# COMPARATIVE STUDIES OF THE OCCUPANTS' BEHAVIOUR IN A UNIVERSITY BUILDING DURING WINTER AND SUMMER TIME

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## ABSTRACT

The paper focuses on the assessment of indoor comfort and the energy consumption in a University building, during winter and summer time. The examined building belongs to the Cyprus University of Technology, it is located in coastal city of Limassol and it is used for teaching and offices. The main aim of the paper is to make a comparative study of the occupants' behaviour and its effects on the building's energy consumption, as well as on the indoor thermal and optical comfort, between winter and summer season.

ASHRAE Standards (American Society of Heating, Refrigerating and Air conditioning Engineers) are used through a questionnaire campaign and the thermal comfort of occupants' is analysed with the indicator of PMV (Predicted Mean Vote), and PPD (Predicted Percent of Dissatisfied People). The occupants' answers are analyzed using SPSS (Superior Performance Software System) software.

The study and measurements are carried out during the summer and winter months of 2012 and 2013, respectively. The air temperature, the relative humidity and the levels of lighting of the building are monitored using temperature, humidity and lux meter tools. The data are collected on a daily basis for two weeks, during the period of the two seasons. The monthly energy consumption cost is calculated based on the bills of the Electricity Authority of Cyprus for 2012.

The recorded measurements; the completed questionnaires are analysed for both seasons, summer and winter. From the analysis of results, comparative studies of the occupants' behavior for the two seasons conclude to various patterns of effects on the thermal and optical comfort of the building, as well as on its energy consumption.

**Keywords:** Indoor comfort, occupants' behaviour, energy consumption.

## 1 INTRODUCTION

Inefficient energy use in buildings is both, increasingly expensive and unsustainable [1]. The increasing energy, already threatens the future of the planet, as research shows that 10% of the world population exploits 90% of energy resources [2]. Energy consumed in many ways in buildings, and the maximum consumption depends on the type of building, construction and building services details, and the climate in which the building is located [1]. Based on a research, the two characteristics with the greatest influence on energy use, is the option of building size and weather conditions [3]. Therefore, the reduction of energy consumption of a building begins from improving the design of buildings [1] and [3]. Also, during the design phase of the building, the rate of heat loss and the number of users who are in the building, are the two parameters which must be given more attention due to high impact on building energy performance [4]. Various studies have indicated large differences in energy consumption in buildings, which are caused by the occupants' behavior of each building, which exerts a strong influence. In fact, several studies discuss that energy savings can be achieved with low-cost measures and a change in the attitude of occupants towards the energy consumption and save energy [4], [5], [6] and[10]. For example, energy is wasted needlessly if employees do not switch off their computer before they leave the job, or if they leave the lights on most of the working hours even if they are absent from the office, or even if there is sufficient natural light. By the proper use of natural lighting, the electric light can be eliminated, and so, in this way, energy saving can be achieved for lighting, cooling and electricity. Also, by switching off appliances that are not needed during the working hours, savings will be even higher. However, because of the poor occupants' energy behavior in the buildings, more energy is used during non-working hours than during working hours [5] and [7]. These are directly related to the thermal comfort of the buildings, because the use of the building by its users can lead to an improvement of the internal environment, or to degradation. However, people under the same climatic conditions do not all feel comfortable at the same time with the same conditions [11]. Of course, there are different behavioral patterns and user profiles that affect differently the energy consumption of a building. These differences in wasted energy are based on gender, age and years of service of the employees. For example, high-income couples request comfortable housing without concern for energy saving and these families are usually those which use more devices daily. Older people need higher levels of thermal comfort [5] and [8]. A study has also shown that the maximum energy consumption for heating usually is caused by bedrooms, offices and working rooms [8]. While the use of renewable sources of energy can contribute to reduce energy consumption, the focus is on the recognition of the wasting from occupants. This will facilitate the acceptance of energy-saving measures, since as a result this will improve the quality of life, protect the environment and reduce the power budget of their household, company or space [5].

## 2 METHODOLOGY

In the present report, the study of indoor comfort and the energy consumption in the Building Service of Academic and Student Affairs of the Cyprus University of Technology (CUT) is being studied. Specifically, the occupants' behavior affecting the energy consumption in the building, as well as the indoor thermal and optical comfort is examined during summer and winter season of 2012 and 2013, respectively. The study was carried out with questionnaires addressed to the employees and the students, instruments for daily measurements and calculations for the energy consumption.

The study compared the behavior of the occupants and the completed questionnaires. A total number of 60 occupants participated in the study, 30 occupants each season. During summer season, 60% of the participants were females and 40% males. Respectively, during winter 67% were females and 33% males. The questionnaires were given at the same time and collected after the occupants' responded. The questionnaire based on ASHRAE Standard (American Society of Heating, Refrigerating and Air conditioning Engineers) and was divided into two main sections. The sections included: a) the thermal comfort which consists of 7 questions and b) the natural lighting with 4 questions. The occupants' answers are analyzed using SPSS (Superior Performance Software System) software and were organized in diagrams showing percentages for each question based on the total occupants' responses. Thermal comfort of occupants' is analyzed with the indicator of PMV (Predicted Mean Vote), and PPD (Predicted Percent of Dissatisfied People). For the scope of this research, employees and students in the building were chosen as the occupants under investigations.

Air temperature, relative humidity and the levels of lighting of the building are monitored using temperature, humidity and lux meter tools. The data are collected three times a day, during the period of two weeks for each season, excluding weekends. During summer season, the measurements were during 07:00 – 08:00 am, 13:30 – 14:30 pm and 17:30 – 18:30 pm, in the morning, noon and afternoon, respectively. The noon measurements were during the working hours, while the morning and afternoon hours were during non-working hours. During winter season, the measurements were during 08:00-09:00 am, 12:30-13:30 pm and 16:00-17:00 pm for the morning, noon and afternoon, respectively. The measurements were during working hours. The position and orientations of each occupant, according to that of the building, are recorded, as well as the daily observations.

The monthly energy consumption cost is calculated based on Electricity Authority of Cyprus charges for 2012 and on the data from energy bills for the building, during a summer month.

Finally, the last step was to compare the occupants' behavior for the two seasons concluding to various patterns of effects on the thermal and optical comfort of the building, as well as on its energy consumption. These were essential to evaluate how occupants may influence building energy use through their actions and behaviour.

## 3 THE CASE STUDY

The building of the Students Affairs of the Cyprus University of Technology is located in the center of Limassol on the corner of Athens and Nicholas Xiouta Street. Limassol has a Mediterranean and temperate climate, which is mostly hot with dry summers and mild winters. The humidity in Limassol is at high levels due to its coastal position. In the summer of 2012, the average maximum temperature in Limassol was about 34.53 °C, the average minimum temperature at 23.67 °C, while the average rainfall is 0 mm. In December of 2012, the average maximum temperature was 19.9 °C, the average minimum temperature at 12.1 °C, while the average rainfall is 48.7 mm.

Table 1: Maximum/Minimum Temperature (°C) and Precipitation (mm)

| Month | Average Maximum (°C) | Average Minimum (°C) | Rain (mm) |
|---|---|---|---|
| June | 32.2 | 22 | 0 |
| July | 35.2 | 24.9 | 0 |
| August | 36.2 | 24.1 | 0 |
| December | 19.9 | 12.1 | 48.7 |

The building was built in 1978 and functioned as a bank. In 2002 retrofitting and upgrading of 1st and 2nd floor was done, until the 1/5/2011 when the Cyprus University of Technology bought the

Figure 1: The Service of Academic and Student Affairs building.

building. In July of 2011 the renovation of the second floor of the building started; in December of 2011 that of the ground and the mezzanine. The building of Student Affairs is a three storey building with a mezzanine on the first floor. Specifically, there is a ground floor of 500 square meters ($m^2$), mezzanine 497 $m^2$, first and second floor area of 560 $m^2$ each one. Based on the main facade, the building has a northwest orientation.

Figure 2: Architectural Design of the building a) Ground floor, b) Mezzanine, c) First Floor, d) Second floor

The height of each floor in the building is 3.25 meters (m). The building is made of reinforced concrete frame structure and 20cm brick walls; in the interior it incorporates plasterboard panel walls of 10 cm. The facades of the building are mainly glazed, except the south façade which is opaque; the panels of windows are single glazed.

The building under study is used as offices for employees and teaching classes for students. Specifically there are offices, lecture rooms, conference rooms, computer rooms, corridors, toilets and kitchens. Also, it is equipped with all the typical appliances (computers, photocopying machines, printers, refrigerators, etc.) as well as machinery and equipment for the needs of users. On the ground floor and the mezzanine of the building, there are twenty two (22) people employed. The first and the second floor house a large number of students. The ground floor and mezzanine operates from 7:30 a.m. until 14:30 pm and from 07:30 am to 18:00 pm, in the summer and in winter periods, respectively. The first and second floor, which have classes operate from 8:00 a.m. until 20:00 pm, throughout the academic semester. However, during the 3 months of summer, the students are not attending the university, however, the staff of Student Affairs continues to work. For the summer, the survey of questionnaires was conducted in late August when the students returned to the University for their registration for the new academic year.

# 4 RESULTS AND DISCUSSIONS

## 4.1 Questionnaire Results

Prior to conducting any statistical analysis, descriptive statistics were performed. The most significant results derived from the responses given by the University's employees and students according to the questionnaire are presented below. Also, correlations between the users' responses have been made and all these are presented in Fig. 3 – 10.

### 4.1.1 Thermal Comfort

The first section of the questionnaire focuses on the users' thermal comfort. In Figs.3-5 indicate the relationship between indicators PMV and PPD through the question how users feel regarding thermal comfort, for summer and winter season. The predicted percentage dissatisfied (PDD) for summer is 43,35% and PMV = (-1,4). The PPD for winter is 43,35% and PMV = (+1,4). According to the standards of Ashrae the 43,35% PDD is not within accepted limits, since the PMV is -1,4 and +1,4. The majority of users indicate that in summer it feels slightly cold to cold and in winter it feels hot. The main reason that the users do not feel comfortable, in either season, is found in their answer of the question whether the air conditioning is turned on. Apparently the air conditioning was turned on at very low temperatures in summer and at very high temperatures in winter season.

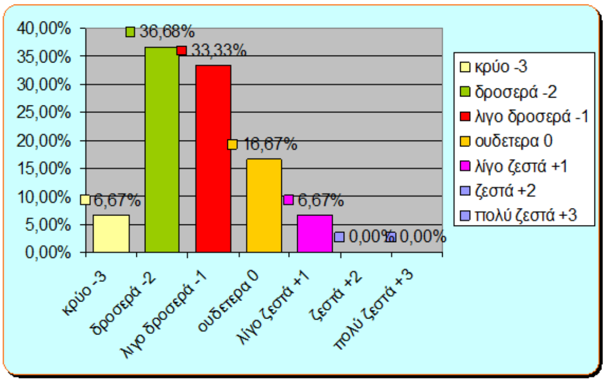


Figure 3: Percentages on the users' satisfaction for thermal comfort in summer.

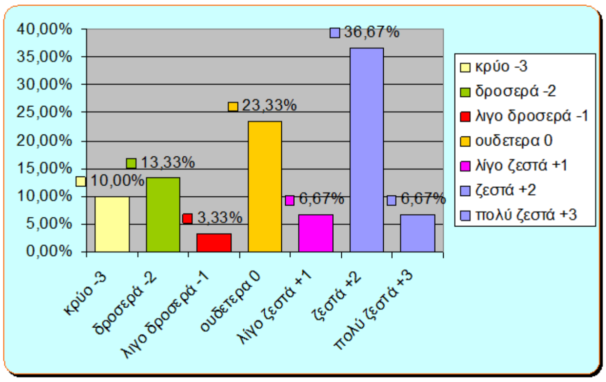


Figure 4: Percentages on the users' satisfaction for thermal comfort in winter.

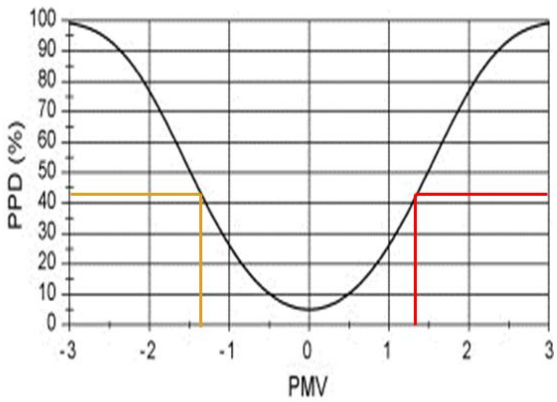


Figure 5: PPD according to the PMV. Orange colour shows the summer and red the winter

Users were asked to indicate their habits concerning the air conditioner. As shown in Fig. 6 and 7, almost 50% and 28% of employees switch off the air conditioner in their office when they leave their offices, in summer and winter, respectively. It is noteworthy that in the summer up 58,85% and in winter 62,5% of the surveyed students do not know when the air conditioner switches off, as opposed to employees. This perhaps indicates a tendency of indifference on behalf of the students concerning air conditioning in their space.

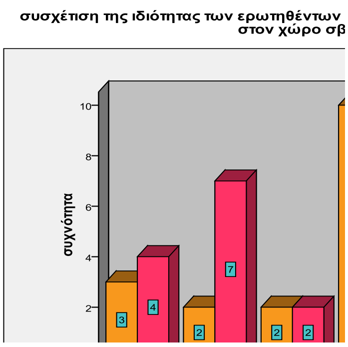


Figure 6: Correlation a
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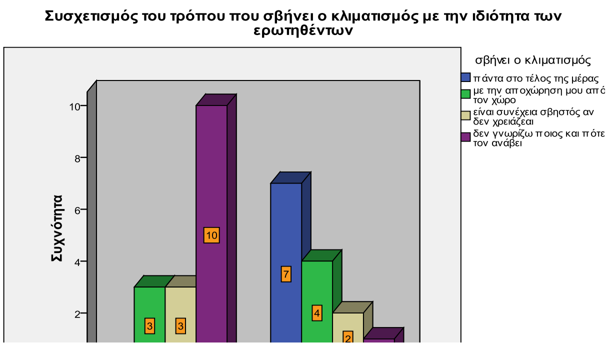


Figure 7: Correlation and frequencies of users (employees or students) habits concerning the air conditioner in winter

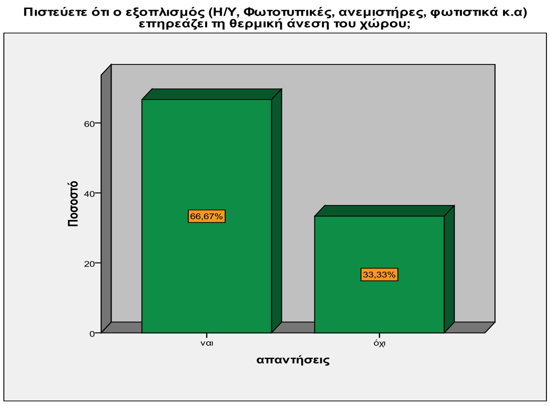


Figure 8: Percentages on the users’ opinion if the equipment affects the thermal comfort in summer.

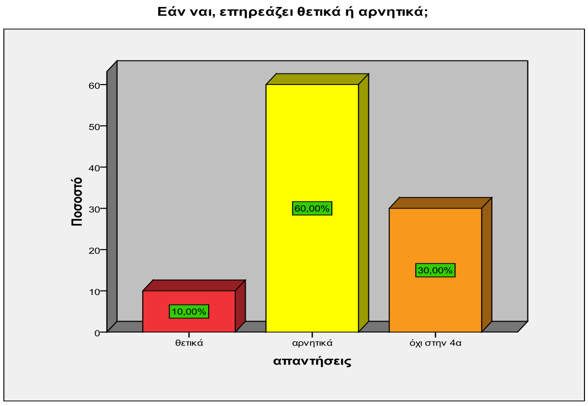


Figure 9: Percentages on the users’ opinion if the equipment affects positively or negatively the thermal comfort in summer.

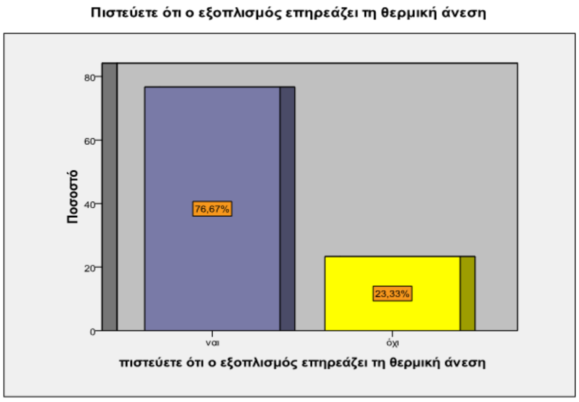


Figure 10: Percentages on the users’ opinion if the equipment affects the thermal comfort in winter.

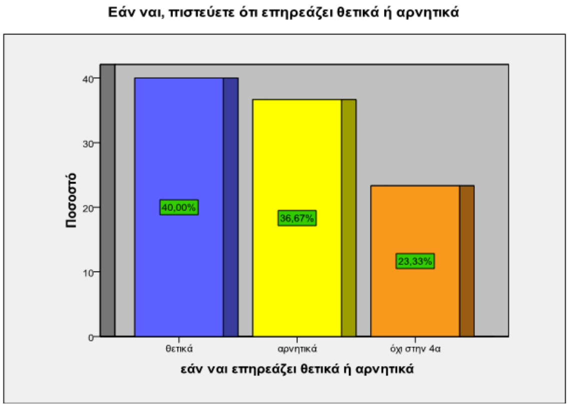


Figure 11: Percentages on the users’ opinion if the equipment affects positively or negatively the thermal comfort in winter.

From the users’ replies in Figs. 8 and 9, 66,67% responded positively and 33,33% responded negatively on the question of whether electronic or any other equipment affected the thermal comfort of the office/teaching areas in the summer. Also, up to 85,71% of those who responded positively in this question, believe that the electromechanical equipment adversely affects the thermal comfort of the room. During the winter, the vast majority of respondents replied positively to the specific question (76,67%), but from this percentage only 40% answered that it affects the thermal comfort positively and 36,67% that they are adversely affected (Figs. 10 and 11).Nevertheless, during the daily measurements it was observed that almost all users leave the equipment switched on for 24 hours the day.

4.1.2 Natural lighting

The second section of the questionnaire aimed in examining the natural lighting of the users’ space. The users’ level of satisfaction in terms of natural lighting in their office/teaching areas is presented in Fig. 12. It is shown in the figure that the employees replied that they are dissatisfied with the availability of the natural lighting in their offices in the summer. It is also shown that half of the students are dissatisfied, too. The larger numbers of the employees expressing dissatisfaction in comparison with those of the students are justified since the employees are

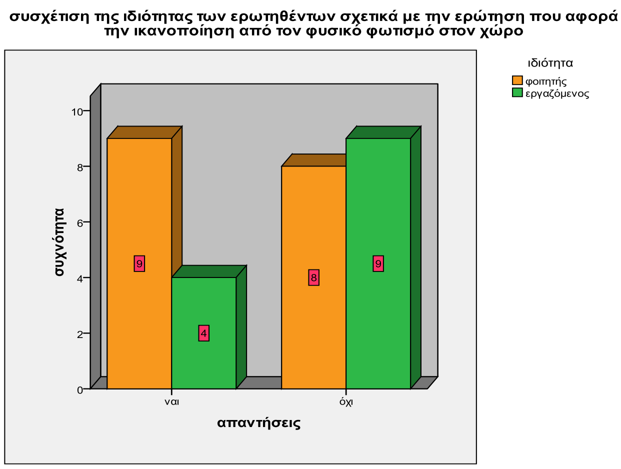


Figure 12: Correlation and frequencies of users (employees or students) habits concerning the satisfaction level for natural lighting in summer and winter.

permanently based in their offices and spend more and longer hours in the building than the students.

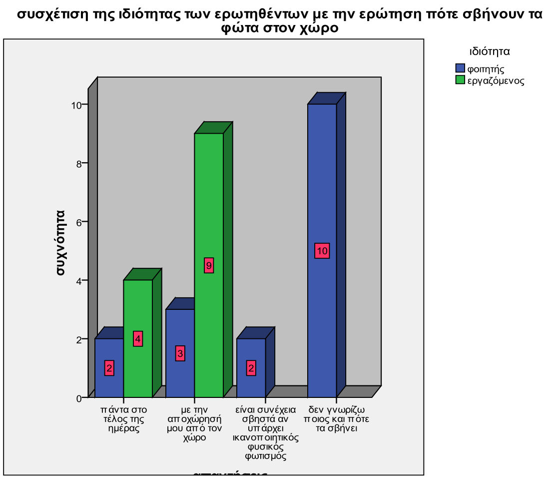


Figure 13: Correlation and frequencies of users (employees or students) habits concerning the lighting in summer and winter.

Furthermore, users were asked to indicate their habits concerning the lighting in their own space. As shown in Fig. 13, for both seasons, the majority of employees switch off the lights of their office when they leave the work. It was noted, that up to 57% of the surveyed students do not know when the lights are switched off in the teaching areas, as opposed to employees. This possibly indicates lack of the sense of responsibility on behalf of the students concerning the switching off the lights when leaving their classes.

4.2 Field measurements and indoor comfort

According to Ashrae standards, in office and educational buildings / rooms the optimal thresholds for natural lighting for open or closed-type offices and classrooms are 300 lux. In a conference room the minimum rate is 500 lux.

Figures 11 - 15 show the average temperature, humidity and lighting measurements in different spaces and orientations in the building. Figures 14a-b, show the lighting measurements in an office on the ground floor facing south. It is an open plan office for a single occupant. The light measurements in the morning and in the afternoon hours are taken with artificial lights turned on, since the specific office, as well as its adjacent one, have very porr or even no natural light at all. There are no windows or other skylights in the offices. In summer, the temperature in the afternoon with activated air conditioning is at 25,5 °C and humidity 50%. In the morning and evening measurements, the temperature in the office is around 28 °C. This is not the free running office temperature since the air conditioners remained switched on after the employee left work in the afternoon, so the temperature remains at 28 °C until the next morning. In winter the temperature measurements were at 23,5 °C and humidity 10 points lower than that of the summer.

In Figures 15a-b, measurements were made in a conference room for about 30 people, facing south with no external windows for natural light. The conference room has windows opening in an interior open space, with the shutters permanently closed. The measurements showed levels of lighting to be less than 10 lux for both seasons. The increased moisture content in the field (60 – 68 %) is due to the fact that is aired and illuminated only when in use, which is not daily. In the summer, half of the days of measurements, the temperature is around 26 °C, with air-conditioning on in the room, without any occupants. In winter, the temperature was at about 23 °C.

Figures 16a-b, illustrate measurements performed in a lecture room of the first floor with northwest orientation, with 21 computers. The room has glass panes with north, northwest and west orientation. In the summer, the measurements were taken with the air conditioning off and it was observed that the temperature in the morning hours, compared with that of other rooms in which the air conditioning was also closed, was higher at about 2-2,5 °C. This is probably due to the fact that the mechanical equipment in the room (computers and printer) affects the natural temperature of the room. During the days that the measurements were taken, in both seasons, it was observed that more than half of the computers were in operation, even if there were no lessons in session. The lighting in the room at the location of the measurements was very low and this is because the shutters of the windows were all closed. Based on measurements of adjacent rooms / offices with the same orientation, it is speculated that during the midday hours if the shutters of the windows were open, natural light is largely satisfactory. Nevertheless, based on field visits on a daily basis, it was observed that the users, choose not to open the shutters of the windows, instead they turn on the lights.

Figures 17a-b, show the measurements of a classroom of 20 people (60 $m^2$) with southwest orientation on the second floor. Based on the measurements in the room, with the lights and shutters closed, the levels of natural light was measured to be about 100-110 lux, whereas with the blinds open it exceeded the 290 Lux at midday. On the west side of this room there are windows that cover an area of approximately 20 $m^2$. However, natural light is not allowed in the room; during the field visits, it was noticed that the occupants preferred the artificial light instead of opening the shutters. The natural temperature of the room without air conditioning is 31 to 33 degrees in the morning until the afternoon and humidity 55– 60 %, in the summer season. In winter, the temperature measured at about 21-22 °C and humidity 49-50%.

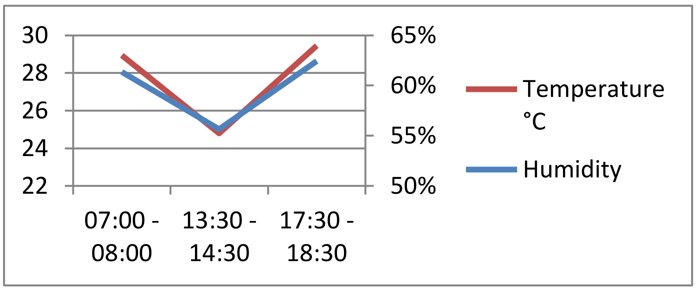


Figure 14a: Results of temperature and humidity measurements in an office at south in summer.

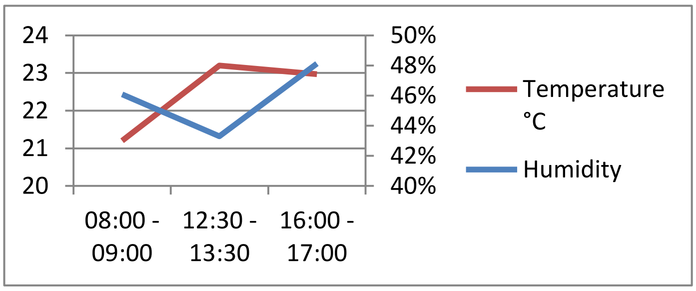


Figure 14b: Results of temperature and humidity measurements in an office at south in winter.

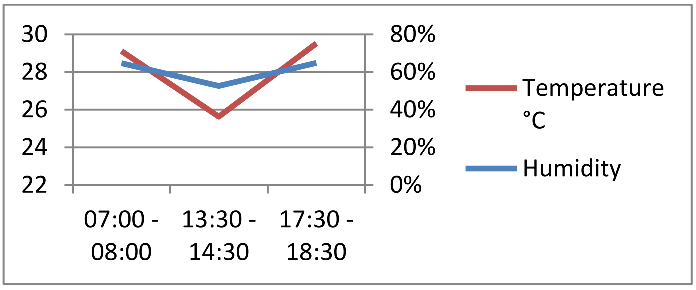


Figure 15a: Results of temperature and humidity measurements in a conference room at south in summer.

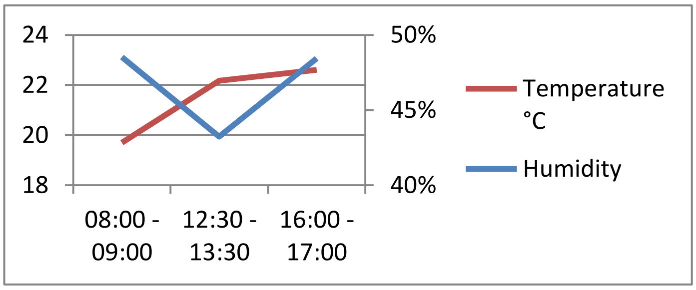


Figure 15b: Results of temperature and humidity measurements in a conference room at south in winter.

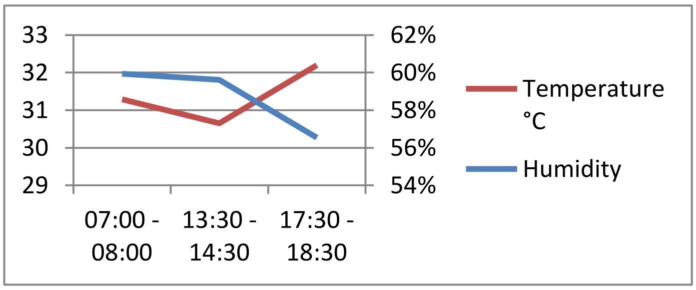


Figure 16a: Results of temperature and humidity measurements in a lecture room at northwest in summer.

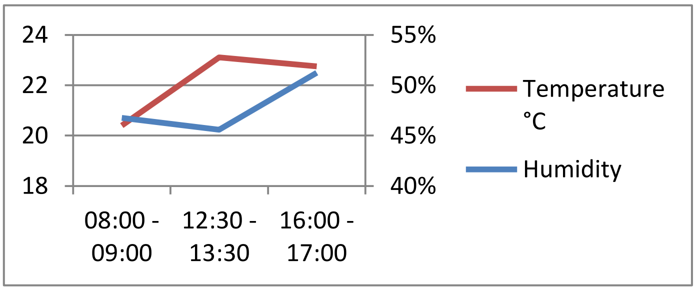


Figure 16b: Results of temperature and humidity measurements in a lecture room at northwest in winter.

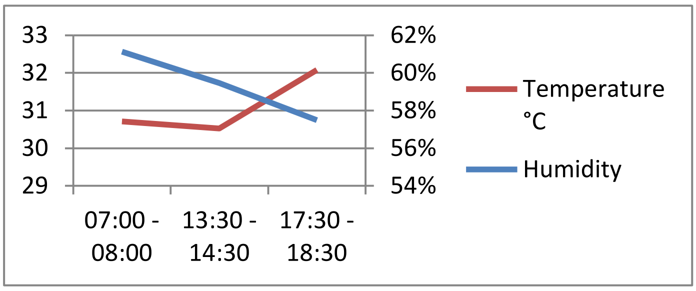


Figure 17a: Results of temperature and humidity measurements in a lecture room at southwest in summer.

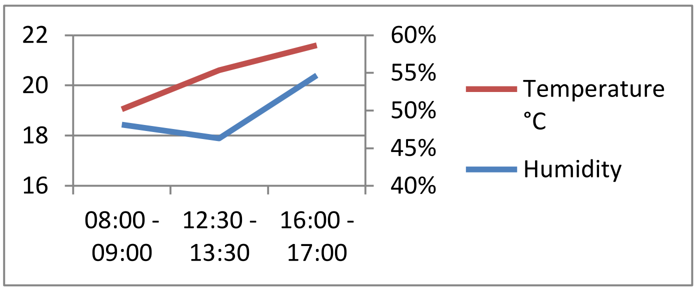


Figure 17b: Results of temperature and humidity measurements in a lecture room at southwest in winter.

4.3 Energy consumption and occupants' behavior

The official working time for the building is the crucial time for energy demand charge. However, by visiting the building in the early morning hours that no one was in it, it was confirmed that some occupants leave their computers on over-night and over the weekends. Also, all the equipment was left running throughout the semester even though no one was in the building. Fig.ure 18 shows two scenarios of consumption by equipment of the building, including air conditioners and lamps, representing the apportionment of energy between 24 and 12 hours per day. According to measurements and calculations, if all equipment remains open 24 hours a day, then consumption amounts to 1505,76 kWh for 1 day. This amounts to 33126,72 kWh for 1 month. Therefore the monthly cost of consumption amounts to 10931 €. It is estimated that if all the equipment is reduced to 12 hours of operation, then there is a great energy saving and consumption descends to 970,38 kWh for one day and therefore to 21438,36 kWh for one month. Thus, the monthly cost of consumption drops to 7044 €. However in order to achieve this, it is necessary to raise the energy awareness and change the behaviour of the occupants in order to consume less.

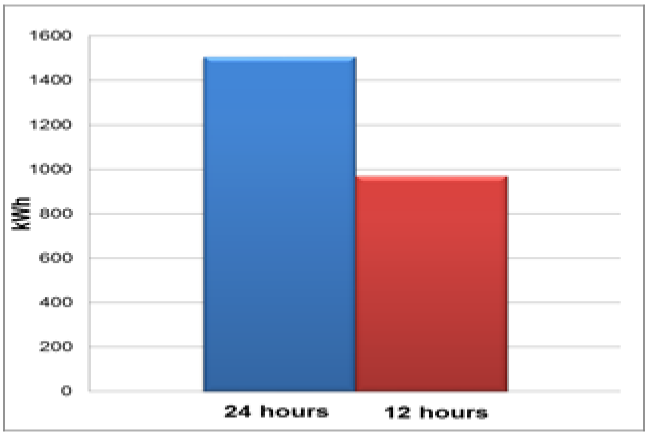


Figure 18: Scenarios of energy consumption

## 5 CONCLUSIONS

Indoor comfort and energy consumption has been examined in the Building of Student Affairs of the Cyprus University of Technology (CUT) during summer and winter time. Specifically, a comparative study between winter and summer season was carried out of the occupants' behaviour and its effects on the building's energy consumption, as well as on the indoor thermal and optical comfort. The survey was conducted using both questionnaires regarding thermal comfort and natural light, and field measurements with appropriate instruments for daily measurements. Also, the energy consumption of the building is calculated for two scenarios.

Thermal comfort of occupants in the building, during the summer and winter months, is not satisfactory in the office / lecture room, given that the predicted percentage dissatisfied PPD is 43.35% and 43.34%, respectively, and PMV -1.4 and 1.4, respectively. According to the results, the thermal comfort is affected negatively by the equipment in use in summer and positively in winter. Also, the majority of users and especially the students, leave the air conditioning, lights and equipment on when they are leaving the room / office and throughout the day. This indicated the lack of proper energy use from the occupants of the building.

The south and southwest side of the building can be an important advantage for space heating naturally by solar radiation (with horizontal blinds to avoid overheating in summer), as for ventilation in the use of the building, such as offices, classrooms and conference rooms. This is not possible since the entire south side of the building is built and enclosed, without any benefit for heating and ventilation. Additionally, every effort is made to improve the many weaknesses of internal and external layout of the building and in turn the occupants' behavior (employees and students) adapt accordingly, but indicate an intense indifference in regards to the energy consciousness and behavior.

For energy benchmarking, if air conditioners, lamps and general building equipment are used only during the operating hours and not 24 hours per day, then a high amount of energy could be saved and the cost of the consumption for the building will be much lower. Simply by switching off appliances at the end of the day could save energy. The savings will be higher if the equipment is switched off when is not required even during the operating hours. Meanwhile, ongoing studies in the same sector for this building will be carried out for the other two seasons.

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