ANALYSIS, CLASSIFICATION AND SIMULATION OF ENERGY EFFICIENCY OF COMMERCIAL TYPOLOGIES DOWNTOWN PELOTAS CITY

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ABSTRACT

The concern on the natural resources defense and their sources has increasingly gained space worldwide. Several countries have already adopted energy conservation policies, and this has changed the way of designing. This way, the aim of this work is to identify the pattern of the energy efficiency of commercial typologies of Pelotas-RS, based on the typological analysis and the choice of buildings for observation in order to obtain a characterization and comprehension on the level of the energy efficiency of typologies, comprehending the different possibilities of improvement and taking into account the results of computer simulation. The work is in progress, but it is possible to observe that the buildings of up to two floors, built in lots, until the 1980s, where light colors on the façades prevail, and the percentage of transparent medium envelope characterizes the buildings downtown the city.

INTRODUCTION

Energy has become serious issue worldwide because of the energy crisis in the 1970s and the increase of the population in urban centers in the 1980s. To overcome the crisis, the production of energy had to grow significantly since then. Therefore, this alternative brings disadvantages of environmental impact caused by new plants like: possible floods and population dislocation, as for hydroelectric, pollution and the risks with public safety, in the case of nuclear and thermo-electrics. Furthermore, the demand of great investments by the government implies in the reduction of investments in other areas such as: health, education and housing, antagonizing the idea of progress included in this policy (Lamberts et al, 2004).

The alternative which is thought to be the most adequate to this scenario is to increase the energy efficiency in the use of energy, since it is quite feasible to save it than supply it, thus it reduces the expenses with the public sector, transferring to the manufacturers of equipments and to consumers the necessary investments. It is worth emphasizing that electricity passes by three different stages until it reaches the building: generation, transmission, distribution and, finally, consumption. The higher the performance of components of each of these stages the lowest the energy loss of the process as a whole. But it is the architect's responsibility the conception of projects that make the accomplishment of more efficient building feasible, this way providing more comfort to users and the rational use of energy (Geller, 1994).

Many countries began its research towards the search for energetic efficiency after the first gas crisis. Countries like France, which based on the definition of an Energy Efficiency regulation, characterizing coefficients of global losses first, that is, defining a series of restrictions as for the choice of materials of the external part of the buildings, reduced in 25% the consumption of energy of buildings after eight years. Later, between 1982 and 1989, based on new normative prescriptions as for shading of frames, façades, composed of glasses basically, and insulation of coverings, they reduced in more than 25% of the consumption of energy in buildings. Then, the regulation of air conditioning and water heating equipments generated a third reduction of 25% general consumption. The United States of America, between 1974 and 1983, kept their energy consumption growth stable, based on an increase of the tax value as well as the definition of prescriptive measures with relation to insulation of the buildings envelope. In Germany, from the WSVO regulation, in 1974, the constant normative evolutions allowed, currently, to obtain a performance norm, through which it is possible to verify the maximum final energy per unit of area in kWh/m² year, based on the buildings compactness.

In Brazil, the main mark was the energetic blackout of 2001, since then, the concern about energy saving has increasingly gained space worldwide. After this fact, Law n°10.295 of Energy Efficiency (Brazil, 2001a) was enacted, which is on the National Policy of Conservation and Rational Use of Energy. After the approval of Decree n°4.059 of December 19^{th}, 2001 and the creation of the Buildings Work Group to propose a way to regulate buildings built in Brazil, aiming at the rational use of electricity (Brazil, 2001b). Then, Brazil commenced its path towards the change of the paradigm with relation to generation vs energy saving. Until the energy blackout in 2001, the governmental proposal, concerning the energy matrix, was clearly based on the increase of the generating matrix, not giving the necessary focus on buildings energy efficiency, since they consume around 42% of the Brazilian energy (Lamberts et al, 2004).

Several studies have already been accomplished with relation to electricity consumption through the final use in commercial and public buildings (Geller, 1994). Commercial and public buildings consume 19% of the national electricity production. From these 19% of energy consumption an average of 44% is consumed with lighting, 20% with air conditioning equipments and 36% with other equipments (Lamberts et al, 2004).

The main steps fulfilled with relation to thermal performance of buildings became real because of NBR 15220 (ABNT, 2005), which defines the minimum acceptable requirements of thermal performance for housing of social interest, and the Brazilian territory is divided into eight bioclimatic zones, indicating strategies to improve thermal comfort of buildings passively; later, NBR 15575 (ABNT, 2008) determined that buildings of up to five floors were regulated in order to evaluate their performance.

Important steps concerning the approval of the Technical Regulation of the Quality of the Energetic Efficiency Level of Commercial, Services and Public Buildings - RTQ-C and the Technical Regulation of the Quality of the Energetic Efficiency Level in Residential Buildings - RTQ-R by the Ministry of Mines and Energy were taken into account in order to change the paradigm towards the Brazilian construction industry as for the Energetic Efficiency in Buildings.

Voluntary tagging regulation defines that all commercial, public and service buildings must be tagged according to their energy efficiency characterization. The levels of efficiency vary from “A” to “E”, where “A” is the highest index and “E” characterizing the lowest efficiency. It was defined in the regulation that each building shall have four efficiency evaluations, where the items evaluated were the lighting system, air conditioning, envelope and building as a whole (INMETRO, 2010).

The RTQ-C presents the criteria for the complete classification of the level of energy efficiency of the building through partial classifications of the envelope, and lighting and conditioning system. An equation considers this system through weights established in the regulation and allows to add bonuses to final score that may be acquired with technological innovations, use of renewable energies, cogeneration or with rationalization in water consumption (INMETRO, 2010).

But the objective of the RTQ-R is to create conditions to the energy efficiency tagging of single and multi-familiar residential buildings, specifying technical requirements and methods for the classification of residential buildings as for energy efficiency, and later, to assign a classification that varies from the level A (more efficient) to E (less efficient). (INMETRO, 2010).

Energy efficiency tagging of buildings must be accomplished through prescriptive or simulation methods. Both shall meet the requirements relative to the envelope performance, efficiency and power installed of the lighting system and efficiency of the air conditioning system. The prescriptive method is a simplified method that evaluates buildings through equations and tables. The simulation method is an alternative for a more complete and/or flexible efficiency evaluation. It is indicated to allow freedom to the fulfillment of projects, in the form of the building, in the nature of their openings, solar protection as well as in the systems used; the incorporation of technological innovations, proving high levels of efficiency; Use of conditioning passive strategies, making non conditioning or partially conditioning buildings feasible; Incorporation of solution which are not foreseen at RTQ-C (INMETRO, 2010).

In the context of implementing a new regulation, it is important to publish a new paradigm change as for new prescriptions, and in this sense, mapping and analysis of commercial typologies with relation to levels of efficiency is an important aspect to consolidate a new model of efficiency.

METHOD

The method used to reach the objective of this research will be divided into four parts, which will be detailed as follows:

Survey of commercial typologies which are present downtown the city of Pelotas-RS, based on the methodology proposed by Marina Waisman (1972).

This stage is consisted of two kinds of surveys: General and specific.

General Survey:

In order to obtain a characterization of typologies located downtown the city of Pelotas, a profile which includes 22 streets in axis East-West between Almirante Barroso and General Osório streets and in axis North-South between Bento Gonçalves Av. and Dom Pedro II street was defined, streets which represent the commercial area of the city. In this profile, data from al buildings downtown will be surveyed, classifying them as for function, age, location in the lot, colors of the façades, number of floors, percentage of opaque and transparent envelope, etc. In order to do that, catalographic cards of the buildings, photographic survey and research in the files of the Municipal City Hall of Pelotas city are used.

This stage of the research is in process and it counts on the assistance of the CNPq (National Council for Scientific and Technological Development) scholars. With the data obtained so far, it is possible to visualize the important results that help to define choice parameters of the typologies which will be evaluated in the specific survey.

Specific Survey:

In order to list the buildings that will be simulated, that is, the most representative buildings of typologies downtown Pelotas, a representative sample of the total of buildings that will be surveyed will be calculated, and from this later, it will be necessary to achieve a more detailed survey which explains constructive features like: Type of materials used in the building envelope, their transmittances, colors of external coatings, ceiling height of the ambient, type of internal coatings, frames positioning, type of frames, their materials, type of glass, solar factor; percentage of the façades openings (PAFT) of all buildings faces; Lighting and air conditioning system, when these data are available in the projects filed in the city work office, source of research of the specific survey.

After the analysis of the representative sample of the typologies in the business area, the most significant buildings of different spatial configurations evaluated will be chosen, based on one spatial-temporal classification.

Typological classification of buildings

In this stage, buildings will be classified as for their structure, function and relationship with the envelope defined as analysis categories of (Waisman, 1972), they will be treated in the research as construction, program and place. Based on the programmatic analysis, spatial relationships will be defined between internal spaces as well as interior versus exterior. The programmatic analysis will allow the comprehension of variables such as: use of spaces, areas of functional spaces, ceiling height, internal volumes, areas of opaque and transparent envelope, in the vertical plan as well as in the horizontal. The technological analysis will allow the definition of variables as solar factor – type of glass, characteristics of the air conditioning system, transmittance of vertical and horizontal envelope, characteristics of the system of artificial and natural lighting, among other aspects. The analysis of the place will allow to verify the relationship of the building with adjacent in the sense of solar accessibility, as well as shading of the air conditioning system.

Tagging of samples of each typology verified, considering the temporal-spatial analysis of central areas of Pelotas city.

The third stage of the research is consisted of tagging of the emblematic buildings chosen. For each building, four tags of performance will be verified, namely: general concept, artificial lighting system, air conditioning system and building envelope. From the definition of the level of efficiency of the air conditioning system, artificial lighting and building envelope it is possible to determine the general classification of the efficiency level of the building analyzed as a whole (values from 1 to 5, levels of efficiency of E and A) (INMETRO, 2010).

Compilation and definition of the performance of different typologies with relation to the energy efficiency

Based on the analysis of the tagging process of commercial typologies chosen as sample of analysis in the city of Pelotas-RS, the results will be contextualized and the comprehension of the aspects as a whole involved in the analysis of the energy efficiency of buildings will be possible. In this stage, possible strategies of energy performance improvement of typologies will be analyzed, considering variables air conditioning, lighting system and building envelope. The aspects as the need for retrofit of lighting systems, including the set reactor, bulb, lamp and air conditioning, as well as the need for solar protection, or alteration in the solar factor of opaque envelope, shall be analyzed.

Simulation of the energy efficiency level of samples of each typology verified

The third stage of the research is consisted of simulating the buildings analyzed in order to check the level of energy efficiency, considering as comparative reference efficiency levels "A, B, C and D", that is, real models will be compared, following the project with the ones of reference. To simulate both buildings, criteria which take into account the same characteristics of the real model and the reference model, will be adopted, to wit: Same program of simulation, climatic file, geometry, direction with relation to the geographic north, value of ILD in equipments, use pattern of people, with the same value of heat dissipated, air conditioning system will be used, therefore, the COP established in the model of reference according to the level of efficiency intended, same use pattern and systems operation ; the pattern of use will be according to the use and real occupation of the building.

English Software Designbuilder will be the computer program of thermo-energetic simulation, which algorithms are compatible with the requirements validated by ASHRAE (1993), verifying the yearly modeling of 8760 hours with occupation hourly variations, power of lighting and equipments and air conditioning systems, as well as observing modeling of thermal multi-zones, it models effects of thermal inertia. In the end, the results will be compiled, aiming at the verification and comparison with the process of tagging achieved with real models.

Real Building Model

The model that represents the real building must use all characteristics of buildings according to the project proposed (transmittance of wall and coverings; type of glass, PAFT, absorptance of walls and coverings, VSA, HAS) in the case of the real building has different air conditioning systems, all different systems in each thermal zone must be represented; Utilizing the Density of Lighting Power of the project proposed; Considering the devices of shading when they were coupled in the building proposed; Shading from the envelope may be part of the method of simulation (optional use) and, when it is used, it must be included in the real building model only.

Models of Reference

The models of reference will be simulated, considering that: the envelope must reach the level of classification intended, that is, level A. The equation, which volumetry indicated is similar to the one of the project, will be used, and value of the Envelope Consumption Indicator (ICenv) of the maximum limit of the classification level interval desired will be adopted. If Factor Form (Rate between the area of the envelope and volume of the building) of the building projected is over or lower Factor Form limit of the equation, limit value will be used; in the general classification, the model of reference must reach the level of efficiency intended according to the weights distribution in the equation of the general classification, Equation (1).

Maximum values of thermal transmittance and solar absorptance to the level of efficiency intended and specific pre-requirements of the envelope will be used; A POFT (percentage of the façades openings) calculated according to: the formula of ICenv related to the envelope of the building proposed according to the Bioclimatic Zone of the building location will be adopted; Adopt VSA=0 and HAS=0; Adopt a simple glass of 3 mm, with a solar factor of 0.87.

The value of POFT must be the greatest as possible to the level of efficiency intended. In the case of existing zenital lighting with POZ (Percentage of Opening Zenith) greater than 5% in the real model, the models of reference to the levels A and B must have POZ of 2% with light glass and solar factor of 0.87; The density of the Lighting Power must be modeled in the maximum limits tabled according to the function and W/m², depending on the environmental index, activity and level of efficiency intended; Adopt the same Air Conditioning System proposed in the Real Model.

$$PT = 0.30.\{(EqNumEnv.\ AC/AU)+[(APT/AU.5 +ANC/AU.EqNumV]\}+0.30.\ EqNumDPI)+0.40.\{(EqNumCA.\ AC/AU)+ (APT/AU.5+ANC/AU.EqNumV)\}+b_{o}^{1} \qquad (1)$$

The general classification includes all systems plus bonuses and they refer to the whole building or a part of it. The partial tags refer to the efficiency of the systems separately; the general tag is defined by Equation (1) that contains weights to balance the relationship among the systems, these weights are shown in Table1.

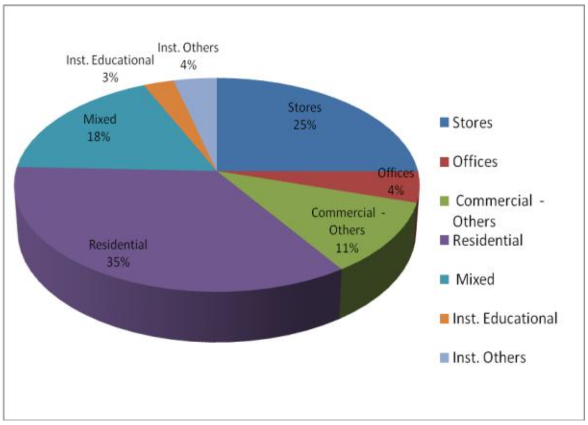
Table 1

VARIABLE	WEIGHT
Lighting System (DPI)	30%
Air Conditioning System (ACS)	40%
Envelope (Env)	30%

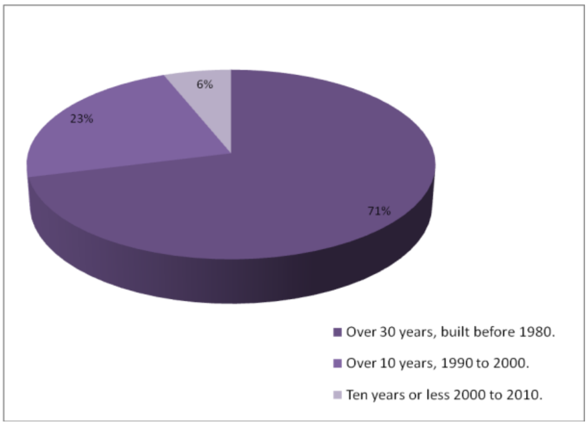
DISCUSSION AND ANALYSIS OF THE RESULTS

The results of the work will be obtained along with the post-graduation course and they will be presented and defined in format of Master Thesis submitted to evaluation of the Post-Graduation Program in the Architecture and Urbanism Courses of UFPel. Up until now, 60% of the buildings downtown Pelotas was surveyed, where the research is in the survey and classification stage of the architectural typologies.

It is possible to observe that the percentage of 58% of typologies downtown are directed to commercial and mixed use, according to Graphic 1, from these 71% were constructed before the 1980s, according to Graphic 2.

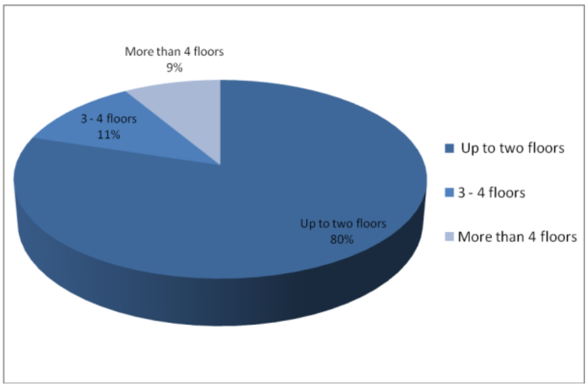


Graphic 1 Functions of central typologies

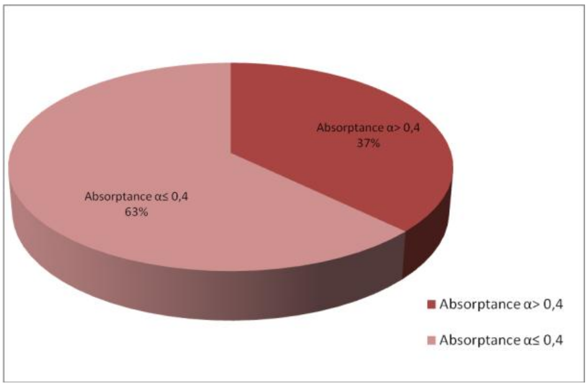


Graphic 2 Age of constructions

The buildings downtown are characterized by two floors in their great majority, with a percentage of 80%, according to Graphic 3. But with relation to the characteristics of absorptance of the façades it is observed the predominance of light colors, where a percentage of 61% façades have absorptance lower/equal 0.4, according to Graphic 4.

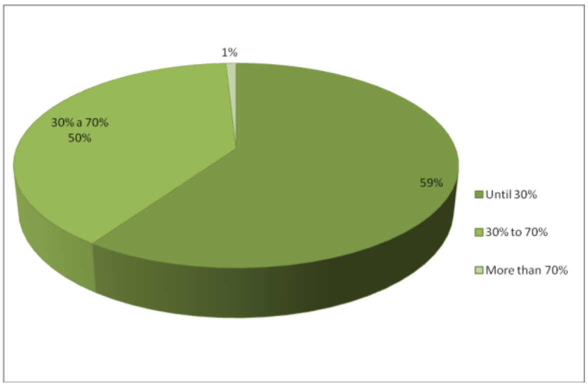


Graphic 3 Height of central typologies

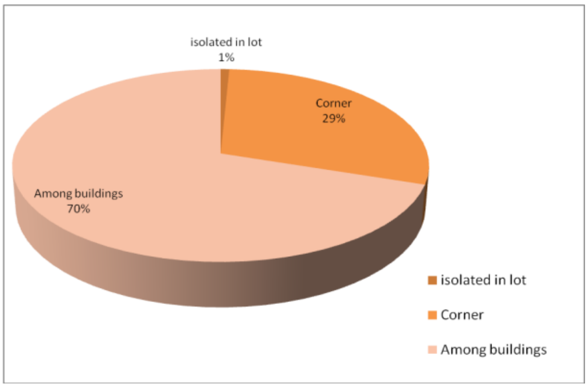


Graphic 4 Percentage of the façades absorptance

It was observed that 54% of the façades shows a percentage of transparent envelopes from 30% to 70%, with relation to the opaque envelope, according to Graphic 5; and 68% of the buildings evaluated with relation to their envelope are located in the middle of blocks and among buildings, according to Graphic 6.



Graphic 5 Percentage of transparent envelope of the façades



Graphic 6 Position in the lot

From these preliminary results, one of the representative typologies downtown Passo Fundo was defined. It is located in the business area, with up to two floors, built before the 1980s, among buildings and with façades which percentage of transparent envelope is from 30% to 70% and which absortance is lower or equal 0.4. For analysis in this study, a store, which fits the parameters defined by the typological survey, was chosen, in order to evaluate the results of percentage of comfort obtained and Degree-hours for heating and cooling, taking into account its materials and constructive techniques configuration.

In order to simulate the commercial building chosen, software DesignBuilder version 2.0.3 was used. The city of Pelotas is located in bioclimatic zone 2, but as it does not have climate file yet, file TMY of Santa Maria-RS, which was available for the zone, was used.

The model was configured according to the following descriptions: Soil temperature was configured based on the instructions of the RTQ-R (INMETRO, 2010). To define the soil temperature values, software Slab must be used, since it is assistant software of EnergyPlus to calculate the soil mean temperature for each month of the year, based on the mean values of internal and external temperature of the building for the climate that will be simulated. Main façade is turned to north. The working hour is from 9:00am to 8:00pm from Monday to Friday and Saturdays from 9:00am to 01:00pm, closed on Sundays and holidays. Occupancy density is 0.15 people/m², following values set by NBR16401-3 (ABNT, 2008). The metabolic rate used for people standing, with moderate work and walking, was 93w/m², according to ISO 7730. Wearing adopted established a resistance of 0.5 clo for summer and 1.0 clo for winter, considering ISO 7730.

The building was simulated considering that it was naturally conditioned to evaluate the role of the envelope of the commercial building. Ventilation setpoint was configured from the work of (Martins et al, 2009) and determines that: when internal temperature reaches 25°C and external is inferior to it, doors and windows open and ventilate. The internal temperature setpoint for glasses opening was defined in 25°C. The level of lighting for the ambient was defined in 750lux with heat dissipation of 17w/m² NBR16401-1 (ABNT, 2008). The load density of equipments was defined as 5.4w/m² according to NBR16401-1 (ABNT, 2008). Modeling and configuration of the typology envelope was accomplished considering the specific characteristics of the building.

The building has the characteristics previously defined as representative and its construction for commercial use dates from 1946. To include the data in software DesignBuilder it is necessary to change the heterogeneous and homogeneous elements with equivalent thickness and density according to Table 2 as follows:

Table 2

ELEMENT	e (cm)	ρ (Kg/m³)	λ (W/m.k)	c (J/Kg.K)
External walls	0.198	1976	0.90	920.00
Internal walls	0.12	1860	0.90	920.00
Walls plastering	0.025	2000	1.15	1000
Concrete blocks	0.10	2200	1.30	1000
Ceramic tile	0.015	2000	1.05	920.00
Ceramic floor	0.006	1600	0.90	920
Concrete subflooring	0.15	2200	1.75	1000

Single 3mm glasses were used in the transparent envelope, protected by wood-wicket. The internal part of the model was divided into thermal zones according to the project.

Figure 1 presents the model generated from software DesignBuilder.

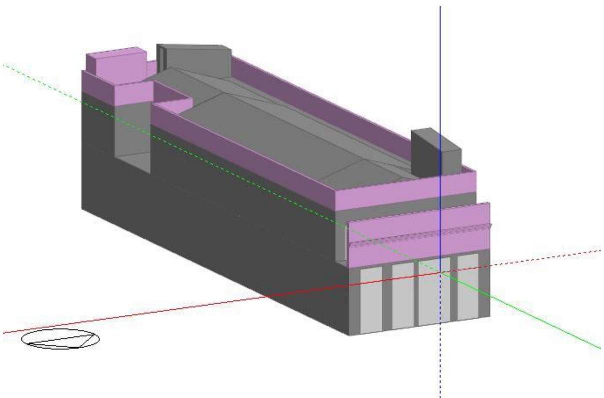


Figure 1Commercial Building simulated

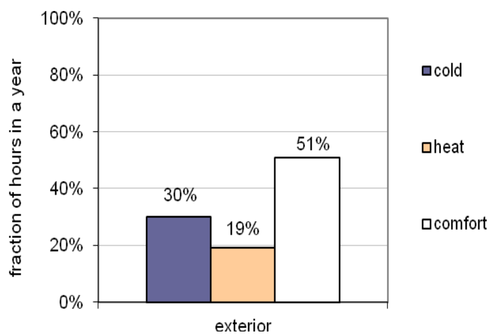
Analysis of the results for thermal comfort

The data obtained from simulations of the models that were submitted to the calculation of the adaptive model De Dear and Brager for (ASHRAE 55, 2004) were used in the thermal comfort analysis. It relates to internal temperatures designed or acceptable scales of temperature with external climate and meteorological parameters for naturally conditioned ambient. For that, the space must be provided with functional windows which open to outside, and thermal conditions of the space are regulated by occupants mainly, through the opening and closing of the windows, and the occupants' thermal reaction depends part on the external climate, physical activity close to sendentarism varying from 1.0 met to 1.3 met, air humidity and speed limits are not necessary. The monthly mean temperature is included in Equation 2.

$$toc = 18.9 + 0.255text \qquad (2)$$

After defining the toc, the limit of comfort for 90% of people satisfied was found, where the comfort zone is defined with the toc variation. The operative temperature of comfort is 2.5°C added and 2.2°C reduced. An ambient may be considered in comfort when operative temperature, which relates air temperature to radiant mean temperature, is between the rate of minimum and maximum temperatures previously established. Over this value the ambient is in discomfort because of heat and lower it because of cold.

The results obtained show that in 51% of hours of the year, users of this building are in the thermal comfort zone, in 19% of hours they are in discomfort caused by heat and in 30% of hours they are in discomfort because of cold, according to Graphic 7.



Graphic 7 Percentage of hours in the year in comfort, discomfort because of heat and cold

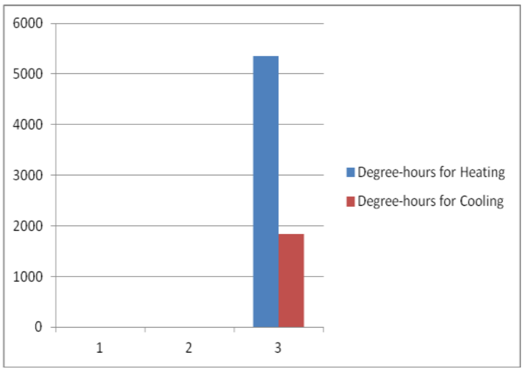
Analysis of the results for degree-hours

Temperatures limit of comfort are established and from these values, how many hours in the day and how many degrees, equation 3, the temperature is over or lower the limits, where degree-hours is an index that can determine the need for heating and cooling.

$$GH = \Sigma\,(Th - Tb) \qquad (3)$$

By calculating the number of hours and multiplying the quantity of degrees the temperature is over the limit was set, the number of degree-hours for cooling is obtained. In order to obtain the number of degree-hours for heating you multiply the number of hours by the number of degrees the temperature is lower the limit. For this work, the minimum and maximum limits were defined, considering the adaptive model of De Dear and Brager (ASRHAE 55, 2004). In this sense, it is emphasized that the base temperature considered, for cooling as well as for heating, varied according to the external temperature.

For the index degree-hour of heating and cooling, the result of 5362 degree-hours for heating and 1845 degree-hours for cooling was obtained, according to Graphic 8.



Graphic 8 Degree-hours for heating and cooling

CONCLUSION

When observing the data surveyed so far, it is possible to realize that significant parts of the buildings downtown Pelotas are directed to the commercial area, which is the focus of study in this paper. They follow a pattern, in their great majority, of two floors and they are implanted in lots in the middle of the blocks, becoming limited with relation to insulation, depending on the solar position. They were built in the 1980s, have façades painted with light colors and a mean percentage of transparent envelope. Such data of the first stage of the research will help to identify the pattern of energy efficiency of commercial typologies of Pelotas, based on the typological analysis and choice of emblematic buildings for the observation.

With the results obtained from the computing simulation, it can be observed that the building analyzed presented a percentage of 51% hours of the year in the comfort zone, possibly because its walls are 0.25cm thickness (equivalent wall which thickness is 0.198cm), and lower transmittance indeed, and because its covering is composed of ceramic tiles and concrete blocks, leading thermal range in the interior of the building is lower. Frames have common glass of 3mm, with wood-wickets which provide good thermal isolation. Façades absortance is lower than 0.4 and the percentage of transparent envelope is from 30% to 70% in the main façade.

The percentage of discomfort because of cold was 30% of hours in the year and the index of 5362 degree-hours for heating. Therefore, the walls and covering show low transmittance U par=2,40 W/(m^2.K) and U cob= 2,70 W/(m^2.K)m, because of this and the thickness of the walls, thermal lag is higher in the walls which are consisted of more mass, leading heat to the interior of the building not during the time that was established for assessment, that is, from 9:00am to 08:00pm.

NOMENCLATURE

PAFT percentage of the façades openings (%);
ILD Internal Load Density (W/m^2);
COP Coefficient of Performance;
VSA vertical shading angle;
HAS Horizontal angle of shading ;
POZ Percentage of Opening Zenith (%);
EqNumEnv, numerical equivalent of the envelope;
EqNumDPI, numerical equivalent of the lighting system, identified by acronym DPI, of Lighting Power Density;
EqNumCA, numerical equivalent of the air conditioning system;
EqNumV, numerical equivalent of non-conditioned and/or naturally ventilated environments;
APT, useful area of ambient of temporary permanence, since they are not conditioned (m^2);
ANC, useful area of non-conditioned ambient of prolonged permanence, where the percentage of occupancy hours of comfort by natural ventilation (POC) through method of simulation (m^2) was evident;
AC, useful area of conditioned ambient (m^2);
AU, useful area (m^2);
b, punctuation obtained by bonuses, which vary from zero to 1;
toc, comfort operative temperature (°C);
text, external temperature (°C);
e equivalent thickness (cm);
ρ equivalent density (Kg/m^3);
λ thermal conductivity (W/m.k);
c specific heat (J/Kg.K),
GH, degree-hour (°C.h);
Th, ambient mean temperature (°C);
Tb, base temperature for heating and cooling (°C);
U, thermal transmittance (W/(m^2.K));
Upar, walls thermal transmittance (W/(m^2.K));
Ucob, covering thermal transmittance (W/(m^2.K));

AKNOWLEDGEMENTS

The authors would like to thank to CNPq and CAPES for the support to the accomplishment of this research and to scholars Gabriela Beraldi, Jéssica

Busnello, Luiza Coelho Quintana, Monica Wilges, Oberdan Mendonça, Patrícia Malfati, Raquel Mota and Tatiane Ballerini Fernandes.

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