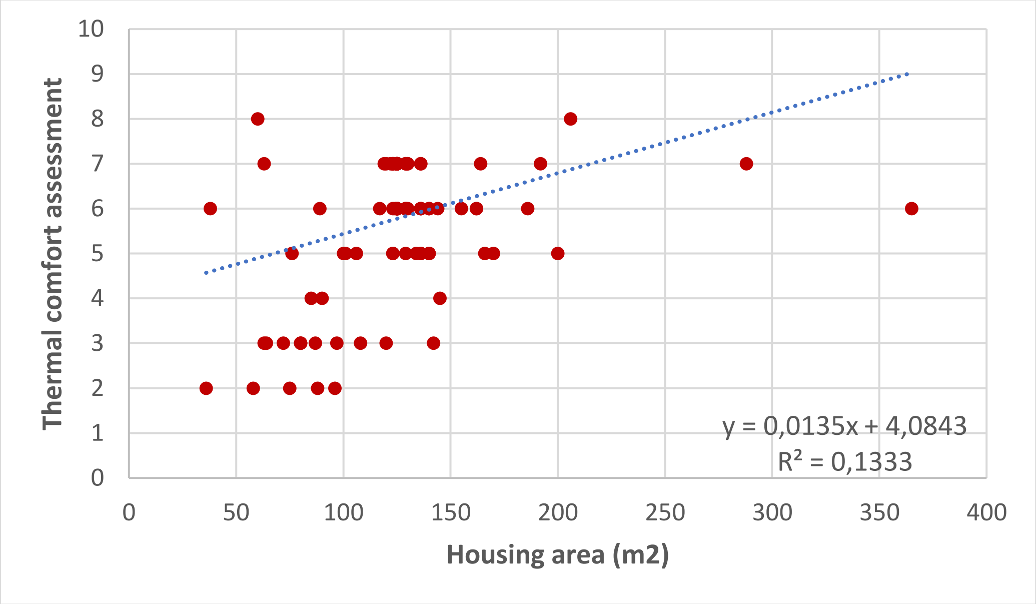

Figure 26. Thermal comfort assessment per housing area (m²).

The analysis of the relationship between housing area and perceived thermal comfort shows a weak correlation (R² = 0,1333). Although there is a slight trend for larger homes to have a higher level of comfort, this relationship is not very significant.

Under normal conditions, the size of the home should have a clearer influence on thermal comfort, as a larger area would allow for better distribution of thermal conditions. However, in the homes analysed, comfort is not determined by square footage but by factors such as the quality of the thermal envelope and the partial use of the home by households.

- **Energy cost vs. thermal comfort**

The following analysis examines the relationship between the annual electricity cost of the homes and the thermal comfort perceived by their residents, to check whether higher financial effort in paying for energy translates into better living conditions.

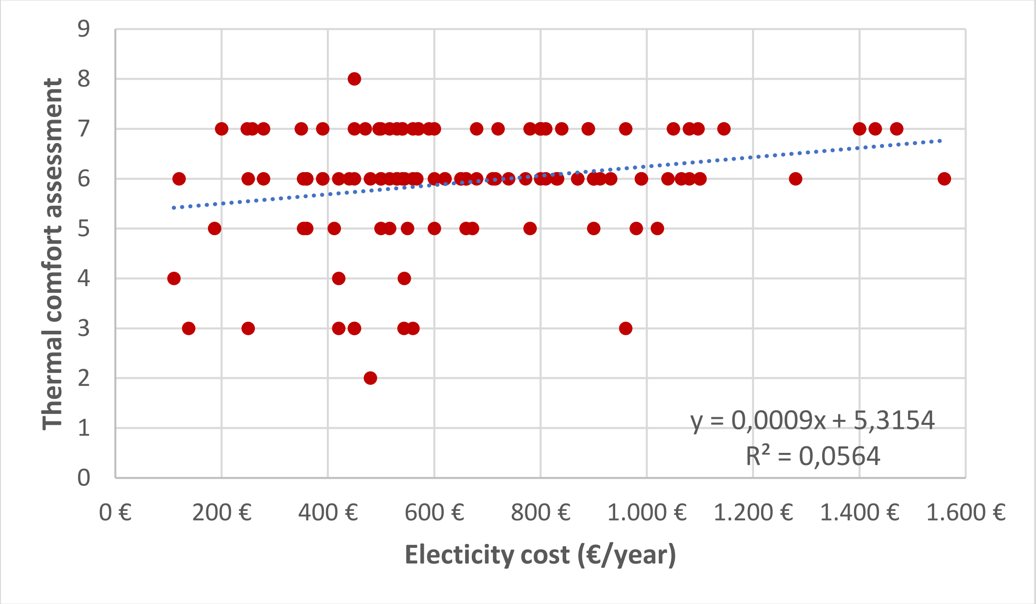

Figure 27. Thermal comfort assessment per energy cost.

The analysis of the relationship between annual electricity cost and perceived thermal comfort shows a practically non-existent correlation ($R^2 = 0,0564$). This indicates that higher electricity expenditure does not result in improved comfort conditions in the home.

Under normal conditions, higher spending on energy should allow for better thermal conditions. However, in the homes analysed, households paying higher bills do not report greater comfort than those with lower costs.

This result highlights a situation of energy inefficiency, where families make significant financial efforts without this translating into a real improvement in their thermal wellbeing.

1.9. Score of the energy assessment

According to the guide, three vulnerability levels have been defined for the homes analysed in these energy studies: Low, Medium, and High. The threshold values for each level are selected so that the upper limit of the score for each category indicates the urgent need for energy rehabilitation interventions in those homes.

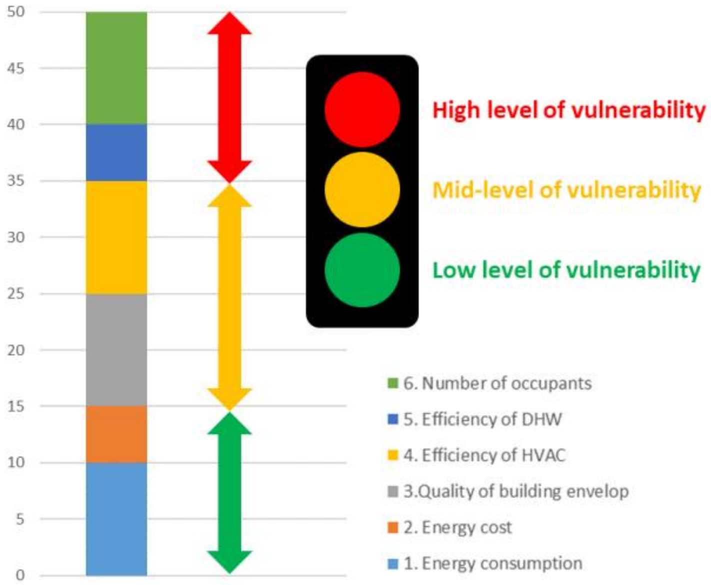

Figure 28. Example of thresholds determined to differentiate the three levels of housing energy vulnerability.

For the 129 homes studied in Lorca, the results obtained are as follows:

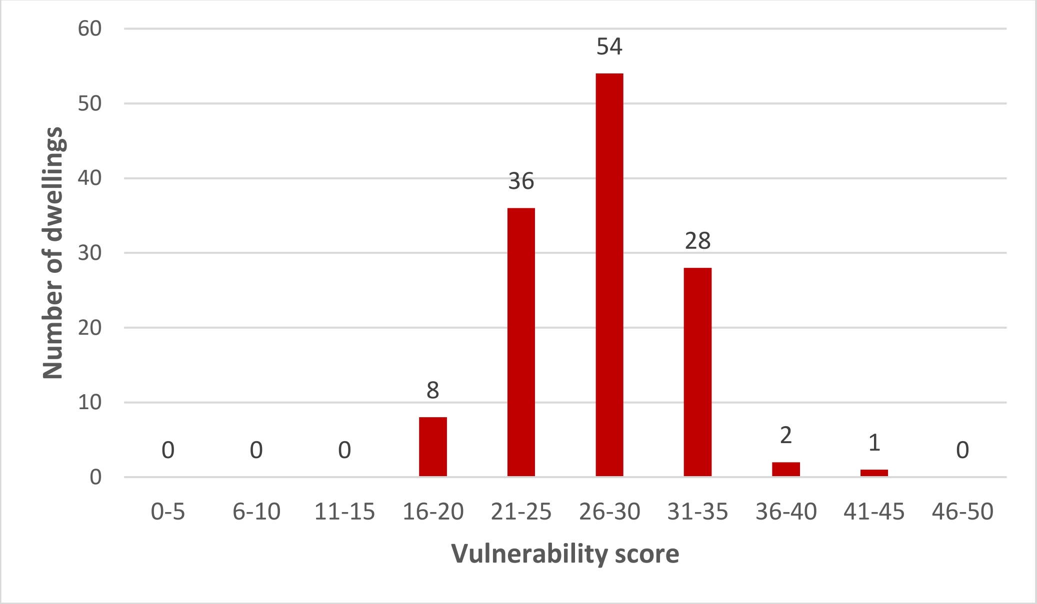

Figure 29. number of dwellings per vulnerability level.

From this data, the following conclusions can be drawn:

- 126 homes are within the medium vulnerability level (with scores between 15 and 35 points), representing 97,7% of the total. Within this group, 28 homes are very close to the high vulnerability threshold (31-35 points), suggesting that these homes should receive priority attention, followed by the rest of the homes in this level.

- 3 homes have a high vulnerability level, representing 2,3% of the total. These homes should be considered the absolute priority for the implementation of energy improvement measures.
- No homes have been identified with a low vulnerability level.

This analysis reveals that **the vast majority of homes in Lorca require urgent energy rehabilitation interventions**, as no homes have been recorded in the low vulnerability level. The absence of homes in this level underscores the urgency of improving energy efficiency in the homes of the city to reduce the energy vulnerability of the population.

2. GOSPIĆ

Gospić is a city located in the mountainous region of Croatia. Its climate is classified as continental, characterized by cold winters with temperatures dropping below 0°C, and warm summers with temperatures reaching up to 30°C. This seasonal temperature fluctuation results in significant energy demand in homes, particularly during the winter months when heating needs are particularly high. Additionally, many of the residential buildings, especially older ones, do not meet current energy efficiency standards, which further exacerbates the challenge of reducing energy consumption.

A total of 100 vulnerable homes has been analysed in Gospić to assess the energy situation of the households. The aim of this study is to identify potential deficiencies in the energy efficiency of homes, particularly those built before the introduction of modern building regulations and energy standards.

2.1. Building characteristics and their surroundings

This section analyses the main characteristics of the homes, highlighting their type, construction year, average size, number of occupants and other relevant information of the surroundings.

- **Types of dwellings**

  The 100 homes analysed in Gospić are all apartments, accounting for 100% of the dwellings surveyed.

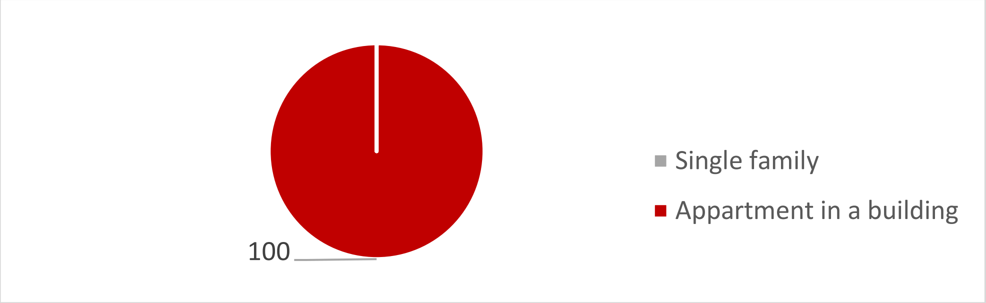

Figure 30. Type of dwellings in Gospić.

  In general, apartments, by sharing walls, roofs, and floors with other units, have fewer surfaces exposed to the external environment compared to single-family homes. This configuration reduces energy losses, as the heat from neighbouring apartments can help maintain a more stable indoor temperature. However, in a region like Gospić, where cold winters and high heating needs are prevalent, many of the older apartment buildings may still suffer from inadequate insulation, leading to higher energy consumption.

- **Year of construction**

The updated data on the year of construction for buildings in Gospić has revealed that a significant number of buildings (33%) were constructed before the introduction of thermal protection regulations.

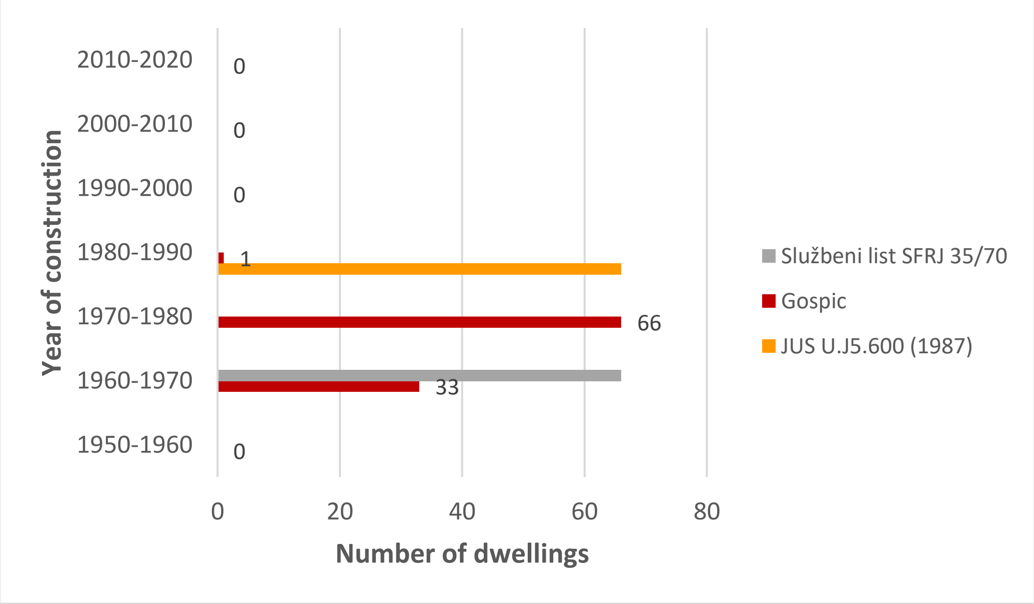

Figure 31. Number of dwellings by year of construction in Gospić.

The analysis done in Figure 31 shows the following:

- 33 buildings were constructed between 1960 and 1970 and were built before the entry into force of the Službeni list SFRJ 35/70 regulations, which were introduced in 1970. These buildings likely lack modern thermal insulation standards, leading to inefficiencies in energy consumption, particularly during heating seasons. As a result, they are prone to higher energy costs, contributing to energy poverty.
- 66 buildings were constructed between 1970 and 1980, which were built before the implementation of the JUS U.J5.600 (1987) regulations. This regulation, introduced in 1987, was an improvement over previous standards, but these buildings were still built under less stringent energy efficiency requirements than modern standards. While some thermal improvements may have been made during this period, these buildings are still relatively inefficient compared to more recent constructions.
- 1 building, constructed between 1980 and 1990, complies with the JUS U.J5.600 (1987) regulations. This represents the only building in this period that has adhered to the more advanced thermal protection standards, although it still may require updates to align with modern energy efficiency criteria.

The fact that most buildings in Gospić were built before the implementation of modern energy efficiency standards highlights the urgent need for energy renovation efforts to improve insulation, reduce energy consumption, and alleviate the risk of energy poverty.

- **Housing size**

The data on the floor area of buildings in Gospić shows that the majority of the analysed homes are smaller than the national average for new dwellings in Croatia. The average floor area of the buildings in Gospić is 64,43 m², which is considerably smaller than the national average of 95,0 m², as reported in the Croatian Bureau of Statistics' 2024 report on completed buildings. The 95 m² average potentially comes from combining all residential units, including both apartments in buildings and large family houses, which is why our analysis in Gospić indicates that the apartments in the city are smaller than the national average; it is important to emphasize that this analysis was conducted strictly on apartments within Gospić and its administratively managed area, even though the city has more family houses than apartments.

Most homes in Gospić fall into the 40-80 m² range, as they are flats in multiapartment buildings, indicating that they are relatively compact. Only a small fraction of the buildings (4%) exceed the national average in size, which suggests that the majority of the dwellings in the city are smaller compared to new homes across the country.

The smaller average size of homes in Gospić is an important factor when considering their energy needs. While smaller homes typically require less energy to maintain a comfortable temperature, the age of the buildings and their potential lack of modern insulation could result in high energy consumption despite their smaller size. Therefore, renovations to improve energy efficiency should take into account both the size of the homes and their energy inefficiencies due to older construction methods and outdated regulations.

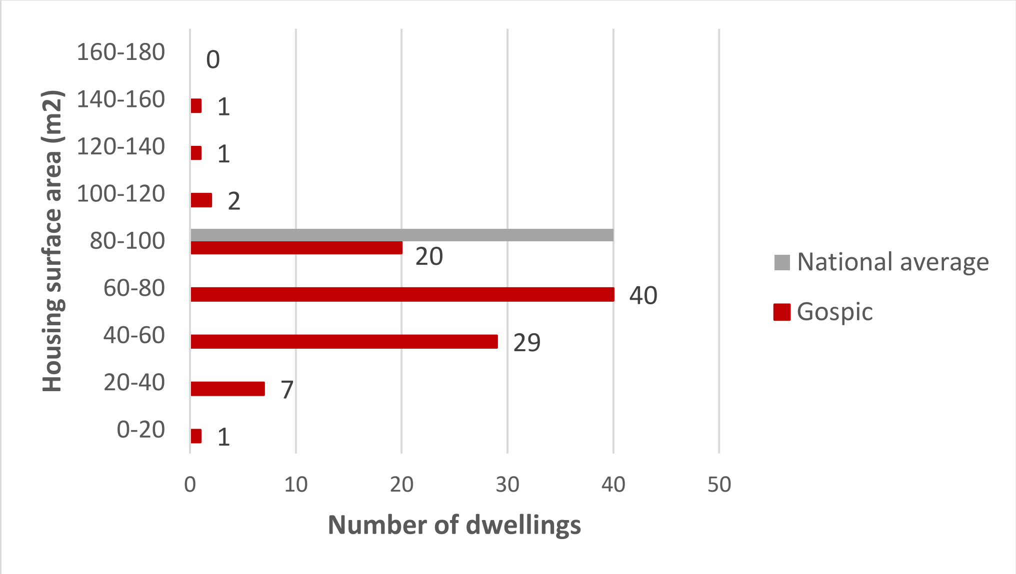

Figure 32. Number of dwellings by housing surface area in Gospić.

- **Number of occupants per home**

The data on occupants per dwelling in Gospić provides valuable insights into household composition and occupancy patterns. The majority of dwellings in Gospić have relatively low occupancy rates, with 33 homes having 2 occupants, and 23 homes having 1 occupant. Additionally, 20 homes have 3 occupants and 22 homes accommodate 4 people. Only a small number of homes (2) have 5 occupants, and there are no dwellings with 6 or more occupants.

In comparison to Croatia’s national average, where the average occupation is 2,7 persons per household according to Eurostat (2025 Edition), Gospić appears to have a slightly lower average number of people per household. The dominance of smaller households (1-4 occupants) suggests that many homes in Gospić are either one-person or small-family households, which is relatively typical in rural or smaller towns. This can be caused by the dramatic population decline that Gospić has experienced due to long-term emigration of working-age residents, the loss of young people during and after World War II, economic collapse in rural areas, post-war internal migration to cities and abroad, and during the 1991–1995 Homeland War, resulting in nearly a 70% decrease in inhabitants from 1900 to 2021.

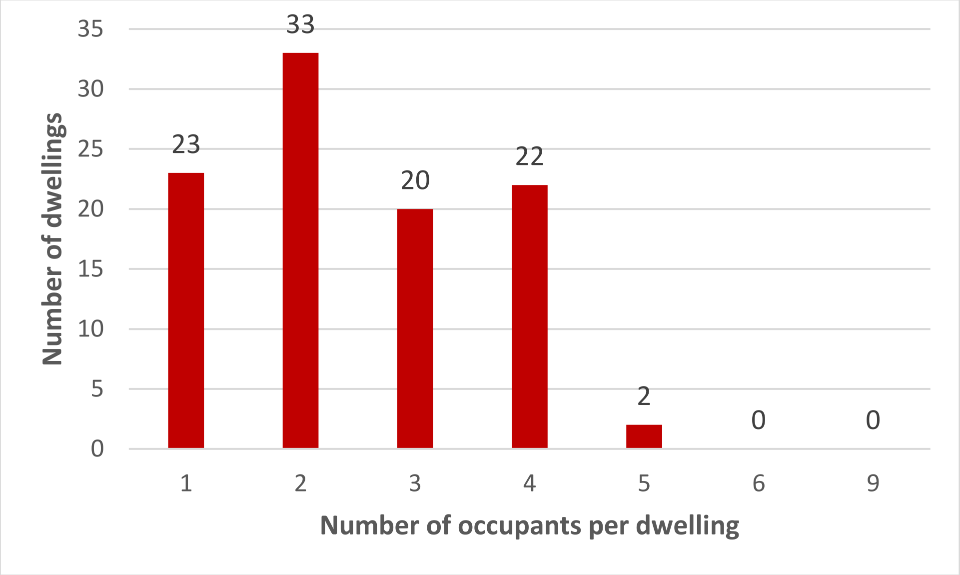

Figure 33. Occupants per dwelling in Gospić.

The analysis of vulnerable groups in households in Gospić highlights that a significant portion of the population is at increased risk due to factors like age, health, and family status. Out of the total population of 247 individuals, 44% belong to vulnerable groups, including children, elderly, and sick people, who are particularly susceptible to the effects of energy poverty.

Adults make up 56% of the population, while children represent 23%, elderly individuals account for 15%, and sick people make up 5%. These vulnerable groups face heightened risks from living in homes that may lack adequate insulation and energy-efficient systems, as poor thermal conditions can negatively affect their health and comfort.

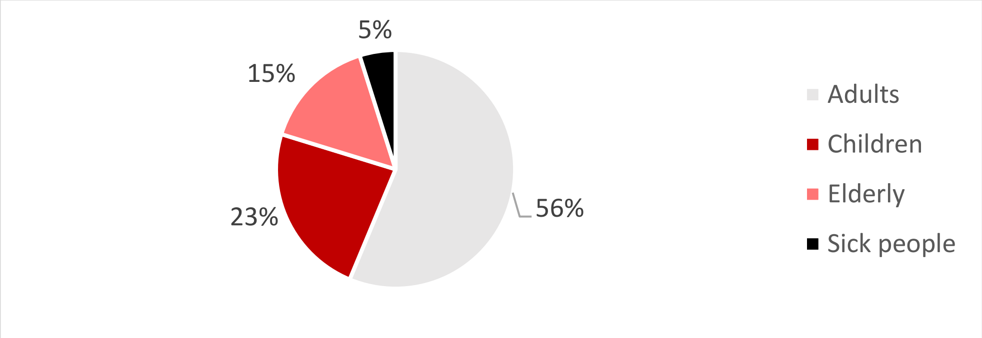

Figure 34. Vulnerable groups in households in Gospić.

Children, the elderly, and those with chronic illnesses are particularly vulnerable to temperature extremes due to reduced ability to regulate body heat. Additionally, lower incomes often limit their access to proper heating, exacerbating health issues and increasing their risk of energy poverty.

Co-funded by
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- **Access to green areas**

  In Gospić, 100 out of 100 homes have access to green spaces.

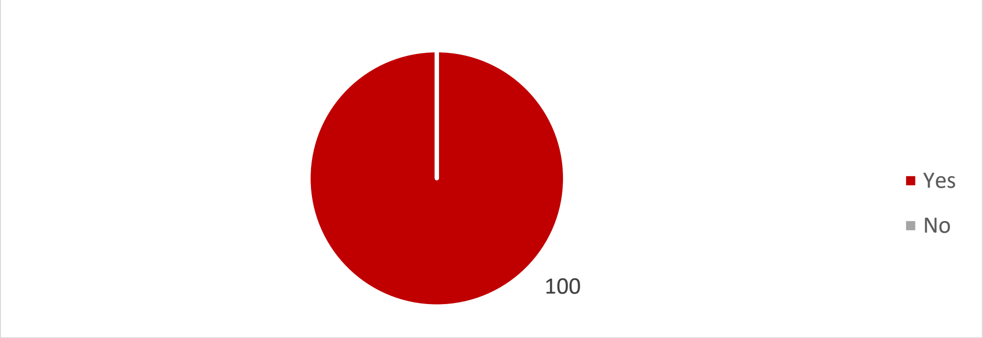

Figure 35. Number of dwellings in Gospić with and without access to green areas.

Indeed, during the project meeting in Gospić in March 2025, it was noticeable that the buildings are well-spaced, with large green areas featuring tall trees. Many residents take advantage of the space in front of or behind their homes to create beautiful flower gardens, which they take great pride in. Overall, the neighbourhood is very well planned, combining buildings with abundant green spaces.

Picture 1. Gardens in the city of Gospić.

2.2. Comfort at home

In addition to analysing the characteristics and composition of the homes, we have also assessed the level of comfort within them, considering three key aspects: thermal, acoustic, and lighting comfort. These factors are essential for understanding the quality of life of the residents and their energy vulnerability, as a comfortable environment directly contributes to the physical and emotional well-being of individuals.

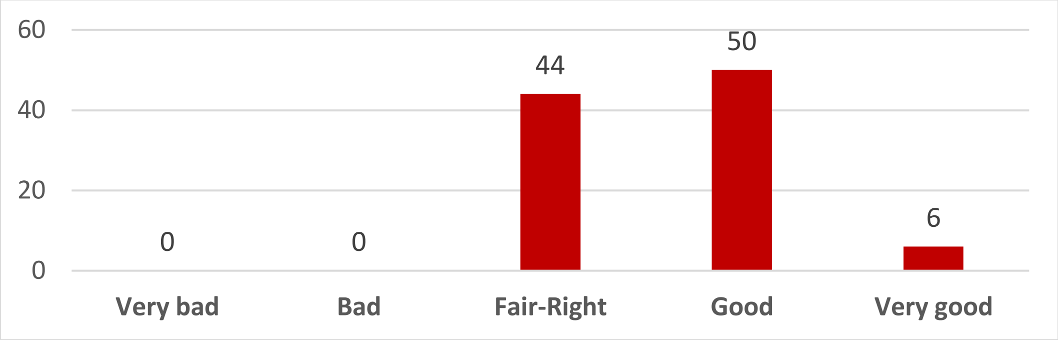

Figure 36. Thermal comfort in Gospić households.

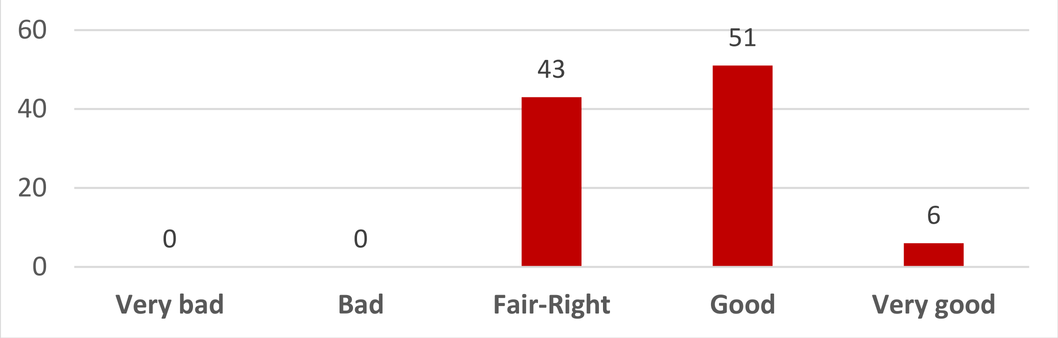

Figure 37. Acoustic comfort in Gospić households.

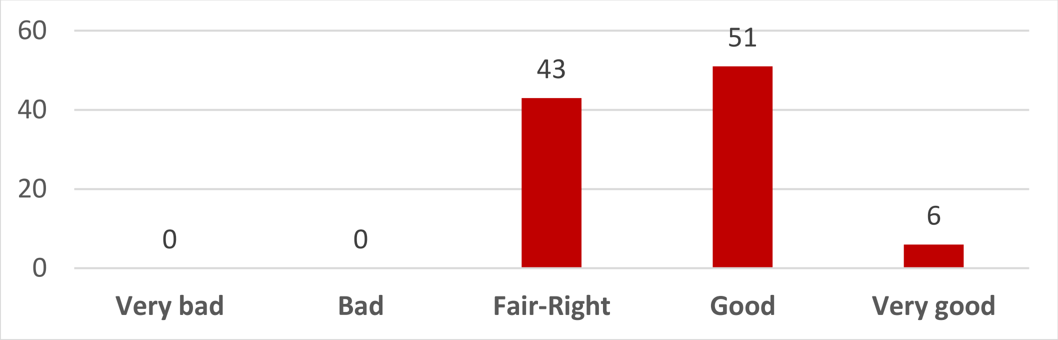

Figure 38. Lightning comfort in Gospić households.

The data on thermal comfort, acoustic comfort, and lighting comfort in Gospić suggests that the majority of the dwellings experience moderate to good conditions in all three aspects, but there is still room for improvement.

For thermal comfort, most homes (50%) report good thermal comfort, followed by fair-right conditions in 44% of the dwellings. In addition, there is a small portion (6%) that report very good thermal comfort, indicating that some homes may not benefit from thermal renovations in the buildings.

In terms of acoustic comfort, the distribution is quite similar, with 43% of homes reporting fair-right conditions, and 51% reporting good acoustic comfort. While most homes experience acceptable levels of acoustic comfort, a small proportion (6%) report very good acoustic comfort, which suggests that some homes may still face issues such as noise pollution or inadequate sound insulation.

Regarding lighting comfort, the pattern is again similar to the previous categories. 43% of homes report fair-right lighting comfort, and 51% report good lighting comfort. Finally, as with the other two categories, 6% of homes report very good lighting comfort.

Overall, while the majority of homes in Gospić experience acceptable or good levels of comfort in these areas, there is still a noticeable portion of homes that could benefit from improvements in thermal insulation, acoustic treatment, and lighting solutions, which would contribute to enhanced energy efficiency and overall comfort for the residents.

This analysis also sought to examine the impact of the current regulations on the perception of comfort in the homes studied.

Table 4. Thermal comfort distribution in dwellings before and after the Službeni list SFRJ 35/70 and JUS U.J5.600 (1987) regulations

Thermal comfort	Number of dwellings	Before Službeni list SFRJ 35/70		Before JUS U.J5.600 (1987)		After JUS U.J5.600 (1987)	
Very bad	0	0	0%	0	0%	0	0%
Bad	0	0	0%	0	0%	0	0%
Fair-Right	44	11	33%	33	50%	0	0%
Good	50	18	55%	31	47%	1	100%
Very good	6	4	12%	2	3%	0	0%

Table 5. Acoustic comfort distribution in dwellings before and after the Službeni list SFRJ 35/70 and JUS U.J5.600 (1987) regulations.

Acoustic comfort	Number of dwellings	Before Službeni list SFRJ 35/70		Before JUS U.J5.600 (1987)		After JUS U.J5.600 (1987)	
Very bad	0	0	0%	0	0%	0	0%
Bad	0	0	0%	0	0%	0	0%
Fair-Right	43	11	33%	32	48%	0	0%
Good	51	18	55%	32	48%	1	100%
Very good	6	4	12%	2	3%	0	0%

Table 6. Table 6: Lightning comfort distribution in dwellings before and after the Službeni list SFRJ 35/70 and JUS U.J5.600 (1987) regulations.

Lightning comfort	Number of dwellings	Before Službeni list SFRJ 35/70		Before JUS U.J5.600 (1987)		After JUS U.J5.600 (1987)	
Very bad	0	0	0%	0	0%	0	0%
Bad	0	0	0%	0	0%	0	0%
Fair-Right	43	11	33%	32	48%	0	0%
Good	51	18	55%	32	48%	1	100%
Very good	6	4	12%	2	3%	0	0%

The analysis of thermal comfort in dwellings before and after the introduction of the Službeni list SFRJ 35/70 and JUS U.J5.600 regulations reveals significant improvements in thermal conditions. Before the implementation of the Službeni list SFRJ 35/70, 33% of the dwellings were rated as Fair-Right, with 55% of the homes reporting Good thermal comfort. After the JUS U.J5.600 regulations were introduced, 50% of the homes were rated Good for thermal comfort, and a smaller proportion (3%) reported Very good comfort. While the regulations led to improvements, achieving optimal thermal comfort in all homes is still a work in progress, with no homes reaching the Very good category.

In terms of acoustic comfort, before the Službeni list SFRJ 35/70, 33% of the homes reported Fair-Right acoustic comfort, while 55% rated their acoustic comfort as Good. After the introduction of the JUS U.J5.600 regulation, there was a notable improvement, with 48% of the dwellings reporting Good acoustic comfort. However, only 3% of homes reached the Very good level, indicating that while the regulations improved sound insulation, further efforts are needed to achieve optimal acoustic comfort across all homes.

For lighting comfort, the situation is similar. Before the Službeni list SFRJ 35/70 regulation, 33% of the dwellings experienced Fair-Right lighting comfort, with 55% rating it as Good. After the JUS U.J5.600 regulations, 48% of the homes reported good lighting comfort, with only 3% reporting Very good. While the regulations did improve lighting conditions, there is still room for improvement to achieve optimal lighting comfort across all homes.

While the introduction of the JUS U.J5.600 regulation led to some improvements in thermal, acoustic, and lighting comfort, it is important to note that only one dwelling in the dataset complies with this regulation. Due to the limited number of homes adhering to the JUS U.J5.600 standards, it is not possible to draw meaningful conclusions about the overall impact of this regulation on comfort levels in Gospić.

2.3. Heading

Of the 100 homes analysed in Gospić, all of them have some type of heating system.

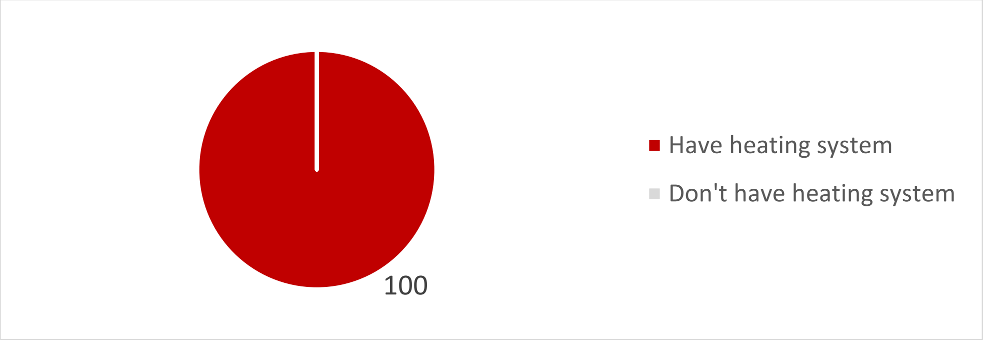

Figure 39. Number of dwellings with or without heating systems in Gospić.

- **Types of heating system**.

  The data regarding the heating systems in the 100 surveyed homes in Gospić reveals that fireplaces powered by biomass are the only heating system in the area. These heating systems are typically associated with wood-burning stoves or open fireplaces that use local biomass, such as wood or other organic materials, to provide warmth.

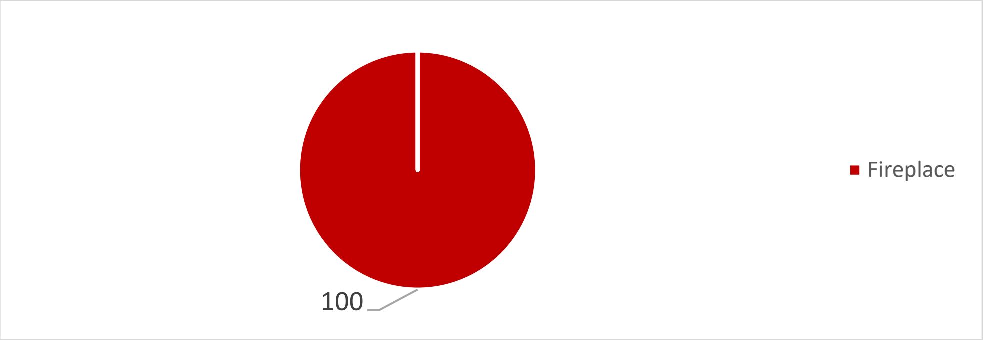

Figure 40. Type of heating system in the dwellings in Gospić.

In terms of maintenance and conservation, the majority of homes have ratings between 5 and 8 on a scale from 1 to 10. This indicates that while the heating systems in these homes are generally maintained at a moderate level, there is still room for improvement, especially in older systems. A significant portion of homes (around 30%) has heating systems that could be considered average or slightly above average in terms of upkeep, while a smaller percentage (less than 10%) has better-maintained systems.

Regarding the control system, almost all homes have no control system in place for regulating the heating. This suggests that the homes rely on manual control, which can lead to inefficiencies in energy use. Without a modern control system, it is likely that these homes may face higher energy consumption and less comfort because heating cannot be adjusted automatically based on temperature changes or time of day.

- **Energy sources**

In terms of energy sources, the 100 dwellings of the study use biomass as energy source for heating.

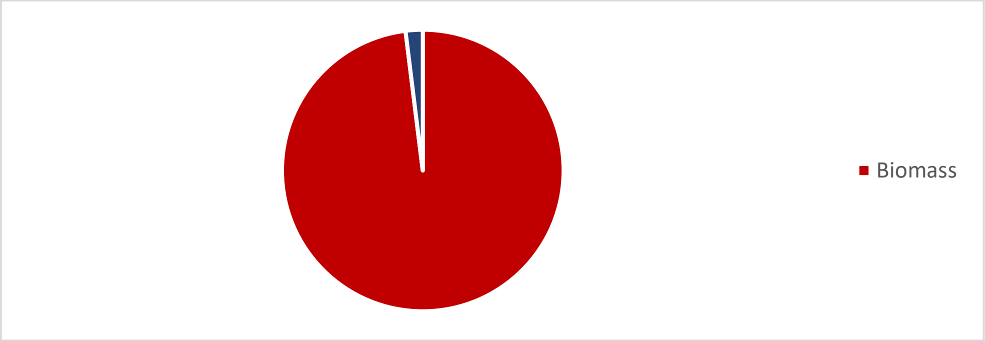

Figure 41. Type of energy source in heating systems in Gospić.

Currently, the city of Gospić lacks a district heating system, and the gas network has only recently been introduced. Some buildings are expected to be connected to the gas network, such as the hospital and schools. However, public sentiment in Gospić indicates that many residents prefer to continue using their individual biomass heating systems.

This reluctance may also be influenced by current gas prices and uncertainty due to the situation in Ukraine, making residents hesitant to switch. Despite this, the gas network was still extended through the city as part of a broader plan by the Croatian government to expand gas infrastructure to Dalmatia—a region of Croatia that currently lacks both gas and district heating networks. The goal is long-term regional energy development, even if immediate uptake by citizens is limited.

- **Heating energy consumption**

When comparing the thermal energy consumption in Gospić with the national average for Croatia, it becomes clear that many homes in Gospić consume more energy than the average figures reported at the national level. According to the Odyssee-Mure / Hrvoje Požar Energy Institute (EIHP), the average total energy consumption per dwelling in Croatia is 0,51 toe (tonnes of oil equivalent), which is approximately 5.931 kWh per year. For space heating, which typically accounts for around 70% of the total energy consumption, the average is 0,357 toe, or about 4.152 kWh per year.

The average energy consumption for heating in Gospić is 9.438 kWh/year, which is 127% higher than the national average. This significant increase in energy consumption suggests that homes in Gospić are experiencing higher heating costs due to inefficiencies in their heating systems. For example, some homes report energy consumption levels ranging from 2.500 kWh/year to 25.000 kWh/year, which far exceed the national average for space heating. Even homes with smaller living areas often have energy consumption levels above the national average, with many reporting values in the range of 2.500 to 5.000 kWh/year.

This suggests that energy efficiency may be a significant concern in Gospić, as many homes, even those with smaller spaces, are consuming energy at higher rates than what would be expected based on the national averages. The use of biomass fireplaces and the lack of modern control systems could be contributing to this elevated energy consumption. To reduce energy costs and align with national standards, improvements in energy efficiency and heating system upgrades would be essential.

- **Heating energy price**

The analysis of energy costs in Gospić shows that the annual thermal energy expenses vary widely depending on the size of the dwelling and its energy consumption. As the data indicates, the thermal energy costs for the surveyed homes range from 240€ to 7.000€ per year, reflecting significant differences based on energy usage.

In general, homes with larger living areas, such as those with 90 m² or more, tend to have higher energy costs. For example, homes consuming 20.000 kWh/year or more report annual costs ranging from 1.000€ to 1.800€. These higher costs are likely due to the larger spaces requiring more energy for heating, as well as potentially inefficient heating systems that lead to greater energy consumption.

On the other hand, smaller homes, especially those in the 45 m² to 60 m² range, have lower energy costs. Their annual thermal energy expenses generally range from 240€ to 600€, indicating that smaller dwellings are more energy-efficient when it comes to heating, although this is still influenced by the age and condition of the heating system.

When compared to the Croatian national average for energy consumption, it appears that the homes in Gospić are facing relatively higher heating costs. This could be due to several factors, including the lack of modern heating controls and older, inefficient heating systems, such as the biomass fireplaces used in many homes

- **Heating energy consumption per household**

The data presented in the chart clearly shows that the majority of the 100 homes reporting electricity consumption in Gospić have annual heating consumption higher than the national average for Croatia. In fact, 84% of these homes have energy consumption levels exceeding the national average of 4.152 kWh/year for space heating.

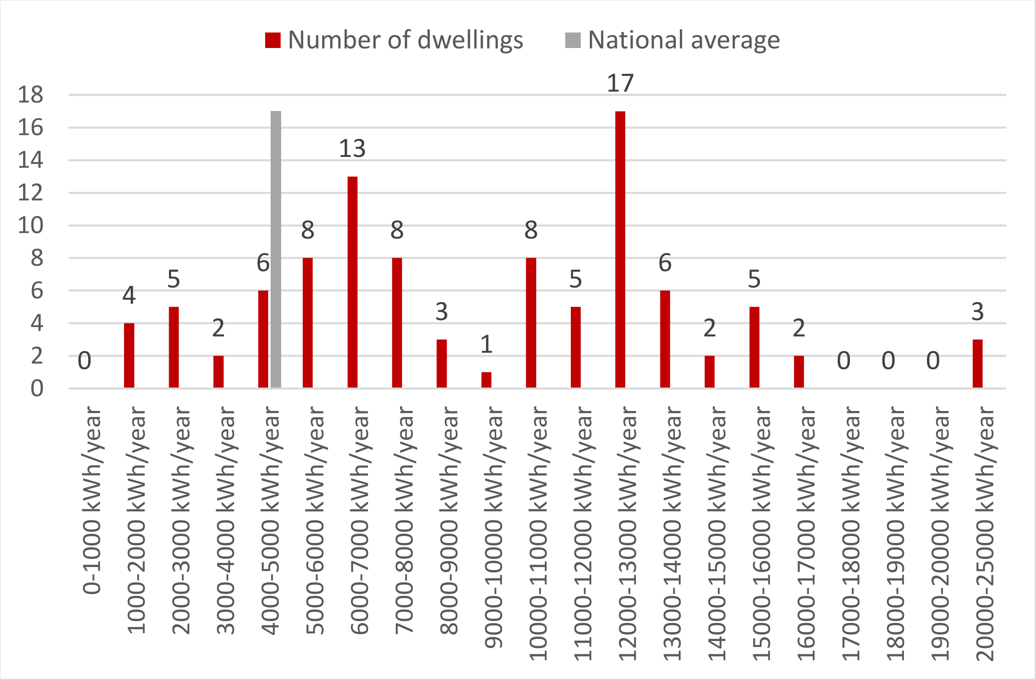

Figure 42. Heating consumption per dwelling in Gospić.

This significant difference in energy consumption raises questions about the efficiency of the biomass fireplaces used in these homes compared to other more modern heating systems, such as gas or district heating. Biomass fireplaces, while environmentally friendly and often cheaper to operate when considering fuel costs, can be less efficient than other systems, particularly when it comes to controlling and distributing heat. Biomass fireplaces typically require manual loading of fuel, and their heating efficiency can vary depending on the type of biomass, its quality, and the design of the system. This can lead to higher energy consumption if the stoves are not well-maintained or if the homes are not well-insulated.

2.4. Cooling

Of the 100 homes analysed in Gospić, none are equipped with air conditioning system. This is particularly notable given the high summer temperatures in the region, where daytime temperatures can regularly exceed 30°C, creating uncomfortable indoor conditions during the warmer months. Without air conditioning, residents must rely on passive cooling methods, such as opening windows or using fans, which may not be sufficient during heatwaves.

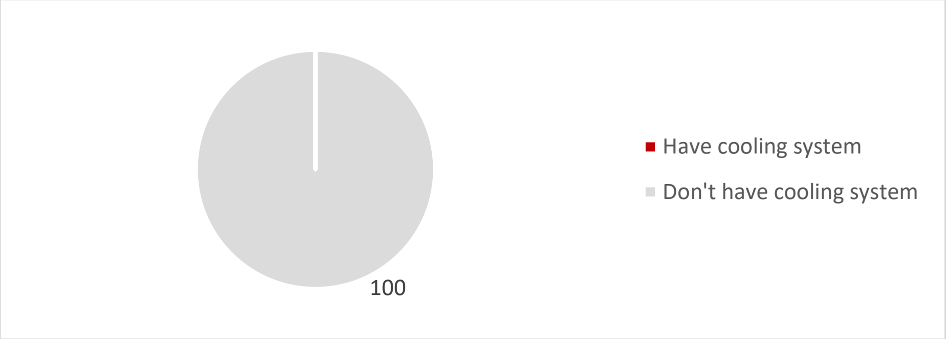

Figure 43. Number of dwellings with or without cooling systems in Gospić.

This lack of modern cooling systems highlights a potential gap in energy services, contributing to energy poverty. Many households, particularly those with low incomes, may struggle to afford the installation and operation of such systems, leaving them vulnerable to both high summer temperatures and the increased energy costs of more inefficient cooling methods. This situation exacerbates the challenges faced by vulnerable groups, such as the elderly, children, and those with chronic health conditions, who are especially at risk from extreme heat.

2.5. Domestic hot water

According to the data collected, of the 100 homes analysed in Gospić, all of them have domestic hot water systems (100%).

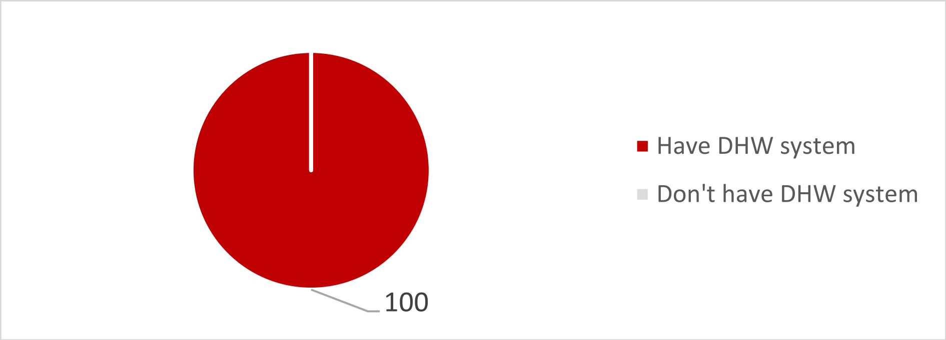

Figure 44. Number of dwellings with or without DHW systems in Gospić.

- **Types of DHW systems**

  Of the 100 homes with a hot water system, all of them use electric water heaters powered by electricity (Joule effect).

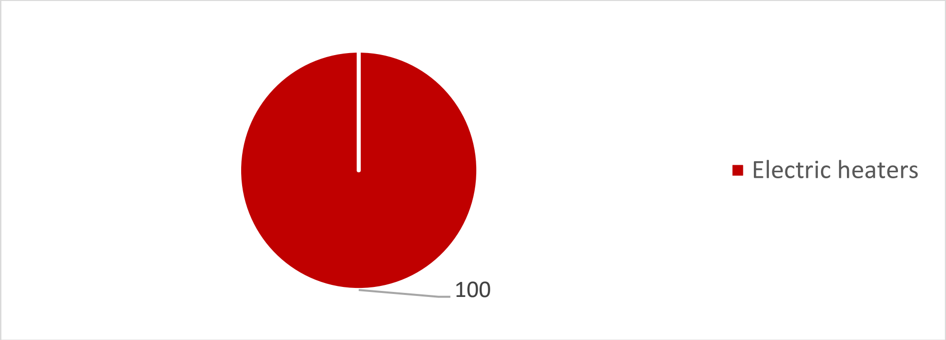

Figure 45. Type of DHW system in the dwellings in Gospić.

- **Energy consumption.**

  We cannot analyse the specific energy consumption for DHW, as this consumption is included within the total electricity consumption.

2.6. Lightning

Of the 100 homes analysed, 28 still rely on incandescent bulbs, while the majority, 72 homes, have switched to LED bulbs. This shift towards LED technology is a positive sign in terms of energy efficiency, as LED bulbs consume significantly less energy than incandescent bulbs and have a longer lifespan.

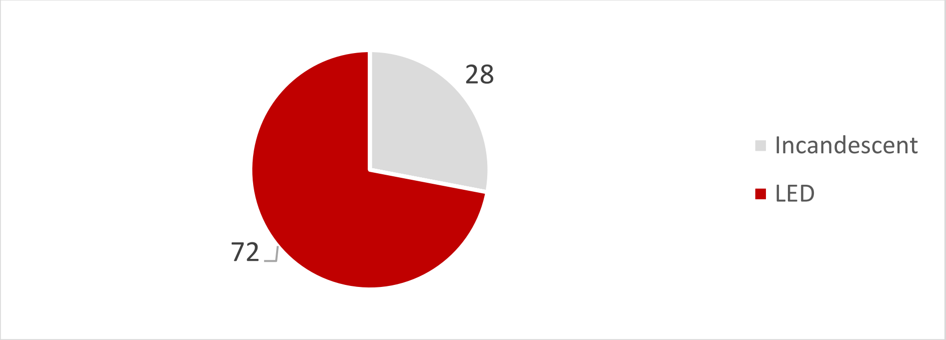

Figure 46. Type of lightning system in the dwellings in Gospić.

2.7. Electricity

In the specific case of Gospić, electricity consumption includes not only general electricity use but also the use of domestic hot water (DHW) systems.

- **Energy consumption.**

  The average electricity consumption per household in Croatia is 4.600 kWh per year, according to data from the Odyssee-Mure / Energy Institute Hrvoje Požar (EIHP). This figure provides a benchmark for comparing electricity use across regions, including Gospić.

  The average electricity consumption in Gospić for homes involved in the ReHABITA project is 3.484 kWh per year, which is 24% lower than the national average of 4.600 kWh per year in Croatia. This suggests that the homes in the Gospić are consuming less electricity compared to the national average.

  This lower consumption can be seen as a positive indicator, as households that use less energy tend to face fewer difficulties in managing their energy bills. However, it is important to recognize that lower energy consumption can sometimes indicate limited access to basic services. For instance, the lack of air conditioning is especially relevant considering the high summer temperatures in the region, where temperatures regularly exceed 30°C. Without air conditioning, residents must rely on passive cooling methods, which may not be sufficient during heatwaves.

  This situation could reflect a form of energy poverty, where households are forced to limit their energy usage not necessarily because of energy efficiency but due to financial constraints or limited access to cooling systems. While lower energy consumption helps reduce bills, it may also mean that residents are sacrificing comfort and facing difficulties during hot summer months.

- **Energy price**

  The average annual electricity cost for a household in Croatia is approximately 547,32€ (45,61€ per month), with prices projected for 2026 following recent tariff adjustments. This data is provided by the Government of the Republic of Croatia and the Croatian Energy Regulatory Agency (HERA). The average electricity cost for homes involved in the ReHABITA project in Gospić is 541,80€ per year, which is 1% lower than the average electricity cost in Croatia

  It's important to note that despite having 24% lower energy consumption compared to the national average, the bill is only 1% lower. The 2026 projection reflects both higher electricity prices and lower consumption. This is due to a 17% price increase that took effect on February 1, 2026, following the cessation of government subsidies, which had been in place since the 2022 war in Ukraine. This explains why the price shows only a modest 1% decrease, despite a significant 24% drop in consumption. Essentially, the 2026 energy cost is much higher, with electricity prices now 17% more expensive, which accounts for the small reduction in the bill.

- **Energy consumption per household**

  Of the 100 homes that have reported electricity consumption, only 19 of them (19%) have an annual electricity consumption higher than the national average.

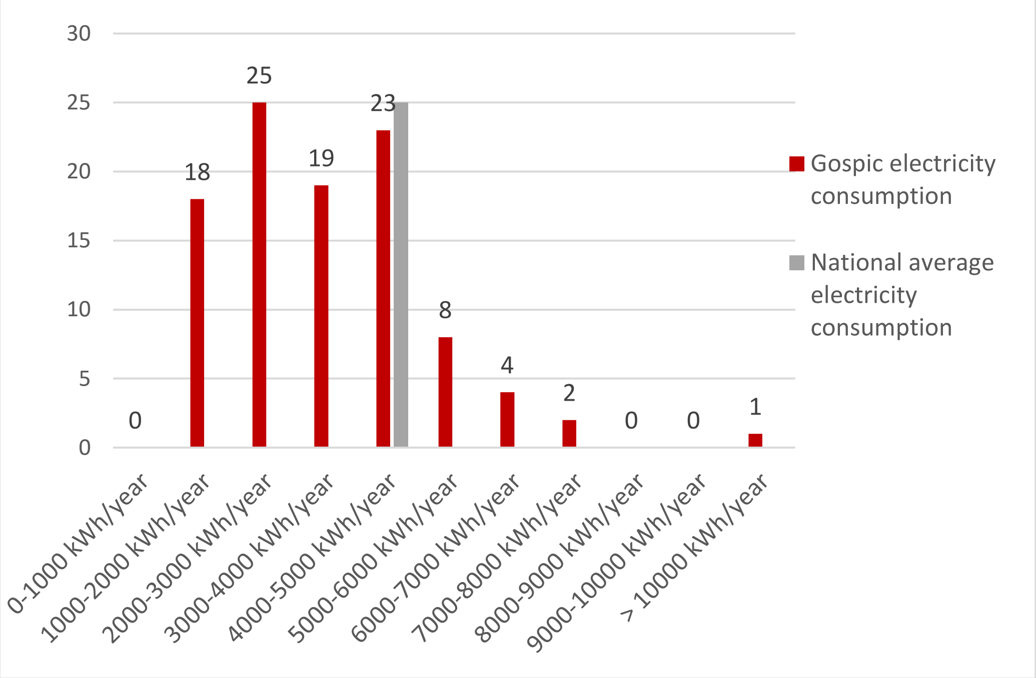

Figure 47. Electricity consumption per dwelling in Gospić.

This lower consumption could be linked to the small size of many homes in Gospić. Smaller homes generally have lower heating demands and require less

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energy to maintain comfortable temperatures. However, this reduced consumption might also indicate energy-saving behaviour, where households, particularly those with limited financial resources, might be reducing their energy use in response to high energy costs.

2.8. Data analysis

- **Energy consumption vs. housing area**

Figure 48 represents the energy consumption (heating + electricity) of the homes in Gospić against the housing area.

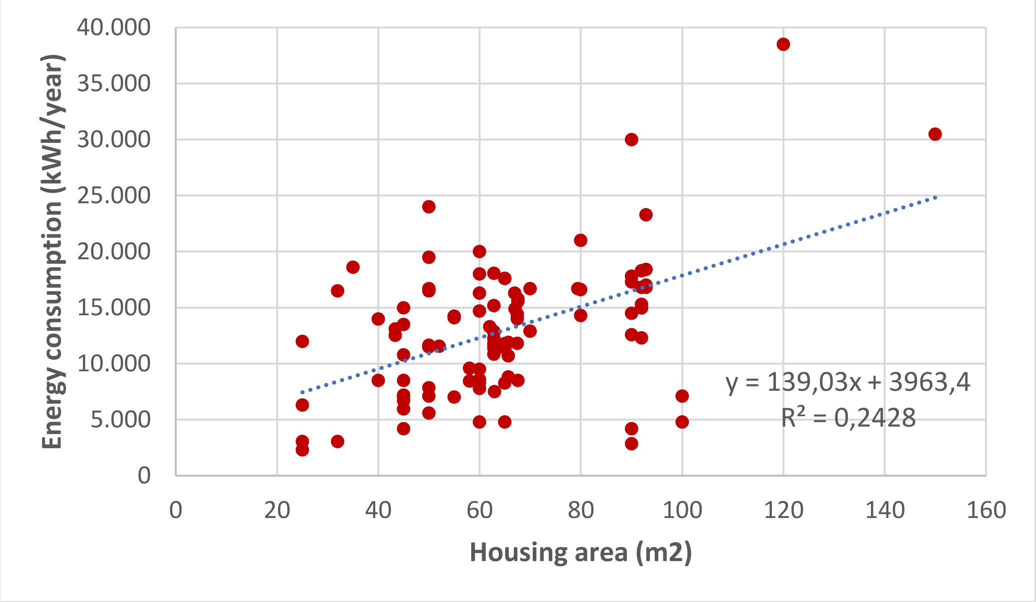

Figure 48.Energy consumption per housing area.

The trendline indicates a positive correlation between housing area and energy consumption. As the size of the home increases, so does the energy consumption. This makes sense because larger homes typically require more energy for heating, cooling, and the operation of household appliances. However, the R² value of 0.2428 suggests that the correlation between housing area and energy consumption is relatively weak, meaning that only about 24% of the variation in energy consumption can be explained by the size of the house. This highlights that while larger homes tend to consume more energy, factors like heating systems, insulation quality, and household habits also significantly influence overall energy consumption.

- **Energy consumption vs. number of occupants**

  Figure 49 shows the relationship between number of occupants per dwelling and energy consumption (in kWh/year). The trendline suggests a positive correlation, indicating that as the number of occupants in a dwelling increases, the energy consumption also increases.

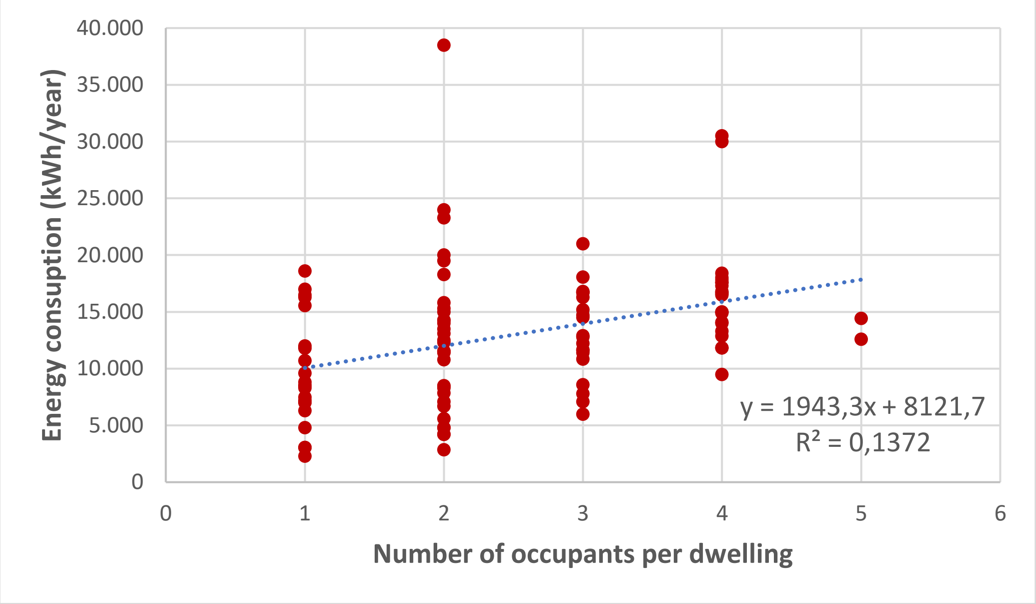

Figure 49. Energy consumption per number of occupants in Gospić.

The equation for the trendline is y = 1.943,3x + 8.121,7, where x represents the number of occupants, and y represents energy consumption. This suggests that each additional occupant adds approximately 1.943,3 kWh/year to the overall energy consumption.

However, the R^2 value of 0,1372 indicates a weak correlation between the two variables, meaning that only 13,72% of the variation in energy consumption can be explained by the number of occupants. This suggests that other factors, such as energy efficiency, the type of heating system, or the size of the dwelling, play a more significant role in determining energy consumption than the number of occupants alone.

- **Energy consumption vs. year of construction**

  Figure 50 shows energy consumption (kWh/year) in relation to the year of construction for the homes in Gospić. The trendline suggests a very weak positive relationship between the year the homes were built and their energy consumption.

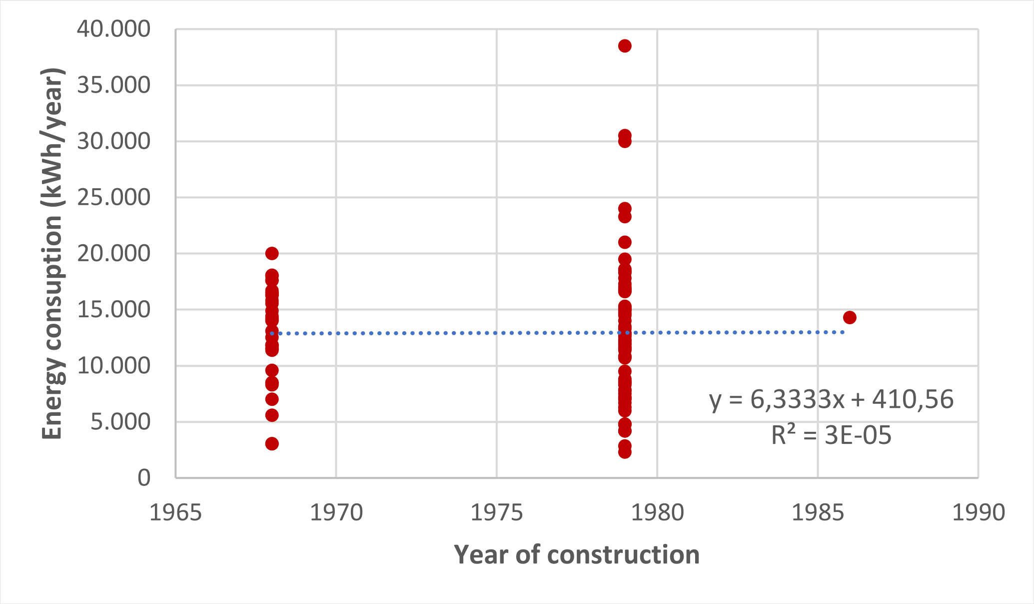

Figure 50. Energy consumption in Gospić dwellings per year of construction.

It is also worth noting that the sample size of 100 homes may not be large enough to provide a fully representative analysis, especially when considering that other factors, like local climate, household habits, and the condition of the buildings, may have a more substantial effect on energy consumption than the construction year. Therefore, while the trendline shows a slight increase in energy consumption with newer homes, this finding is not robust enough to draw firm conclusions about the relationship between energy consumption and the year of construction.

- **Energy consumption vs. thermal comfort**

In Figure 51, the relationship between energy consumption (kWh/year) and thermal comfort assessment for the homes in Gospić is illustrated, to verify whether higher energy expenditure translates into better living conditions.

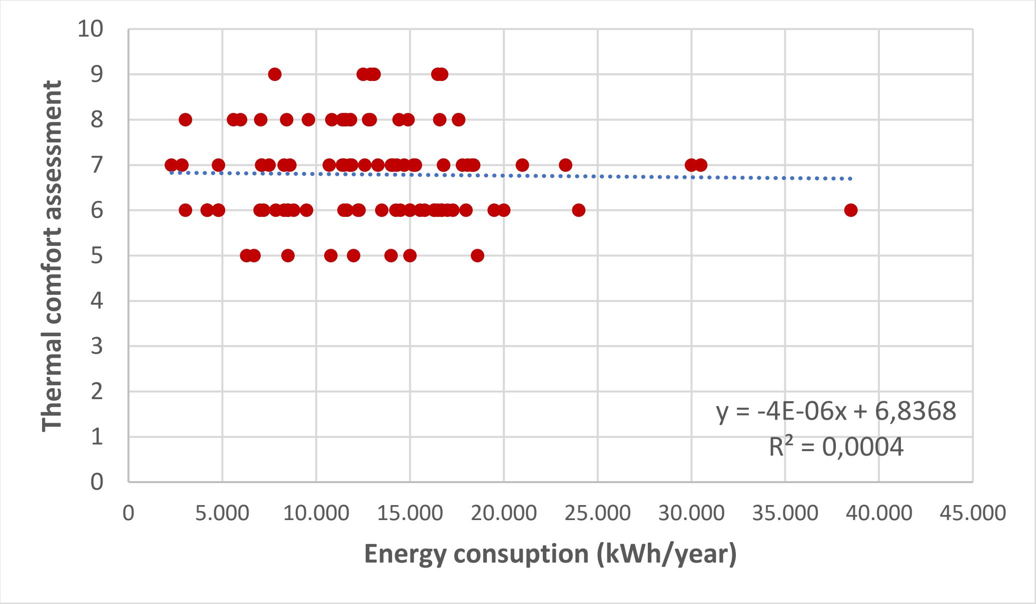

Figure 51. Thermal comfort assessment per energy consumption.

The trendline shows a negligible negative correlation, with an R² value of 0,0004, which is extremely low. This suggests that energy consumption has almost no impact on the thermal comfort assessment of the dwellings. In other words, changes in energy consumption do not lead to significant changes in the residents' assessment of their thermal comfort.

It is also possible that thermal comfort is being evaluated based on perceptions of comfort rather than actual energy usage or heating performance, which might explain why there is little correlation between the two variables.

- **Housing area vs. thermal comfort**

Figure 52 analyses the relationship between housing area (m²) and thermal comfort level for homes in Gospić, to check if the size of the home influences the living conditions and thermal wellbeing of its residents.

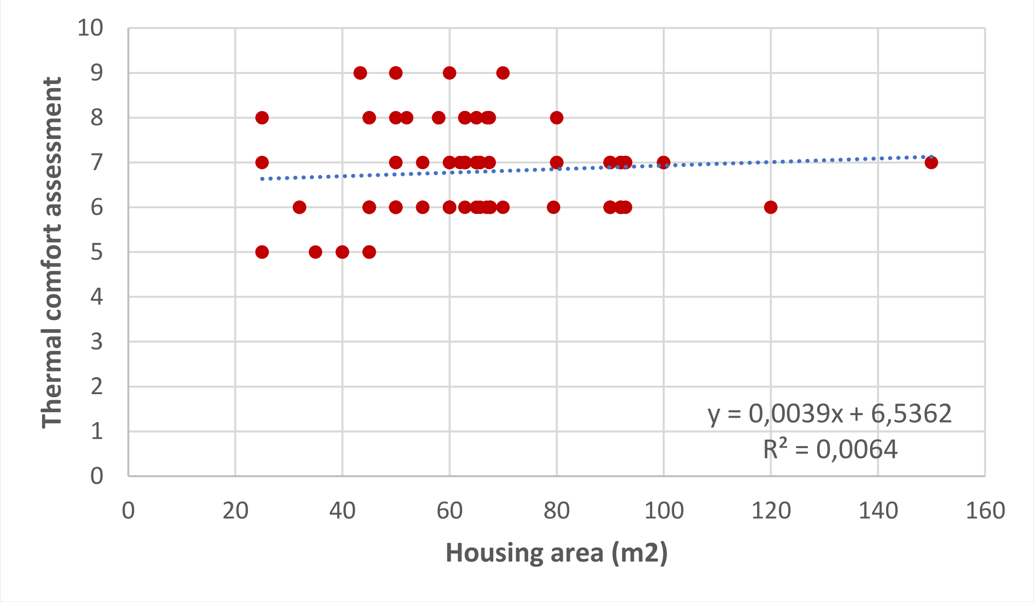

Figure 52. Thermal comfort assessment per energy consumption.

The trendline suggests a very weak positive correlation, with an R² value of 0,0064. This extremely low R² value suggests that only 0,64% of the variation in thermal comfort can be explained by the size of the home.

Despite a slight upward trend, the weak correlation indicates that housing area is not a significant factor in determining thermal comfort in these homes. Larger homes do not necessarily lead to higher comfort ratings. In this regard, since the size of the homes in the dataset is relatively similar, with most homes being moderate size, there is not enough variability in the data to draw meaningful conclusions about the effect of housing area on thermal comfort.

2.9. Score of the energy assessment

According to the guide, three vulnerability levels have been defined for the homes analysed in these energy studies: Low, Medium, and High. The threshold values for each level are selected so that the upper limit of the score for each category indicates the urgent need for energy rehabilitation interventions in those homes.

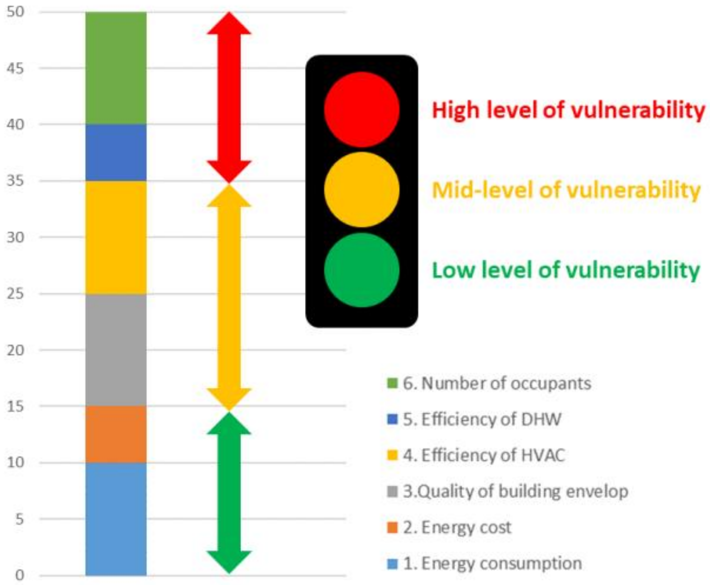

Figure 53. Example of thresholds determined to differentiate the three levels of housing energy vulnerability.

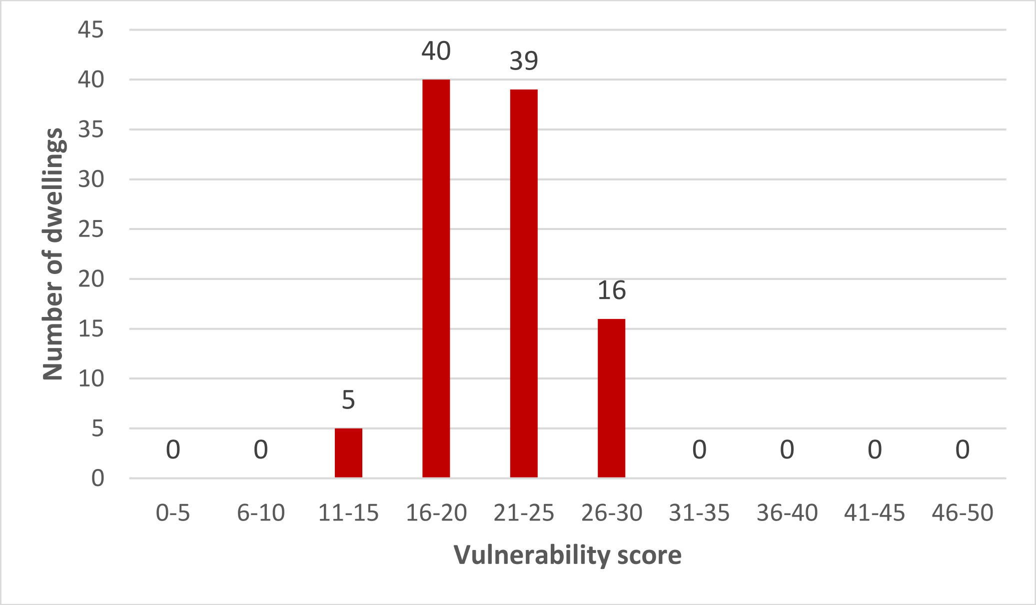

Figure 54. number of dwellings per vulnerability level.

From this data, the following conclusions can be drawn:

- A total of 95 homes fall within the medium vulnerability level, with vulnerability scores ranging between 15 and 35 points. This accounts for 95% of the total homes analysed. Among these, 16 homes have scores in the 26-35 range, which places them near the high vulnerability threshold. These homes should be prioritised for interventions, followed by the remaining homes within the medium vulnerability range.

- 0 homes fall into the high vulnerability level, indicating that no homes have been classified as critically vulnerable based on the provided scores.
- Only 5 homes fall under the low vulnerability level, with scores between 0 and 15 points. These homes exhibit minimal vulnerability and require less immediate attention compared to the other categories.

This analysis reveals that the vast majority of homes in Gospić require urgent energy rehabilitation interventions, as only 5 homes have been recorded in the low vulnerability level.

3. PLOIESTI

Ploiesti is a municipality in southern Romania, about 60 km north of Bucharest. The city has a continental climate, with cold winters that increase the demand for heating in residential buildings. As in many Romanian cities, natural gas is widely used for space heating and hot water in households. Although gas prices remain relatively low compared with many other European countries, heating costs can still represent a notable share of household expenses, especially in older buildings. A significant part of the housing stock in Ploiesti was built during the second half of the 20th century and does not fully meet current European energy efficiency standards, which leads to higher energy consumption for heating and reduced thermal comfort in winter

A total of 100 vulnerable homes has been analysed in Ploiesti to assess the energy situation of these households. The primary objective of this study is to identify technical deficiencies in energy efficiency and to understand the impact of building age and outdated construction regulations on the residents' quality of life.

3.1. Building characteristics and their surroundings

This section details the physical and structural attributes of the surveyed homes, including typology, age, and environmental context.

- **Types of dwellings**

  The 100 homes analysed in Ploiesti are all apartments, accounting for 100% of the dwellings surveyed.

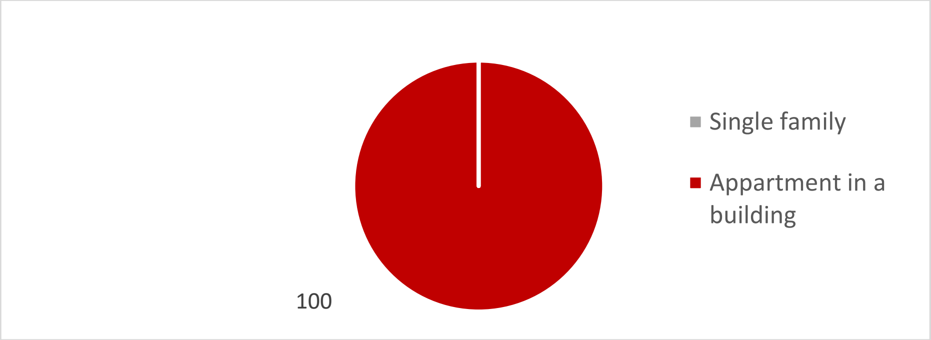

Figure 55. Type of dwellings in Ploiesti.

In a climate like Romania's, apartment buildings offer an advantage, as dwellings share internal walls, floors, and ceilings, which helps reduce the surface area exposed to low outdoor temperatures during winter. However, since many of these buildings are old, this advantage is often limited by poor thermal performance in the building envelope, including inadequate insulation, outdated windows, and other construction features that do not meet current energy efficiency standards

- **Year of construction**

  Based on the data obtained for Ploiesti, we can differentiate between the year of construction of the apartments: those built before 1977 and those built after 1977. Those built up to 1977 followed the standard "C107-1970 Normativ privind calculul termotehnic al elementelor de construcție ale clădirilor" and those built after 1977 followed "C107-19707 Normativ privind calculul termotehnic al elementelor de construcție ale clădirilor," which was a revision and update of the previous standard.

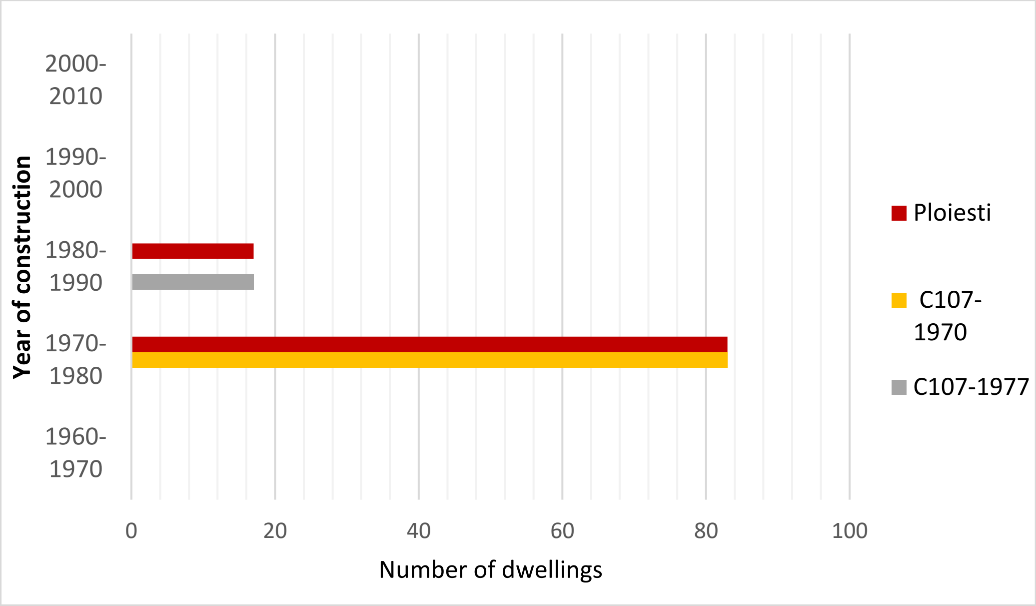

Figure 56. Number of dwellings by year of construction in Ploiesti.

The analysis done in Figure 56 shows the following:

- For buildings constructed before 1977 (83 dwellings): The applicable regulation during this period was "C107-1970 – Normativ privind calculul termotehnic al elementelor de construcție ale clădirilor". This standard defined the thermal calculation of building envelope elements such as external walls, roofs, and floors. However, its requirements were mainly aimed at ensuring basic indoor thermal comfort rather than reducing energy consumption. As a result, many buildings constructed under this regulation have limited thermal insulation and relatively high heat losses through the envelope.
- For buildings constructed in 1984 (17 dwellings): These buildings were designed under the updated "C107-1977 – Normativ privind

calculul termotehnic al elementelor de construcție ale clădirilor", which replaced the 1970 version. This revision introduced some improvements in thermal design and more structured calculation methods for heat losses. Nevertheless, insulation requirements remained significantly lower than those required by current European energy efficiency standards.

Overall, the analysed apartments in Ploiești were built under historical Romanian construction standards that do not reflect current energy efficiency requirements. As a result, this housing stock is likely to show significant heat losses and a relatively high heating demand to ensure adequate indoor comfort during winter.

- **Housing size**

The data on the floor area of the analysed buildings in Ploiesti shows that the dwellings are generally of moderate size and relatively consistent with the typology of apartment blocks constructed during the socialist period. The living areas recorded across the sample are as follows:

- For dwellings constructed in 1975–1976, the apartments are relatively standardized, with floor areas mainly ranging from 50 m² to 75 m², and several units around 60–65 m², which reflects the typical layout of medium-size apartments built during this period.
- For dwellings constructed in 1978, the range of dwelling sizes is slightly wider, varying approximately from 20 m² to 77 m². Most units, however, fall between 50 m² and 68 m², indicating a continued use of standardized apartment designs within prefabricated residential blocks.
- For dwellings constructed in 1984, the apartments tend to be somewhat larger and more uniform, generally ranging between 51 m² and 77 m², with many units around 62–65 m².

When considering the broader national context, these values are broadly aligned with the typical size of apartments built in Romanian cities during the late socialist period. The analysed dwellings therefore represent a relatively typical urban housing stock in terms of size.

The dwelling size is an important factor in understanding energy demand. While apartments of this scale do not require extremely large heating loads due to their moderate floor area, the construction standards applied at the time

(C107-1970 and C107-1977) included limited thermal insulation requirements. As a result, despite their moderate size, these buildings are likely to experience notable heat losses through the envelope, which increases heating demand during the winter period. Renovation strategies should therefore focus on improving the thermal performance of the building envelope while maintaining the spatial characteristics of these apartments.

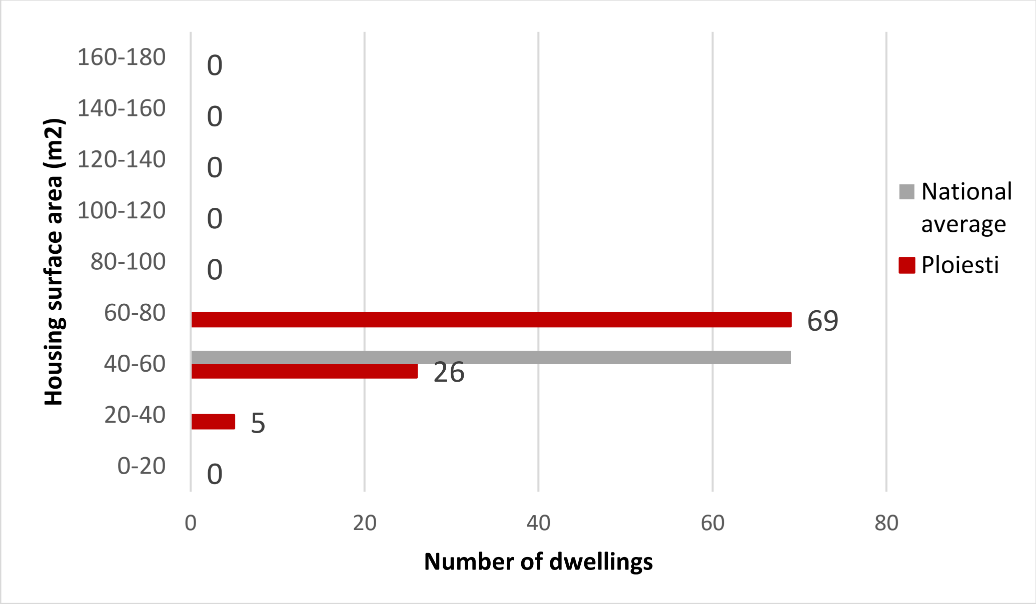

Figure 57. Number of dwellings by housing surface area in Ploiesti.

- **Number of occupants per home**

The occupancy levels across the 100 surveyed dwellings in Ploiești provide useful insight into household composition and potential social vulnerability. The distribution of occupants per dwelling shows a predominance of small households. The largest group corresponds to three-person households (39 dwellings), followed by two-person households (33 dwellings) and single-person households (18 dwellings). Larger households are less common, with nine dwellings housing four occupants and only one dwelling with five occupants, while no cases of six occupants were recorded.

When compared with the broader national context, this distribution appears relatively consistent with household patterns in Romania, where the average household size is around 2.5 persons according to Eurostat data. The analysed sample in Ploiești therefore reflects a typical urban household structure, dominated by small and medium-sized households.

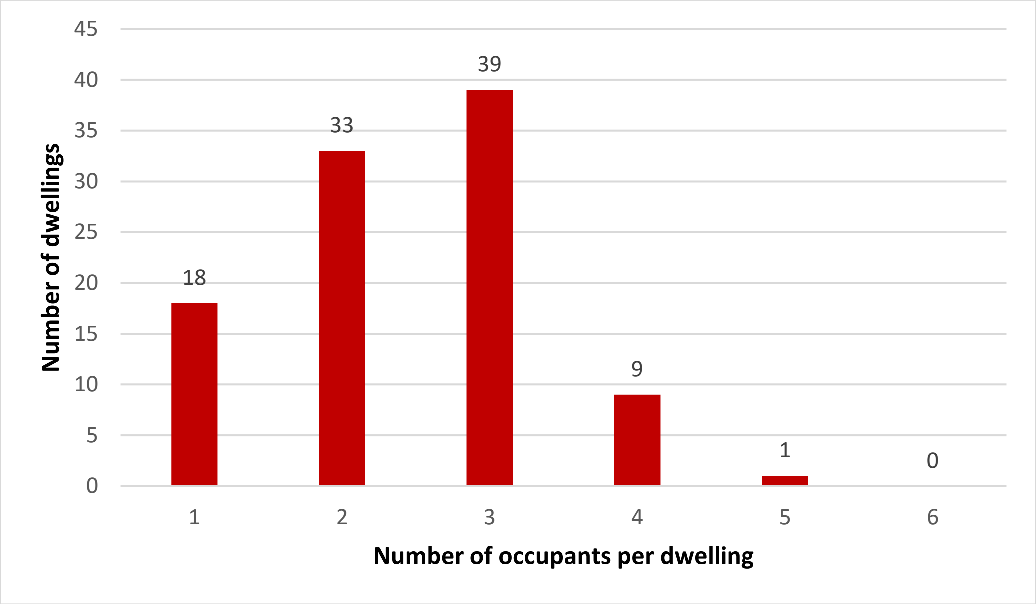

Figure 58. Occupants per dwelling in Ploiesti.

The demographic analysis of the surveyed dwellings in Ploiești shows that 76% of residents are adults and 24% are children. This means that households are mainly composed of adult residents, although children also represent a relevant share of the population. Given that these apartments were built under older Romanian construction standards with limited insulation requirements, maintaining adequate indoor comfort may involve high heating demand during winter. Improving the energy performance of these buildings would therefore help ensure better thermal comfort for both adults and children.

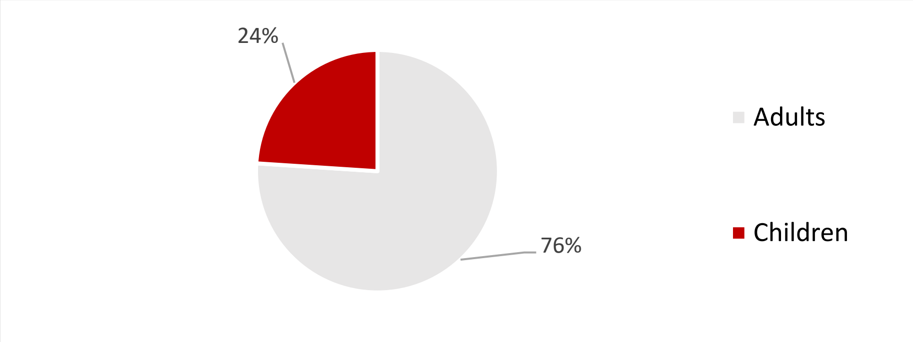

Figure 59. Vulnerable groups in households in Ploiesti.

- **Access to green areas**

In Ploiesti, 100 out of 100 homes don´t have access to green spaces.

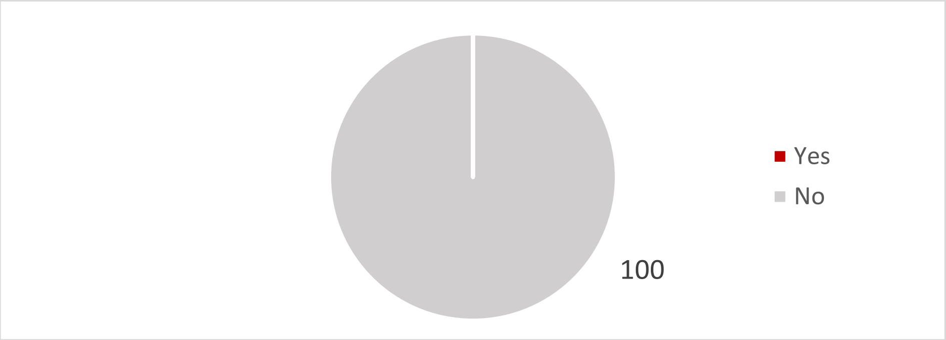

Figure 60. Number of dwellings in Ploiesti with and without access to green areas.

3.2. Comfort at home

The assessment of residential comfort in Ploiesti evaluates three essential pillars: thermal, acoustic, and lighting comfort. These indicators are fundamental to understanding the residents' quality of life and their energy vulnerability, as the indoor environment directly impacts both physical health and emotional well-being. Based on the 100 dwellings surveyed, the data reveals distinct perceptions of comfort that vary according to the age of the building.

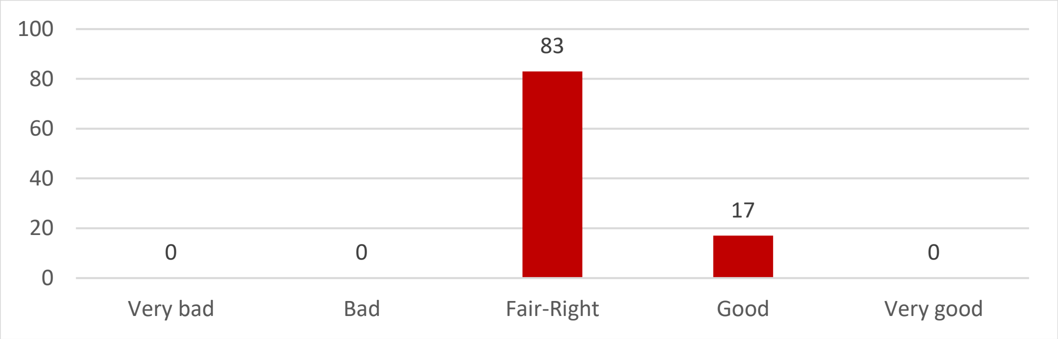

Figure 61. Thermal comfort in Ploiesti households.

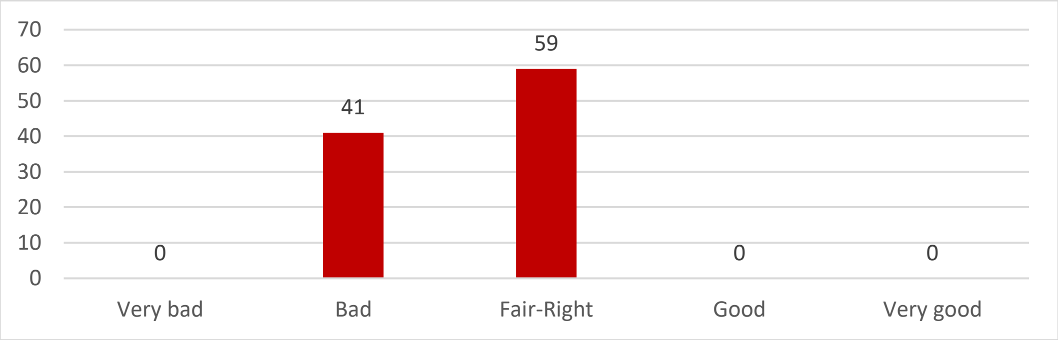

Figure 62. Acoustic comfort in Ploiesti households.

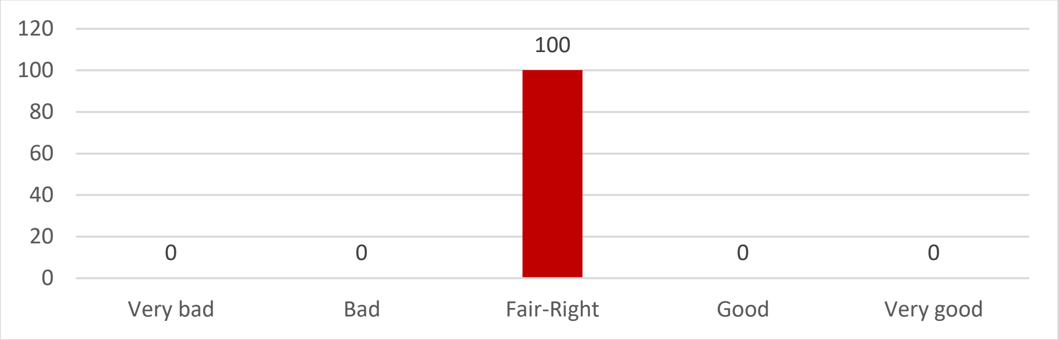

Figure 63. Lightning comfort in Ploiesti households.

Regarding thermal comfort in Ploiesti, there is a noticeable difference between the two construction periods. Residents living in buildings constructed in 1975–1978 report a consistent thermal comfort rating of 5 out of 10, which is classified as "Fair-Right." On the other hand, those living in apartments from 1984 generally rate their thermal comfort higher, with ratings ranging from 5 to 7 out of 10, indicating a moderate level of comfort. Despite the 1984 buildings being newer, the thermal environment in these homes is still not particularly satisfactory compared to what would be expected with more modern energy standards. All of these buildings, however, fall under the C107-1970 and C107-1977 technical frameworks, meaning that even the higher ratings in the newer buildings could still face challenges in maintaining comfort during extreme seasonal changes due to poor insulation.

In contrast, both acoustic and lighting comfort scores remain consistent across the entire sample. Whether the buildings were constructed in 1975, 1978, or 1984, all residents rated their acoustic and lighting comfort as 5 out of 10, reflecting the "Fair-Right" category. This suggests that the homes provide only basic levels of sound insulation and lighting quality, which is common in buildings from this era.

This analysis also sought to examine the impact of the current regulations on the perception of comfort in the homes studied.

Table 7. Thermal comfort distribution in dwellings built after the C107-1970 and C107-1977 regulations.

Thermal comfort	Number of dwellings	After C107-1970		After C107-1977	
Very bad	0	0	0%	0	0%
Bad	0	0	0%	0	0%
Fair-Right	83	37	86%	46	81%
Good	17	6	14%	11	19%
Very good	0	0	0%	0	0%

Table 8. Acoustic comfort distribution in dwellings built after the C107-1970 and C107-1977 regulations.

Acoustic comfort	Number of dwellings	After C107-1970		After C107-1977	
Very bad	0	0	0%	0	0%
Bad	41	17	40%	24	42%
Fair-Right	59	26	60%	33	58%
Good	0	0	0%	0	0%
Very good	0	0	0%	0	0%

Table 9. Lightning comfort distribution in dwellings built after the C107-1970 and C107-1977 regulations.

Lightning comfort	Number of dwellings	After C107-1970		After C107-1977	
Very bad	0	0	0%	0	0%
Bad	0	0	0%	0	0%
Fair-Right	100	43	100%	57	100%
Good	0	0	0%	0	0%
Very good	0	0	0%	0	0%

The results indicate that thermal comfort is perceived more favorably in properties built under the C107-1977 regulation, with a higher percentage of dwellings rated as "Good" compared to those built under the C107-1970 regulation. However, there is still substantial room for improvement across both groups. In terms of acoustic comfort, the ratings are notably lower, especially in buildings constructed after C107-1970, where 40% of dwellings are rated as "Bad". Similarly, lighting comfort is perceived consistently as "Fair-Right" across all dwellings, regardless of the construction period, with 100% of properties in both groups rated as "Fair-Right".

These mediocre ratings for acoustic and lighting conditions highlight a clear opportunity for technical interventions. Implementing upgrades to improve both the thermal, acoustic, and lighting comfort would not only enhance energy efficiency but also significantly improve the overall living standards for these vulnerable inhabitants.

3.3. Heating

All 100 surveyed dwellings in Ploiesti are equipped with a heating system, ensuring that every household analysed has access to thermal energy during the cold Latvian winters.

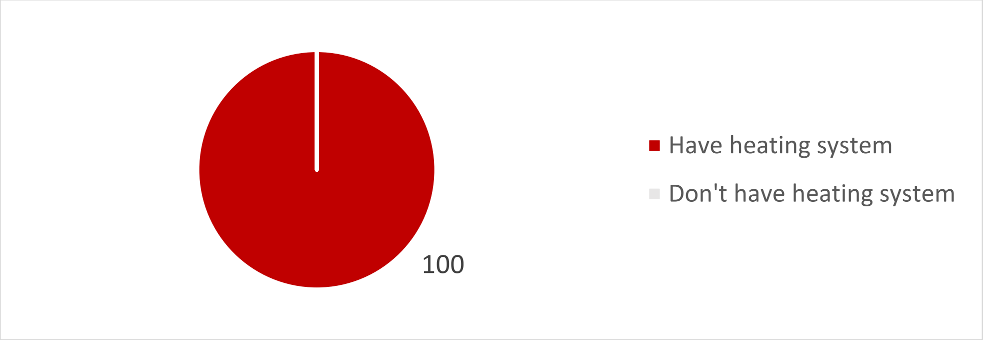

Figure 64. Number of dwellings with or without heating systems in Ploiesti.

- **Types of heating system**.

  The primary technical solution for all surveyed properties, regardless of their age, is District Heating, which provides a more consistent and automated form of warmth for the inhabitants. Heating system maintenance data is not shown, as it is a district heating system.

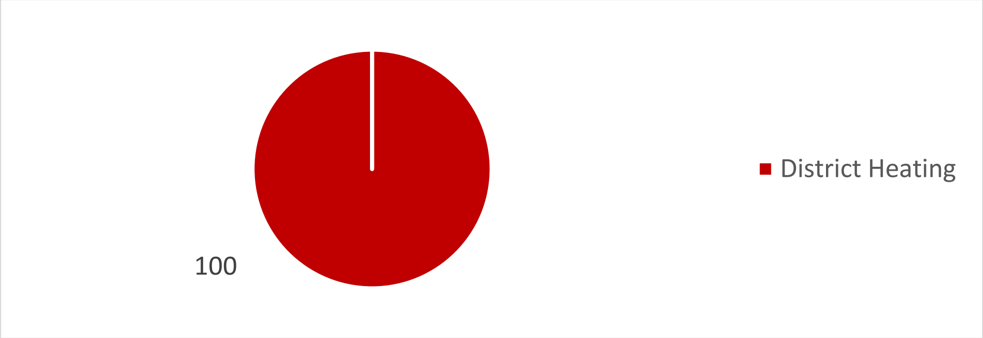

Figure 65. Type of heating system in the dwellings in Ploiesti.

Regarding the control system, almost all homes have no control system in place for regulating the heating. This suggests that the homes rely on manual control, which can lead to inefficiencies in energy use. Without a modern control system, it is likely that these homes may face higher energy consumption and less comfort because heating cannot be adjusted automatically based on temperature changes or time of day.

- **Energy sources**

  In terms of energy sources, the 100 dwellings of the study use natural gas as energy source for heating.

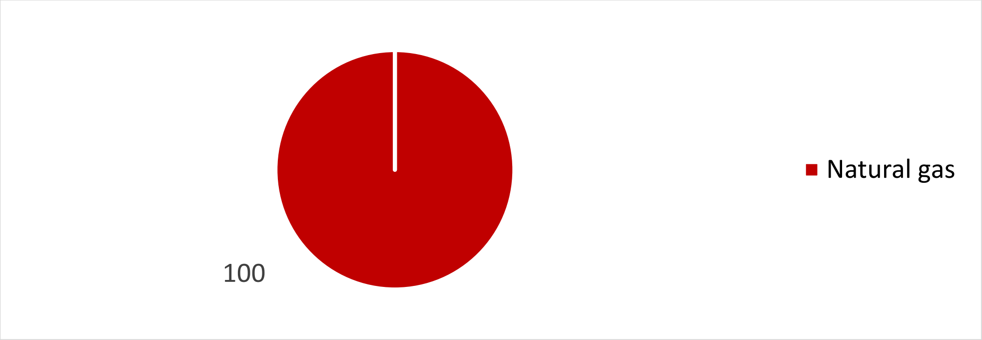

Figure 66. Type of energy source in heating systems in Ploiesti.

- **Heating energy consumption**

  The thermal energy consumption across the surveyed 100 dwellings in Ploiești is closely related to both the physical dimensions of the apartments and their construction periods.

  For the apartments built in 1975, the annual thermal energy consumption ranges between 4.000 kWh and 11.820 kWh. This variation is mainly due to the differing sizes of the apartments, which range from 50 m² to 75 m². The higher consumption in these properties can be attributed to their larger size compared to the older buildings, as well as the construction standards in place at the time, which did not prioritize energy efficiency.

  In contrast, for the dwellings built in 1984, the thermal energy consumption is generally more standardized, with most units reporting an annual thermal demand between 2.843 kWh and 11.548 kWh. These apartments are similarly sized, ranging between 51 m² and 77 m². While the thermal demand is higher than in 1975 properties, this is partly due to the increased size of the apartments and the still limited thermal insulation of the buildings under the C107-1977 regulation.

  Thus, despite the construction year differences, overall thermal energy consumption remains significant in both cases, highlighting the ongoing need for improvements in insulation and heating efficiency across these building types.

- **Heating energy price**

  The analysis of heating energy prices in Ploiești reveals a clear correlation between the age of the building, the floor area, and the resulting financial burden on the residents. For the dwellings constructed in 1984, the annual cost for natural gas consumption varies significantly depending on the apartment's size. The typical energy cost for these apartments ranges from 158,07€ for the smallest units (approx. 51 m²) to 642,07€ for the largest apartments (approx.

77 m²). This range reflects the impact of both the floor area and the technical standards of the time, with larger apartments requiring more energy for heating.

In contrast, the properties built in 1975 and 1978 show a wider distribution in terms of energy costs. The annual thermal costs for these buildings range from 269,49€ for smaller units (approx. 25 m²) to 657,19€ for larger apartments (approx. 75 m²). These variations reflect differences in the size and energy demand based on the building's age and insulation standards.

Thus, the analysis highlights those newer constructions, while larger in size, generally have higher energy costs due to their increased heating requirements, while older buildings with smaller units have more varied, but generally lower, energy costs.

- **Heating energy price per household**

Using the technical data collected from the Ploiesti sample, the project dwellings have an energy consumption for heating of 8769,59 kWh/year and a cost of 487,59€ on average. By dividing the consumption by the cost, a conversion ratio of approximately 0,0555€ per kWh. Applying this conversion rate to the average heating cost for Romanian dwellings (500 €), we obtain the average national energy consumption for heating: 8.992,80 kWh/year.

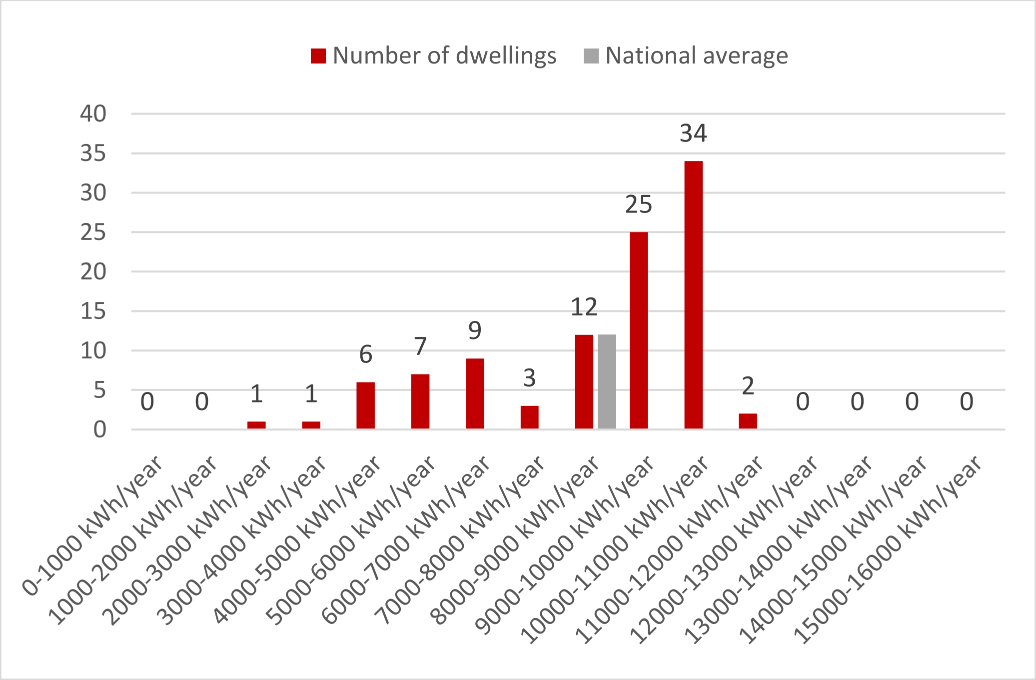

Figure 67. Heating consumption per dwelling in Ploesti.

In conclusion, the analysis of the 100 surveyed dwellings in Ploiesti reveals that every property, regardless of whether it was constructed in, exhibits an annual heating consumption consistently higher than Romanian national average of 8.992,80 kWh.

3.4. Cooling

The analysis of the 100 surveyed dwellings in Ploiesti reveals a complete absence of active cooling systems across the entire sample. None of the properties, whether constructed in 1975 or 1984, are equipped with air conditioning or any other form of mechanical cooling installation. Consequently, residents are entirely reliant on passive cooling strategies, such as manual ventilation through opening windows or the use of portable fans, to manage indoor temperatures during the warmer summer months.

While the local climate in Romania is characterized by cold winters and significant heating demands, the limited cooling infrastructure presents a notable gap in energy services. This situation is particularly relevant for vulnerable groups in Ploiești, where the absence of proper cooling systems during hot periods may cause discomfort or stress, especially in households that may struggle with the added energy costs.

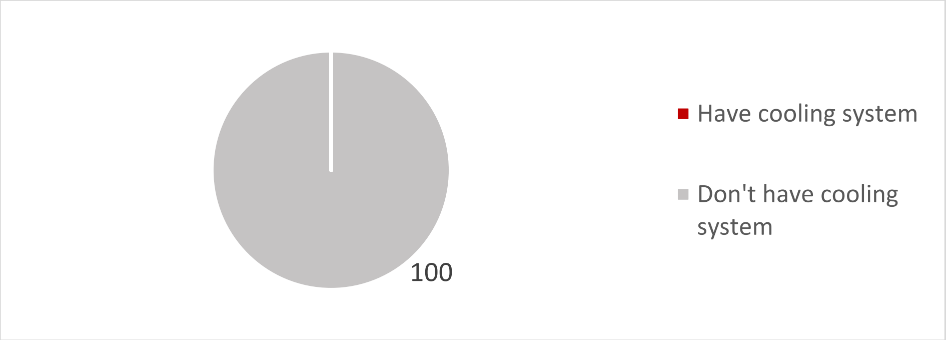

Figure 68. Number of dwellings with or without cooling systems in Ploiesti.

3.5. Domestic hot water

According to the data collected, of the 100 homes analysed in Ploiesti, all of them have domestic hot water systems (100%).

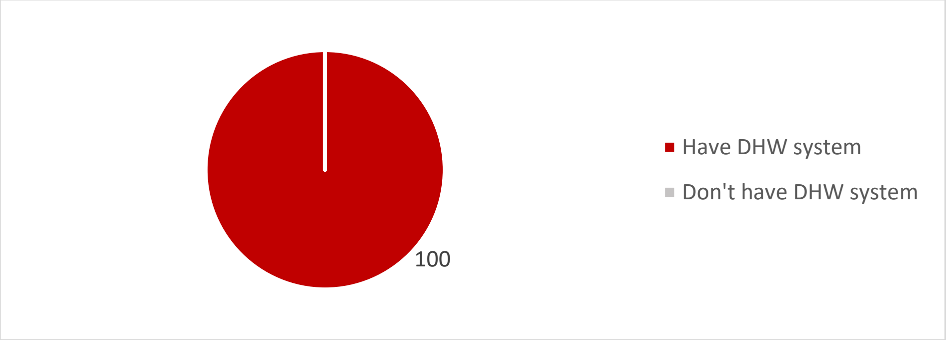

Figure 69. Number of dwellings with or without DHW systems in Ploiesti.

- **Types of DHW systems**

  All the apartments in the Ploiești sample are equipped with hot water systems that are integrated with a centralized heating network. These systems operate on natural gas and lack individual control mechanisms, meaning residents do not have the ability to regulate the temperature or hot water usage according to their personal preferences or needs. These DHW systems were installed in 2010, but no detailed records or data are available, regarding their maintenance history or any potential updates made since their installation. This lack of control and maintenance oversight may affect the overall efficiency and performance of the systems, potentially leading to higher energy consumption and costs for the residents.

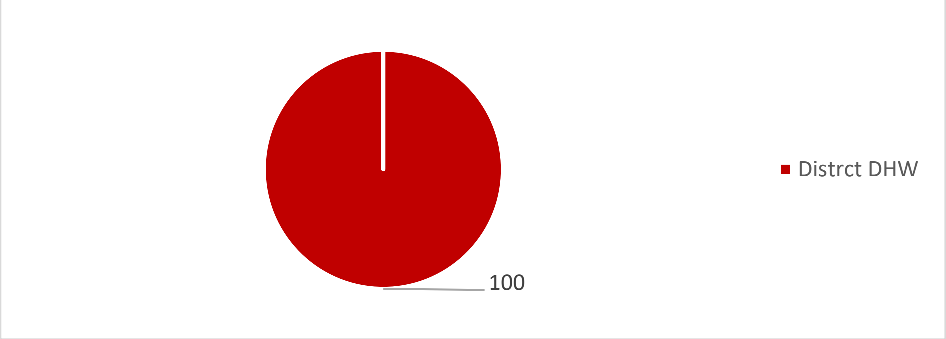

Figure 70. Type of DHW system in the dwellings in Ploiesti.

- **Energy consumption.**

  We cannot analyse the specific energy consumption for DHW, as this consumption is included within the total electricity or heating consumption.

3.6. Lightning

Of the 100 apartments analysed in Ploiești, all use LED lighting. This transition to LED technology is a positive development in terms of energy efficiency, as LED bulbs consume significantly less energy than traditional lighting systems, such as incandescent bulbs or fluorescent tubes, while also offering a longer lifespan.

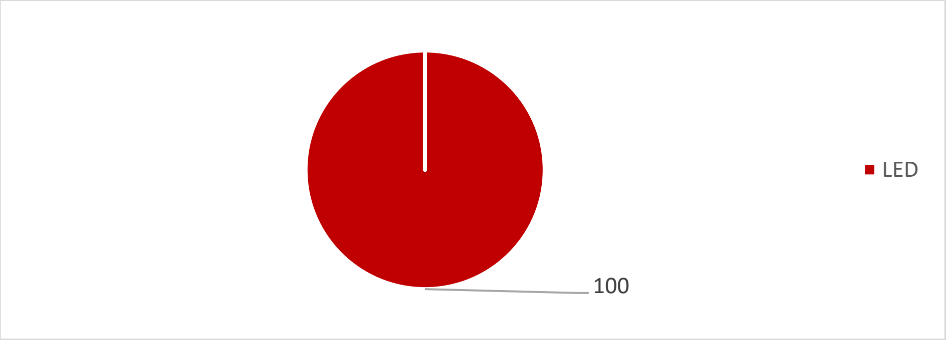

Figure 71. Type of lightning system in the dwellings in Ploiesti.

It should be noted here that despite having LED lighting, apartment occupants rate lighting comfort at 5 out of 10, or "acceptable." This indicates that while LED lighting systems meet the minimum functional requirements for housing, they do not provide the high-quality lighting necessary to improve the physical and emotional well-being of residents. Even so, from an economic perspective, this type of lighting is more suitable because it offers energy and cost savings compared to traditional lighting systems.

3.7. Electricity

- **Energy consumption.**

  For the apartments constructed in the 1970´s , the annual consumption varies between 847 – 3.132kWh per year. And for the dwellings built in 1984, consumption varies between 843 kWh and 2.548 kWh per year. This wide range of consumptions is related with the variation of the living area of each apartment (20,2 m^2 to 77,18 m^2).

  However, this relatively low consumption should not be seen as a sign of high energy efficiency. Instead, it likely reflects the smaller living spaces and the energy-conserving behaviours of the residents, many of whom may face financial limitations. Given that natural gas is used for hot water heating, the relatively low electricity consumption suggests that residents are likely limiting their use of electrical appliances, possibly due to budget constraints. This behaviour is particularly likely among families or those living alone, who may be focusing on minimizing energy costs wherever possible.

- **Energy price**

  The data gathered from the 100 surveys shows that residents in 1984 buildings pay an average annual electricity bill of €234,69 to €642,07, depending on the size of the apartment, with larger units (around 77 m²) having higher electricity costs. In comparison, residents of 1975 buildings have a more varied annual electricity cost, ranging from 115,34 € to 504,14 €, also reflecting the differences in apartment sizes. For apartments built in 1978, the electricity costs range from 193,96 € to 486,28 €, with similar trends of higher costs for larger units.

- **Energy consumption per household**

  Based on the technical data collected from the Ploiesti surveys, a unit price of 0,16 €/kWh can be deduced by dividing the recorded annual electricity costs by the corresponding consumption data. By applying this unit price to the estimated national average household electricity expenditure of 800 €we can calculate that the average electricity consumption per household in Romania is 4.995,88 kWh. Taking this data as reference, we can state that 2 of the 100 homes have an annual electricity consumption higher than the national average.

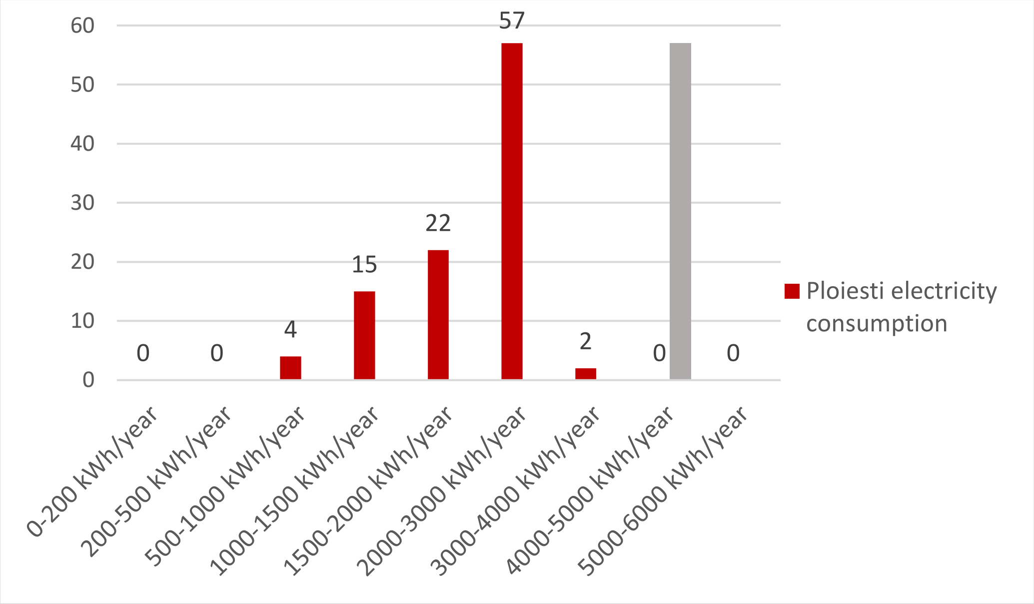

Figure 72. Electricity consumption per dwelling in Ploiesti.

3.8. Data analysis

- **Energy consumption vs. housing area**

Figure 73 represents the energy consumption (heating + electricity) of the homes in Ploiesti against the housing area.

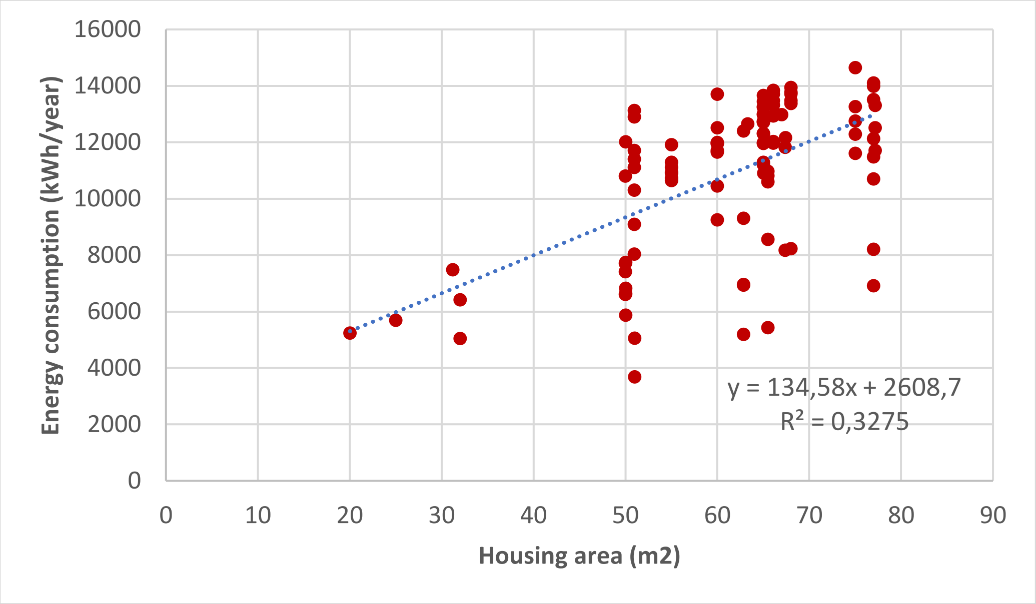

Figure 73. Energy consumption per housing area.

This analysis demonstrates correlation of R² = 0,3275 between housing area and annual energy consumption. According to the regression equation (y = 134,58x + 2.608,7), every additional square meter of housing area increases energy consumption by approximately 134,58 kWh/year. While the correlation is positive, the R² value indicates a moderate relationship, suggesting that while housing size is an important factor influencing energy demand, other variables (such as the building's energy efficiency, number of occupants, and individual household behaviours) also play significant roles in determining overall energy consumption.

- **Energy consumption vs. number of occupants**

Figure 74 shows the relationship between number of occupants per dwelling and energy consumption (in kWh/year).

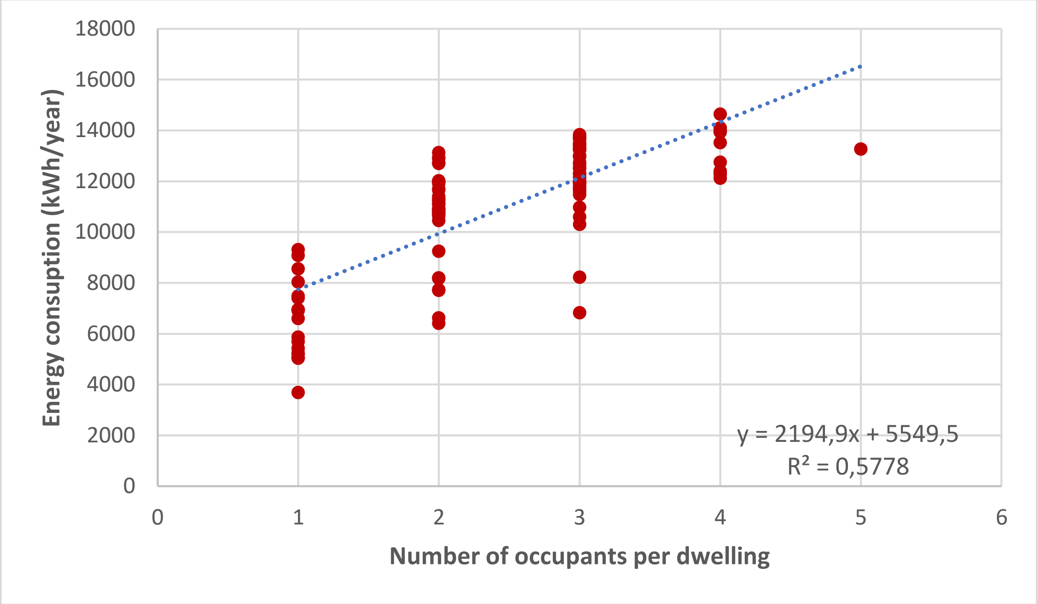

Figure 74. Energy consumption per number of occupants in Ploiesti.

An analysis of energy consumption based on the number of occupants in Ploiești reveals a moderate positive relationship, as indicated by a coefficient of determination ($R^2 = 0,5778$). This suggests that the number of occupants has a notable influence on energy consumption, with an increase in the number of residents generally leading to higher energy usage. The regression equation ($y = 2.194,9x + 5.549,5$) shows that each additional occupant increases annual energy consumption by approximately 2.194,9 kWh.

However, while the number of occupants is an important factor, other variables such as the size of the dwelling and its thermal performance continue to play a significant role in energy demand. The data suggest that while more occupants tend to lead to higher consumption, structural factors like insulation quality and the dimensions of the apartments are still dominant drivers of energy use.

- **Energy consumption vs. year of construction**

Figure 75 shows energy consumption (kWh/year) in relation to the year of construction for the homes in Ploiesti. The analysis reveals a non-significant correlation ($R^2 = 0,1119$) between the two variables.

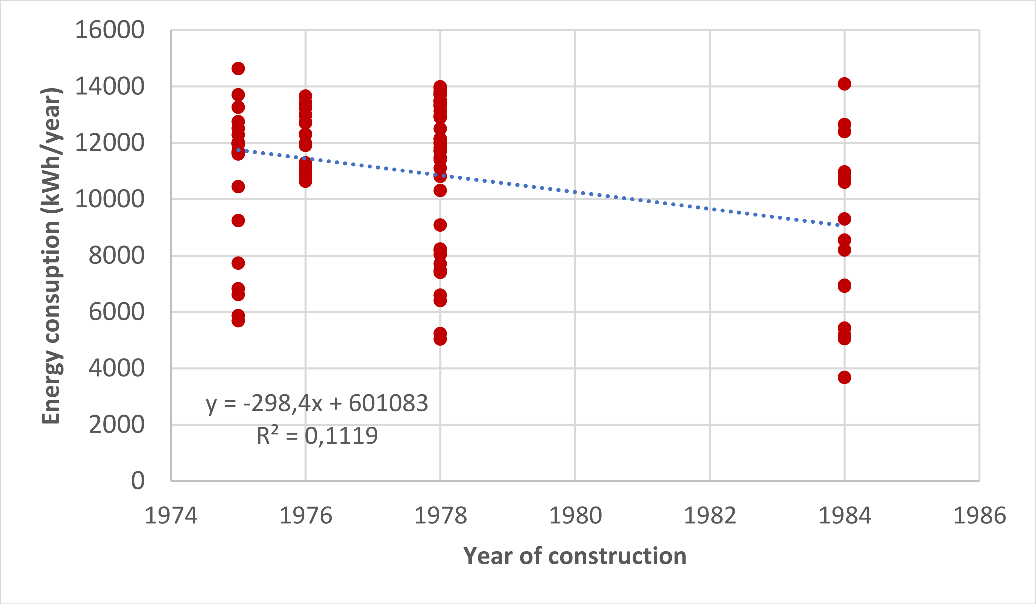

Figure 75. Energy consumption in Ploiesti dwellings per year of construction.

According to the regression equation y = -298,4x + 601.083, buildings constructed later in the 1970s and 1980s tend to show a slightly lower total energy consumption compared to those built in the mid-1970s. However, this trend is not due to improvements in construction or energy efficiency; it is instead driven by the increasing size of the dwellings over time. While buildings constructed in the mid-1970s were relatively small (around 50–60 m²), the 1980 buildings are generally larger and more standardized in size.

Although the 1980 properties followed the slightly more sophisticated C107-1977 regulations, which included some improvements in thermal design, their insulation requirements were still significantly lower than current European standards. As a result, the advantages of "newer" construction are mostly offset by the increased internal volume and the continued presence of thermal bridges in the pre-cast concrete panels. This leads to higher energy consumption in the 1980 properties, demonstrating that the increased size of the apartments exacerbates the energy burden for residents, despite the improvements in construction standards.

- **Energy consumption vs. thermal comfort**

In Figure 76, the relationship between energy consumption (kWh/year) and thermal comfort assessment for the homes in Ploiesti s is illustrated, to verify whether higher energy expenditure translates into better living conditions.

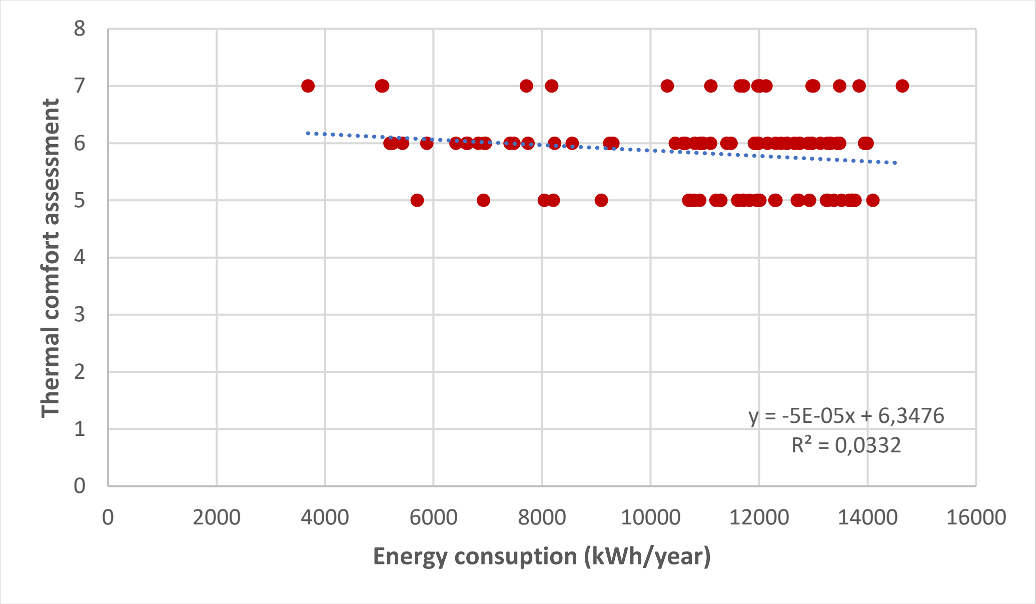

Figure 76. Thermal comfort assessment per energy consumption.

The analysis of energy consumption and thermal comfort in Ploiești reveals a very weak correlation ($R^2 = 0,0332$), suggesting that higher energy expenditure does not significantly improve thermal comfort. Regardless of energy consumption levels, thermal comfort ratings remain around a "Fair-Right" level (5 out of 7), indicating that the heating systems in the buildings are ineffective. This reflects structural inefficiencies, such as poor insulation, in both older and newer buildings. High energy consumption is thus a symptom of heat loss rather than an indicator of comfort, highlighting the need for energy efficiency improvements to enhance both comfort and reduce energy costs.

- **Housing area vs. thermal comfort**

Figure 77 analyses the relationship between housing area (m²) and thermal comfort level for homes in Ploiesti, to check if the size of the home influences the living conditions and thermal wellbeing of its residents.

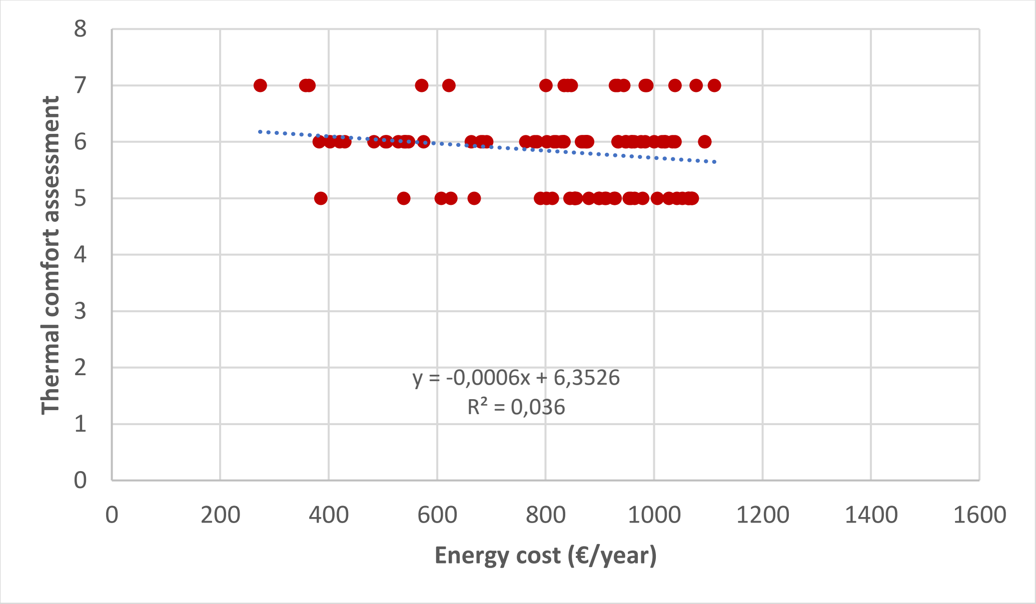

Figure 77. Thermal comfort assessment per energy consumption.

An analysis of the relationship between annual energy costs and thermal comfort in Ploiești reveals a very weak correlation ($R^2 = 0,036$). The graph shows that as residents spend more on energy, their perceived level of thermal comfort remains largely unchanged. This suggests that higher energy costs are not a reflection of better living conditions, but rather a result of heat loss due to poor insulation in the buildings. Despite higher expenditure, the thermal comfort assessment remains around the "Fair-Right" level, indicating that the energy costs are primarily linked to inefficiencies in the building's thermal performance, not an improvement in comfort.

3.9. Score of the energy assessment

According to the guide, three vulnerability levels have been defined for the homes analysed in these energy studies: Low, Medium, and High. The threshold values for each level are selected so that the upper limit of the score for each category indicates the urgent need for energy rehabilitation interventions in those homes.

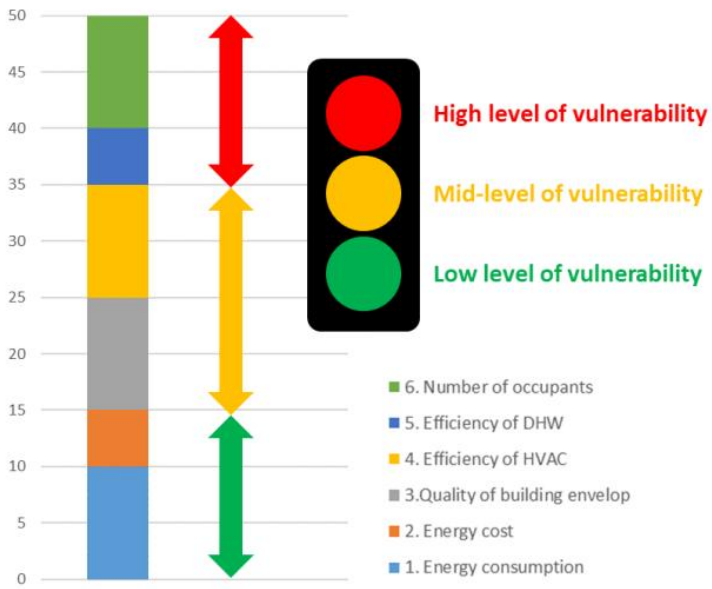

Figure 78. Example of thresholds determined to differentiate the three levels of housing energy vulnerability.

For the 100 homes studied in Ploiesti, the results obtained are as follows:

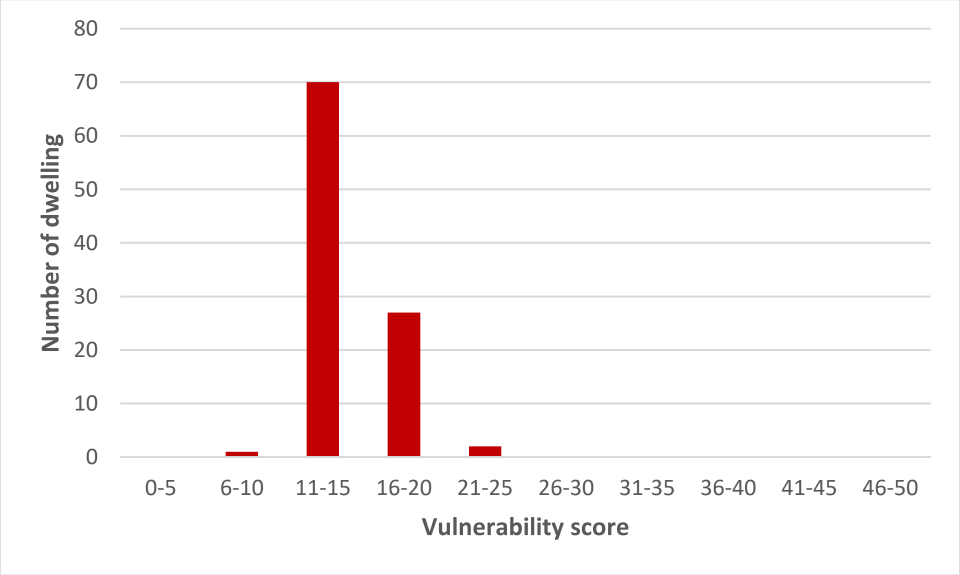

Figure 79. Number of dwellings per vulnerability level.

From this data, the following conclusions can be drawn for Ploiesti:

- A total of 70 homes fall within the medium vulnerability level, with vulnerability scores ranging between 11 and 15 points. This accounts for 70% of the total homes analysed.

- No homes fall into the high vulnerability level, indicating that no homes have been classified as critically vulnerable based on the provided scores.
- 30 homes fall under the low vulnerability level, with scores between 6 and 10 points. These homes exhibit minimal vulnerability and require less immediate attention compared to those in the medium category.

The energy assessment in Ploiești identifies a significant percentage of surveyed homes (70%) as being at a medium vulnerability level. Although no properties have reached the "high vulnerability" threshold, the fact that a large majority of the households require prioritised energy rehabilitation highlights the ongoing impact of outdated construction standards on resident well-being. While 30 homes currently exhibit low vulnerability, technical interventions should focus on the 70 medium-vulnerability units to prevent further deterioration of living standards and reduce the financial strain caused by structural energy inefficiencies.

4. SALDUS

Saldus is a municipality located in Latvia. Its climate is characterized by significant seasonal temperature variations, with cold winters that necessitate a high demand for thermal energy to maintain indoor comfort. Like other regions in the Baltic states, many residential buildings in Saldus do not meet contemporary European energy efficiency standards, as a large portion of the housing stock was built several decades ago.

A total of 116 vulnerable homes has been analysed in Saldus to assess the energy situation of these households. The primary objective of this study is to identify technical deficiencies in energy efficiency and to understand the impact of building age and outdated construction regulations on the residents' quality of life.

4.1. Building characteristics and their surroundings

This section details the physical and structural attributes of the surveyed homes, including typology, age, and environmental context.

- **Types of dwellings**

  The 116 homes analysed in Saldus are all apartments, accounting for 100% of the dwellings surveyed.

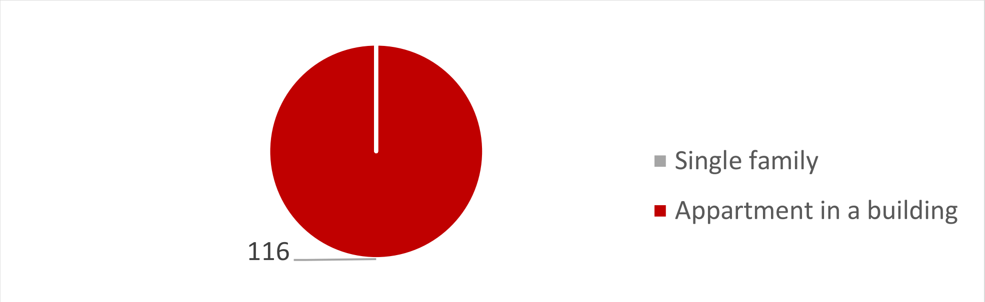

Figure 80. Type of dwellings in Saldus.

  In a climate like Latvia's, the apartment configuration is beneficial as units share internal walls, floors, and ceilings, which reduces the total surface area exposed to the cold external environment. However, because these are older structures, the benefit of shared surfaces is often offset by the lack of modern thermal insulation in the building envelope.

- **Year of construction**

  According to the data collected for the 116 dwellings in Saldus, both the buildings from 1960 and 1980 were built following the Soviet Standard SNiP (Stroitel'nye Normy i Pravila).

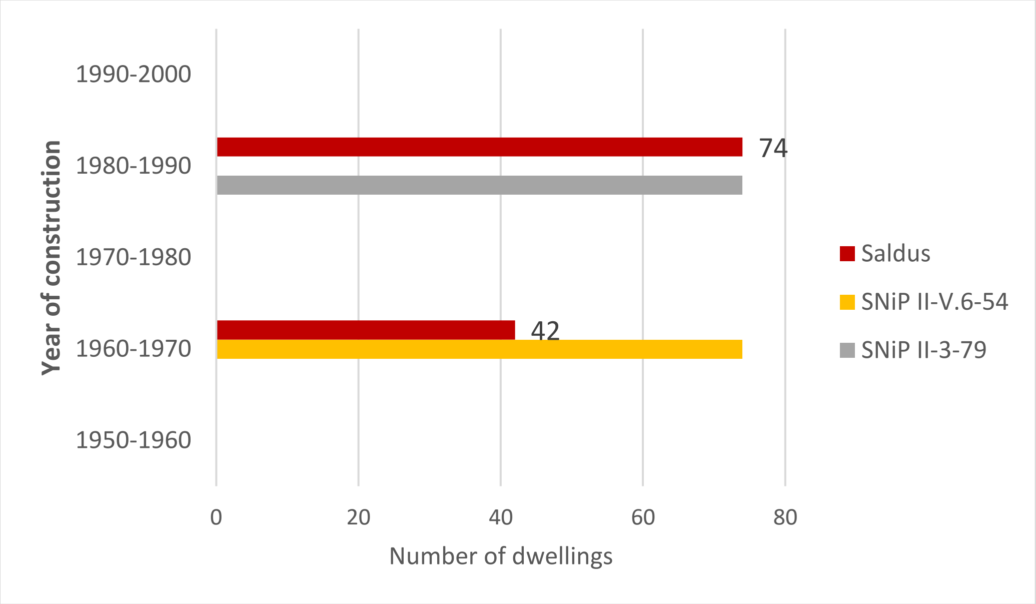

Figure 81. Number of dwellings by year of construction in Saldus.

The analysis done in Figure 81 shows the following:

- For buildings constructed in 1960: The regulation in force during this period was primarily SNiP II-V.6-54 (and its early 60s revisions). These codes were designed for the rapid and mass construction of prefabricated apartment blocks. The primary focus was on structural speed rather than thermal efficiency, meaning these buildings typically have poor insulation and very high thermal conductivity in their external walls.
- For buildings constructed in 1980: By 1980, the technical standard had evolved into SNiP II-3-79 ("Building Heat Engineering"). While this was a more sophisticated regulation that attempted to improve thermal performance after the 1970s energy crises, the insulation requirements remained 3 to 4 times lower than current European standards. These buildings often suffer from thermal bridges at the joints of the pre-cast concrete panels.

The fact that 100% of the surveyed homes in Saldus adhere to these outdated Soviet Standards confirms that the entire analysed housing stock lacks modern energy efficiency features. This results in a high demand for heating to maintain comfort, particularly in the oldest dwellings, which are older and more vulnerable.

- **Housing size**

  The data on the floor area of the analysed buildings in Saldus shows that the dwellings are remarkably compact and significantly smaller than the current national standards. The living areas recorded across the sample are as follows:

  - For dwellings constructed in 1960, the apartments are extremely small, with floor areas ranging from 11,5 m² to 28,6 m².
  - For dwellings constructed in 1980, there is a high degree of standardization, with almost all units reporting a living area of 35,4 m².

  This local data stands in sharp contrast to the national context of the country. According to official data from the Central Statistical Bureau of Latvia (CSB), the average floor area of a dwelling in Latvia is approximately 66,6 m². This indicates that the households analysed in this study live in spaces that are, on average, nearly 50% smaller than the national average size.

  The smaller housing size of these homes is a critical factor when considering their energy needs. While smaller homes typically require less total energy to maintain a comfortable temperature due to their reduced internal volume, the fact that 100% of these buildings (either from 1960 or 1980) follow the outdated Soviet Standard means that structural inefficiencies likely lead to high energy consumption relative to their size. Therefore, renovations must account for the high thermal conductivity typical of these construction periods while acknowledging the benefits and challenges of such compact living spaces

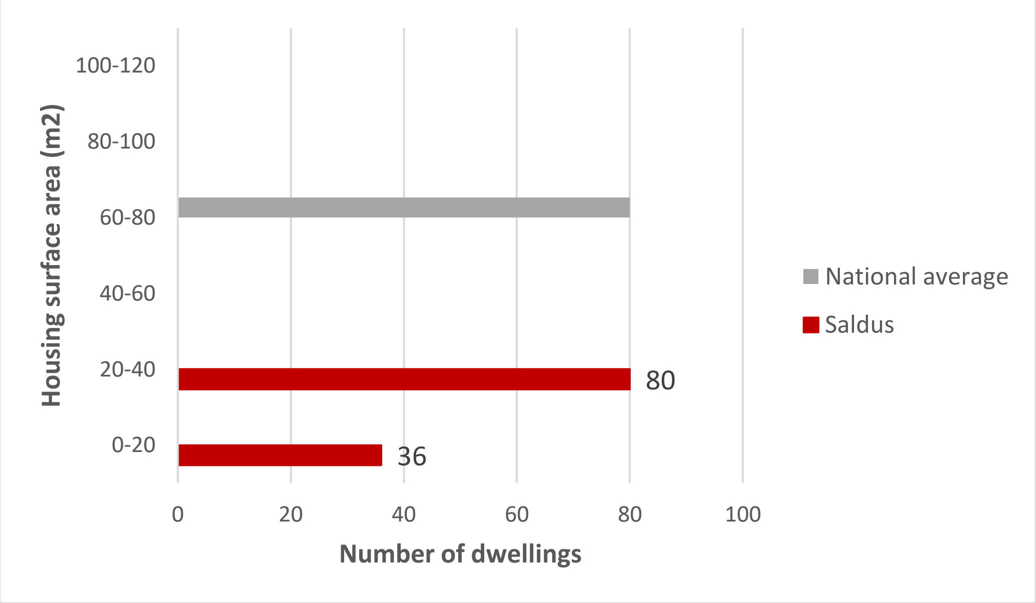

Figure 82. Number of dwellings by housing surface area in Saldus.

- **Number of occupants per home**

The occupancy levels across the 116 surveyed dwellings in Saldus provide significant insight into local social vulnerability, especially when viewed alongside the compact living areas previously examined. In buildings dating from 1960, households consist almost exclusively of one or two residents, with the vast majority being single-person homes. Dwellings constructed in 1980 show a slightly broader distribution but remain dominated by low occupancy rates, with only a marginal number of units housing three or more people.

When compared to the broader national context of Latvia, where the average household size is approximately 2,5 persons according to official Eurostat figures, the analysed sample in Saldus reveals a notably lower average. This high concentration of single-person households indicates that many residents are bearing the full weight of energy costs alone, which often heightens the risk of financial strain compared to larger multi-earner households.

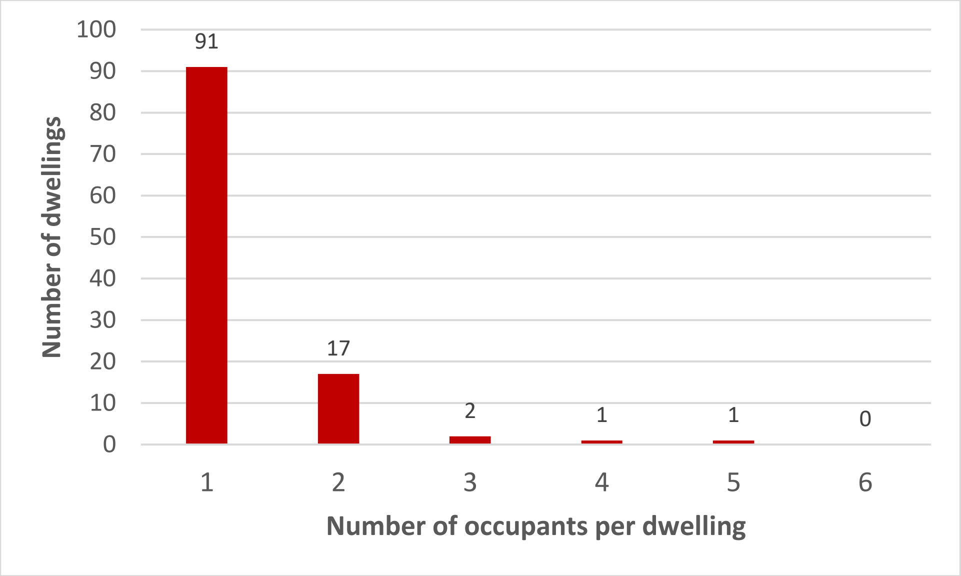

Figure 83. Occupants per dwelling in Saldus.

The demographic analysis further highlights a substantial presence of vulnerable groups within these homes. Elderly residents are common across both construction periods, often living alone in properties that comply with outdated Soviet Standards. Additionally, the study recorded individuals suffering from chronic illnesses or health issues in several units. While children are present in a few households from the 1980 dwellings, they are almost entirely absent from the older 1960 properties.

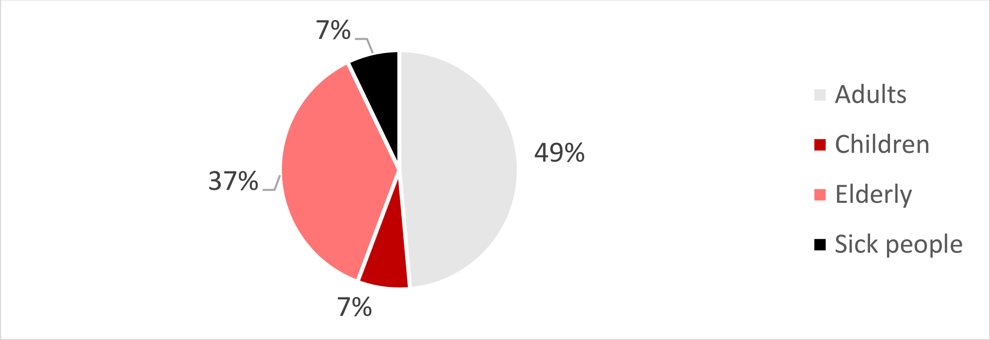

Figure 84. Vulnerable groups in households in Saldus.

As seen in comparable energy studies, these specific groups—particularly the elderly and the infirm—are at a higher risk of health complications due to poor thermal regulation in the building envelope. They are also more likely to experience energy poverty as they often struggle to afford adequate heating on fixed or low incomes while living in structures that lack modern insulation.

- **Access to green areas**

In Saldus, 116 out of 116 homes have access to green spaces.

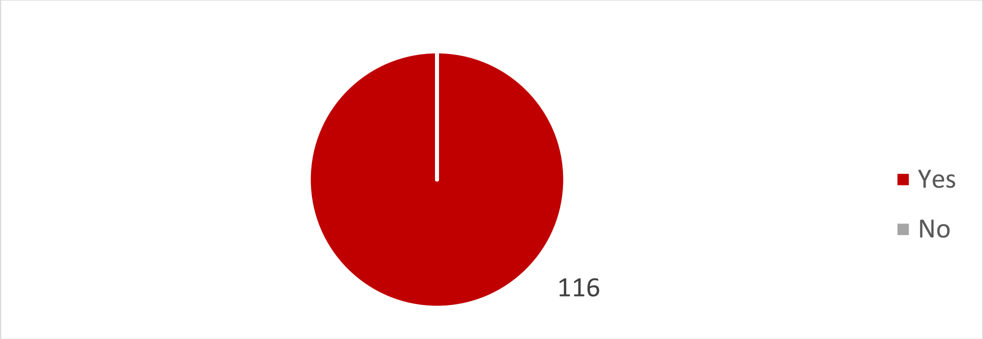

Figure 85. Number of dwellings in Saldus with and without access to green areas.

4.2. Comfort at home

The assessment of residential comfort in Saldus evaluates three essential pillars: thermal, acoustic, and lighting comfort. These indicators are fundamental to understanding the residents' quality of life and their energy vulnerability, as the indoor environment directly impacts both physical health and emotional well-being. Based on the 116 surveyed dwellings, the data reveals distinct perceptions of comfort that vary significantly according to the age of the building.

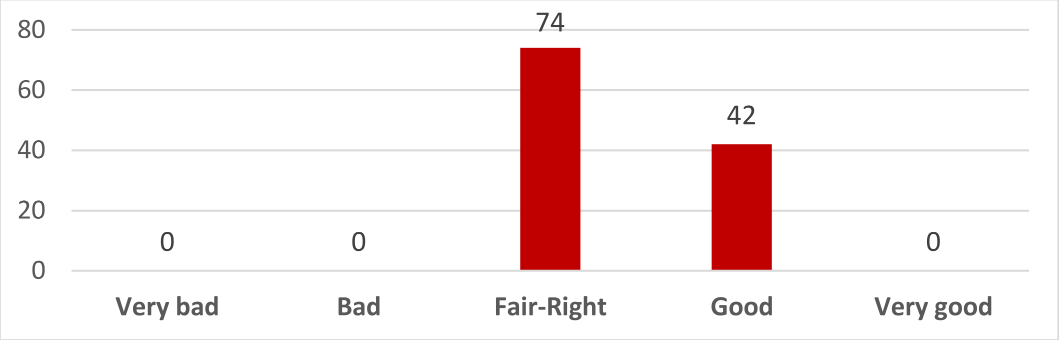

Figure 86. Thermal comfort in Saldus households.

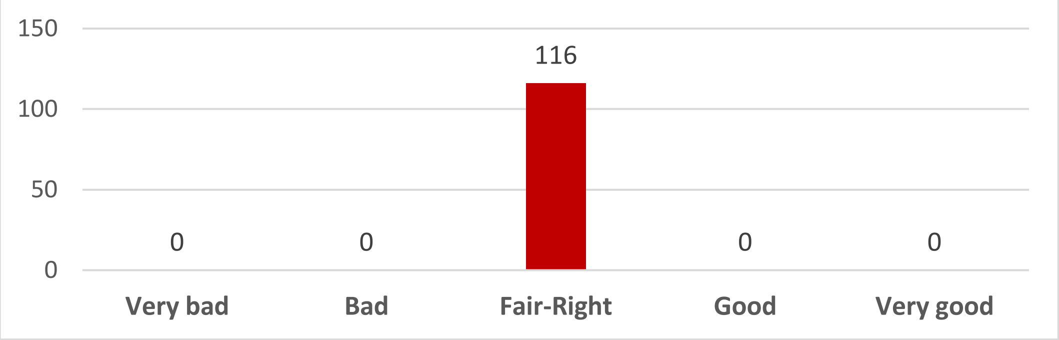

Figure 87. Acoustic comfort in Saldus households.

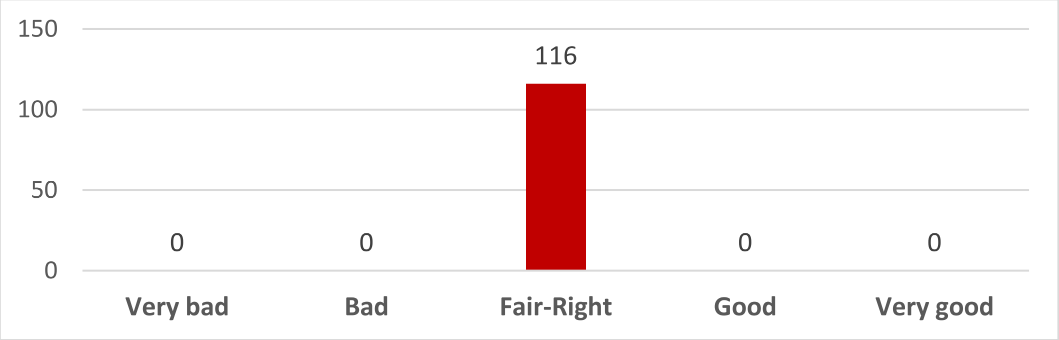

Figure 88. Lightning comfort in Saldus households.

Regarding thermal comfort, there is a notable disparity between the two construction periods. Residents living in properties built in 1960 report a consistent comfort level of 8 out of 10, which is classified as "Good". Conversely, those residing in buildings from 1980 provide a lower rating of 5 out of 10, placing their thermal experience in the "Fair-Right" category. This indicates that, despite the 1980 buildings being newer, the perceived thermal environment is considerably less satisfactory than in the older stock. Both groups, however, remain under the Soviet Standard technical framework, suggesting that even the "Good" ratings in older buildings may still face challenges during extreme seasonal fluctuations.

In contrast to the thermal data, acoustic and lighting comfort scores show absolute uniformity across the entire sample. Every surveyed household, regardless of whether the building was constructed in 1960 or 1980, rated both their acoustic and lighting comfort at 5 out of 10. This consistent "Fair-Right" assessment suggests a widespread perception that these homes offer only the bare minimum acceptable levels of sound insulation and light quality.

This analysis also sought to examine the impact of the current regulations on the perception of comfort in the homes studied.

Table 10. Thermal comfort distribution in dwellings built after the SNiP II-V.6-54 and SNiP II-3-79 regulations.

Thermal comfort	**Number of dwellings**	**After SNiP II-V.6-54**		**After SNiP II-3-79**	
Very bad	0	0	0%	0	0%
Bad	0	0	0%	0	0%
Fair-Right	74	0	0%	74	100%
Good	42	42	100%	0	0%
Very good	0	0	0%	0	0%

Table 11. Acoustic comfort distribution in dwellings built after the SNiP II-V.6-54 and SNiP II-3-79 regulations.

Acoustic comfort	**Number of dwellings**	**After SNiP II-V.6-54**		**After SNiP II-3-79**	
Very bad	0	0	0%	0	0%
Bad	0	0	0%	0	0%
Fair-Right	116	42	100%	74	100%
Good	0	0	0%	0	0%
Very good	0	0	0%	0	0%

Table 12. Lightning comfort distribution in dwellings built after the SNiP II-V.6-54 and SNiP II-3-79 regulations.

Lightning comfort	**Number of dwellings**	**After SNiP II-V.6-54**		**After SNiP II-3-79**	
Very bad	0	0	0%	0	0%
Bad	0	0	0%	0	0%
Fair-Right	116	42	100%	74	100%
Good	0	0	0%	0	0%
Very good	0	0	0%	0	0%

The results indicate that while thermal comfort is perceived more favourably in the older properties, there is substantial room for improvement across the board. The mediocre ratings for acoustic and lighting conditions highlight a clear opportunity for technical interventions. Implementing these upgrades would not only improve energy efficiency but also significantly elevate the overall living standards for these vulnerable inhabitants.

4.3. Heating

All 116 surveyed dwellings in Saldus are equipped with a heating system, ensuring that every household analysed has access to thermal energy during the cold Latvian winters.

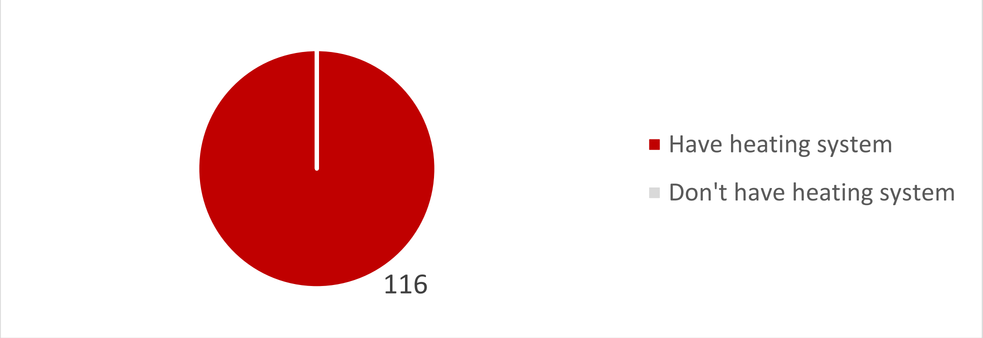

Figure 89. Number of dwellings with or without heating systems in Saldus.

- **Types of heating system**.

  The primary technical solution for all surveyed properties, regardless of their age, is District Heating, which provides a more consistent and automated form of warmth for the inhabitants.

  The maintenance and conservation of these heating systems vary depending on the construction period of the buildings. Residents in properties built in 1960 report a maintenance score of 7 out of 10, indicating a good level of upkeep for their technical installations. In contrast, those living in the buildings constructed in 1980 provide a lower rating of 5 out of 10, suggesting that these systems, despite being newer, are perceived to be in only a fair state of repair. A positive finding across the entire sample is that 100% of the dwellings possess a control system, allowing residents to regulate their heating, which is a significant advancement in energy management compared to systems that rely solely on manual fuel loading.

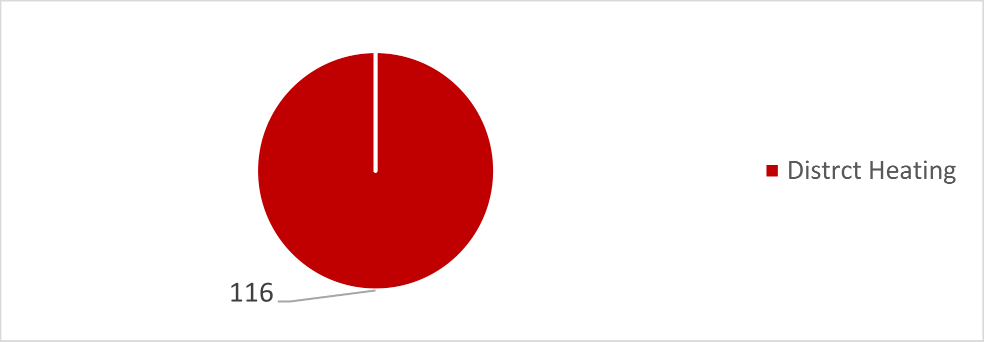

Figure 90. Type of heating system in the dwellings in Saldus.

In terms of maintenance and conservation, the majority of homes have ratings between 5 and 8 on a scale from 1 to 10. This indicates that while the heating systems in these homes are generally maintained at a moderate level, there is still room for improvement, especially in older systems. A significant portion of homes (around 30%) has heating systems that could be considered average or slightly above average in terms of upkeep, while a smaller percentage (less than 10%) has better-maintained systems.

Regarding the control system, almost all homes have no control system in place for regulating the heating. This suggests that the homes rely on manual control, which can lead to inefficiencies in energy use. Without a modern control system, it is likely that these homes may face higher energy consumption and less comfort because heating cannot be adjusted automatically based on temperature changes or time of day.

- **Energy sources**

In terms of energy sources, the 100 dwellings of the study use biomass as energy source for heating.

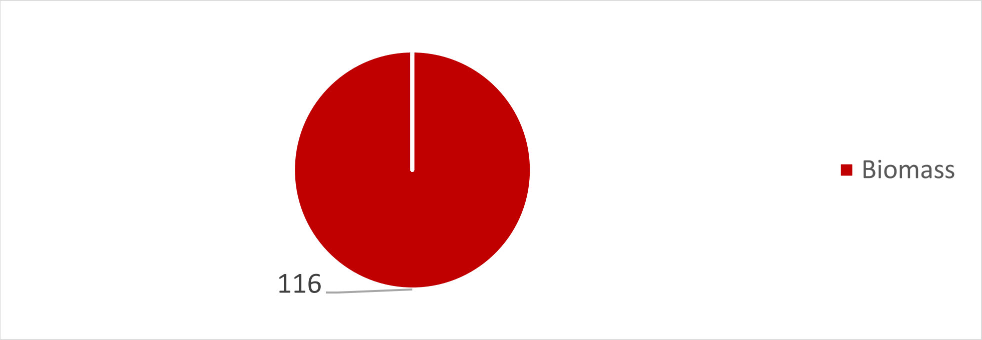

Figure 91. Type of energy source in heating systems in Saldus.

- **Heating energy consumption**

  The thermal energy consumption across the 116 surveyed dwellings in Saldus is intrinsically linked to the physical dimensions of the properties and their respective periods of construction, all within the technical framework of a uniform centralised district heating system. For the apartments constructed in 1960, the annual thermal energy consumption is found to be notably low in absolute terms, typically ranging between 1.368 kWh and 3.401 kWh per year. This reduced energy demand is primarily a reflection of the extremely compact living areas of these units, which range from 11,5 m² to 28,6 m², meaning there is a much smaller volume of space to heat compared to standard residential properties.

  In contrast, the dwellings built in 1980 exhibit a highly standardised consumption pattern, with most units reporting an annual thermal demand of approximately 5.391 kWh. This higher figure is consistent with the larger area of 35,4 m² in the survey.

- **Heating energy price**

  The analysis of heating energy prices in Saldus reveals a clear correlation between the age of the building, the floor area, and the resulting financial burden on the residents. For the standardised dwellings constructed in 1980, the annual cost for district heating is consistently recorded at 507,70€ per household. In contrast, the properties built in 1960 show a more varied price range due to their smaller and more diverse floor areas, with annual thermal costs typically ranging from 128,80€ for the smallest units (approx. 11,5 m²) to 320,30€ for the larger apartments (approx. 28,6 m²).

  Based on 2019 Household Budget Survey (HBS) data, the average expenditure for central heating in Latvia was approximately 138,02€ per person annually. For an average household in the Saldus municipality, which consists of 2,5 persons, the total energy expenditure in 2019 was calculated as 345,05€ per year. However, According to EU-SILC, the total monthly housing maintenance expenditure per household increased approximately 62,42%. Applying this growth rate to energy-related housing costs, we can estimate that the national average household energy expenditure for heating would be 560,43€.

  The project average energy price is 390,11, a 30,4% lower than the national average. However, this is a result of the apartments being significantly smaller than the national average, rather than a reflection of higher energy efficiency, as all buildings still adhere to the outdated Soviet Standard. In addition, for the single-occupancy households that dominate the Saldus sample, the energy prices are above the national average, which indicates that heating prices are consuming an increasingly large portion of their fixed incomes.

- **Heating energy price per household**

  Using the technical data collected from the Saldus sample, the project dwellings have an energy consumption for heating of 4.142kWh/year and a cost of 390,12€ on average. By dividing the consumption by the cost, a conversion ratio of approximately €0.094 per kWh. Applying this conversion rate to the average heating cost for Latvian dwellings (560,43€), we obtain the average national energy consumption for heating: 5.950,91€.

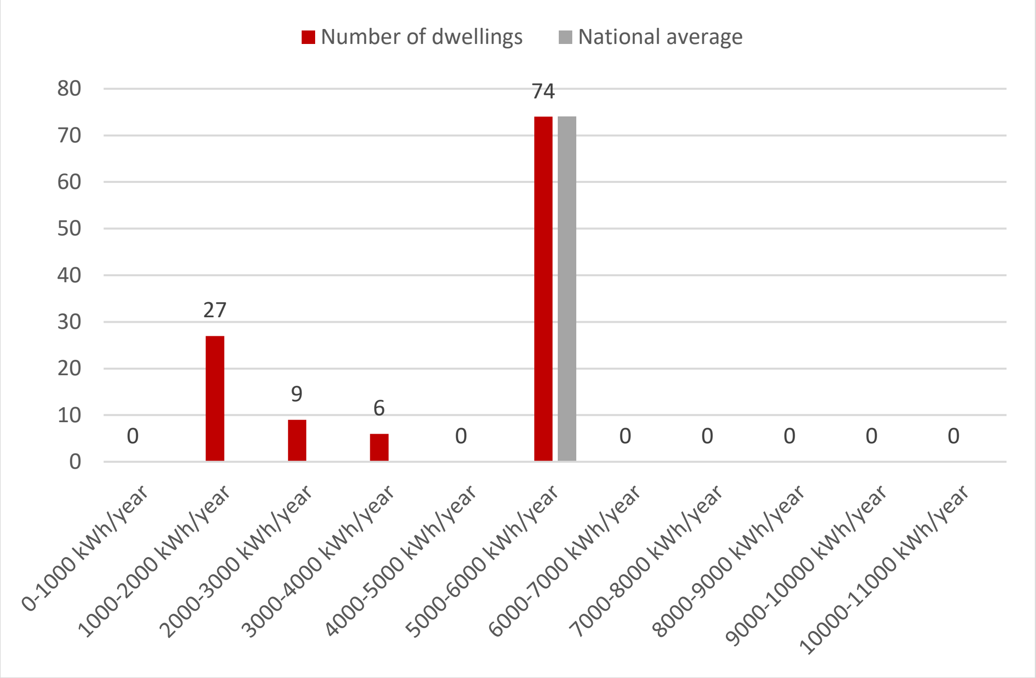

Figure 92. Heating consumption per dwelling in Saldus.

In conclusion, the analysis of the 116 surveyed dwellings in Saldus reveals that every property, regardless of whether it was constructed in 1960 or 1980, exhibits an annual heating consumption consistently below the estimated Latvian national average of 5.950,91 kWh. While individual consumption figures across the sample range from 1.368 kWh to 5.391 kWh, this lower absolute demand is predominantly a consequence of the exceptionally compact floor areas of the analysed units rather than superior energy performance.

1.1.4. Cooling

The analysis of the 116 surveyed dwellings in Saldus reveals a complete absence of active cooling systems across the entire sample. None of the properties, whether constructed in 1960 or 1980, are equipped with air conditioning or any other form of mechanical cooling installation. Consequently, residents are entirely reliant on passive cooling strategies, such as manual ventilation through opening windows or the use of portable fans, to manage indoor temperatures during the warmer summer months.

While the local climate in Latvia is predominantly defined by its rigorous winters and high heating demands, the total lack of cooling infrastructure represents a significant gap in energy services. This situation poses a heightened risk to the vulnerable groups identified within the Saldus demographic, particularly the high proportion of elderly individuals and those with chronic health conditions, who are physiologically more susceptible to heat stress.

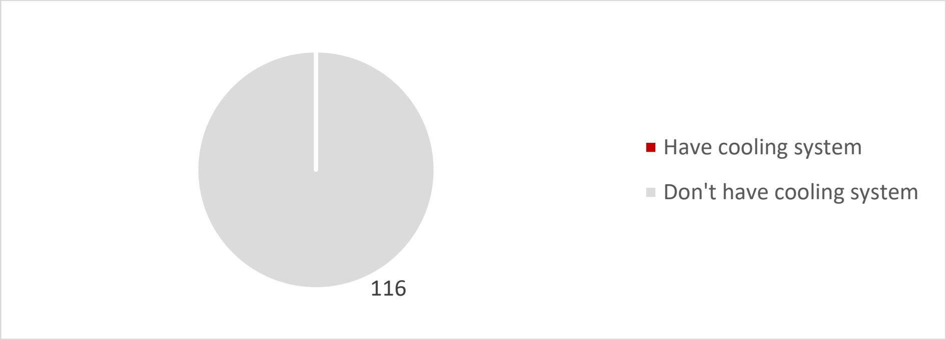

Figure 93. Number of dwellings with or without cooling systems in Saldus.

4.4. Domestic hot water

According to the data collected, of the 116 homes analysed in Saldus, all of them have domestic hot water systems (100%).

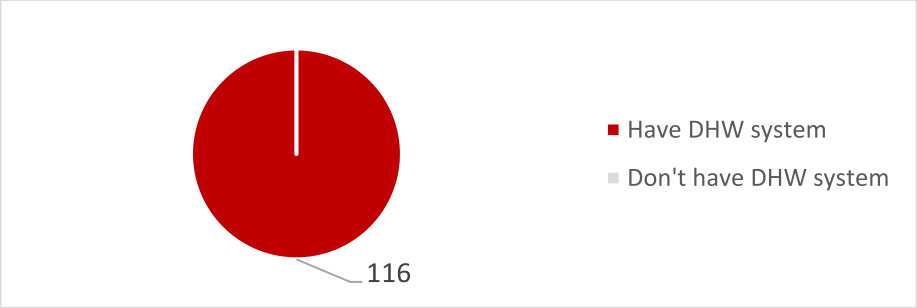

Figure 94. Number of dwellings with or without DHW systems in Saldus.

- **Types of DHW systems**

  For the dwellings constructed in 1960, the domestic hot water is provided by decentralised electric boilers. These systems operate via the Joule effect with a reported technical performance of 100%, but they lack any form of control system, which can lead to inefficient energy use and higher standby losses. This reliance on individual electric water heaters places a substantial burden on the electricity consumption of these residents, many of whom are elderly individuals living alone in very compact spaces.

  In contrast, the buildings constructed in 1980 are fully integrated into the centralised district heating network for their hot water supply. These systems are powered by biomass, aligning them with more sustainable energy practices compared to the individual electric solutions of the older cohort. A significant advantage for the 1980 residents is the presence of control systems in 100% of the dwellings, allowing for better management of hot water delivery. Despite these technical differences, residents from both construction periods provide a consistent maintenance and conservation score of 5 out of 10, indicating a perception that the DHW infrastructure is in only a fair state of repair across the entire sample.

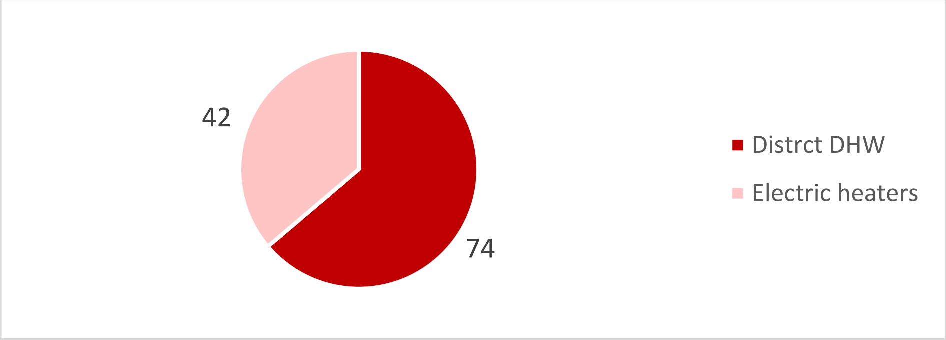

Figure 95. Type of DHW system in the dwellings in Saldus.

- **Energy consumption.**

  We cannot analyse the specific energy consumption for DHW, as this consumption is included within the total electricity or heating consumption.

4.5. Lightning

Of the 116 homes analysed in Saldus, 100% of them continue to rely on compact fluorescent bulbs. This shift towards LED technology is a positive sign in terms of energy efficiency, as LED bulbs consume significantly less energy than incandescent bulbs and have a longer lifespan.

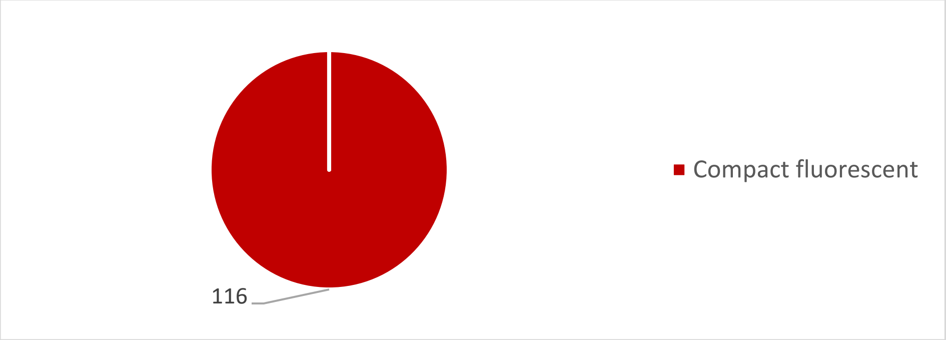

Figure 96. Type of lightning system in the dwellings in Saldus.

This homogeneity is directly linked with the lightning comfort of the occupants, as all of them rated as 5 out of 10, classifying their conditions as "fair-right". This indicates that while the current lighting systems meet the bare minimum functional requirements for habitation, they fail to provide the high-quality illumination required to enhance the physical and emotional well-being of the residents. In addition, from an economic perspective, the continued reliance on compact fluorescent bulbs instead of LEDs represents persistent and avoidable pressure on the electricity bills of these low-income households.

4.6. Electricity

In the specific case of Saldus, electricity consumption in some households includes not only general electricity use but also the use of domestic hot water (DHW) systems.

- **Energy consumption.**

  The average electricity consumption for the 116 households surveyed in Saldus is found to be significantly lower than national benchmarks. For the uniform dwellings constructed in 1980, the annual consumption is 1.094 kWh per year. For the older dwellings built in 1960, consumption varies between 355 kWh and 884 kWh per year, directly correlating with their extremely compact floor areas (11,5 m² to 28,6 m²).

  This notably low consumption is not necessarily an indicator of high energy efficiency. Instead, it reflects the limited living space and the potential energy-saving behaviours of a vulnerable demographic. In the 1960 building, this electricity demand must also cover the operation of electric boilers (Joule effect), which provide 100% of the household's hot water. The fact that total electricity use remains so low despite the inclusion of water heating suggests that these residents, many of whom are elderly and live alone, may be severely limiting their use of electrical appliances and hot water to manage their limited budgets.

- **Energy price**

  The data gathered from the 116 surveys shows that residents in 1980 buildings pay an annual electricity bill of 219€, whereas residents in 1960 buildings (who have individual electric boilers for DHW), have annual electricity costs between 71€ and 177€.

  These figures are notably lower than the national benchmarks. Based on 2019 Household Budget Survey (HBS) data, the average expenditure for electricity in Latvia was approximately 138,38€ per person and year. For an average household in the Saldus municipality, which consists of 2,5 persons, the total electricity expenditure in 2019 was calculated as 345,95€ per year. However, According to EU-SILC, the total monthly housing maintenance expenditure per household increased approximately 62,42%. Applying this growth rate to energy-related housing costs, we can estimate that the national average household energy expenditure for heating would be 561,89€.

  The data gathered from the surveys shows that the dwellings in Saldus have an electricity consumption 68,7% lower than the national average. This reflects that owners, particularly those in the 1960 building with electric water heating, spend so little on electricity due to a forced limitation of energy use.

- **Energy consumption per household**

  Based on the technical data collected from the Saldus surveys, a unit price of 0,20€/kWh can be deduced by dividing the recorded annual electricity costs by the corresponding consumption data. By applying this unit price to the estimated national average household electricity expenditure of €561,89 we can calculate that the average electricity consumption per household in Latvia is 2.809.46 kWh. Taking this data as reference, we can state that all of the 116 homes have an annual electricity consumption higher than the national average.

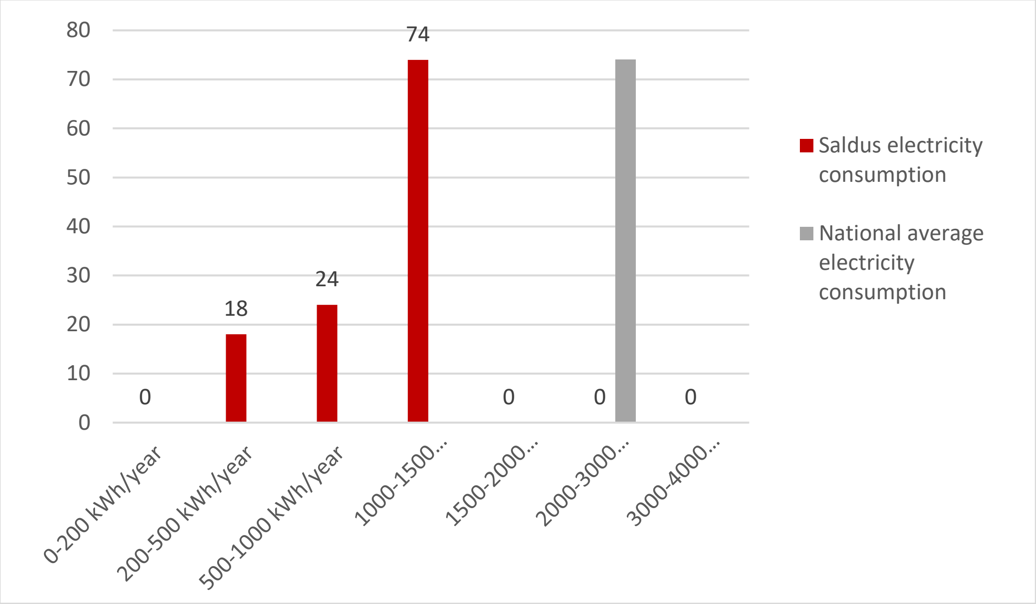

Figure 97. Electricity consumption per dwelling in Saldus.

This disparity underscores the technical and economic vulnerability of the Saldus residents, whose exceptionally low electricity use reflects both the compact size of the Soviet dwellings and a forced limitation of energy services to maintain household budgets.

4.7. Data analysis

- **Energy consumption vs. housing area**

  Figure 98 represents the energy consumption (heating + electricity) of the homes in Saldus against the housing area.

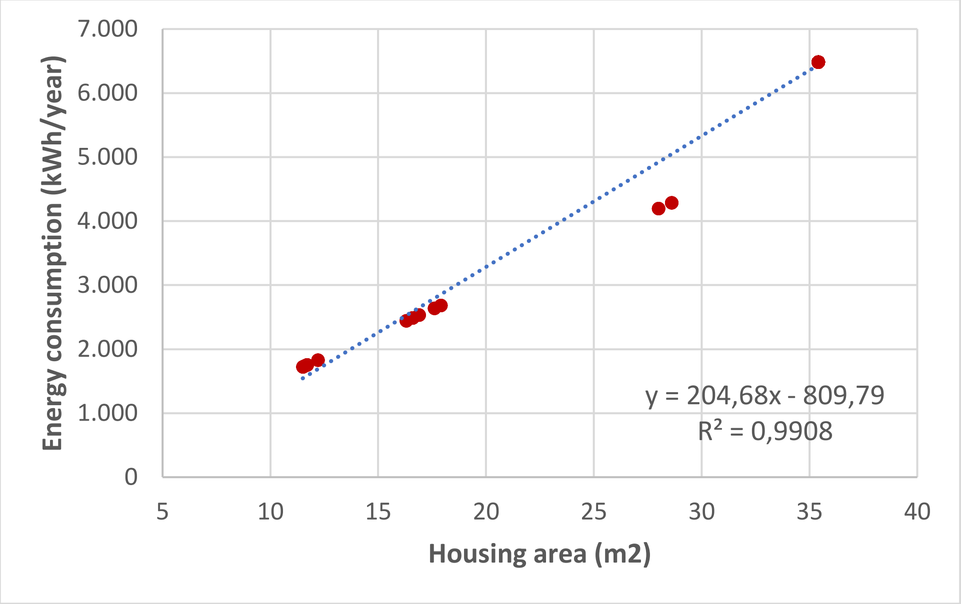

Figure 98. Energy consumption per housing area.

This analysis demonstrates an exceptionally strong positive correlation (R^2=0,9908) between housing area and annual energy consumption. According to the regression equation (y = 204,68x – 809,79), every additional square meter of floor area increases consumption by approximately 204.68 kWh/year. The high R^2 value confirms that, within these standardised prefabricated structures, the physical dimensions of the property are the primary determinant of energy demand, largely overriding other factors such as the number of occupants or individual household habits.

- **Energy consumption vs. number of occupants**

  Figure 99 shows the relationship between number of occupants per dwelling and energy consumption (in kWh/year).

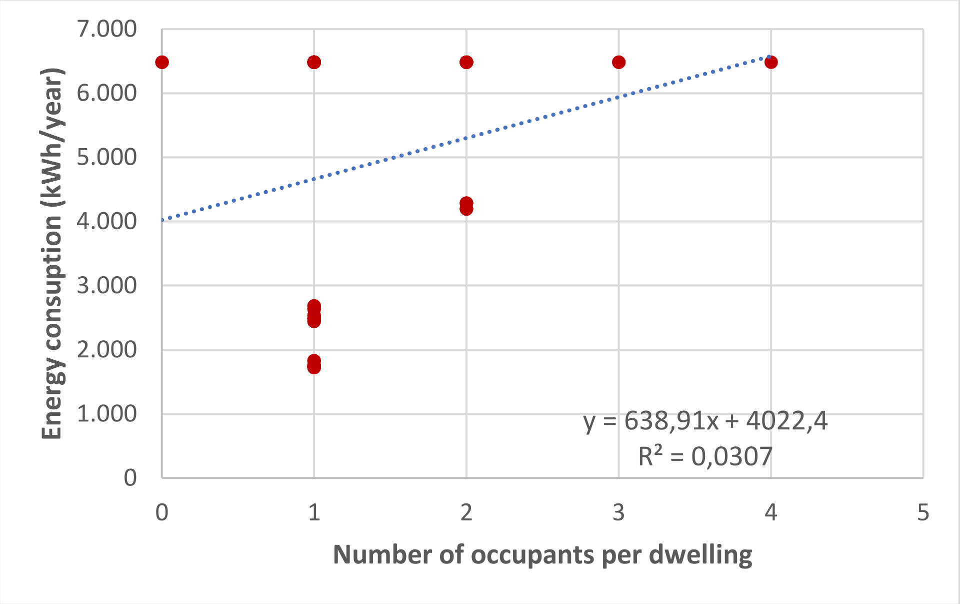

Figure 99. Energy consumption per number of occupants in Saldus.

In contrast to the strong correlation with housing area, an analysis of energy consumption based on the number of occupants in Saldus reveals a negligible relationship, as shown by a very low coefficient of determination (R^2=0,0307). This lack of correlation is primarily due to the predominance of single-person households among the elderly and vulnerable, who live in properties built under obsolete Soviet Standards. These residents often severely limit their use of electrical appliances and heating to manage fixed incomes, effectively decoupling energy use from the number of people in the home. Consequently, structural factors such as poor thermal insulation and compact housing dimensions remain the dominant drivers of consumption, overriding individual demographic variables.

- **Energy consumption vs. year of construction**

Figure 100 shows energy consumption (kWh/year) in relation to the year of construction for the homes in Saldus. The analysis reveals a significant positive correlation (R^2 = 0,9335) between the two variables.

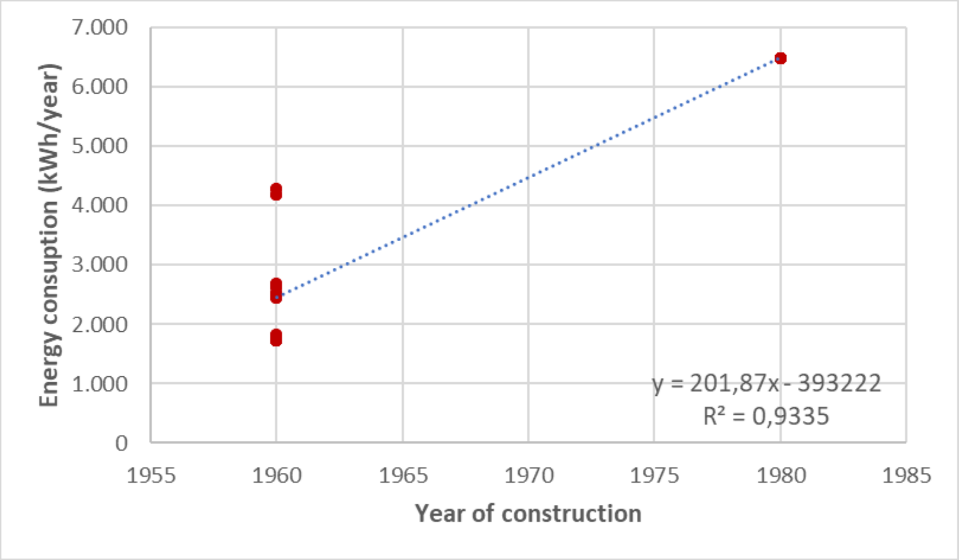

Figure 100. Energy consumption in Saldus dwellings per year of construction.

According to the regression equation y = 201,87x – 393.222, buildings constructed later in the Soviet period show higher total energy demand than those from 1960. This trend is driven by the standardised increase in housing area over time. While properties from 1960 are extremely compact (ranging from 11,5 m^2 to 28,6 m^2), the units built around 1980 are larger and more uniform (35.4 m^2). Although the 1980 buildings followed the slightly more sophisticated SNiP II-3-79 thermal regulations, their insulation requirements remained three to four times lower than current European standards. Consequently, the benefit of "newer" construction is entirely offset by the increased internal volume and persistent thermal bridges in the pre-cast concrete panels, resulting in a higher overall energy burden for residents in 1980 properties.

- **Energy consumption vs. thermal comfort**

In Figure 101, the relationship between energy consumption (kWh/year) and thermal comfort assessment for the homes in Saldus is illustrated, to verify whether higher energy expenditure translates into better living conditions.

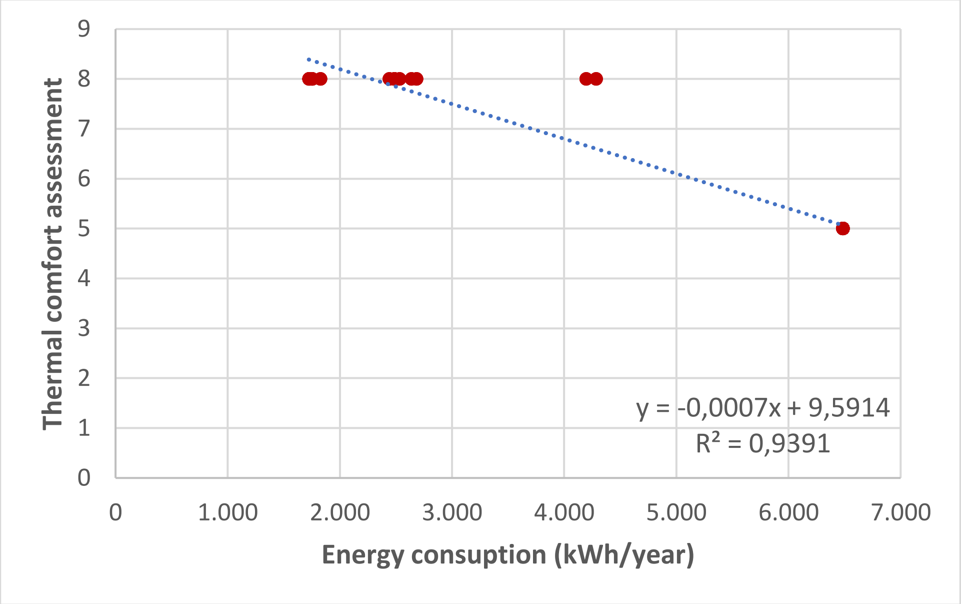

Figure 101. Thermal comfort assessment per energy consumption.

Based on the data provided, the relationship between annual energy consumption and thermal comfort assessment in Saldus reveals a strong negative correlation (R^2 = 0,9391). This implies that higher energy expenditure does not translate into improved living conditions; instead, thermal comfort ratings decline as consumption increases. This inverse relationship is primarily due to the severe structural inefficiencies of the older housing stock. While residents in the 1960 properties report a "Good" comfort level despite lower absolute energy use, those in the 1980 buildings report a lower "Fair-Right" rating (5 out of 10) even with significantly higher consumption. This confirms that in dwellings built to obsolete Soviet Standards, high energy consumption is a symptom of excessive heat loss through uninsulated building envelopes rather than a reflection of a well-heated environment. Consequently, the most vulnerable inhabitants are paying more for a lower quality of life, highlighting the urgent need for energy renovation to reduce energy costs from thermal well-being.

- **Housing area vs. thermal comfort**

Figure 102 analyses the relationship between housing area (m²) and thermal comfort level for homes in Saldus, to check if the size of the home influences the living conditions and thermal wellbeing of its residents.

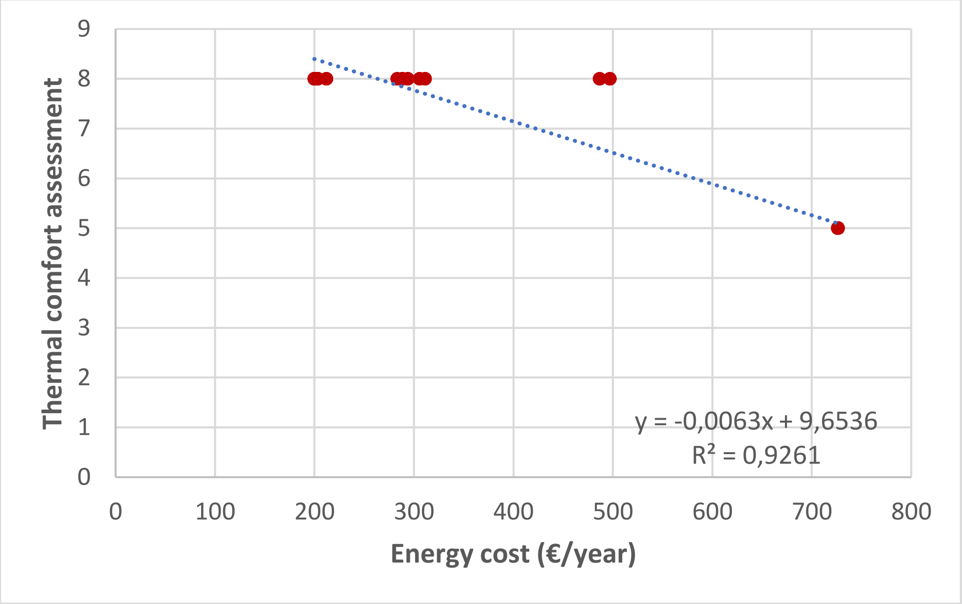

Figure 102. Thermal comfort assessment per energy consumption.

An analysis of the relationship between annual energy costs and thermal comfort in Saldus reveals a strong negative correlation (R^2 = 0,9261). The graph indicates that as residents spend more on energy, their perceived level of comfort decreases. This confirms that higher expenditure is merely a symptom of structural heat loss through uninsulated Soviet Standard walls rather than an investment in better living conditions.

4.8. Score of the energy assessment

According to the guide, three vulnerability levels have been defined for the homes analysed in these energy studies: Low, Medium, and High. The threshold values for each level are selected so that the upper limit of the score for each category indicates the urgent need for energy rehabilitation interventions in those homes.

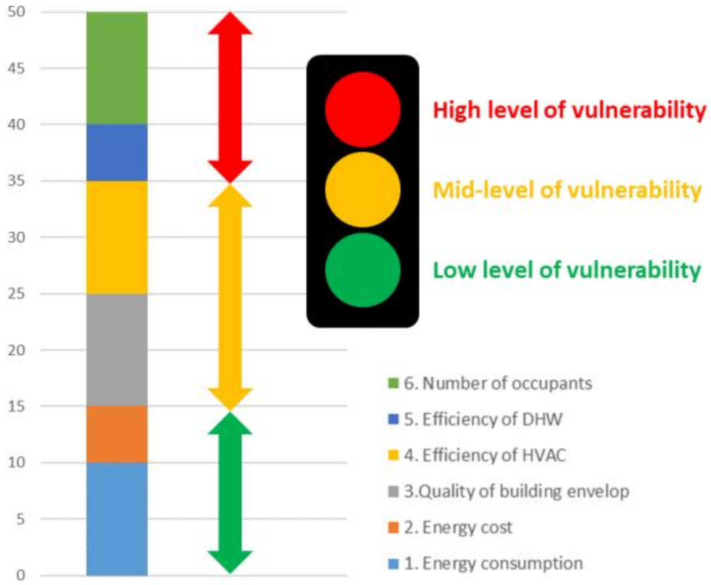

Figure 103. Example of thresholds determined to differentiate the three levels of housing energy vulnerability.

For the 116 homes studied in Saldus, the results obtained are as follows:

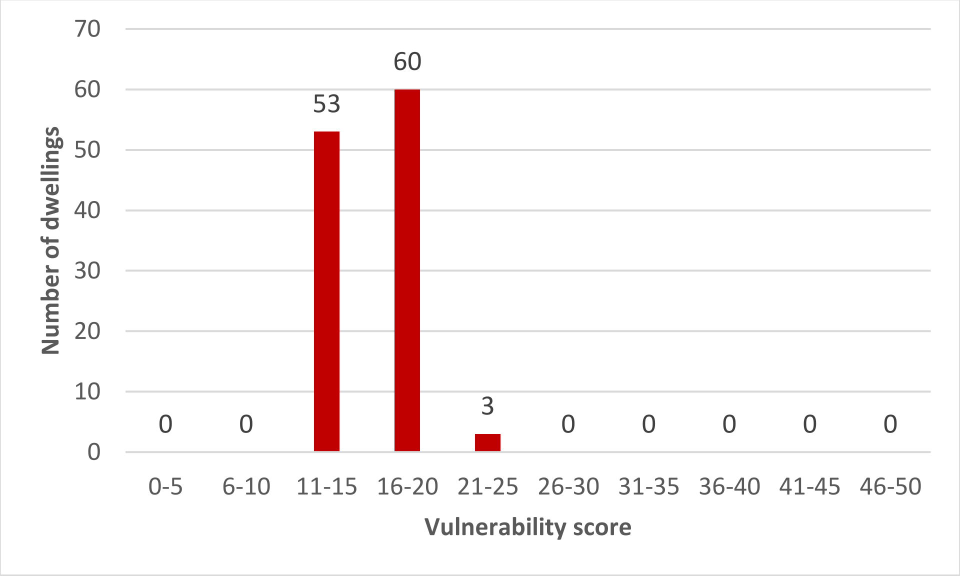

Figure 104. Number of dwellings per vulnerability level.

From this data, the following conclusions can be drawn:

- A total of 63 homes fall within the medium vulnerability level, with vulnerability scores ranging between 15 and 35 points. This accounts for 54% of the total homes analysed.

- 0 homes fall into the high vulnerability level, indicating that no homes have been classified as critically vulnerable based on the provided scores.
- 53 homes fall under the low vulnerability level, with scores between 10 and 15 points. These homes exhibit minimal vulnerability and require less immediate attention compared to the other categories.

The energy assessment in Saldus identifies a significant percentage of surveyed homes (54%) as being at a medium vulnerability level. Although no properties have reached the "high vulnerability" threshold, the fact that over half of the households require prioritised energy rehabilitation highlights the persistent impact of obsolete Soviet-era construction standards on resident well-being. While 53 homes currently exhibit low vulnerability, technical interventions should focus on the 63 medium-vulnerability units to prevent further degradation of living standards and to reduce the financial strain caused by structural energy inefficiencies.

5. PLOVDIV

Plovdiv is a city located in southern Bulgaria, known for its mild continental climate. Winters are generally cold, with temperatures often falling below 0°C, while summers can be warm, reaching temperatures of up to 30°C. This seasonal variation creates a significant energy demand, particularly during the winter months, when heating requirements are particularly high. Furthermore, many residential buildings in Plovdiv, especially older properties, do not meet contemporary energy efficiency standards, which increases the challenge of reducing energy consumption.

As part of the LIFE ReHABITA project, 100 vulnerable homes in Plovdiv have been analysed to assess the energy performance of the buildings. The objective of this study is to identify existing deficiencies in the energy efficiency of these homes, particularly those constructed before the implementation of modern building regulations and energy standards. Through this project, we aim to improve the energy performance of these homes and reduce energy consumption, contributing to the overall sustainability and well-being of the community.

5.1. Building characteristics and their surroundings

This section analyses the main characteristics of the homes, highlighting their type, construction year, average size, number of occupants and other relevant information of the surroundings.

- **Types of dwellings**

  The 100 homes analysed in Plovdiv are all apartments in multifamily residential buildings, accounting for 100% of the dwellings surveyed.

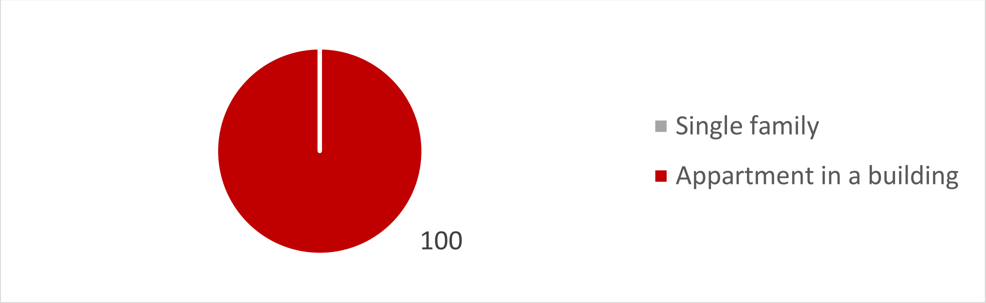

Figure 105. Type of dwellings in Plovdiv.

In general, apartments, by sharing walls, roofs, and floors with other units, have fewer surfaces exposed to the external environment compared to single-family homes. This configuration reduces energy losses, as the heat from neighbouring apartments can help maintain a more stable indoor temperature. However, in a region like Plovdiv where cold winters and high heating needs are prevalent, many of the older apartment buildings may still suffer from inadequate insulation, leading to higher energy consumption.

- **Year of construction**

Updated data on the construction year of the buildings included in this study in Plovdiv shows that all of them were built before the introduction of thermal protection regulations. In 1996, new construction standards (Regulation No. 7/1996) came into force, introducing significantly stricter requirements for the thermal insulation of external walls, roofs, and floors, as well as for windows, glazing, and the overall energy performance of building elements.

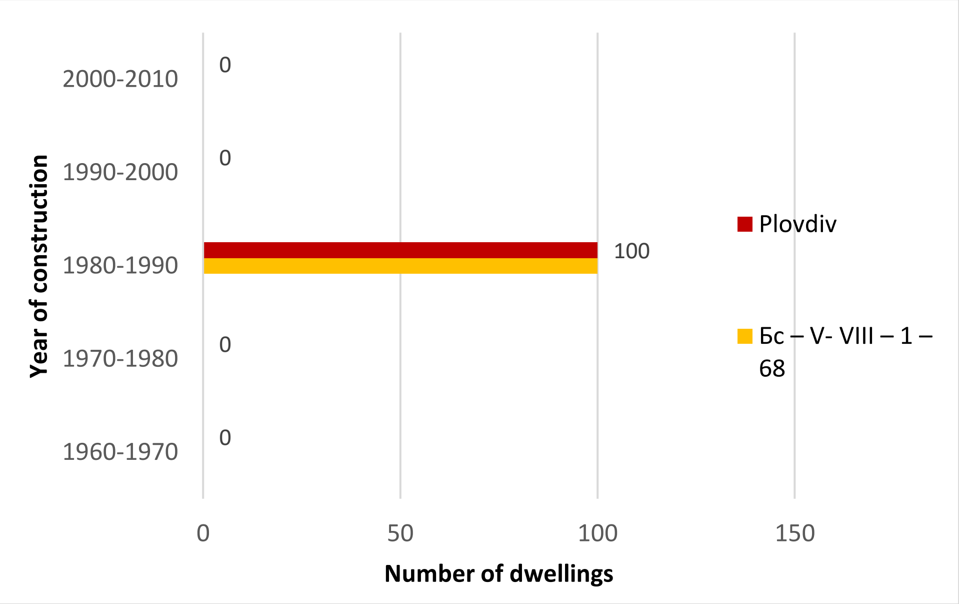

Figure 106. Number of dwellings by year of construction in Plovdiv.

The analysis done in Figure 106 shows the following:

- 100 dwellings in Plovdiv were all constructed between 1980 and 1990, and all of these buildings were built under the Б с – V- VIII – 1 – 68 regulation, which was in force at the time. This regulation, while providing some guidance for construction, did not set the modern standards for thermal insulation and energy efficiency that we have today. As a result, these buildings are likely to lack contemporary thermal efficiency features, leading to higher energy consumption, particularly during the winter heating season.
- The lack of modern insulation standards in these buildings means that they are prone to higher energy costs, which can contribute to energy poverty, especially for vulnerable residents who are already facing financial challenges.

- While the buildings may have complied with the available energy regulations at the time of construction, they were still built under much less stringent energy efficiency requirements than current standards. Therefore, despite some improvements in thermal performance, these buildings remain inefficient compared to more modern construction techniques.

The fact that all the buildings in Plovdiv were constructed under outdated regulations highlights the urgent need for energy renovation efforts to improve insulation, reduce energy consumption, and address the risk of energy poverty.

- **Housing size**

The data on the floor area of apartments in Plovdiv shows that the majority of the analysed homes are relatively large compared to the national average for new dwellings in Bulgaria. The average floor area of the dwellings in Plovdiv is around 80–100 m², which is larger than the national average of 73 m², as reported in the latest statistics for completed buildings in Bulgaria. The national average likely includes a broader mix of both apartments and family houses, which may skew the comparison, but in Plovdiv, most homes are flats in multi-apartment buildings.

Most of the homes in the study (approximately 59 out of 100) fall into the 80-100 m² category, indicating that they are of medium to large size. Only a small number of homes (3) have a smaller floor area, with 38 homes falling into the 60-80 m² range.

The larger average size of homes in Plovdiv could have an impact on their energy needs, as larger homes typically require more energy to maintain comfortable temperatures. However, the age of the buildings and potential insulation inefficiencies may still result in high energy consumption, even in larger homes. As such, renovations should focus on improving energy efficiency, considering the larger size of the homes and the possible energy inefficiencies due to older construction methods and outdated regulations.

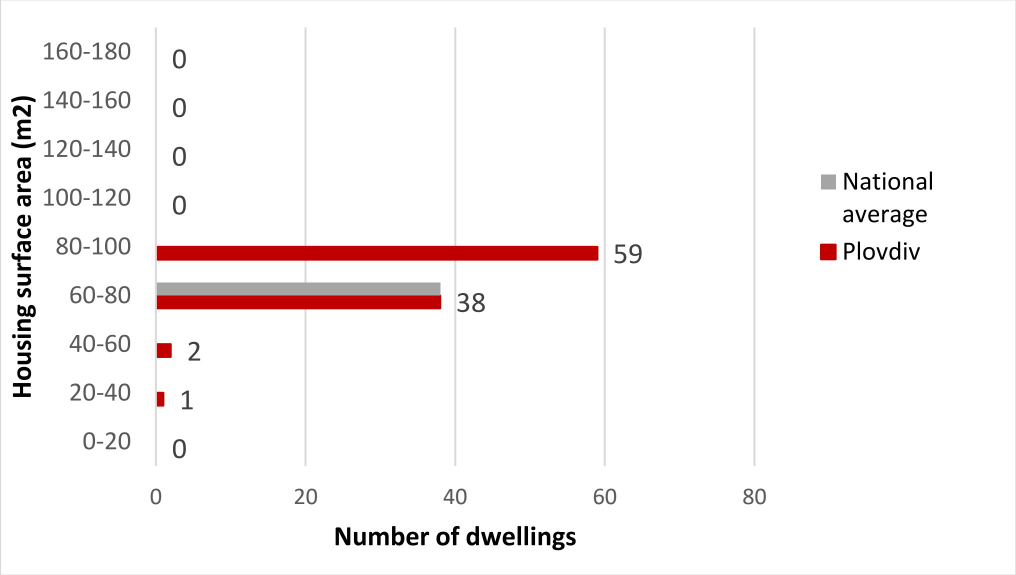

Figure 107. Number of dwellings by housing surface area in Plovdiv.

- **Number of occupants per home**

The data on occupants per dwelling in Plovdiv provides valuable insights into household composition and occupancy patterns. Most dwellings in Plovdiv have relatively low occupancy rates, with 32 homes having 2 occupants, and 28 homes having 1 occupant. Additionally, 23 homes have 3 occupants, and 17 homes accommodate 4 people. There are no dwellings with more than 4 occupants in the sample.

In comparison to Bulgaria's national average, where the average occupation is approximately 2,2-2,6 persons per household, Plovdiv shows a slightly lower number of occupants per dwelling. The dominance of smaller households (1-3 occupants) suggests that many homes in Plovdiv are likely single-person or small-family households, which is common in urban areas or medium-sized cities. This pattern reflects the demographic structure of the city, where smaller family units and single-person households are prevalent, likely influenced by urbanization trends and the evolving housing preferences in recent years.

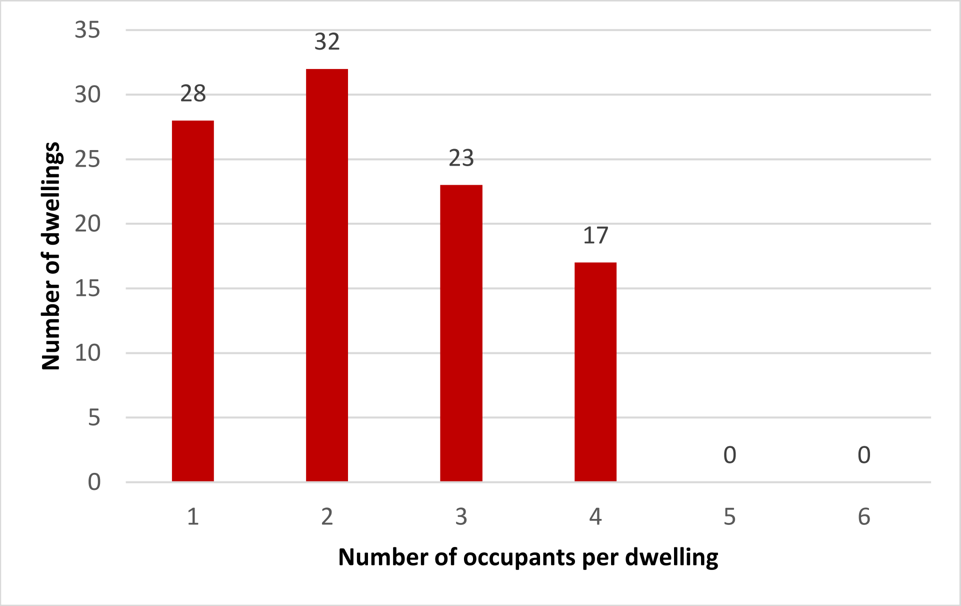

Figure 108. Occupants per dwelling in Plovdiv.

The analysis of vulnerable groups in households in Plovdiv highlights that a significant portion of the population is at increased risk due to factors such as age, health, and family status. Of the total population in the sample, 68% are adults, 18% are children, 13% are elderly, and 1% are individuals with chronic health conditions.

These vulnerable groups are particularly susceptible to the effects of energy poverty. Children, elderly individuals, and those with health issues are more vulnerable to poor thermal conditions, especially in homes that may lack adequate insulation or energy-efficient systems. The discomfort and potential health impacts from insufficient heating or cooling are greater for these groups, making it essential to prioritize energy efficiency improvements in households with higher percentages of vulnerable individuals.

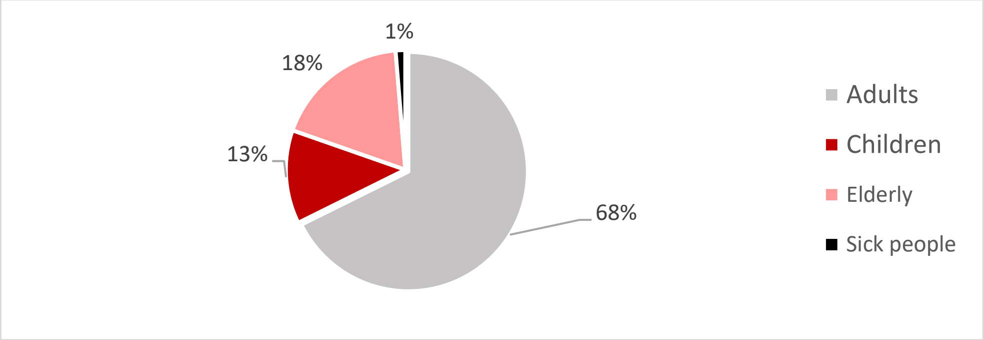

Figure 109. Vulnerable groups in households in Plovdiv.

Children, the elderly, and those with chronic illnesses are particularly vulnerable to temperature extremes due to reduced ability to regulate body heat. Additionally, lower incomes often limit their access to proper heating, exacerbating health issues and increasing their risk of energy poverty.

- **Access to green areas**

  In Plovdiv 100 out of 100 homes have access to green spaces.

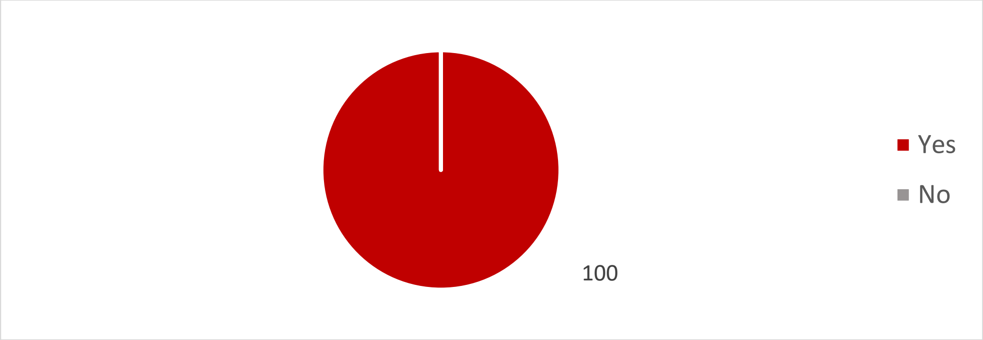

Figure 110. Number of dwellings in Plovdiv with and without access to green areas.

5.2. Comfort at home

In addition to analysing the characteristics and composition of the homes, we have also assessed the level of comfort within them, considering three key aspects: thermal, acoustic, and lighting comfort. These factors are essential for understanding the quality of life of the residents and their energy vulnerability, as a comfortable environment directly contributes to the physical and emotional well-being of individuals.

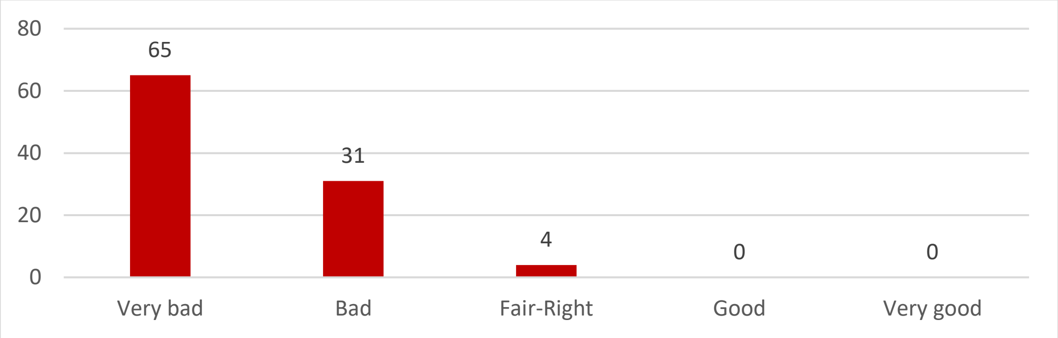

Figure 111. Thermal comfort in Plovdiv households.

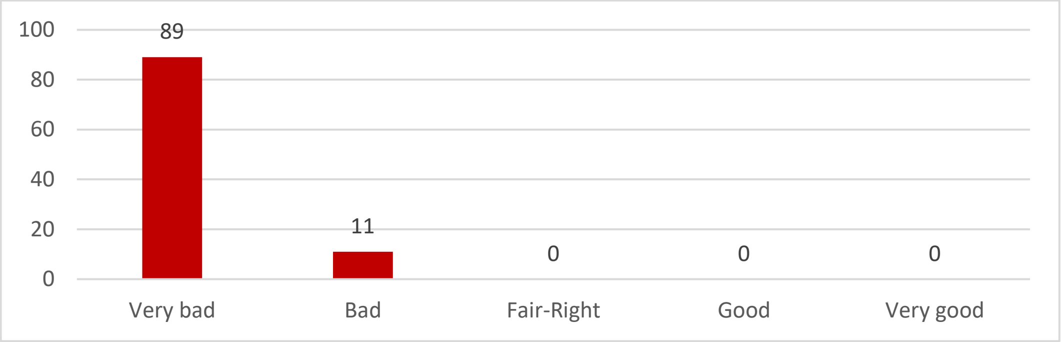

Figure 112. Acoustic comfort in Plovdiv households.

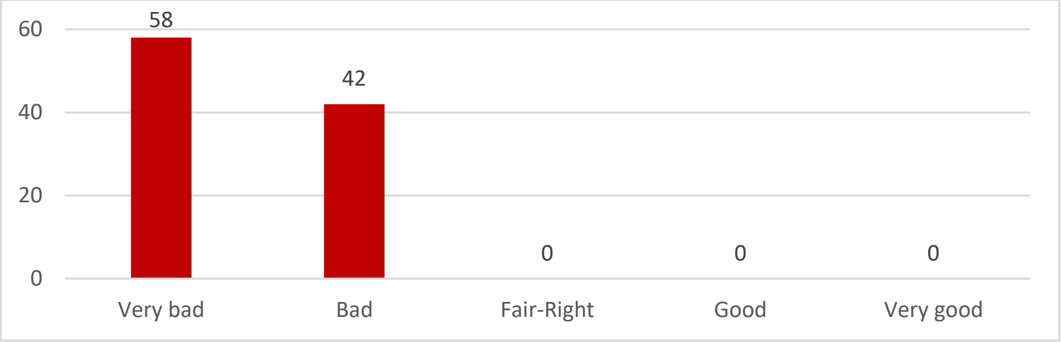

Figure 113. Lightning comfort in Plovdiv households.

The data on thermal comfort, acoustic comfort, and lighting comfort in Plovdiv suggests that the majority of the dwellings experience poor to fair conditions in all three areas, with a significant portion of homes facing challenges in maintaining comfortable living environments.

For thermal comfort, the majority of homes (65%) report very bad conditions, followed by bad conditions in 31% of the dwellings. Only a small portion (4%) report fair-right thermal comfort, suggesting that most homes suffer from significant inefficiencies in maintaining a comfortable indoor temperature, which may be a result of inadequate insulation and heating systems.

Vulnerable households typically do not heat the entire dwelling, but only one or two rooms where they spend most of their time – for example, the living room and the bedroom, with the bedroom usually heated only during sleeping hours.

In terms of acoustic comfort, the situation is even more concerning, with 89% of homes reporting very bad acoustic conditions, indicating a widespread issue with poor sound insulation or noise pollution. Only 11% of the dwellings report bad acoustic comfort, and there are no homes that experience better than bad conditions, suggesting that noise control measures are severely lacking in these buildings.

Regarding lighting comfort, 58% of the dwellings report very bad lighting conditions, and 42% report bad lighting comfort. Again, no dwellings report fair-right or better

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lighting conditions, highlighting the need for improvements in natural light access or artificial lighting solutions in these homes.

Overall, the data indicates that most homes in Plovdiv face significant challenges in thermal, acoustic, and lighting comfort. The low comfort ratings in these areas are likely due to older building stock, insufficient insulation, inadequate soundproofing, and poor lighting systems. Addressing these issues through renovations and upgrades would significantly improve the energy efficiency and overall comfort for the residents, reducing energy costs and enhancing living conditions.

5.3. Heating

Of the 100 homes analysed in Plovdiv, all of them have some type of heating system.

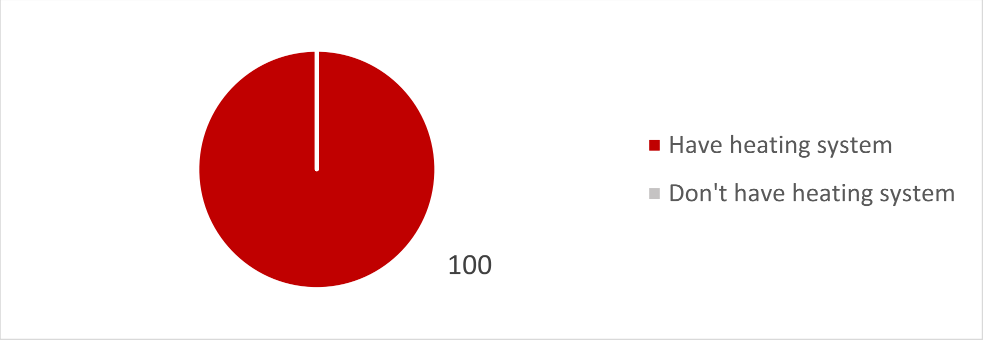

Figure 114. Number of dwellings with or without heating systems in Plovdiv.

- **Types of heating system**.

  The data on heating systems in the 100 surveyed homes in Plovdiv shows that the majority of households (74 out of 100) rely on heat pump (HP) as their primary heating source. A smaller portion of homes (26 out of 100) use district heating (DH) for heating. This indicates that heat pump remains the dominant system in the area, providing centralized heating for a large portion of the population.

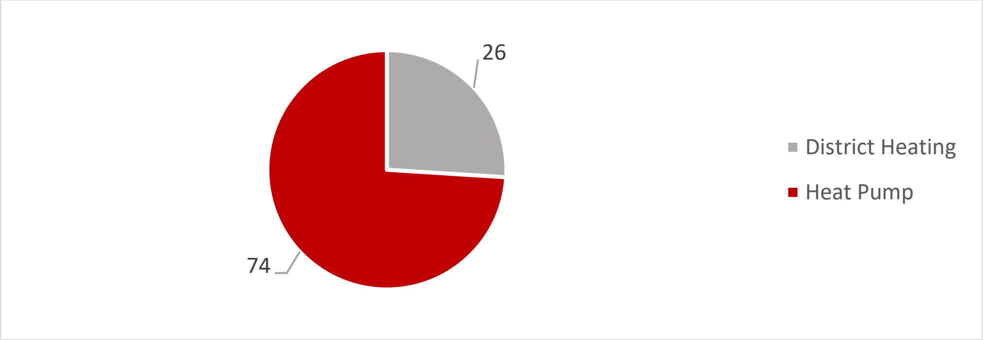

Figure 115. Type of heating system in the dwellings in Plovdiv.

Regarding maintenance and conservation, most of the homes with district heating systems have relatively high ratings (between 8 and 10 on a scale of 1-10), which suggests that the maintenance of these systems is generally well-managed. In contrast, homes with heat pumps tend to have lower ratings (between 1 and 3), indicating that these systems may not be as well-maintained or are newer installations with fewer regular checks.

In terms of the control system, all homes have a control system in place, indicating that heating can be managed and regulated. This suggests that there is a level of modernization in the systems, especially in comparison to older homes that may still rely on manual controls.

In conclusion, most homes in Plovdiv use electricity for heating. The maintenance of these systems varies, with district heating systems receiving better conservation scores, while heat pump systems may need further attention. The presence of control systems in both types of heating suggests a potential for improved energy efficiency and comfort.

- **Energy sources**

In terms of energy sources, the 74% of the sample of the study use electricity as energy source for heating, and the remaining 26% have district heating.

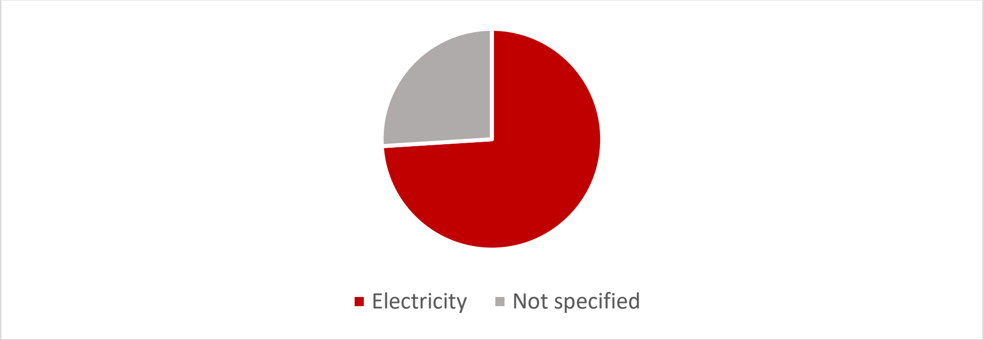

Figure 116. Type of energy source in heating systems in Plovdiv.

Currently, the city of Plovdiv has a well-developed district heating network. The supply of thermal energy to residential and non-residential consumers is provided through a mixed radial and looped distribution system with a total length of over 170 km. The customers of Plovdiv District Heating are less than 20% of the households in the city. This is due to the high prices of heating energy, so households are choosing not to use them and are looking for alternative options However, public sentiment in Plovdiv suggests that many residents are hesitant to switch from their current heating systems, which mainly rely on electricity.

This reluctance may be influenced by the ongoing uncertainty regarding energy prices, as well as concerns about the stability of energy supply due to regional tensions.

- **Heating energy consumption**

The analysis of electricity consumption in the surveyed 100 dwellings in Plovdiv shows a direct correlation between the size of the apartments and their energy demand, with variations based on the building's construction year.

For the apartments built in 1985, the annual electricity consumption ranges from 1,181 kWh to 8.553 kWh. This variation is primarily due to the differences in apartment sizes, which range from approximately 35 m² to 93,6 m². Larger apartments generally consume more energy, which is expected, as these units have a higher internal volume and heating needs compared to smaller homes. Additionally, the building standards from the time of construction did not prioritize energy efficiency, contributing to higher energy consumption in these larger units.

In contrast, for the apartments built in 1989, the energy consumption continues to follow a similar pattern, with consumption ranging from 1.584 kWh to 9.028 kWh. The apartments constructed in this period are also larger on average, ranging from 59,7 m² to 94,9 m². Despite slight improvements in building standards by the late 1980s, these properties still show significant energy consumption, mainly due to their larger size and potentially outdated insulation standards.

Overall, the analysis shows that, while newer buildings tend to be larger and thus have higher energy demands, energy inefficiencies persist due to the lack of modern thermal insulation and energy-efficient systems. This reinforces the need for energy efficiency improvements across all building types in Plovdiv, particularly in terms of insulation and modernizing heating systems.

- **Heating energy Price**

The analysis of energy consumption in Plovdiv reveals a clear relationship between the size of the dwelling and the annual electricity consumption, with larger homes tending to have higher energy costs. For the apartments constructed in 1985, the annual electricity consumption varies significantly depending on the floor area. The typical energy cost for these apartments ranges from 115,34€ for the smallest units (approximately 51 m²) to 504,14€ for the largest apartments (approximately 93,6 m²). This variation reflects both the floor area and the technical standards of the time, with larger apartments requiring more electricity for heating and cooling.

In comparison, the dwellings built in 1989 show a similar pattern, with electricity consumption and costs varying between 128,06€ for smaller units (approximately 59,7 m²) to 9.028€ for the largest apartments (approximately 93,6 m²). These differences highlight that larger dwellings generally have higher electricity costs due to increased energy demand.

This analysis underscores that while newer buildings are generally larger and therefore consume more energy, the size of the apartment plays a significant role in the overall energy costs. Furthermore, the lack of modern energy efficiency measures in these older buildings suggests that there are substantial opportunities for energy-saving renovations, particularly for larger units, to reduce overall consumption and the financial burden on residents.

- **Heating energy consumption per household**

The data presented in the chart clearly shows that the majority of the 100 homes reporting electricity consumption in Plovdiv have annual heating consumption higher than the national average. In fact, 75% of these homes fall within the 4.000 to 6.000 kWh/year range, with 28 homes consuming between 5.000 and 6.000 kWh/year. This is notably higher than the national average of 3.500 kWh/year, indicating a significant increase in energy use for heating.

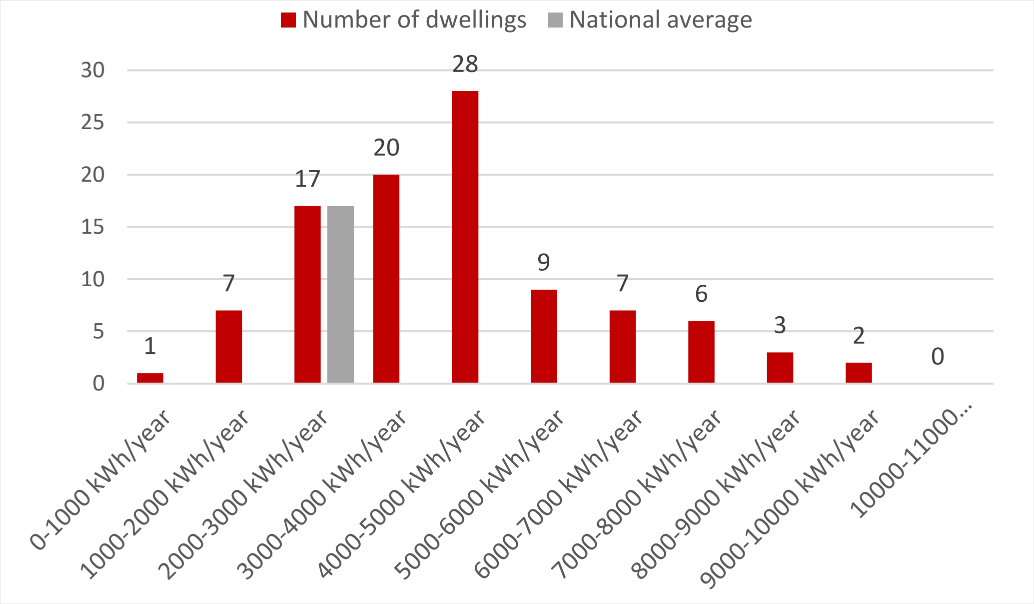

Figure 117. Heating consumption per dwelling in Plovdiv.

This disparity in energy consumption raises concerns about the efficiency of the heating systems in these homes. While some homes are connected to district heating (DH) network, a considerable portion uses electricity-based heating systems. The lower energy efficiency of electric heating, especially when compared to modern heating solutions like gas or district heating, could contribute to higher overall consumption.

Electric heating systems, though simple to use, may not be as efficient in distributing heat compared to other options. They are often more expensive to operate and less effective at maintaining consistent indoor temperatures. This inefficiency could be exacerbated by the age of the buildings, potential lack of modern insulation, and the absence of advanced control systems in many of the homes.

To reduce energy consumption and costs, it would be beneficial for Plovdiv to explore improvements in building insulation, heating system modernization, and more efficient energy management systems to optimize the use of energy and enhance comfort for residents.

5.4. Cooling

Based on the data provided for the cooling systems in the homes of Plovdiv, it is clear that all of the 100 surveyed dwellings are equipped with cooling systems, specifically heat pumps. This is notable, especially given that in many regions, cooling systems may not be as prevalent in older buildings.

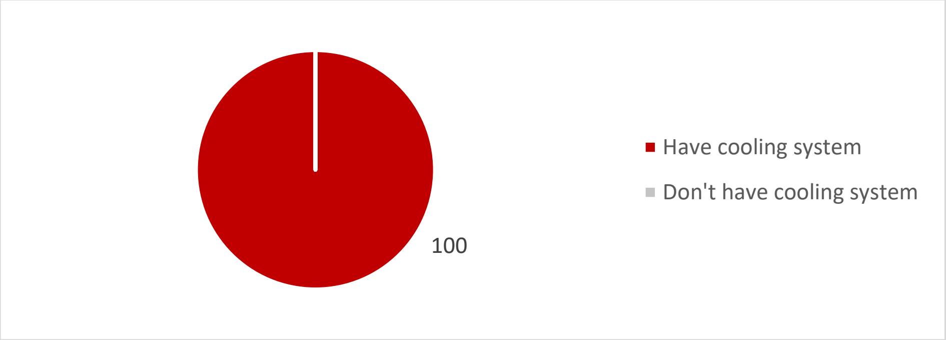

Figure 118. Number of dwellings with or without cooling systems in Plovdiv.

The widespread use of heat pumps suggests that these systems may be a more modern and energy-efficient alternative to traditional air conditioning systems. Heat pumps, which are typically used for both heating and cooling, are known for their efficiency and environmental benefits, as they consume less energy compared to conventional electric air conditioners. The relatively recent installation dates, ranging from 1999 to 2019, further highlight that these cooling systems are modern solutions that may have been introduced as part of energy renovation efforts or as part of an increasing trend toward energy-efficient systems in residential buildings.

This widespread adoption of heat pumps in Plovdiv contrasts with other regions were older, less efficient cooling methods might still be in use. The reliance on heat pumps as a cooling solution in Plovdiv indicates a commitment to improving energy efficiency and mitigating the risks associated with rising summer temperatures. However, despite the advantages of heat pumps, it is important to consider the potential barriers that some residents might face, such as the initial installation cost or the long-term maintenance of these systems.

5.5. Domestic hot water

According to the data collected, of the 100 homes analysed in Plovdiv, all of them have domestic hot water systems (100%).

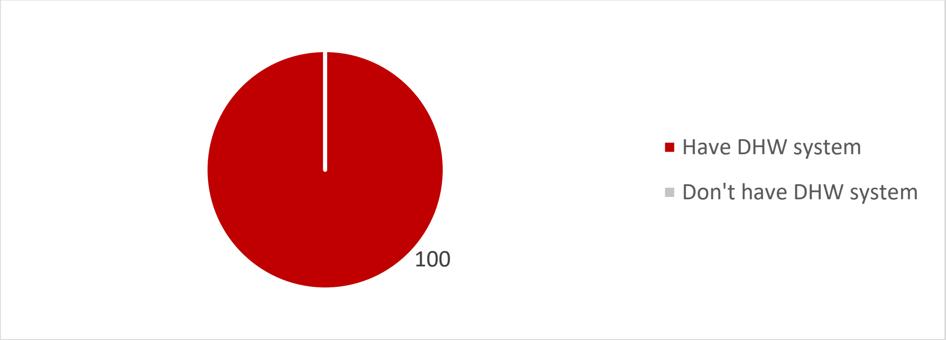

Figure 119. Number of dwellings with or without DHW systems in Plovdiv.

- **Types of DHW systems**

  Of the 100 homes with a hot water system, 74 % of them use electric water heaters powered by electricity (Joule effect), and the remaining 26% use district domestic hot water

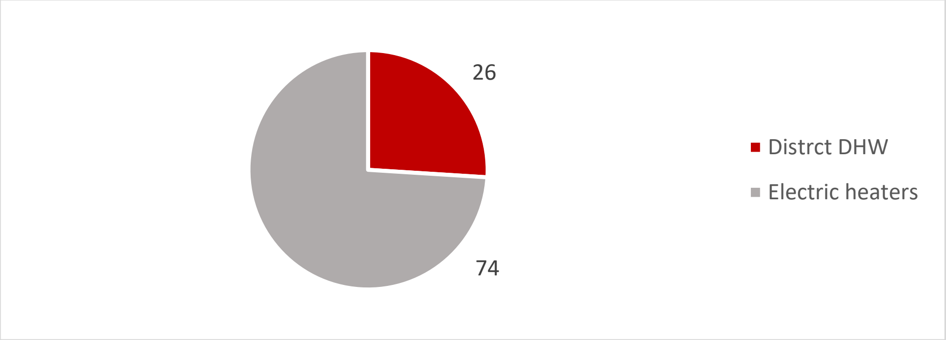

Figure 120. Type of DHW system in the dwellings in Plovdiv.

- **Energy consumption.**

  We cannot analyse the specific energy consumption for DHW, as this consumption is included within the total electricity consumption.

5.6. Lightning

Of the 100 homes analysed, 58 still rely on incandescent bulbs, and 42 of homes, have switched to LED bulbs. This shift towards LED technology is a positive sign in terms of energy efficiency, as LED bulbs consume significantly less energy than incandescent bulbs and have a longer lifespan.

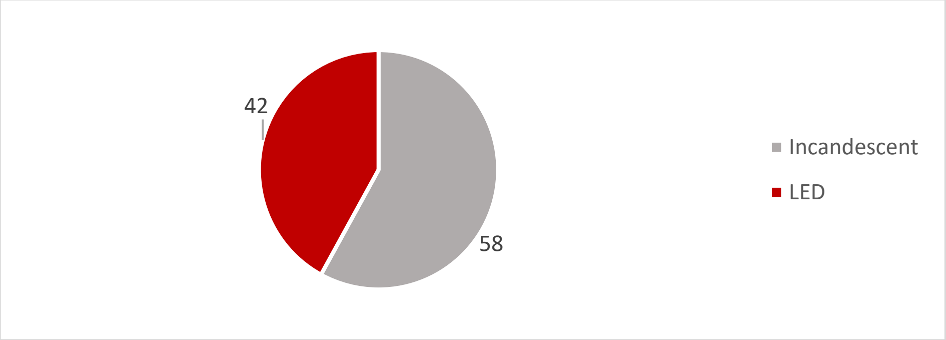

Figure 121. Type of lightning system in the dwellings in Plovdiv.

5.7. Electricity

In the specific case of Plovdiv, electricity consumption includes not only general electricity use but also the use of domestic hot water (DHW) systems.

- **Energy consumption.**

  The data for electricity consumption in Plovdiv reveals a notable contrast with the national average in Bulgaria. The average consumption in Plovdiv is 4.333 kWh per year, which is 21% lower than the national average of 5.476 kWh per year. This suggests that the homes in Plovdiv, on average, consume less electricity compared to the national standard.

  A closer look at the distribution shows a wide range of consumption levels, with some households using as little as 1.181 kWh/year, while others consume up to 9.354 kWh/year. The most common consumption rate falls between 4.000 and 6.000 kWh/year, which includes 48 homes. These homes are closer to the national average but still show a significant variation depending on the size of the dwelling and other factors.

  Lower energy consumption can indicate greater energy efficiency and cost savings, as these homes may be using less energy to maintain comfort levels. However, it can also reflect energy limitations where households restrict their energy use due to financial constraints or a lack of access to modern heating or cooling systems. In this case, the lower consumption may be an indicator of energy poverty, where residents sacrifice comfort to manage their energy bills. This situation, especially during hot summer months when cooling systems are essential, highlights the need for improvements in energy efficiency and access to better cooling systems to ensure both comfort and affordability for the residents of Plovdiv.

- **Energy price**

  The average annual electricity cost for a household in Plovdiv is approximately 510€, which is notably lower (21%) than the national average of 644€. This indicates that residents of Plovdiv are paying less for electricity compared to the average household in Bulgaria.

  The study focused on vulnerable households in Plovdiv, rather than covering all households in the city. This explains the difference between the energy consumption of these households and the national average. Households in Plovdiv tend to consume less electricity on average, which contributes to the reduced energy costs. However, it's important to understand that this lower cost is not necessarily an indicator of greater energy efficiency. Instead, it may reflect limitations in energy use due to financial constraints or the absence of modern systems, especially cooling systems, which are crucial during the hot summer months.

  This could point to a form of energy poverty, where lower electricity costs don't necessarily translate into better living conditions or comfort. In many cases, residents may be forced to limit their energy use despite experiencing discomfort due to inadequate cooling. As a result, although electricity prices in Plovdiv are lower, there is still a clear need for energy-efficient improvements to ensure both affordability and the comfort of residents.

- **Energy consumption per household**

  Of the 100 homes that have reported electricity consumption, only 16 of them (16%) have an annual electricity consumption higher than the national average.

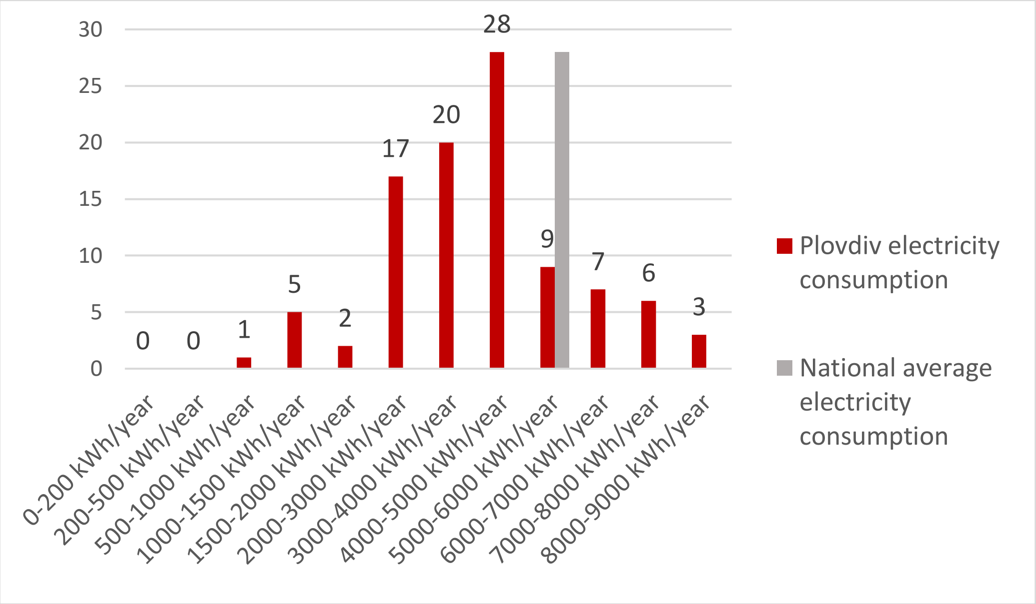

Figure 122. Electricity consumption per dwelling in Plovdiv.

Based on the data presented in the chart for electricity consumption in Plovdiv, most homes report annual electricity consumption falling between 2.000 and 6.000 kWh/year. Of the 100 homes analysed, the majority (approximately 75%) consume between 2.000 kWh and 6.000 kWh per year, with 28 homes consuming between 4.000 and 5.000 kWh/year, which represents the largest group.

Only a small number of homes (around 5-6%) consume electricity above 8.000 kWh/year, which suggests that many households in Plovdiv have relatively moderate electricity consumption.

This lower electricity consumption could be related to factors such as the size of the homes in Plovdiv and their energy efficiency. Many homes in the city may have smaller floor areas, which generally require less energy to maintain a comfortable temperature. Additionally, some households may be engaged in energy-saving practices, particularly in response to financial constraints or high energy costs. This suggests that while overall consumption is within the lower range, it could also reflect efforts to reduce energy usage in the face of potentially high utility costs.

5.8. Data analysis

- **Energy consumption vs. housing area**

Figure 123 represents the energy consumption (heating + electricity) of the homes in Plovdiv against the housing area.

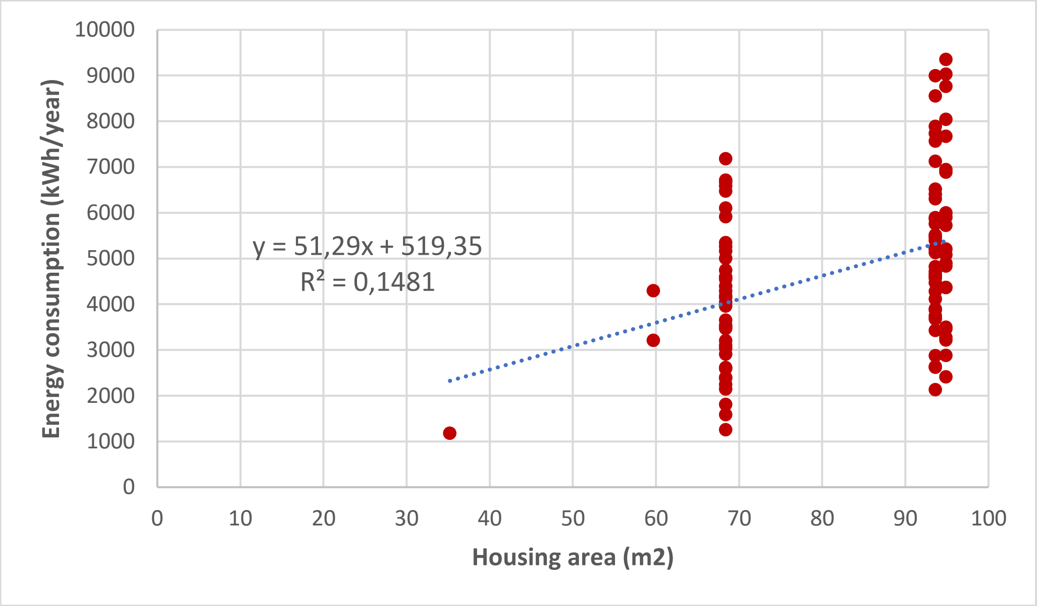

Figure 123. Energy consumption per housing area.

The trendline indicates a positive correlation between housing area and energy consumption in Plovdiv. As the size of the home increases, so does the energy consumption. Larger homes generally require more energy for heating, cooling, and the operation of household appliances. However, the R^2 value of 0,1481 suggests that the correlation between housing area and energy consumption is relatively weak due to the fact that the entire home is not heated, meaning that only about 14.81% of the variation in energy consumption can be explained by the size of the house. This indicates that while larger homes tend to consume more energy, other factors, such as the type of heating system, insulation quality, and household behaviors, also play significant roles in determining overall energy consumption.

- **Energy consumption vs. number of occupants**

  Figure 124 shows the relationship between number of occupants per dwelling and energy consumption (in kWh/year). The trendline suggests a positive correlation, indicating that as the number of occupants in a dwelling increase, tenergyconsumption also increases.

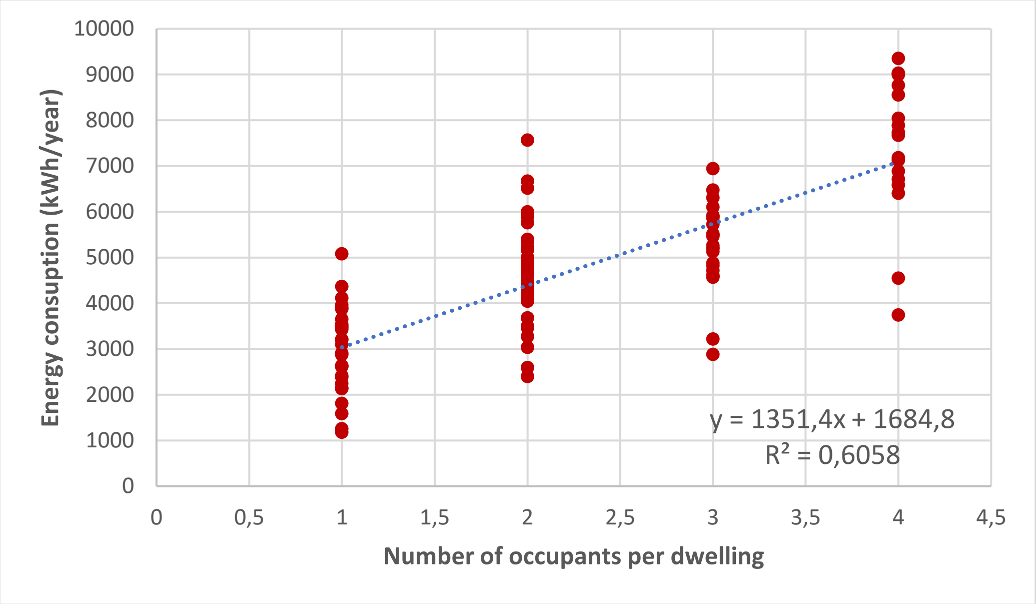

Figure 124. Energy consumption per number of occupants in Plovdiv.

The equation for the trendline is y = 1.351,4x + 1.684,8, where x represents the number of occupants, and y represents energy consumption. This suggests that each additional occupant adds approximately 1.351,4 kWh/year to overall energy consumption.

The R² value of 0,6058 indicates a moderate correlation between the two variables, meaning that about 60,58% of the variation in energy consumption can be explained by the number of occupants. While the number of occupants is a significant factor in determining energy consumption, other elements such as the size of the dwelling, insulation, and the type of heating or cooling systems may still play important roles in influencing overall energy use.

- **Energy consumption vs. year of construction**

  Figure 125 illustrates the relationship between energy consumption (kWh/year) and the year of construction for the homes in Plovdiv. The trendline shows a very weak negative correlation between the year the homes were built and their energy consumption. Specifically, energy consumption tends to decrease as the construction year progresses, but the R² value of 0,0024 suggests that this relationship is extremely weak.

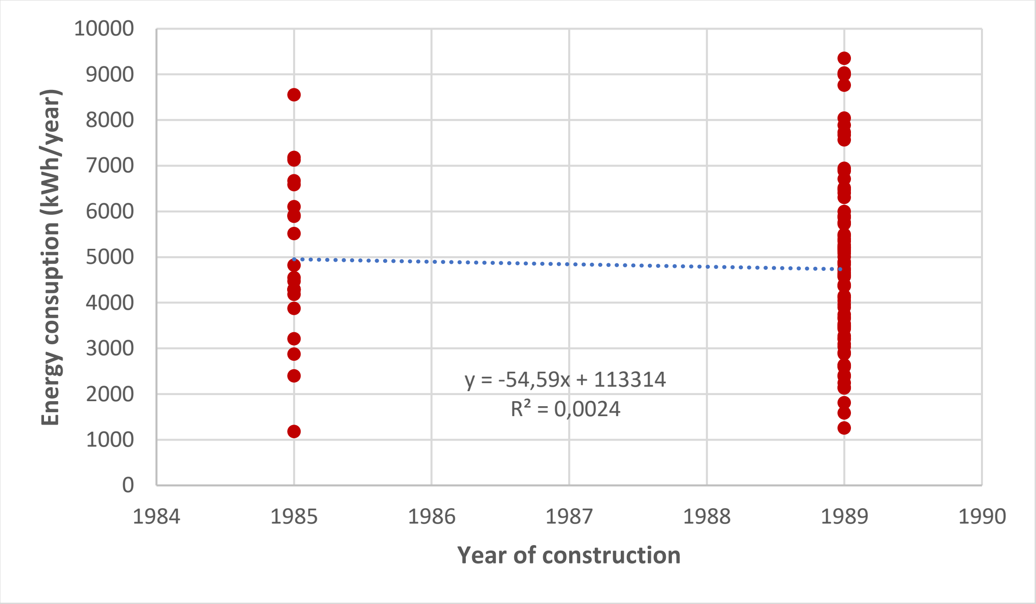

Figure 125. Energy consumption in Plovdiv dwellings per year of construction.

It´s important to consider that the sample size may not be large enough to provide a fully representative analysis, especially since factors such as local climate, household habits, building conditions, and the specific characteristics of the heating systems may have a more significant impact on energy consumption than the construction year itself. Therefore, although the trendline suggests a slight decrease in energy consumption with newer homes, this finding is not conclusive enough to firmly establish a direct relationship between energy consumption and the year of construction.

- **Energy consumption vs. thermal comfort**

In Figure 126, the relationship between energy consumption (kWh/year) and thermal comfort assessment for the homes in Plovdiv is illustrated, aiming to explore whether higher energy expenditure translates into better living conditions.

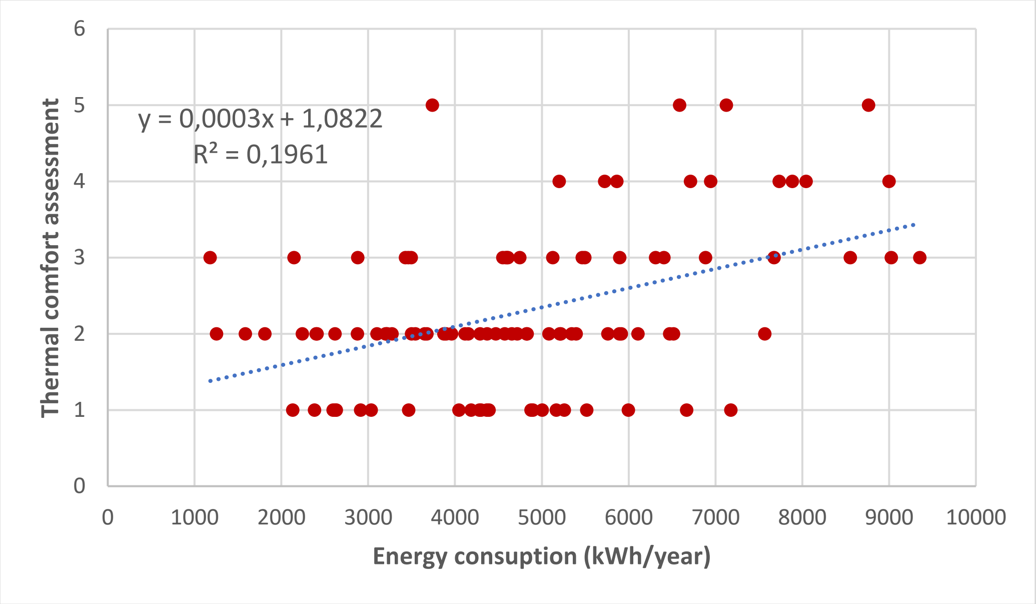

Figure 126. Thermal comfort assessment per energy consumption.

The trendline shows a positive correlation, with an R² value of 0.1961, indicating a weak relationship between energy consumption and thermal comfort assessment. This suggests that while there is some tendency for higher energy consumption to be associated with better thermal comfort ratings, the correlation is not strong. The low R² value means that most of the variation in thermal comfort assessment is not explained by energy consumption.

This moderate correlation could indicate that while energy consumption might have some impact on perceived comfort, factors such as insulation quality, heating system performance, and individual household preferences likely play a more significant role in the residents' thermal comfort assessments. Furthermore, the assessment of thermal comfort could be influenced by subjective perceptions, which might not fully align with the actual energy usage or efficiency of the heating systems.

- **Housing area vs. thermal comfort**

Figure 127 analyses the relationship between housing area (m²) and thermal comfort level for homes in Plovdiv, to determine whether the size of the home influences the living conditions and thermal wellbeing of its residents.

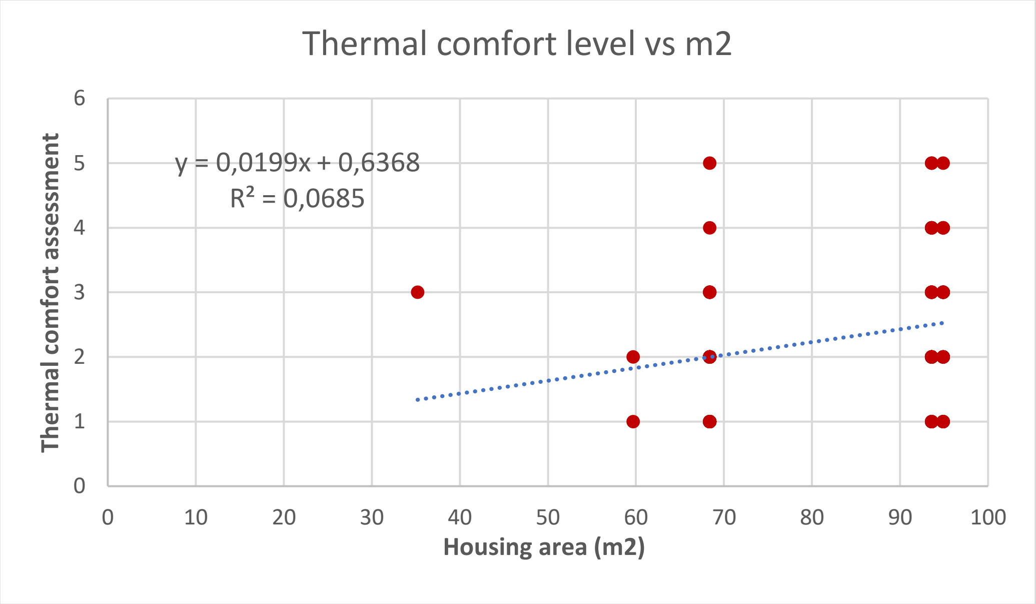

Figure 127. Thermal comfort assessment per energy consumption.

The trendline suggests a very weak positive correlation, with an R^2 value of 0,0685. This low R^2 value indicates that only 6.85% of the variation in thermal comfort can be explained by the size of the home.

Although there is a slight upward trend, the weak correlation shows that housing area is not a major factor in determining thermal comfort in these homes. Larger homes do not necessarily lead to higher comfort ratings. Additionally, since the homes in this dataset have relatively similar sizes, with most being of moderate size, there is not enough variability to make strong conclusions about the impact of housing area on thermal comfort. Other factors, such as insulation quality, heating system efficiency, and individual preferences, may play a more significant role in determining thermal comfort.

5.9. Score of the energy assessment

According to the guide, three vulnerability levels have been defined for the homes analysed in these energy studies: Low, Medium, and High. The threshold values for each level are selected so that the upper limit of the score for each category indicates the urgent need for energy rehabilitation interventions in those homes.

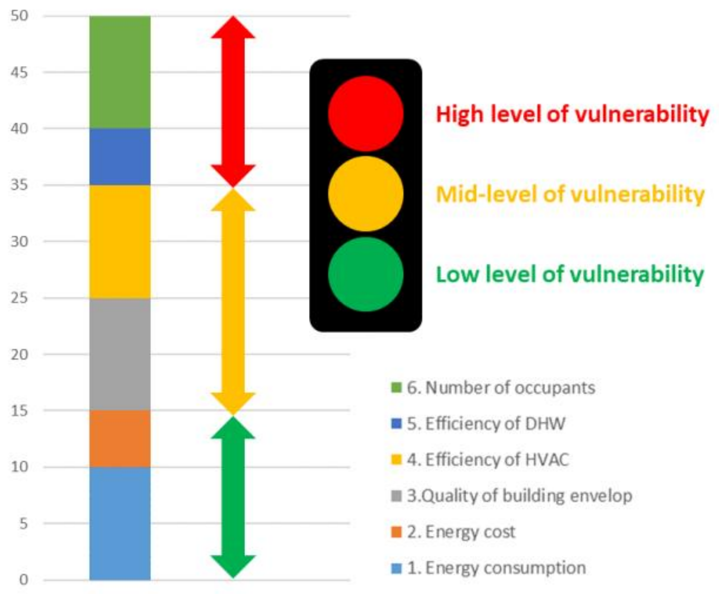

Figure 128. Example of thresholds determined to differentiate the three levels of housing energy vulnerability.

For the 100 homes studied in Plovdiv, the results obtained are as follows:

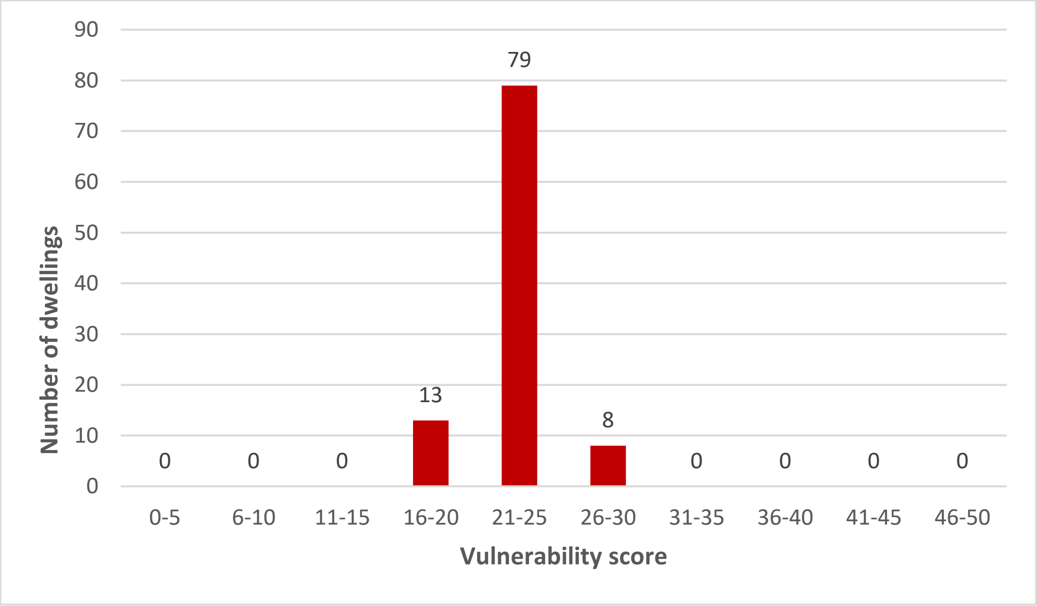

Figure 129. Number of dwellings per vulnerability level.

From this data, the following conclusions can be drawn:

- A total of 79 homes fall within the medium vulnerability level, with vulnerability scores ranging between 21 and 25 points. This accounts for 79% of the total homes analysed. These homes should be prioritized for energy rehabilitation interventions, as they are more vulnerable to energy poverty and inefficient energy use.

- 13 homes have vulnerability scores between 16 and 20, indicating that these properties are on the threshold between low and medium vulnerability. While they are not as vulnerable as those in the 21-25 range, they still require attention to reduce energy inefficiencies and improve living conditions.
- Only 8 homes fall within the low vulnerability level, with scores ranging from 26 to 30 points. These homes are relatively less vulnerable and may not require urgent intervention, although improvements could still enhance their energy efficiency and comfort.

This analysis reveals that many homes in Plovdiv are in the medium vulnerability range, highlighting the need for targeted energy rehabilitation efforts to address the significant energy inefficiencies and mitigate the risks of energy poverty for a large portion of the population

Conclusions

The energy studies carried out in the framework of LIFE ReHABITA confirm that energy vulnerability is a shared challenge across the pilot municipalities analysed. Although each local context presents its own particularities, the results show a common pattern: a large part of the housing stock is old, was built before modern energy efficiency standards, and still suffers from poor thermal performance, outdated systems and limited capacity to provide adequate comfort with a reasonable energy cost. In this sense, the report confirms that energy poverty is not only linked to low income, but also to the poor technical condition of dwellings and to the inefficiency of the systems used to heat, cool and provide hot water.

A second common conclusion is that the dominant situation in the project area is medium energy vulnerability. This means that, although the deficiencies detected are not always extreme, they are widespread and sufficiently serious to justify prioritised intervention. Lorca is the most critical case, as all the analysed dwellings fall within medium or high vulnerability, while in Gospić, Ploiești, Saldus and Plovdiv the majority of the sample is also concentrated in the medium-vulnerability range. This confirms the need for a broad renovation strategy, not limited only to a small number of extreme cases.

The analysis also shows that **higher energy consumption or higher expenditure does not necessarily translate into better comfort**. In several municipalities, households spend more or consume more energy without achieving better thermal conditions. This is especially clear in Lorca, where neither consumption nor energy cost show a meaningful relationship with perceived thermal comfort, and in Saldus, where the relationship is even more severe: higher consumption and higher expenditure are associated with worse comfort. In Ploiești too, higher energy spending does not improve living conditions, but rather reflects structural heat loss linked to poor insulation. These findings are particularly relevant because they show that the problem is not simply a lack of energy consumption, but the inefficiency with which energy is being used in deficient dwellings.

Another important conclusion is that the **size or age of the dwelling alone do not fully explain the observed vulnerability**. Although older buildings generally tend to perform worse, the report shows that other factors are often more decisive: the quality of the envelope, the efficiency of HVAC and DHW systems, the type of energy used, the number of occupants and the coping strategies adopted by households themselves. The studies therefore point to the need for integrated interventions that combine thermal renovation, equipment replacement, improved control systems and support for vulnerable households.

Finally, the report underlines that the technical dimension of energy poverty cannot be separated from its social dimension. In all municipalities, the presence of vulnerable groups such as children, older people and people with chronic illnesses increases the urgency of action. Improving the energy performance of these homes is therefore not only a matter of reducing consumption or emissions, but also of protecting health, improving well-being and guaranteeing decent living conditions.

Municipality-level conclusions

Lorca is the municipality with the most critical overall diagnosis. The housing stock analysed is largely old, with 125 out of 129 homes built before the CTE and 61 before the NBE-CT-79. The municipality also shows a strong dependence on electricity for heating, cooling and often domestic hot water, with 79% of homes using heat pumps and 81 households using electric water heaters. Electricity consumption is high, but neither greater consumption nor greater expenditure lead to better thermal comfort, which points to clear structural inefficiencies. In vulnerability terms, 126 dwellings are in medium vulnerability and 3 in high vulnerability, while none fall into the low-vulnerability category. This makes Lorca the municipality where intervention is most urgent, especially in homes close to the high-vulnerability threshold and in households with greater social vulnerability.

Gospić presents a different but equally relevant profile. All the homes analysed are apartments, most of them built before modern thermal protection standards. Heating is based entirely on biomass fireplaces, often without modern control systems, which contributes to inefficient use of energy. Average heating consumption is far above the Croatian reference, and 84% of homes exceed the national average for space heating. At the same time, no dwellings have air-conditioning, which creates an additional risk in summer and suggests unmet energy needs rather than good performance. Even though electricity consumption is below the national average, this may partly reflect restricted use of services rather than efficiency. In terms of vulnerability, 95 out of 100 dwellings are in medium vulnerability and only 5 in low vulnerability. Gospić therefore requires action focused not only on envelope performance, but also on heating system modernisation and summer comfort.

Ploiești shows a more moderate but still concerning situation. The entire sample consists of apartments built under outdated Romanian standards, which explains the persistence of thermal losses and high heating demand. Although no dwellings fall into high vulnerability, 70 out of 100 are in medium vulnerability, meaning that the dominant condition is still one of significant deficiency. One of the clearest findings is that higher energy costs do not improve comfort, but instead reflect poor thermal behaviour of the buildings. This suggests that in Ploiești the priority should be placed on improving the building envelope and reducing structural heat loss, in order to

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lower financial pressure on households and prevent medium-vulnerability homes from deteriorating further.

Saldus confirms the weight of obsolete construction standards in shaping energy vulnerability. All 116 homes analysed are apartments built under Soviet standards, with insulation requirements far below current European levels. Although these dwellings are very compact and often smaller than the national average, this does not protect residents from energy poverty, because structural inefficiencies remain very high. The report shows a particularly strong and concerning pattern: in Saldus, higher consumption and higher energy expenditure are associated with lower thermal comfort, which clearly indicates that households are paying more without living better. In vulnerability terms, 63 homes are in medium vulnerability and 53 in low vulnerability. Even without homes in high vulnerability, the municipality requires prioritised renovation of the medium-vulnerability stock, especially given the concentration of single-person and elderly households.

Plovdiv also presents a broad concentration of homes in medium vulnerability. All analysed dwellings were built before the introduction of stricter thermal regulations, which suggests a housing stock with limited energy performance. The report indicates that 79 out of 100 homes fall in the medium-vulnerability range, while 13 more are on the threshold between low and medium vulnerability. This means that, even in the absence of high-vulnerability cases, the scale of the need is still considerable. The weak relationship between energy consumption, housing area and comfort further suggests that structural factors such as insulation quality and system performance are more important than dwelling size in explaining living conditions. For Plovdiv, the priority should therefore be to target the large group of medium-vulnerability homes and the dwellings closest to the threshold, in order to improve both efficiency and household well-being.

Final conclusion

Taken together, the results of the report provide a solid basis for the next steps of LIFE ReHABITA. The evidence collected supports the need for interventions that combine building envelope improvement, more efficient and better controlled heating and DHW systems, replacement of inefficient equipment, and specific support for households in vulnerable situations. The studies also show that a common framework can be applied across all pilot municipalities, but that the response must still be adapted to the local reality of each city. In this way, the project can move from diagnosis to targeted action, with a clear technical and social rationale for prioritising renovation in the households that need it most.

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