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Building Assessment and Statistical Characterisation of the Mediterranean Social Housing Stock in Southern Spain

To cite this article: C M Calama-González *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1050** 012020

Building Assessment and Statistical Characterisation of the Mediterranean Social Housing Stock in Southern Spain

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Abstract. Given that the existing residential buildings are expected to become a huge part of the future stock due to their low replacement rate, retrofitting plans are crucial to meet 2030 and 2050 energy efficiency targets. Notwithstanding, an extensive assessment of the current energy and thermal performance of the stock must be conducted prior to the proposal of energy saving measures in order to properly tackle the retrofit process. Thus, the analysis and characterisation of the existing buildings under real variability conditions through statistical techniques is key to provide useful information at the stock level, instead of the most commonly single-building level approach. In the presented study, a statistical analysis on the most predominant variability ranges of the social housing stock of southern Spain (Andalusia) is carried out. Efforts are focused on the building characterisation of the linear block typology. To do so, an extensive database, which contains information on slightly under 39,500 social dwellings, is analysed. The conclusions reported in this study may be implemented into the construction of real case building archetypes through bottom-up building stock modelling techniques with the objective of assessing the real energy and thermal performance of the existing stock, providing useful information for public stakeholders.

1. Introduction

In 2020 the building sector were among the top-3 most dominant energy consumers in the European Union (EU) [1], accounting for 36 % of global final energy consumption and 37 % of energy-related CO_2 emissions, 17 % of which were caused by residential buildings. Even though CO_2 levels were reduced by 10 % compared to 2019, this was mainly due to lockdowns and slower economies derived from the COVID19 pandemic. Climate change is expected to noticeably increase surface temperatures and trigger more frequent and extreme weather phenomena [2]. In the Mediterranean region, this will lead to severe heat waves, which may cause indoor overheating and environment quality issues in buildings [3], with adverse impacts on human health and an increase in cooling energy consumption [4]. Hence, energy efficiency and long-term climate strategies have been promoted in the EU to foster building decarbonisation, reduce energy consumption and minimise CO_2 emissions.

In southern Spain (Mediterranean area), decarbonizing developments entails a major challenge: almost 95 % of the public social dwellings were built prior to the implementation of energy efficiency regulations [5]. Given the low replacement rate of existing buildings by new ones, they are expected to become an extensive proportion of the future stock. Thus, retrofit plans play a crucial role in meeting future energy targets. Yet, prior to the implementation of energy-saving measures, an extensive assessment of the current status of the existing stock is key to propose optimal retrofit strategies.

Building energy performance may be analysed through a macro (stock) or micro (single building) scale. Collecting data on building typologies and construction aspects [6], along with geographical and weather information, is of the utmost importance when assessing buildings under climate change. Even though the micro level allows the report of more precise results of the buildings' performance, this technique requires an extensive collection of data (construction, geometrical and physical characteristics, operational aspects…). To tackle this issue, applying bottom-up approaches through the construction of building archetypes, clustering buildings with similar characteristics, may be a viable solution. These archetypes may be used in urban and regional dynamic stock modelling to assess the current performance of the stock and the impact of retrofit policies [7].

In southern Spain, several studies focus on the performance of existing residential buildings. Monzón-Chavarrías et al. [8] analyse a single building case and extrapolates results to multi-family dwellings built in 1961-1980. Likewise, Caro and Sendra [9] address the analysis of indoor environment and energy performance of three residential case studies built in 1920-1940. Blázquez et al. [10] individually perform Energy Certification reports on selected residential buildings from 1951-1980 and 1970-1975, respectively, that are later implemented into a GIS tool to analyse the stock performance. Nonetheless, all these studies have a noticeable lack of scalability for the stock scale, since specific fixed geometrical, physical and constructive values are considered.

Using real stock statistical data is key to construct precise bottom-up building dynamic models to adequately predict the performance of the existing stock. This study provides statistical data on the building stock characterisation of the social housing dwellings of southern Spain, through the assessment of an extensive database, which contains information on approximately 39,500 dwellings built from 1970-2005. The main aim is to identify the most representative characterisation ranges of building variables, which may be later included into bottom-up building stock modelling approaches, analysing building archetypes instead of single building cases. These results will also be useful to energy policymakers and stakeholders for decision making in the retrofit process.

2. Methods

In order to statistically characterise the public social housing stock of southern Spain, information included in a public database provided by the Andalusian Agency of House and Retrofitting (AVRA) is assessed. This database includes information on 39,486 public social dwellings built between 1970-2005, regarding several variables: cadastral references, addresses, number of dwellings, building floors, building height, typology (single family, multi-family and mixed), year of construction, year and type of retrofit plan, window-to-wall ratio, type of window glass and frame and energy demand. All the aforementioned variables are obtained from Execution Projects and Building Evaluation Reports, which refer to buildings' conservation status, accessibility and energy efficiency aspects. Yet, no data on water heating, space conditioning systems, lighting or other energy end uses are available.

Firstly, this information, included in 5.838 files, is unified and rearranged in a single .csv file. Then, the content of the database is improved through the incorporation of other variables. From the Spanish Electronic Cadastral Platform, data on the average floor area per dwelling, building total built surface, orientation, architectural typology (linear, H block, tower or irregular) and urban typology (isolated, terraced, collective closed blocks, irregular) are collected. Likewise, the southern Spain climatic area according to the Spanish Building Technical Code is also incorporated into the database. This code establishes a specific climatic severity in winter (CSW) and climatic severity in summer (CSS), depending on the degree-day and solar radiation levels, so that the Andalusia territory may be classified into different climatic areas according to the combination of these parameters (figure 1). The CSW is defined by a letter from A to E (from milder to colder winters), while the CSS refers to a number from 1 to 4 (from milder to warmer summers). In southern Spain, the climatic areas resulting by the combination of the CSW and CSS indexes are: A3, A4, B3, B4, C3, C4, D2 and D3. All of these climatic areas are represented in the analysed building database. To obtain the main building characteristics of the social housing stock of Southern Spain, this database is statistically analysed through descriptive techniques, with Microsoft Excel. Although the presented study focuses on the linear block, previous analyses on other representative typologies were conducted [5, 11].

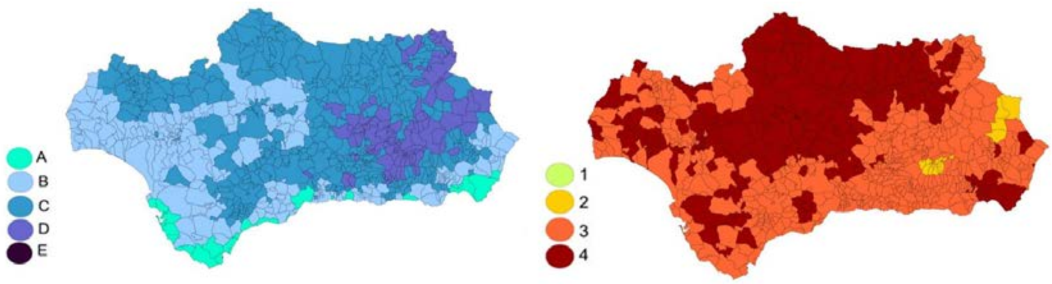


Figure 1. Classification of climatic areas in southern Spain: CSW (left) and CSS (right) indexes.

3. Analysis and discussion

Figure 2 shows a general classification of the social housing buildings in southern Spain into single-family, multi-family or other (mixed of the previous ones) categories. The values on the top represent the total number of dwellings per each climatic area. Since 77.5 % of the total dwellings are multi-family buildings (30.592 dwellings), efforts are focused on this specific category.

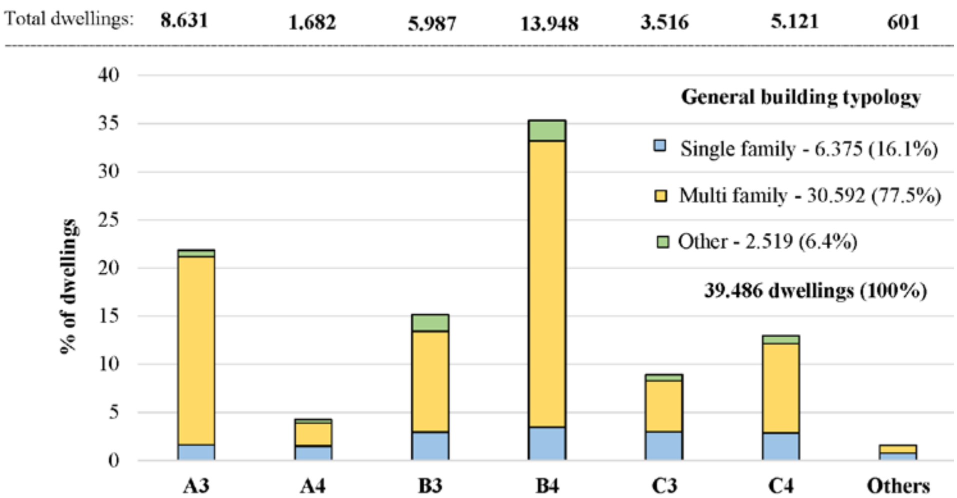


Figure 2. General building typologies of the social housing buildings.

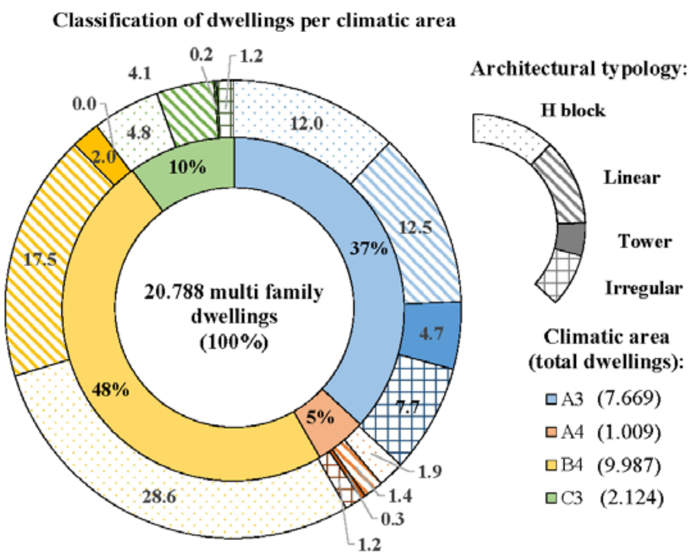


Figure 3. Architectural typologies of multi-family social dwellings.

Figure 3 classifies 22.788 multi-family dwellings in A3, A4, B4 and C3 climatic areas according to their architectural typology (H-block, linear, tower or irregular). It can be seen that the H-block (47.2 %) and linear block (35.5 %) are the most representative typologies in the aforementioned climatic areas, with the overwhelming majority of buildings in B4 (28.6 % and 17.5 %, respectively) and A3 climate regions (12 % and 12.5 %, respectively).

Figure 4 represents the urban typology (isolated, L-shaped, U-shaped, collective closed or irregular) of the total 7.372 linear multi-family dwellings located in A3, A4, B4 and C3 areas. The vast majority are isolated blocks (47.4 % in A3, 100 % in A4 and 73.7 % in C3). In contrast, 53.8 % of buildings are collective closed blocks in B4 area, while isolated blocks represent 20 % of the total dwellings. Generally, there is a negligible amount of L and U-shaped blocks (5 % and 5.8 %, respectively).

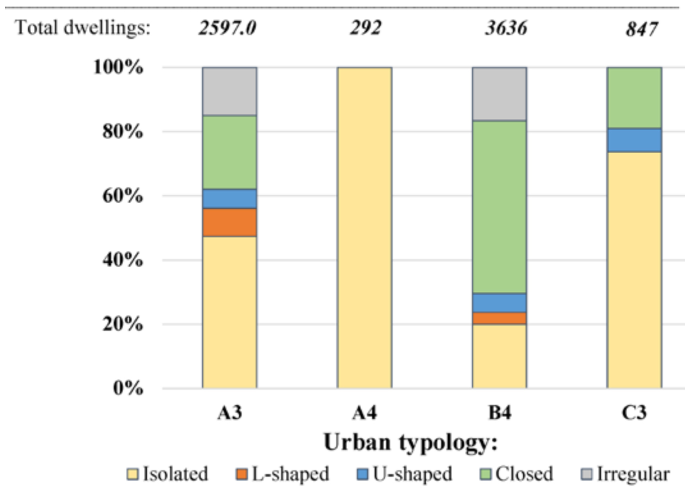


Figure 4. Urban typologies of linear multi-family blocks.

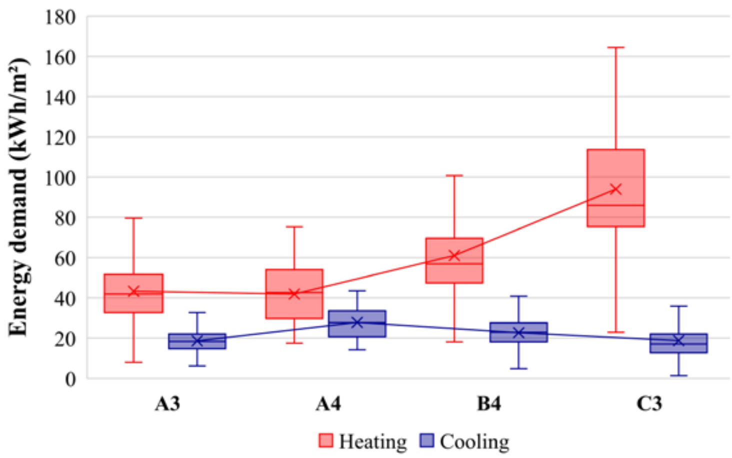
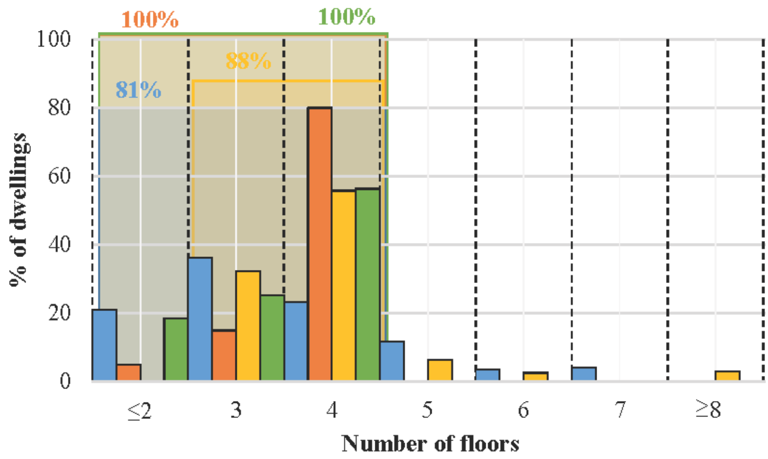


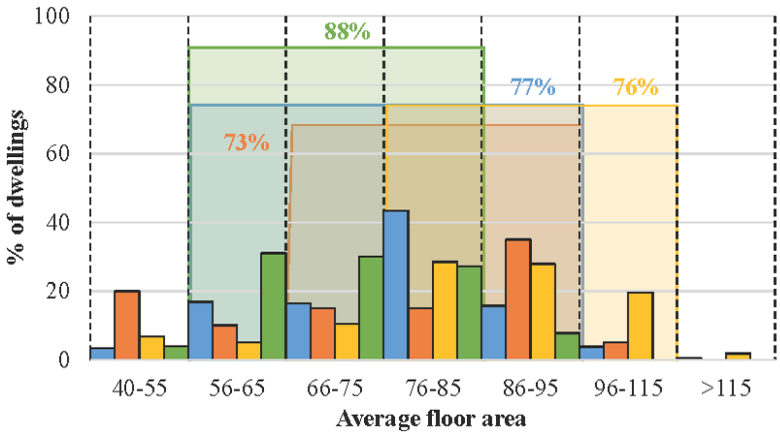
Figure 5. Heating and cooling energy demand of linear multi-family blocks.

Heating and cooling energy demand is shown in figure 5. In all climatic areas, heating demand is significantly higher than cooling demand, proportionally varying according to the climatic conditions. Heating demand ranges from 7.9-164.3 kWh/m^2 and cooling demand from 2.7-42.7 kWh/m^2, this last one being quite similar in all the areas. The highest values of heating demand are located in C3 areas.

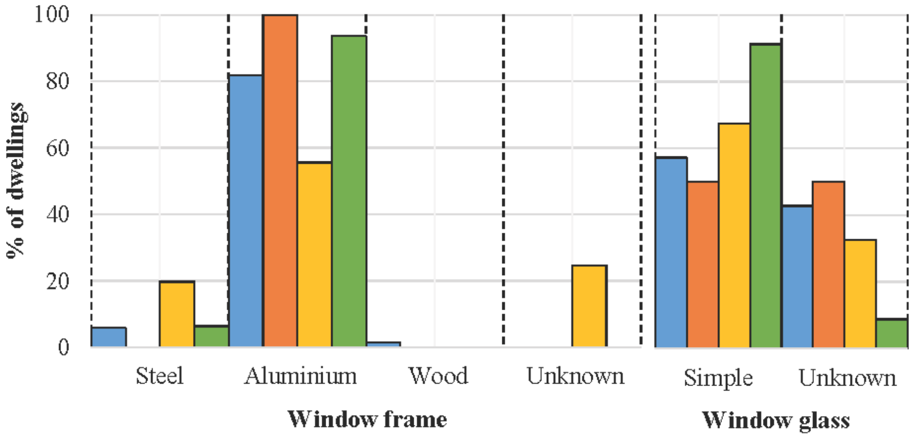
Figure 6 indicates the main variability ranges of several building parameters (number of floors, average floor area, window frame and glass types, percentage of glazing surface) of the linear blocks. Each colour is a climatic area and the numbers included indicate which percentage of blocks are represented when considering the specified value range. For instance, 88 % of the blocks would be represented in B4 climatic area if 3 to 4-floor buildings are considered. When 2 to 4-floor blocks are analysed, all buildings would be represented in A4 and C3 areas, and 81 % of the blocks in A3 region. Likewise, average floor values of 56-95 m^2, 66-95 m^2, 75-115 m^2 and 56-85 m^2 represent around 77 %, 65 %, 76 % and 88 % of the total linear blocks in A3, A4, B4 and C3 climatic areas, respectively. Regarding window characteristics, between 73-88 % of dwellings have a percentage of glazing surface of 10-20 % and the majority of social dwellings have aluminium frame and single-glazing windows.



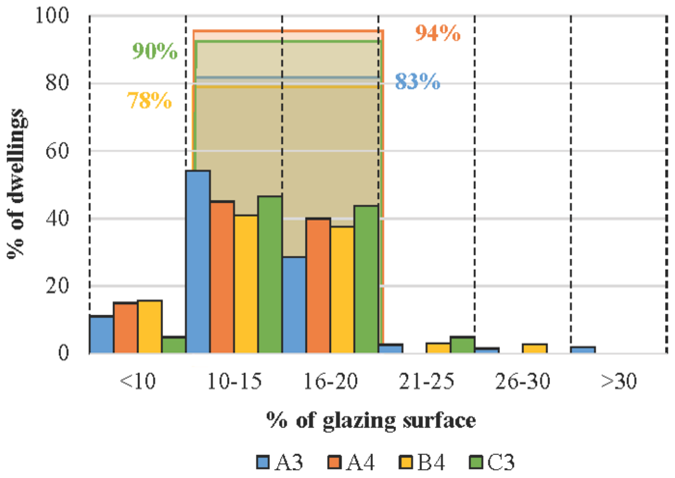
(a)



(b)



(c)



(d)

Figure 6. Variability ranges of main building variables of the linear blocks in southern Spain: (a) Numbers of floors; (b) Average floor area; (c) Window frame and glass; (d) % of glazing surface.

4. Conclusions

The presented study has reported useful data for the building characterisation of the existing social housing stock in southern Spain. This data may be used to adequately define the linear building archetypes that are representative of the main climatic areas of southern Spain, providing the necessary information for bottom-up stock modelling analysis. Among the main results reported, it can be highlighted that more than three quarters of the social dwellings built from 1970 to 2005 in southern Spain are multi-family buildings. Among them, H and linear blocks are the top-2 most representative architectural typologies in A3, A4, B4 and C3 climatic areas of southern Spain. Regarding the linear block typology, most of the buildings are 3 to 4-floor isolated and collective closed blocks, with average floor areas mostly between 56-115 m^2, 10-20 % window-to-wall ratio and with single glazing and aluminium frame windows. Finally, average heating and cooling demand values are around 40-80 kWh/m^2 and 20-30 kWh/m^2 in the linear blocks of southern Spain.

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Acknowledgments
The authors wish to acknowledge the financial support provided by the European Regional Development Fund (FEDER) and the Ministry of Transformation, Economy, Industry, Knowledge and Universities of the Regional Government of Junta de Andalucía, within FEDER 2014-2020 Operational Program through the research project “Energy vulnerability of the Andalusian residential stock. Indicators for decision making in the retrofit process at a regional scale” (US-1380835). Alonso and Calama-González acknowledge the support of the Gobierno de España through the IJC2018-035336-I (funded by MCIN/AEI/10.13039/501100011033 and, as appropriate, by “ESF Investing in your future” or by “European Union NextGenerationEU/PRTR) and FPU17/01375 Programs, respectively. Escandón acknowledges the support of the Aid for the recruitment, incorporation of Research PhD Staff of the European Social Fund and the Regional Government of Junta de Andalucía.