THE ENERGY AND THERMAL PERFORMANCE OF TWO UNIVERSITY BUILDINGS IN SOUTHERN BRAZIL WITH THE AIM OF ACHIEVING ENVIRONMENTAL EFFICIENCY

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Abstract

This paper demonstrates the results of research concerning eco-efficiency at the University of Passo Fundo – Southern Brazil. Its objective is to identify the factors that affect energy consumption in buildings of Higher Education Institutions and to elaborate a methodology that can facilitate the evaluation of the degree of influence of each one with the aim of defining criteria in the following areas: improve the use of natural resources in the building stock and formulate guidelines for the inclusion of objectives which include environmental, energy and thermal comfort in the planning of new installations. For the energy performance analysis, the concepts of Energy Audit were adopted and applied to two buildings of the Engineering and Architecture School, representing the different typologies of UPF’s Campus I. The static data (general characteristics of the buildings and indoor spaces, systems and installations), was analysed. The dynamic data was obtained by checking energy consumption for different uses; the indoor thermal performance and PMV index was also analysed. The real conditions of the buildings were then compared with the results of energy performance simulated by the software DesignBuilder. The results allow for a diagnosis of the building stock conditions of UPF, with the identification of positive and negative points. A proposal of an operative instrument for thermal and energy performance improvement of the existing buildings plus standards of reference for new eco-efficient buildings will be developed.

Keywords

University building stock, energy efficiency, thermal comfort, eco-efficiency.
1. Introduction

The aim of this work is to evaluate the energy and thermal performance of the building stock of the University of Passo Fundo, Rio Grande do Sul, with the aim of proposing guidelines to include environmental and energy criteria in the planning of these new installations, whether they be for isolated buildings or structures within the seven campuses. These guidelines can then be incorporated within an institutional plan of environmental management to include sustainable development within the areas of administration and teaching, embracing these principles in all daily activities (graduation, research, extension and administration).

Various factors contribute to the process of evaluation of the level of adherence to concepts of sustainability within these areas. Kibert (2005; pp. 41-42) refers to eco-efficiency, which includes the analysis of environmental impact and costs as factors of administration efficiency evaluation of institutions or companies. The author quotes the World Business Council on Sustainable Development – WBCSD, which defines seven elaborated elements to achieve eco-efficiency, including energy reduction in its buildings and services.

Environmental efficiency is envisaged on the business field as a factor of cost reduction and increase in competitiveness, yet incorporating the third pillar of sustainability, the social factors. In accordance with the WBCSD (BCSD Portugal, 2000, p.4) eco-efficiency can be attained through the goods and services and competitive prices which satisfy human needs and contribute to the quality of life, simultaneously reducing the ecological impact and intensity of the use or recourses progressively during the whole life cycle.

It should be mentioned that to be efficient means reaching the proposed objectives; in this way the attainment of energy efficiency takes place when the objectives are obtained by equally employing the least amount of recourses possible or, in other words, a building which is efficient in terms of energy should carry out all its activities with the lowest possible consumption of electricity and in a broader manner, all the raw materials which it uses.

Although for the Higher Education Institutions (HEI), the question of economics remains a complementary item in academic development, these aspects reveal their great importance for the administrative management, not only for areas within HEI particularities but also in the public sector; this being that reduction in energy costs can be converted into investments in other areas.

Buildings contribute to approximately 40% of primary global energy consumption and with 35% of gas emissions to the greenhouse effect. According to WBCSD (BCSD Portugal, 2007, p.11) 84% of energy consumption occurs in the operational phase of the life of a building. This data makes decision making to invert the environmental impact which is
caused indispensable in a way which will increase the environmental quality of the buildings and, therefore, establish requisites for efficiency instead of inefficiency (Cuchi, 2009). The implementation of a proper Environmental Management System (EMS) provides a feasible tool to enable higher education institutions to address environmental effects through policies and practices on monitoring and evaluating of the use of resources and their impacts. For this reason, its development provides a way to carry the universities through their sustainable commitment, following the principles of the UNESCO Decade of Sustainable Education for 2005-2014 (UNESCO, 2004).

As a part of the EMS, the Energy and Environmental Audit can provide an overview of all input and output materials and energy flows. Based on this analysis, it will be possible to define which aspects have to be optimized in order to achieve efficiency on the management of natural and economic resources.

According to Brandli et al. (2008) the HEI’s can be compared to small urban nuclei, exhibiting in many cases, complex infra-structures for their operation, which demand natural resources and generate environmental impact. In the case of UPF, for example, in August 2009 the energy consumption was more than 314,000 kWh, which corresponds to approximately 3 thousand residencies with 4 inhabitants or, similar to a town of 12,000 inhabitants.

Viewed like this, energy efficiency is one of the elements of easy implementation in eco-efficient and sustainable construction strategies in HEI’s; this especially in terms of the justification of their economic impact, the focus of many studies, with the permanent programme of the Efficient use of energy being a National reference. This programme - PUREUSP (USP, 2009), was created in 1997 to gather data about energy consumption in all of its 7 campuses and identified consumption per capita of 1.160.2 kWh/yearly for 2008, which lead to the formation of steps for a 20% reduction of monthly consumption of electrical energy, though still maintaining the continuation of the university’s activities.

2 Methodology

This paper is linked to the research that is being developed on the Architecture and Energy Ph.D. programme of the Polytechnic University of Catalonia (UPC), Barcelona, called “A methodology to include the energy efficiency in the university buildings: environmental and economic considerations”, with the objective of proposing a methodology to integrate all aspects involved in the energy consumption of buildings at universities centres.

For the analysis of thermal and energy output of the buildings aforementioned, a methodology of Energy Auditing was adopted which was used in the park constructed by the
Polytechnic University of Catalonia - UPC (López Plazas, 2006; Bosch et al., 2007; Cuchi, 2009), which made it possible to identify each building in relation to the different sources of energy and their respective uses.

The Energy Audit adopted in this paper identifies and evaluates the buildings and system characteristics regarding the energy sources; the study’s premise is that the energy consumption is related to 3 main factors: the energy demand (building location and building shell); the performance and efficiency of systems and installations; and the management of use and occupation (intensity and area-time distribution).

The analysis is based on two sources of information: the “static” data is related to the building location (outdoor and indoor conditions), building characteristics (architecture and construction), systems and infrastructure and energy resources.

On the other hand, the “dynamic” data is obtained by modelling the occupied area, the number of users and the kind of activities together with their energy performance through an automatic control of energy consumption.

This methodology is being applied to another context with the same characteristics of use, in this case to the South Brazilian University of Passo Fundo (UPF). The application is being accomplished based on the contextualization of climatic, cultural, social and conditions.

During its 40 years existence, different kinds of construction were employed on the building stock at Campus 1: the first one used a current system, built with single-brick masonry walls, a 15 mm expanded polystyrene ceiling and a pitched-roof of asbestos cement tiles, without a proper thermal covering and consequently without comfortable conditions. Recently, the design staff adopted double brick walls and concrete ceilings, and shading devices were increased to control solar radiation and natural lighting.

For the application of this methodology at the University of Passo Fundo (Frandoloso et al., 2009), a characterization study was initially developed of Campus I, the main campus with 341ha, where verification of the current use of energy was made. In accordance with the construction of the existing park, two buildings were selected: the Faculty of Engineering and Architecture – Figure 1. These buildings are representative of the diverse construction typologies of Campus 1: the G1 building, administrative and teaching block of Faculty of Engineering and Architecture - FEAR – Figure 1a, and the L1 building with laboratories and classrooms and the Centre of Research in Agriculture - CEPA – Figure 1b.
The real conditions of the buildings were noted concurrently through record cards and temperature and humidity measuring devices (Data-loggers *Testo*, models 175-H2 e 175-T1), analogical energy gauges and software (*SmartGateM* – Gestal, 2009); the comparative analysis of the thermal advantages were obtained by applying the software *DesignBuilder* (2009).

### 3 The UPF and the use of energy resources

The research is being developed at the University of Passo Fundo (UPF), a multi-campus university, i.e. with a regional structure formed of 7 campuses around Passo Fundo, which is a medium-sized city (about 180,000 inhabitants) in Southern Brazil, as shown in Figure 2a. The main campus (Campus I) occupies an area of 341ha. In 2009 the constructed area was 108,104.47m² receiving a population of around 22,000 users (students, teachers and staff).

Campus I was created in 1968 outside the urban area, following the Anglo-Saxon model of university planning, which was dominant in Brazil in the 60’s and 70’s. At that time, the
The campus was situated far from residential zones, at the convergence of national roads but in the last few decades, the number of inhabitants has increased and nowadays the campus boundaries are coincident with an area occupied by middle class housing, service buildings and a commercial area (see Figure 2b).

![Figure 3: Givoni’s Psychometric Chart of Passo Fundo (Climate Consultant, 2008).](image)

The climatic conditions in Passo Fundo indicate a warm summer (561 cooling DD, base 18°C) and cold winter (773 heating DD, base 18°C), with a Csa climate by the Köppen classification. These characteristics indicate the need for improvement of passive solar strategies for cooling and heating, as can be applied using Givoni’s Psychometric Chart shown in Figure 3.

In previous studies (Brandli et al., 2007; 2008; Frandolos et al., 2008) it was noted that within the environmental activities of UPF, energy consumption management of the campuses was included, especially in Campus I. This included ongoing measures, such as the installation of a group generator and, more recently, a computerised system for monitoring energy consumption.

The energy consumption on Campus I corresponded to 84.26% of the total consumption of UPF in 2008, indicating the relevance of a study of tools for control and energy management which, as a consequence, would bring financial control. Table 1 presents the variations of the constructed areas of the park and the energy consumption and respective costs of the period 2004 to 2009.
Table 1: Comparison of the constructed areas, electrical energy consumption and costs 2004-2009.

<table>
<thead>
<tr>
<th>Year</th>
<th>Constructed area (m²)</th>
<th>Energy Consumption (kWh)</th>
<th>Costs (thousand R$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>88.987,99</td>
<td>3.914.408</td>
<td>1.557,56</td>
</tr>
<tr>
<td>2005</td>
<td>90.735,15</td>
<td>3.981.060</td>
<td>1.912,87</td>
</tr>
<tr>
<td>Variation 2005/2004 (%)</td>
<td>1,96</td>
<td>1,70</td>
<td>22,81</td>
</tr>
<tr>
<td>2006</td>
<td>99.071,34</td>
<td>3.694.457</td>
<td>1.314,78</td>
</tr>
<tr>
<td>Variation 2006/2005 (%)</td>
<td>9,19</td>
<td>-7,20</td>
<td>-31,27</td>
</tr>
<tr>
<td>2007</td>
<td>99.147,84</td>
<td>4.421.650</td>
<td>1.439,72</td>
</tr>
<tr>
<td>Variation 2007/2006 (%)</td>
<td>0,08</td>
<td>19,68</td>
<td>9,50</td>
</tr>
<tr>
<td>2008</td>
<td>103.293,84</td>
<td>4.422.510</td>
<td>1.384,08</td>
</tr>
<tr>
<td>Variation 2008/2007 (%)</td>
<td>4,18</td>
<td>0,02</td>
<td>-3,86</td>
</tr>
<tr>
<td>2009</td>
<td>108.104,47</td>
<td>5.490.587</td>
<td>2.214,30</td>
</tr>
<tr>
<td>Variation 2009/2008 (%)</td>
<td>4,66</td>
<td>24,15</td>
<td>59,98</td>
</tr>
</tbody>
</table>

It can be observed that the physical structural expansion is constant with the period from 2004. However, significant growth of the constructed area can be seen between 2005 and 2006 (8.41%). On the other hand, energy consumption presented a decrease of 7.76%, with an economy greater than 45% in the value of the electricity bill as a result of the installation of an independent generating system. This was established to overcome, not only the lack of energy furnished by the provider but also to allow for the incorporation of the feature “interruptible energy”, during peak working hours (between 18h00min and 21h00min), with a price rate reduction.

Over the following years, the growth of the physical structures remained within the percentages up to 4.66% while energy consumption presented considerable differences. During the period 2008/2009 there was a reduction of costs and a levelling out of electrical energy consumption. However, the following factors contributed to the demand of energy, which reached a level of 24.15%: the higher number of enrolments at UPF in 2009; the expansion of computerization in all administrative and academic areas and, of particular significance, the increase of the use of air conditioning in the laboratories. This increase in energy consumption was correspondent to the increase in costs of approximately 60%, which was seen to occur for the period of differentiation of subsidies from the energy provider because of the use of an independent energy generator.
Within the measures adopted of rationalization of energy use, is the substitution of lamps and reactors in the older buildings for more efficient equipment; these criteria having already been adopted in the new constructions. Campaigns for greater awareness are being set up for all members of the entire university about the rational use of electrical energy within the project “Zé Cidadão” by the groups for top quality in Customer Services (GEPS). It should also be mentioned that, until June 2009, energy consumption control was centralised, there being no division into units or isolated buildings. From this moment, a decentralization programme was set up (SmartGateM - GESTAL, 2009), with the installation of equipment in each of the energy consumption units, which made it possible to control and monitor on-line, permitting the detection of specific problems.

Figure 4: Daily energy consumption in building G1 - September/2009 – SmartGateM.

As an example of the presentation of data, figure 4 shows the results of daily active energy consumption for the month of September, 2009, a reduction in energy consumption can be observed at the weekends, though still with values of around 450kWh. This can be accounted for by the continuous functioning of part of the laboratory equipment. The light and dark green lines present the energy consumption within the limits defined by the contracted “horo-sazonal” charges. However, for most of the working days these limits are surpassed at peak working hours, defined by the red lines, and, therefore, incurs extra costs. Today, thanks to the system, it is possible to incorporate energy consumption management for the identified units, such as the high consumption rate in peak hours and charge differentiation in places such as, auditoriums, convention centres and general working areas. Monitoring can take place when the pre-established limits are exceeded and it is also
possible to disconnect these installations or activate the equipment using the independent generator. This alternative has been established to halt the increase of energy consumption and the identified costs for 2009, as can be seen in Table 1.

4. Results of energy performance

4.1 Static data collection

In the first stage of the research, static data was collected, such as the general characteristics of the buildings and their internal spaces, presenting their construction and architectonic characteristics (Frandoloso et al., 2008; 2009).

The other step of the evaluation is to compile dynamic data obtained by the energy consumption monitoring for different uses and subsequent area use and occupations. Table 2 shows the characterizations of useful surfaces (static data), theoretical occupation and energy use profile in order to define the total power.

Table 2: Static data - characterization of theoretical energy demand (Frandoloso, 2008).

<table>
<thead>
<tr>
<th>Bld</th>
<th>Useful surface (m²)</th>
<th>Theoretical occupation</th>
<th>Conditioning Surface (m²)</th>
<th>Conditioning Power (%)</th>
<th>Equipment Power (%)</th>
<th>Lighting Power (%)</th>
<th>Total Power (kW)</th>
<th>Density (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>3.389.77</td>
<td>645</td>
<td>988.70</td>
<td>26.73</td>
<td>65.96</td>
<td>7.31</td>
<td>520.89</td>
<td>153.66</td>
</tr>
<tr>
<td>G1</td>
<td>2.696.56</td>
<td>799</td>
<td>343.03</td>
<td>32.23</td>
<td>56.36</td>
<td>11.41</td>
<td>329.55</td>
<td>122.21</td>
</tr>
</tbody>
</table>

Table 2 shows that the use of energy for equipment reaches more than 65%. This is due to the high degree of potency in Engineering laboratories and Centre of Research in Agriculture - CEPA, specifically concerning the quality control of foodstuffs such as milk and other products of animal origin. These commodities, aside from demanding high potency equipment, require internal temperature control of the atmosphere in building L.1. On the other hand, a small percentage in relation to lighting is related to the fact that the building is of more recent construction, using more efficient lighting devices (32W).

In reference to building G1, the existence of the Information Technology Laboratory of FEAR implies that the approximate 56% of power for the equipment is because the building is of an older construction, still using high energy consuming lamps with low efficiency output (110W), which results in a total of 11.41%.

In both buildings, the areas with air conditioning are basically restricted to some laboratories which require temperature control, which corresponds to 29.17% in L1 and only 12.72% in G1. This results in energy consumption below the thermal demand which is really necessary to find the ideal conditions of comfort, when compared with the analysis of the thermal output.
4.2 Dynamic data collection

For the dynamic data (the variables in accordance with time) as the use and occupation of the spaces of building L1, specific survey files were collected. In this stage, besides the data on use, a survey on occupation showed a theoretical number of users of 799 (G1) and 645 (L1), based on maximum capacity of classrooms by class groups and practical laboratories (information technology and classes) and the real occupation of the specialized laboratories in building L1.

At the same time, the following occupation of the L1 building (Figure 5) shows that the greatest rate of occupation is focused in the evening period because of the types of courses which use the classrooms and this exact same pattern of occupation is observed in the following semesters. In the daytime period, especially in the morning, the main use is by the CEPA laboratories, which represent external services from the university (SARLE – laboratory that analyze the quality of milk, for example), with equipment which is in permanent function.

Concerning electrical energy consumption, the first collection level of data was taken from the reading of electric meters directly from analogical auditors, to register the daily, weekly and/or monthly energy consumption using electronic record cards, tables and graphs, beginning from October, 2008. From June, 2009, the data began to be collected via the SmarGateM system; comparing the two forms of collecting data (analogical and on-line), it can be confirmed that the percentage differences are at an acceptable level (less than 1% difference).

Figure 5: Number of users of building L1 – Aug-Nov 2007 (Frondoloso et al., 2008).
Analysis of the monthly energy consumption of both buildings for 2009, as shown in Figure 6, ratifies the interference from the use and occupation of each building, especially during the summer months, considering that, though academic and administrative activities are reduced with the scholastic vacations, building L1 continues with high energy use due to the laboratories being in continuous function, along with the necessity of maximum energy output for the air conditioning apparatus of these laboratories during periods of heat and maximum solar radiation.

Figure 6: Comparative electrical energy consumption graph for 2009.

5 Results of thermal performance

G1 was built using the original construction system: 14cm single masonry walls with 21 hole vertical holes and internal mortar and 15mm expanded polystyrene ceiling in the upper floor. Shading devices were installed in a recent upgrading of the North-east and North façades. The L1 was built with 24cm double brick walls (external brick as G1 plus an internal compact brick and internal mortar) and concrete ceiling but the North facing windows did not receive any protection from solar radiation or natural lighting controls.

In spite of almost the same construction characteristics, with a $U=1.255W/m^2K$ in G1 and $U=1.105W/m^2K$ in L1, these thermal properties for walls when compared with the precepts of NBR 15220 (ABNT, 2005) are below 3.00W/m²K, the minimal thermal transmittance of the external walls indicated to the Bio-climatic zone Z2.

On the other hand, typological architectonic characteristics, solar orientation and protection are distinct, as can be seen in Figures 1a and 1b, especially due to the fact that in building G1, solar protectors are present in the door and window frame apertures on the North and South sides. In L1, on the other hand, the door and window frames do not possess...
protection systems except for the application of blinds and/or internal shutters in some of the windows or, in cases of emergency, paper fixed onto the windows to control the entrance of solar radiation and dazzling from the sun, as shown in Figure 7.

![Figure 7: Emergency solution for controlling solar radiation – North facade Bld. L1.](image)

In accordance with the temperature measurements in the Meat Laboratory in building L1, it can be seen that for the period from the 22nd of January to the 15th of April, 2010, the internal temperatures (the lighter coloured lines in Figure 8), are more dense in the band between 25ºC and 30ºC, there having been registers of temperatures above 30ºC or even 35ºC. The data for relative humidity remains more constant due to the fact that the door and window apertures of the laboratory remain closed most of the time because it has a controlled atmosphere.

![Figure 8: Temperature and relative humidity measurements – 22/01 – 15/04/2010. Meat Lab. – L1.](image)
The maximum internal temperature recorded during the set period (35.9°C) occurred in the afternoon of the 30th of March, 2010, when it reached above 30°C (minimum internal temperature on the same day at 07h45m was 23.3°C), while the maximum external temperature reached 29.2°C with a minimum of 15°C.

Table 3 shows a comparison of the results for 16h30min in the four monitored classrooms. The Meat Laboratory (L1) and the Architecture Department office are orientated towards the north and the Practice laboratory and the Environmental Engineering department towards the south, with none of them possessing artificial conditioning.

<table>
<thead>
<tr>
<th>Time</th>
<th>L1</th>
<th>G1</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:30</td>
<td>35.9°C</td>
<td>25.9°C</td>
</tr>
</tbody>
</table>

Table 3: Comparison of the indoor temperatures in classrooms of buildings L1 and G1 – 30/03/2010.

The amplitude between the monitored environments in the same building - L1, was 10°C, while the difference for the G1 building was 3.3°C, but in other cases the temperatures presented many problems in relation to the limits of comfort - maximum 29°C for developing countries, according to Givoni (1992).

Figure 9: Temperature and relative humidity measurements – 13/01 – 13/04/2010. Architecture dept office – G1.

Despite the presence of solar protection in the north facing building – G1 of the office of the Department of Architecture, the data obtained – Figure 9, shows internal temperatures with lower values compared with those of the Meat Laboratory, despite the fact that...
temperatures can reach 30ºC, especially during the summer months. Concerning the relative humidity (the darker lines), the greatest variation in this environment is observed during the set period, taking into consideration the administrative use and the greater influence of ventilation.

For the cold periods, the measurements taken in June to August (Figure 10) confirm the complexity of the climate, when at the Architecture Department the minimum indoor temperature that reaches 9.7ºC and the maximum reaches 22.8ºC, below the Givoni’s comfort limits.

Figure 10: Temperature and relative humidity measurements – 06/07 – 23/08/2010. Architecture dept office – G1.

The software DesignBuilder (2009) was adopted for modelling energy and thermal performance, which allows definition of thermal multi-zones, shown in Figures 11a and 11b, the figures show the two different typologies, in different scales. Besides this, this tool presents a graphic interface with an easy adoption for Architecture and allows the final data to be exported for analysis by EnergyPlus (USA - DOE, 2009).

The preliminary simulation results with the software DesignBuilder, show that the intense thermal gains are closely related with the constructive and occupational architectonic typography and the conditions of solar protection. In other words, although in building G1, 67.61% is relative to the gains of the equipment (32.68% by the computers), 24.9% by solar radiation and 7.36% by occupation; in building L1, 34.19% of thermal gains are by solar radiation, with the other factors presenting similar results between them, despite a greater potency of equipment (61.86%). The comparison between the thermal benefits is presented in Figure 12.
6 Results of environment comfort performance

The evaluation of the standards of comfort for users was developed through the Fanger´s Predicted Mean Vote – PMV (Fanger, 1970; Fanger and Toftum, 2002) and the adaptations for temperate and hot climates proposed by Hwang et al. (2006), using averages of the of the internal and external environment variables (average radiant temperature, temperature, humidity and relative air speed) and the global temperature.
With the application of questionnaires for users of the Practice Laboratory, adopting Fanger’s PMV methodology (1970) and the Bedford scale, Figure 13 shows that the action PPD – predicted percentage of people dissatisfied with their thermal environment, in relation to the indoor conditions is 100%:54.55% presented a sensation of little heat (+1), 27.27% with heat (+2) and 9.09% with a lot of heat (+3).

![Figure 13: Thermal sensation of users of room 102, afternoon of 31/03/2010, male sex.](image)

Figure 13 demonstrates the dissatisfaction of the female students in relation to the environmental conditions: 16.67% described a comfortable thermal sensation, neither feeling hot or cold, 50% presented low heat sensation (+1) and 27.78% hot (+2).

In the afternoon of 31/03/2010, when the questionnaire was applied in room 102 of building L1, which has the same solar orientation as the Practice Laboratory, the data logger registered a minimum temperature of 24.4ºC and a maximum of 25.7ºC. The temperature registers obtained in the classroom occupied by the students were from a minimum of 26.6ºC to a maximum of 28.8ºC. Comparing this data, it can be confirmed that the temperature of the classroom is maintained with a variation of 2.2ºC, though
higher than that which was registered in the laboratory. This is due to the fact that the room is occupied.

On the afternoon of 30/03/2010, when the questionnaire was applied in room 11 of building G1, which has the same solar orientation of the office of the Department of Architecture Course, the data logger which was installed registered a minimum temperature of 26.8°C and a maximum of 29.7°C. The temperature registers obtained in the classroom were from a minimum of 25.8°C to a maximum of 27.6°C. It can be observed, however, that the temperature in the classroom, which was occupied by students in sedentary occupation, was less than the register in the Architecture office. The reason for this variation is due to the greater thermal isolation of the room and the lower solar radiation of the location, which is below ground level.

Figure 15: Thermal sensation of users of room 11 - G1, afternoon of 30/03/2010, male sex.

Figure 16: Thermal sensation of users of room 11 – G1, afternoon of 30/03/2010, female sex.
Figure 15 refers to the study carried out in building G1 and shows that the dissatisfaction of the male students in relation to the environmental conditions is the following: 12.5% presented low cold sensation (-1), 37.5% described a comfortable thermal sensation, neither feeling cold nor hot, 25% presented a low heat sensation (+1) and 25% hot (+2). In Figure 16 for the female sex, the sensations of discomfort related to heat were predominant. Future analysis will be necessary in relation to the compatibility of real demands and theoretical results of the simulations with the possible scenarios. In other words, acquaint the consumer with the criteria of eco-efficiency, which includes analysis of environmental impact and costs as evaluation factors of the administrative efficiency of institutions or companies.

7 Conclusions and guidelines for eco-efficiency at UPF

In the first place, the university’s responsibility in preparing for a more conscious and responsible professional future through knowledge generated is remarkable, and especially being an example of concrete actions in order to achieve the principles of a sustainable society in a collaborative and responsible way by involving the entire university community in the imperative process of changing procedures and habits.

The research brings results that will be able to provide some criteria in order to improve the building stock by upgrading it with regard to better indoor conditions that really correspond to climate conditions (hot and humid summers and cold and damp winters), using passive strategies for heating and cooling and at the same time to improve the efficient and rational use of natural resources and to reduce the environmental impact. Probably, the improvement of comfortable conditions will increase energy consumption but there is a potential reduction of lighting and use of equipment.

An observation of the establishment of standards for energy and thermal efficiency is that Brazilian norms are simply of an orientating form without any kind of obligatory certification apart from the fact that there is a general lack of specific norms for public and educational buildings.

In relation to the thermal performance of the studied buildings, it can be concluded that the following factors contribute to the increase in demand for electric energy: the architectonic typography; the design of the door and window apertures of both buildings and the division of internal spaces. Also included is the unfavourable orientation, in particular, of the laboratories, together with a lack of ventilation. All these factors contribute to a high thermal charge for air conditioning reflecting directly by a consequential increase in energy consumption.
The research presents some results which allow for the definition of guidelines for the establishment and consequently, the increase of eco-efficiency in the park constructed at UPF, both in existent buildings and those to be yet constructed:

- analysis of the useful life of the buildings and application of sustainable construction principles;
- revision of construction parameters for new constructions, utilizing adequate thermal insulation coverings;
- adoption of criteria to define adequate solar orientation for the restrictions of the habitation of the different divisions of the architectonic programme, such as laboratories and classrooms;
- projects for upgrading with the implementation of better thermal comfort conditions which correspond to the local climatic conditions (hot and humid in the summer and cold and damp in the winter);
- use of passive strategies for cooling and heating;
- implementation of natural ventilation together with the mechanical ventilation systems (when indispensable in accordance with the use);
- adoption of door and window aperture designs with external solar protection to guarantee effective reduction of solar effect together with passive heating strategies;
- increase in the use of efficient natural recourses and a reduction in the associated environmental impact.

The results should be analysed, taking into consideration all the factors which present an influence on the thermal and energy output, especially concerning the use and occupation of the spaces and the efficiency of the equipment in areas such as illumination and air conditioning or the various equipment which make part of the scope of the developing research. In this way, the systematic analysis indicates that, as a priority, to meet the real needs of the users, energy consumption should be greater because living/working conditions in both buildings are inexistent, especially during the cold periods.

The energy audit method applied to universities, constitutes a valuable tool to understand the real condition of each building in order to propose a concrete plan of action and investments to achieve energy efficiency, with corresponding economic results for the entire building stock. This means achieving eco-efficiency in all its dimensions: economic, social and environmental.

At the end of the research it will be possible to improve the method as an operational tool, to help in decisions making during the whole process of design, construction and use of buildings. In the specific case of the application to the University of Passo Fundo, the final
results of the research will provide elements to propose an instrument to improve the performance of the buildings stock in the campus and also to elaborate the guidelines for “Environmental Efficiency and Energy Programme” applicable to all the UPF campuses.

References


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