A PILOT STUDY OF THERMAL COMFORT IN SINGLE-FAMILY SOCIAL HOUSING IN THE CITY OF SANTA MARIA-RS, BASED ON QUALITATIVE DATA ANALYSIS

Kananda Lima (1); Minéia Scherer (2)
(1) Architect and Urban Planner, Master's student at the Post-Graduation Program in Architecture, Urbanism and Landscape Architecture in UFSM, kananda_lima@hotmail.com
(2) Doctor in Architecture, Professor at the Post-Graduation Program in Architecture, Urbanism and Landscape Architecture in UFSM, mineiaarq@gmail.com

ABSTRACT
Thermal comfort analysis in buildings has long been a tool capable of measuring the user's relationship with the designed environment. Based on an adequate project implementation, considering typologies and orientation of openings and envelopes, one can offer several possibilities of thermal conditions for a single space. In order to provide the best comfort conditions, based on the user's perception, it is necessary to master the characteristics of the local bioclimatic zoning and the properties of building materials, as well as their respective behaviors during different temperatures. In view of the aspects raised, the present work brings the realization of a pilot study on the thermal comfort of the user. The present research seeks to analyze qualitatively the perception of residents of single-family social housing Minha Casa Minha Vida in the Dom Ivo Residence, in the city of Santa Maria, Rio Grande do Sul. For the case study, forty interviews were conducted with residents between 18 and 84 years old, focusing on the sensations of thermal comfort during summer and winter in environments of prolonged stay as living room, kitchen and bedrooms. To validate the questionnaire model, it was submitted and later approved by the Ethics Committee of the Universidade Federal de Santa Maria. As a basis for the research, the forty interviews were equally distributed among dwellings implanted in four different orientations, which are: Southeast, Northeast, Northwest, and Southwest. The comparison of results between each of the façade orientations made it possible to verify which directions of openings and envelopes present higher levels of discomfort due to cold and heat. In addition to investigating the user's perception of the thermal comfort of a building typology, this research seeks to contribute to future works on the same theme, essentially in the optimization of social housing projects.

Key words: Thermal comfort, user perception, social housing.

1. INTRODUCTION

Thermal comfort in buildings is one of the architectural constraints that directly influences the quality of life of the user in several ways, ranging from providing sensations of well-being in the environment to promoting solutions capable of reducing energy consumption in housing. By studying the behavior of buildings related to solar orientation at different times of the year, it is possible to provide adaptations that enhance thermal comfort conditions, making artificial cooling or heating equipment less used.

One of the problems in the production of social housing in Brazil is the low financial investment in the construction of units. According to Moraes (2018), based on the SINAPI and SETOP spreadsheet, the average cost for the construction of a single-family social housing unit of 42.95m² with concrete walls (two bedrooms, living room, kitchen, and bathroom) the investment is R$42,354.65. The choice of materials, especially the building envelope, reduces the final cost significantly. In comparison with the use of conventional masonry, the cost for the production of the same building increases to R$ 61,180.12. Despite the existence of studies and relevant norms about the choice of adequate materials that provide a good thermal performance for the building, in most cases of social housing construction, lower cost units are chosen, directly compromising the good thermal performance of the building.

From the aspects of thermal comfort in buildings, the suitability for different bioclimatic zones becomes a tool capable of optimizing the performance as a whole. To this end, the NBR 15.220 standard - Thermal performance for buildings of social interest (ABNT, 2005) presents relevant recommendations applicable to the design phase of the building. Through appropriate design choices, such as an analysis of the solar orientation of the façade, ventilation and lighting strategies, and a study of the thermal transmittance of the envelope materials, it is possible to ensure that the dwelling will provide greater thermal comfort, especially during more atypical seasons of the year, with situations of more intense cold or heat.

With better adaptations of the buildings to climatic conditions, it is possible to obtain longer periods of thermal comfort in the dwelling, reducing the use of cooling and heating equipment, thus minimizing the use of electricity. Based on data from the National Energy Balance, it is estimated that the Brazilian residential sector is responsible for the consumption of 25.6% of the country's electricity (MINISTÉRIO DE MINAS E ENERGIA, 2017). According to data from the same source (2017) between the years 2005 and 2017, electricity consumption in households increased from 83 TWh to 134 TWh, representing a 61% growth over the respective years. Regarding the conditions that led to the increase in energy consumption, one can notice the growth in the purchase of air conditioning equipment, with data from the same source showing a 237% increase in the purchase of the product between 2005 and 2017.

Besides the costs for the acquisition of equipment that provide thermal comfort, the electricity bill becomes an additional burden on the income of the Brazilian population, especially for the residents of social housing that already have other financial limitations for being framed in specific income ranges. Based on these issues, this study aims, through the application of qualitative questionnaires, to assess the opinion of residents of single-family social housing units in the city of Santa Maria, Rio Grande do Sul, Brazil, about the thermal comfort of the housing units.

The research had as a case study the Dom Ivo complex, located in the Diácono João Luiz Pozzobom neighborhood, which has five hundred and seventy-eight housing units. It was applied to buildings with the same construction typology, financed by the Minha Casa Minha Vida program. Above all, the method was based on analyzing different solar orientation arrangements. Forty interviews were carried out, equally divided among four façade orientations: Southwest, Northeast, Northwest and Southeast. From the questions in the interview, it was possible to estimate which environments presented greater thermal comfort and discomfort during the summer and winter seasons, as well as to identify which electrical equipment was used to mitigate situations of cold and heat. After obtaining the data, the research was able to compare which façade orientation presented the most discomfort in the two most extreme seasons.

2. OBJECTIVE

The general objective of this article is to qualitatively analyze user perception regarding thermal comfort in single-family social housing in the city of Santa Maria, Rio Grande do Sul, located in Bioclimatic Zone 2. To organize the methodological steps, the research was categorized into three specific objectives:

- Determine the method for the elaboration of the questionnaire, identifying a scale that best defines the thermal sensations of the user;
- To analyze the building typology of single-family social housing, presenting the characteristics of the building envelope and openings;

- To study the thermal comfort of the dwellings in the case study based on user perception, using qualitative questionnaires as a method.

3. METHOD

The method used for the development of the research was the application of questionnaires based on the user's perception in a qualitative way. To prepare the model form, the typology of the housing units in the case study was analyzed, directing the questions to the analysis of thermal comfort in environments of prolonged stay, such as living room, kitchen and bedrooms, disregarding the bathroom. The body of the questionnaire presented in its totality ten objective questions, relating the user's feeling of comfort in the dwelling environments during the summer and winter seasons.

To define the degree of comfort perceived by the users, it was used the Fanger scale, which relates seven different levels of thermal sensation for the human being. The method applied by Ole Fanger, in 1972, sought to associate the heat lost by the skin due to the surface area of the body, the internal heat generated by metabolic processes, and the average skin temperature. The purpose of Fanger's experiment was to obtain a method that could predict the sensation and degree of thermal discomfort of people subjected to moderate conditions and determines which thermal conditions are more acceptable for human well-being (COUTINHO, 2014). The figure 1 shows the scale determined by Fanger to measure different sensations of comfort:

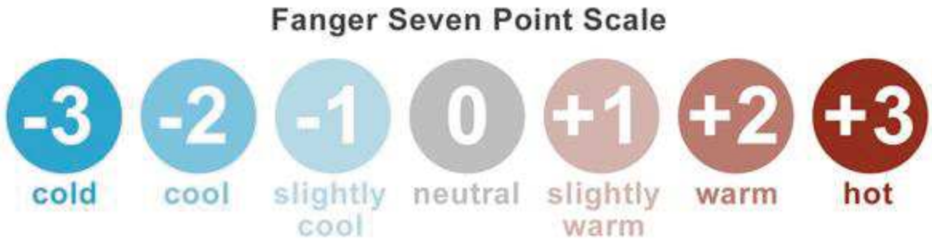

Figure 1 – Fanger Seven Point Scale (Overbey, 2013).

After preparing the questions of the model questionnaire and using the Fanger scale as an alternative for the answers about thermal comfort, pilot interviews were conducted so that the final form could receive the final adjustments. After consolidating the model questionnaire, the research was applied in forty housing units of the case study, using as criteria the variation in solar orientation of the entrance of the houses. The exploratory basis of the research was the relationship between the solar orientation that offers shorter periods of thermal discomfort during the summer and winter seasons.

As this is an article that is the product of the methodology applied in a dissertation in progress, the research seeks to address the user's perception during the summer on the thermal comfort of environments of prolonged stay in single-family social housing, taking as a variant the different facade orientations in the implementation of the housing complex of the case study. The questionnaires were validated through approval by the Ethics Committee of the Universidade Federal de Santa Maria. Thus, it was possible to verify if the model had the appropriate format to be definitively applied.

Other parameters taken into consideration were the characteristics of Bioclimatic Zone 2 and the solar trajectory of the region, which causes environments to present varying thermal sensations throughout the year. Because of the following climatic profile, users were also asked whether heating or cooling equipment was used during periods of intense cold or heat.

3.1. Characterization of the Bioclimatic Zone and the Case Study Dwellings

According to data from IBGE (2010), it is estimated that the city of Santa Maria in Rio Grande do Sul has a population of 278,838 inhabitants. In view of the climate characterization presented by NBR 15220 - Part 3 - Brazilian Bioclimatic Zoning and construction guidelines for single-family houses of social interest (2005 p.3), the Brazilian territory is divided into eight distinct bioclimatic zones. Each of the demarcated areas presents different climatic behaviors throughout the year. The figure 2 shows the demarcation of the city of Santa Maria, in Rio Grande do Sul, in the following bioclimatic context:

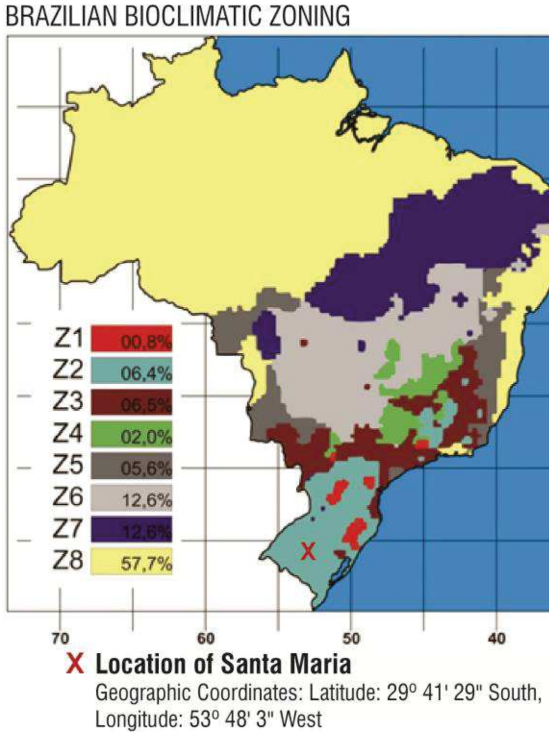

Figure 2 – Brazilian Bioclimatic Zoning (Bioclimatismo. Adaptaded by the authors, 2020).

According to the climatic data presented by the Projeteee platform (2021), the average monthly temperature has a variation between 24.93ºC and 13.42ºC, with higher temperatures during the month of January and lower in June. The monthly relative humidity varies between 68.95% and 86.25%, with higher percentages in June and lower ones in January. The period with the heaviest rainfall occurs in December, which can reach an average of 329 mm of rain during the respective month. The predominant wind direction for the region is eastward, followed in a secondary manner by the southeast direction.

About the housing complex of the case study, the Dom Ivo residential complex is located in the Diácono João Luiz Pozzobom neighborhood. According to Oliveira (2016), it was built under the Minha Casa Minha Vida program, and was completed and delivered by the Santa Maria City Hall in December 2015. The complex presents five hundred and seventy-eight housing units, consisting of a living room integrated with the kitchen, two bedrooms, and a bathroom, with a total floor area of 36.04 m². The dwellings were implanted each on 8.25-meter wide lots and are terraced by the wall of the bedrooms. With the same layout of areas, there are units with adaptations for people with special needs (PNE).

Also according to Oliveira (2016), it is pointed out that, as well as other housing developments, the Dom Ivo residential complex has the same construction typology parameters as other residential buildings built nearby. According to Linck (2013), the Zilda Arns residential, built in the same phase as the case study, has the same standardization. According to the author, the external wall envelopes are made of cast-in-place concrete, with air incorporation and a thickness of ten centimeters. The internal walls have the same air incorporation and thickness in the bathroom and kitchen, only in the bedrooms the wall thickness is reduced to eight centimeters. In the wall where the twinning of the two housing units is done, the thickness is thirteen centimeters.

It is presented by Linck (2013) that the roofing is composed of ceramic tiles with a thickness of one centimeter. The lining used is composed of PVC and is one centimeter thick. Regarding the building's openings, the windows are made of steel and painted white, with sliding leaves in the living room windows. In the bedrooms, the shutters have blinds, while in the bathroom the opening is through a fully reversible window. The external doors are also made of steel combined with glass to provide natural lighting and are also painted white. The internal doors are made of semi-hollow wood. The figures 3 and 4 shows the model of the semi-detached house in the Dom Ivo Residence, with a variation of the model specified by an external painting in yellow, blue and orange:

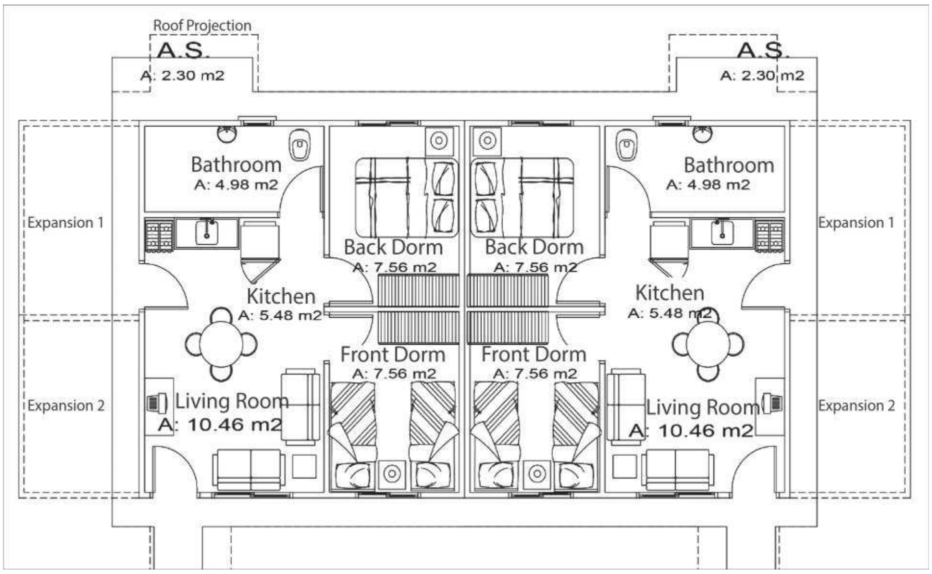

Figure 3 - Model of the semi-detached units of the Dom Ivo residence (Santa Maria City Hall. Adapted by the authors, 2020).

Figure 4 - Housing Unit of the Dom Ivo Residential Complex (Authors, 2020).

4. RESULTS

As described in the methodological step, the pilot questionnaires were applied face-to-face during the summer of 2019/2020 to obtain partial results and to certify that the questionnaire model was adequate. The test application took place on February 8, 2020, before the pandemic, along the hours of 3:00 pm to 5:30 pm in the Dom Ivo Housing Estate. Through meteorological data provided by INMET (2020) about the Santa Maria-A803 station, it was detected that the maximum temperature presented on the day was 34.8°C and maximum wind speed of 2.8 m/s.

Residents of 40 different dwellings were interviewed, being divided among four types of solar orientation existing in the cluster, with reference to the main entrance of the dwelling: Northeast, Northwest, Southwest and Southeast. Ten questionnaires were distributed for each type of orientation of the main façade. For the application of the definitive questionnaire model and the final product of the dissertation, interviews will be carried out during the winter period in order to compare the sensations of the two most extreme seasons, seeking to observe if the weather at the time of application directly influences the results of the answers.

During the execution of the pilot questionnaires, houses that did not present many changes in relation to the original model delivered were chosen. To this end, houses with very high and closed walls or gates without bars were considered inappropriate so that there would be no interference with the ventilation or natural lighting aspects. Likewise, the questionnaires were not applied in units that presented later expansions, increased coverage, or change of use to commercial. The application was also avoided in dwellings with a lot of vegetation and, as a priority, that was protecting the openings.

The map in figure 5 shows the distribution of the homes in the region where the questionnaires were applied, considering a margin of non-existent or non-respondent homes:

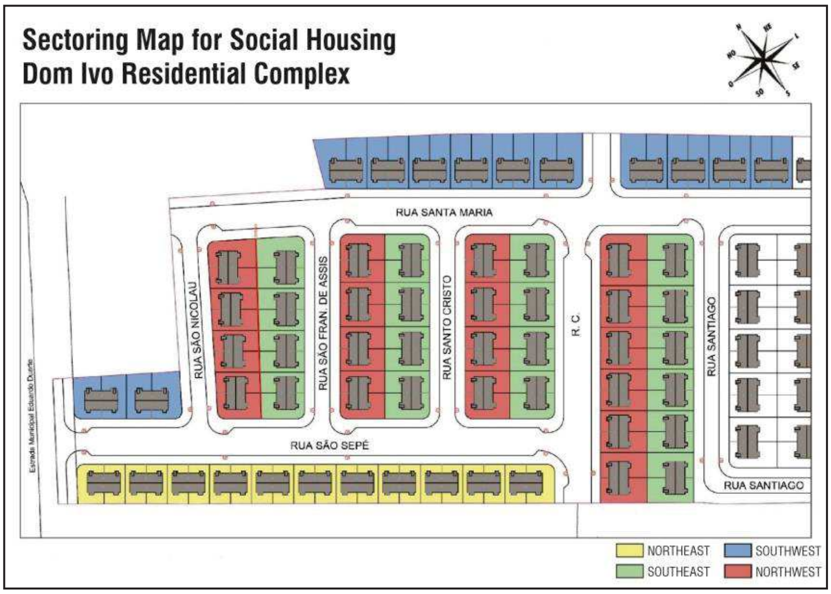

Figure 5 - Map of the Questionnaire Application Region (Authors, 2020).

The age range of the respondents varied between 18 and 84 years old, with the greatest participation of elderly women who lived alone. The average obtained by adding up the age of the interviewees is 45 years old. Through the same method, it was possible to estimate that the average number of residents per unit is 3.4 people per dwelling. Following the preliminary data collection, the respondents were asked about their thermal preferences. The question aimed to verify whether the respective factor directly influences the users' perception of thermal comfort, with the possibility that those who prefer cold were more sensitive to heat, and vice versa.

For the individuals in the houses on the Northeast façade, five people showed a preference for mild weather and five for cold. In the case of the Northwest orientation, only two people answered a preference for cold, while five opted for mild weather and three for warmth. For the Southwest orientation, six responses were obtained for cold and four for mild weather. For the Southeast orientation, six respondents were estimated to have a preference for cold, three for mild weather, and one for warm.

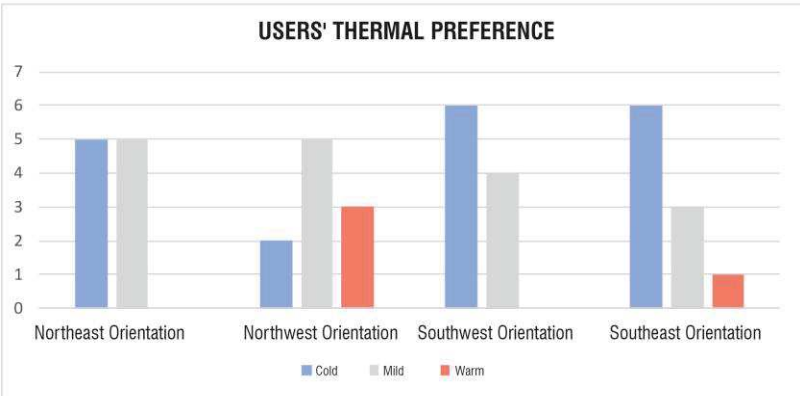

Figure 6 - Users' Thermal Preference Graph (Authors, 2020).

For the phase of questions related to thermal comfort, the Fanger seven point scale, described in the methodology, was used to obtain the perception of users. As previously mentioned, for each type of orientation, 10 questionnaires with objective questions were applied. The first question referred to the most used room in the residence, and most residents answered that the living room/kitchen was the most used room for prolonged stay. It was also described by the interviewees that the sensations in the living room and in the kitchen were the same, because the two environments were integrated. For these and the other questions in the questionnaire, the living room and kitchen were considered as a single room. Through the process and data analysis, the following chart was developed:

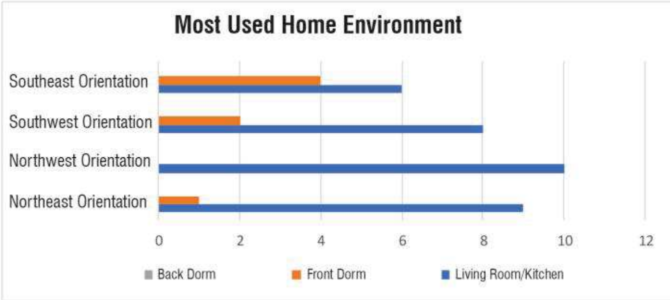

Figure 7 - Chart (Author, 2020).

Regarding the other questions in the questionnaire, it was asked about the thermal sensation in the long-stay environments described above: living room/kitchen, front dorm, and back dorm. The basis of the survey alternated between asking about the thermal sensation in the environment during the summer and during the winter. Since it was a form with objective questions, the alternatives available to the respondents were taken from the Fanger scale, as mentioned in the methodological stage. The structure of the questions was brought as shown below:

Questionaries' Structure – 10 Questions Interview	Possible Answers
1-Most used room of the house	Living Room/Kitchen; Front Dorm; Back Dorm
2-Evaluate the Living Room during the summer	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
3-Evaluate the Living Room during the winter	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
4- Evaluate the Kitchen during the summer	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
5- Evaluate the Kitchen during the winter	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
6- Evaluate the Front Dorm during the summer	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
7- Evaluate the Front Dorm during the winter	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
8- Evaluate the Back Dorm during the summer	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
9- Evaluate the Back Dorm during the winter	Hot; Warm; Slightly Warm; Neutral; Slightly Cool; Cool; Cold
10-Do you use any heating or cooling equipment in the house?	Yes; No; If yes, what types

Table 1 - Structure of the applied questionnaire (Authors, 2020).

In order to synthesize the acquired data, it can be seen that the living room/kitchen located in the dwellings with the main entrance of Southwest orientation presented the highest number of respondents with heat discomfort during the summer. Consecutively, the buildings of Northwest orientation presented the second highest heat discomfort ratio in the mentioned environment. The lowest ratio of heat discomfort in the living room/kitchen was detected in the Northeast oriented dwelling. For the winter period, the living room/kitchen presented the highest discomfort by cold in the dwellings of Southeast main facade. On the other hand, the living room/kitchen orientation with the least cold feeling was in the Southwest direction.

The responses obtained for the front dorm were similar to those of the living room/kitchen, since both have their openings facing the same façade. The northwest-facing front bedroom showed the highest summer heat discomfort index, followed by the southwest-facing one, with an almost identical number of answers for the two orientations. The front dormitories with a Northeast layout showed lower levels of heat discomfort during the summer. About the feeling of the same environment in winter, the dwellings of main Southeast orientation were detected with higher discomfort by cold. On the other hand, the Southeast and Northeast orientations presented higher neutrality and thermal comfort in the described environment.

Concerning the data about the back dorm, it was noticed that, because it is opposite the openings of the living room and front bedroom, it generally has lower rates of heat discomfort in the summer. Above all, the Southeast orientation manifested higher levels of this type of discomfort in the summer. The Northeast orientation was the one that presented, according to the respondents, the least sensation of heat in this season. For the winter period, higher perceptions of cold were detected in the back dorm. The Northeast and Northwest orientations of the main façade presented the most this type of discomfort. The southeast orientation showed a greater sensation of neutrality in the environment during the winter period.

The following scheme presents the systematization of the mentioned data, using a color scale to demonstrate the thermal sensation in each of the mentioned environments. Next to each of the colors, the number of votes of the respondents is presented:

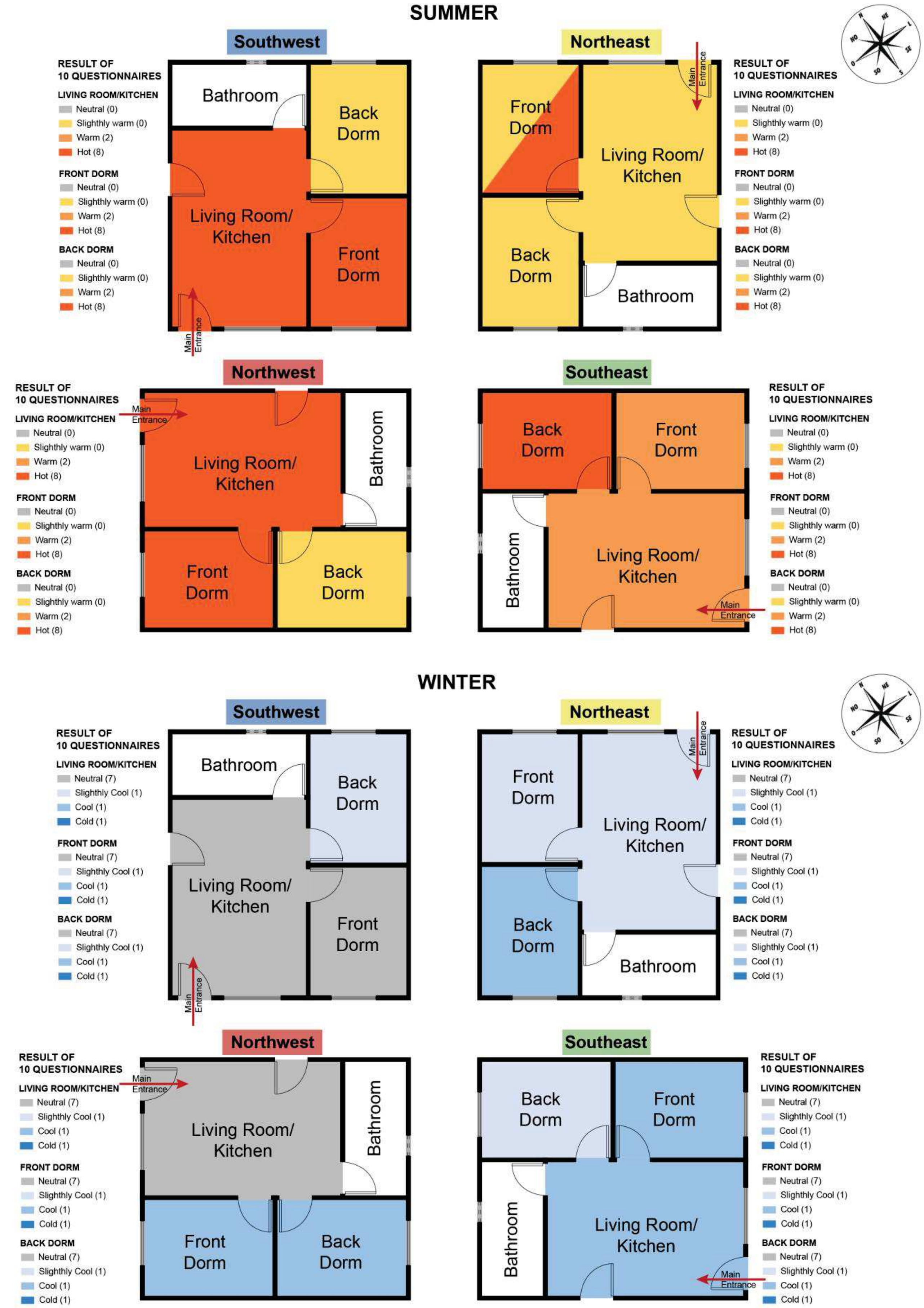

Figure 8 - Diagram About the Thermal Sensation of The Users in the Case Study (Authors, 2021).

In the last alternative of the questionnaire, it was asked about the use of artificial heating and cooling equipment, disregarding devices such as fans and humidifiers and accounting for air conditioners and heaters because they consume more energy and have greater potential to optimize environmental comfort. Unlike the other questions, the following question referred to the use of the equipment in any room of the building. Above all, as the respondents said, most of the equipment was located or installed in the front and/or back dorms.

For the respondents from the dwellings of the main façade orientation in the Northeast direction, six respondents stated that they did not have any cooling or heating equipment, while two stated that they had air conditioning and two had heaters. For the Northwest orientation, five respondents said they had no equipment of any kind, three said they had air conditioning, and two said they had a heater. For the Southwest orientation, nine people stated having none of the equipment, while only one respondent stated having air conditioning. In the Southeast orientation, eight people had no equipment, one person had air conditioning, and one last respondent used both air conditioning and a heater. The following chart shows the relationship of the data on the use of artificial cooling and heating equipment in dwellings:

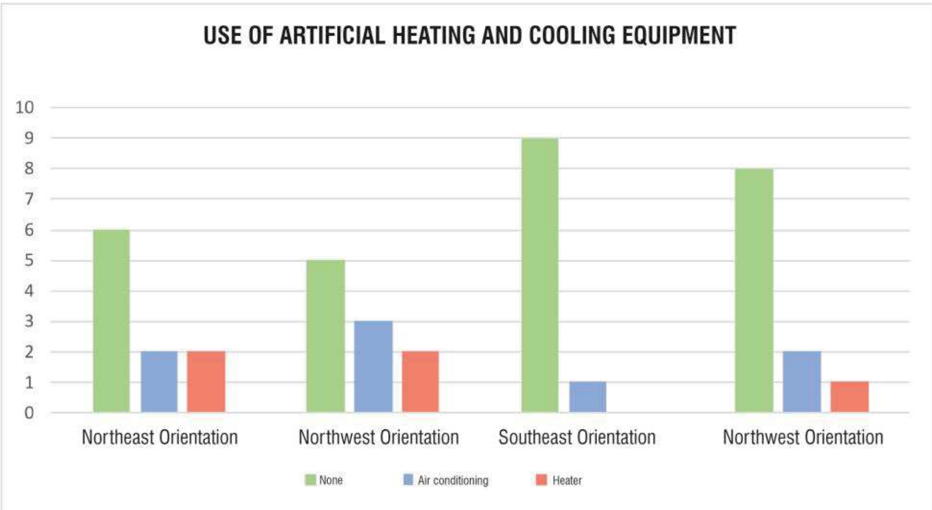

Figure 9 - Graph on the Use of Artificial Heating and Cooling Equipment (Authors, 2020).

5. CONCLUSIONS

From the qualitative analysis of the results, it was possible to verify the perception of thermal comfort of different types of users in the social housing units of the case study. Despite the different physical and age profiles of the interviewees, their sensations about the thermal comfort and discomfort have linearity and convergence of opinions. Based on the division of the questionnaire application into four types of orientations, with the main façade of the building as reference, it can be observed how the solar trajectory interferes directly in the well-being of the users of the buildings. Besides the fact that solar orientation impacts in the permanence in environments, the research suggests that the use of artificial heating and cooling equipment can have prolonged use in the case of environments that present higher levels of thermal discomfort.

Although this is a pilot study, the consistency of the method applied has raised that the research can be resumed along similar lines to the pilot phase. Preliminarily, it is also analyzed that the implementation of social housing has a significant influence on the users' feelings of thermal comfort. For environments with prolonged stay, it is notable that the orientation of the openings and, above all, the insolation time of the envelopes during the hottest or coldest periods of the day are the main factors that compromise the feeling of comfort in the environments studied.

Given the data collected, this research seeks to contribute to future works in the production of tools that bring concisely the user's perception of thermal comfort, especially in social housing. In addition to the analysis of the residents' sensations, the research emphasizes the importance of solar orientation in the project implementation process. During the following stages of the dissertation, due to the pandemic, the application of the questionnaires was done virtually, especially the quality of the data was preserved, despite a smaller number of respondents.

REFERENCES

ASHRAE55. **Thermal environmental conditions for human occupancy**. American Society of Heating, Refrigerating and Air-conditioning Engineers Inc. Atlanta, GA, USA, 2013.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. **NBR 15.220-2:** Desempenho térmico de edificações: Parte 2: métodos de cálculo de transmitância térmica, da capacidade térmica, do atraso térmico e do fator solar de elementos e componentes de edificações. Rio de Janeiro, 2005.

_______. **NBR 15.220-3:** Desempenho térmico de edificações: Parte 3: zoneamento bioclimático brasileiro e diretrizes construtivas para habitações unifamiliares de interesse social. Rio de Janeiro, 2005.

COUTINHO, Brenda Rodrigues. **Avaliação De Conforto Térmico Em Ambientes Naturalmente Ventilados: Um Exemplo Em Restaurante Universitário**. 2014. 170 f. Dissertação (Mestrado em Arquitetura, Tecnologia e Cidade) - Faculdade de Engenharia Civil, Arquitetura e Urbanismo da Unicamp, Campinas, 2014.

FANGER, P. O. **Thermal comfort analysis and application in environment engineering**. New York: McGraw-Hill. 1970.

Instituto Nacional de Meteorologia. Available in: www.inmet.gov.br. Acessed in 13th abril of 2020.

MINISTÉRIO DE MINAS E ENERGIA. **Balanço Energético Nacional**, EPE, 2017. Disponível em: https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2017.pdf

LINCK, Gabriela Inês. **Avaliação Do Desempenho Higrotérmico De Habitações De Interesse Social Em Santa Maria/RS**. 2013. 259 f. Dissertação (Mestrado em Arquitetura e Urbanismo) - Universidade Federal de Santa Maria, Santa Maria, 2013.

MORAES, Bruna Demétrio. **Comparação de Custos de Unidades Habitacionais de Interesse Social Produzidas por Sistemas Construtivos Convencional e Paredes de Concreto.** 2018. Trabalho de Conclusão de Curso (Graduação em Engenharia Civil) – Faculdade de Engenharia Civil – Universidade Federal de Uberlândia, Uberlândia, 2018.

OLIVEIRA, Daiana Fauro de. **Avaliação Pós-ocupação em Conjunto Habitacional de Interesse Social Construído com Paredes de Concreto Moldadas In Loco na Cidade de Santa Maria, RS**. 2016. 117 f. Dissertação (Mestrado em Engenharia Civil) - Faculdade de Engenharia Civil da Universidade Federal de Santa Maria, Santa Maria, 2016.

OVERBEY, D. **Evaluating Human Thermal Comfort, Indianapolis**, February 7, 2013. Available in: http://danieloverbey.blogspot.com/2013/02/evaluating-human-thermal-comfort.html. Acessed: 10th april of 2021.

PROJETEEE – Projetando Edificações Energeticamente Eficientes. **Dados climáticos**: Santa Maria/RS. 2020. Available in: http://projeteee.mma.gov.br/dados-climaticos/?cidade=RS+-+Santa+Maria&id_cidade=bra_rs_santa.maria.839360_inmet. Acessed: 4th april of 2021.

ACKNOWLEDGEMENTS

The authors thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for the financial support.