# OPEN UNIVERSITY OF CYPRUS

## FACULTY OF PURE AND APPLIED SCIENCES

*Master in Sustainable Energy Systems*

# Energy consumption and thermal comfort in office building

**By Bakalis Panagiotis**

Submitted in fulfillment of the requirements for SES701 Master Thesis I (Capstone)

Academic Coordinator: Dr. Effrosyni Giama

**2017/2018**

# Table of contents

# Introduction

The existence of buildings, whether these serve as spaces to live in or as working places, aim to assists the human activity, as well as it provides protection from exterior weather conditions. However, very often in the interior of the buildings are presented problems with regard to the thermic conditions that prevail. The results of problem have direct impact not only in the conditions of comfortable existence in the buildings but also in the health of their users. It is rendered therefore obvious that the appearance of phenomena of thermic dissatisfaction of users in the buildings is by definition opposite with the reason of their existence.

Examining each building as a separate sub-system of the exterior environment and given the interaction between each other, the significance of the conditions indoor climate is unbreakably connected with the characteristics of manufacture and operation of building. The more general regard of problem concerns the internal environment globally. Apart from the evaluation of the thermic conditions, are evaluated also other factors such as the quality of internal air, the noise and the lighting. The additional factors that are imported with this more general regard influence the health, the comfort and the performance of residents of the building.

The complexities of the problems that are related with the thermic comfort are increased, if we import also the factor of cost. The buildings constitute investments of intensity of capital, with high initial cost and with big duration of life. Meaning that this we are committed to pay is the compensation for any omission, negligence or failure in the planning and the manufacture for entire decades.

The Greek legislation included for the first time regulations relative with the buildings heat insulation in 1979, with the Regulation of Heat insulation of Buildings, which was influenced from the corresponding German DIN 4108 and the method of calculation of thermic needs of DIN 4701. The most recent regulation became in 2010, when was also published the Regulation of Energy Attribution of Buildings. The KENAK substantially renewed the Regulation of Heat insulation, incorporating the relative with of the buildings sector provisions of Community Directive 2007 in regard to the targets of reducing the emission of greenhouse gases at 20%, production of energy in percentage 20% from RES and increase of energy output at 20% until year 2020 (known and as "20-20-20").

The energy renovation of buildings can constitute motive force for rebooting the sector, while the specialized work of renovations and energy upgrades occupies indirectly mechanics, technicians and researchers in the sectors of chemistry, minerals and technical equipment. This work concerns the 2/3 globally occupied in the sector, that in the first place work in small to medium-sized companies, giving thus the possibility to increase their contribution in the RES.

Finally, the affair the thermic comfort and more generally the indoor climate it depends from the human factor. The use of building from his residents, can lead to improvement of internal environment or to its revalorization. In the evaluation indoor climate and particularly with regard to the conditions of comfort, subjective criteria influence the result of evaluation. Any study round the internal environment of building should take into consideration the users, which conceive differently each one the indoor climate. Consequently the issue of thermic comfort receives also the human component, as for the evaluation and the solution.

The building that we will study in this thesis concerns office buildings. The energy consumption of office buildings in Greece varies in connection with their energy installations (being air-conditioned or not), their way of use and their age. With energy data base from many hundreds of buildings in Greece, has resulted the distribution of energy consumption as well as the classification of this buildings in three energy categories, and concretely:

- The energy formal building, that corresponds in the 50% of sample of office buildings.
- The most optimal building, that corresponds in the 20% of the best energy office buildings and
- The passive building, that corresponds in the 5% of the best energy office buildings.

As a result, the formal air-conditioned office building consumes almost 138 $kWh/m^2/year$, (final consumption), where:

- the air conditioning represent almost 35 $kWh/m^2/year$ and
- Heating almost 85 $kWh/m^2/year$.

The average consumption of the not air-conditioned office buildings it oscillates around 75 $kWh/m^2/year$, from which the 57 $kWh/m^2/year$ are consumed for thermic reasons.

# 1. Thermal Comfort

Various studies that were materialized with target to measure the satisfaction that show the workers in an office environment, showed that one from the most important factors that influence the satisfaction of workers is the temperature, which constitutes also an important factor of creation of complaints. [1]

The thermal comfort constitutes a very complicated issue in the office environment, in which the tendencies in the architectural planning of offices and systems of control the office environment, many times are contrary to the needs of workers. But what precisely is the thermal comfort?

The energy problem with the problem of pollution of environment, and at extension of climatic change, they have acquired in the last few year particular importance, while the changes that take place in the energy map are rapid. As a result, the EU placed as at the heart of her energy policy the target to decrease the emissions of greenhouse gases at 20% up to 2020, compared to the levels of 1990.

It is well-known that the 50% of emissions of dioxide of coal (and the other gases of greenhouse) and the 40% of total final energy consumption at European Level emanate from the energy consumption in the buildings sector. Consequently, it is obvious that an important percentage of energy could be saved from the improvement of energy behavior of buildings and the more rational use of energy in them.

On the other hand, the modern way of life has led most of the people to pass a big part of their life in "closed spaces". Roughly the 90% of our time we spend it in various artificial environments as residences, offices and in means of transport (cars, trains, etc.). It is consequently reasonable, the existence, in the past few years, of an increasing interest for the study of that factors that create conditions of thermal comfort in this closed spaces.

For the definition of the significance of thermal comfort are existing three different approaches, one physiologic, one thermal-physiologic and the last one is based on the energy balance of human body [2].

According to the first approach and as it is determined by model ISO 7730 and ASHRAE 55-2004, thermal comfort for an individual it is defined "this situation of brain that expresses satisfaction concerning the thermal environment".

The obvious subjectivity at this definition it reflects a wider fluctuation of individual thermic sense. The thermal-physiologic approach of comfort is based on the activation of thermic sensors in the skin and the hypothalamus and is fixed as the most minimum rhythm of nervous signals from them.

Finally according to the energy definition the situation of thermal comfort is achieved when the heat that flow from and to the human body are equally weighted and the temperature of skin and the rhythm of perspiration oscillate in a scale of comfort that it depends from the metabolism.

The average temperature of skin plays also decisive role in the last two definitions. The prices for the temperature of skin can result from models of energy balance and models of empiric relations. [50]

Parameters that influence the thermal comfort.

1. Natural parameters
   - Temperature of air [$^0$C]
   - Medium temperature of radiation of internal surfaces [$^0$C]
   - The humidity and the relative humidity of air [Pa]
   - The speed of internal air [m/s]
2. Biological parameters
   - The sex of the users of space
   - The age of the users of space
   - The habits of the users of space
3. External parameters
   - The type of activities of the users of space [met] (1 met = 58,15 W/m$^2$)
   - The type of clothing of the users of space [clo] (1 clo = 0.155 m$^2$ $^0$C/W)

All the above parameters, and mainly the natural, influence the flow of energy under the form of heat from the people to the environment. The person allocates mechanisms which as objective have to maintain the thermic situation of body constant and to adapt it in the conditions of the environment. Counterbalancing the thermic profits and the losses of heat (fluctuation of combustions, perspiration); our body determines the heat flow.

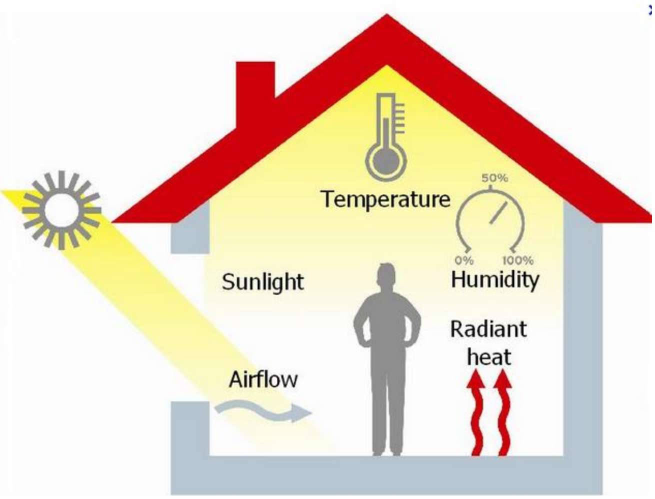


Figure 1: The physiology of thermal comfort

## 1.1. The physiology of thermal comfort

The human body allocates an effective system of regulation of temperature, which is maintained roughly in the 37 $^{0}$C. When the temperature of body begins to increase itself, or because climatic conditions or because intense activity, two mechanisms are activated for her alleviation. Firstly, blood vessel they are expanded, increasing the flow of blood in the skin, so that are increased the losses via conduction and radiation and circumstantially begin the operation of perspiration. The perspiration and its result, the cooling via evaporation, are the basic mechanism of cooling of skin. The increase of one degree in the temperature of core of body can activate the mechanism of perspiration which quadruples the transmission of heat from the human body to the environment. [50]

When the temperature of human body begins to decrease, the blood vessels contract, decreasing the blood flow in the skin, so as to decrease the loss of heat via conduction and radiation. Afterwards, the temperature of core of body is increased with the increase of internal combustions, the activation of muscles and the appearance of shiver. This movement of the muscles increases the "burns", hence also the produced heat from the body.

The system of temperature regulation of the body takes into consideration apart from the sensory parts of skin and the sensory organs of the hypothalamus. The sensory organs of hypothalamus are responsible for the activation of mechanisms of refrigeration of body, when his temperature exceeds the 37 $^{0}$C. Sensory organs of skin activates the defensive mechanisms of body, when his temperature is decreased under the 34 $^{0}$C. [9] The results of the effect of environmental factors are becoming perceptible by the changes of temperature of skin and the type of signals that receive the brain from the sensory organs of skin.

### 1.1.1 The importance of clothing

The resistance in the transmission of heat that is provided by a total clothing (aka. above a clothing), is expressed in units clo (ASHRAE Standard 55, 1995). There are a lot of models for the measurement or the estimate of resistance in the transmission of heat that is produced, from the clothes ASTM F 1291, ENV 342, ISO 9920 and off-hand ISO/CD 1583. ISO 9920 is the only model that deals with the evaporative resistance of clothing. The models of thermal comfort ASHRAE 55-1992 and ISO 7730 require from the users they determine the prices of insulation of clothing, with corresponding of individual clothes with similarly that are given in tables and to suppose that the evaporative resistance of their daily clothing is small [4].

**TABLE ~~B1-~~5.2.2.2A Clothing Insulation Values for Typical Ensembles[a]**

| Clothing Description | Garments Included[b,c] | $I_{cl}$ (clo) |
|---|---|---|
| Trousers | 1) Trousers, short-sleeve shirt | 0.57 |
| | 2) Trousers, long-sleeve shirt | 0.61 |
| | 3) #2 plus suit jacket | 0.96 |
| | 4) #2 plus suit jacket, vest, T-shirt | 1.14 |
| | 5) #2 plus long-sleeve sweater, T-shirt | 1.01 |
| | 6) #5 plus suit jacket, long underwear bottoms | 1.30 |
| Skirts/Dresses | 7) Knee-length skirt, short-sleeve shirt (sandals) | 0.54 |
| | 8) Knee-length skirt, long-sleeve shirt, full slip | 0.67 |
| | 9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater | 1.10 |
| | 10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket | 1.04 |
| | 11) Ankle-length skirt, long-sleeve shirt, suit jacket | 1.10 |
| Shorts | 12) Walking shorts, short-sleeve shirt | 0.36 |
| Overalls/Coveralls | 13) Long-sleeve coveralls, T-shirt | 0.72 |
| | 14) Overalls, long-sleeve shirt, T-shirt | 0.89 |
| | 15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms | 1.37 |
| Athletic | 16) Sweat pants, long-sleeve sweatshirt | 0.74 |
| Sleepwear | 17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks) | 0.96 |

Table 1: clothing insulation values for typical ensembles [3]

**TABLE ~~B2~~ 5.2.2.2B Garment Insulation[a]**

| Garment Description[b,a] | $I_{clu}$(clo) | Garment Description[b,a] | $I_{clu}$(clo) |
|---|---|---|---|
| **Underwear** | | **Dress and Skirts[c,b]** | |
| Bra | 0.01 | Skirt (thin) | 0.14 |
| Panties | 0.03 | Skirt (thick) | 0.23 |
| Men's briefs | 0.04 | Sleeveless, scoop neck (thin) | 0.23 |
| T-shirt | 0.08 | Sleeveless, scoop neck (thick), i.e., jumper | 0.27 |
| Half-slip | 0.14 | Short-sleeve shirtdress (thin) | 0.29 |
| Long underwear bottoms | 0.15 | Long-sleeve shirtdress (thin) | 0.33 |
| Full slip | 0.16 | Long-sleeve shirtdress (thick) | 0.47 |
| Long underwear top | 0.20 | **Sweaters** | |
| **Footwear** | | Sleeveless vest (thin) | 0.13 |
| Ankle-length athletic socks | 0.02 | Sleeveless vest (thick) | 0.22 |
| Panty hose/stockings | 0.02 | Long-sleeve (thin) | 0.25 |
| Sandals/thongs | 0.02 | Long-sleeve (thick) | 0.36 |
| Shoes | 0.02 | **Suit Jackets and Vests[d,c]** | |
| Slippers (quilted, pile lined) | 0.03 | Sleeveless vest (thin) | 0.10 |
| Calf-length socks | 0.03 | Sleeveless vest (thick) | 0.17 |
| Knee socks (thick) | 0.06 | Single-breasted (thin) | 0.36 |
| Boots | 0.10 | Single-breasted (thick) | 0.44 |
| **Shirts and Blouses** | | Double-breasted (thin) | 0.42 |
| Sleeveless/scoop-neck blouse | 0.12 | Double-breasted (thick) | 0.48 |
| Short-sleeve knit sport shirt | 0.17 | **Sleepwear and Robes** | |
| Short-sleeve dress shirt | 0.19 | Sleeveless short gown (thin) | 0.18 |
| Long-sleeve dress shirt | 0.25 | Sleeveless long gown (thin) | 0.20 |
| Long-sleeve flannel shirt | 0.34 | Short-sleeve hospital gown | 0.31 |
| Long-sleeve sweatshirt | 0.34 | Short-sleeve short robe (thin) | 0.34 |
| **Trousers and Coveralls** | | Short-sleeve pajamas (thin) | 0.42 |
| Short shorts | 0.06 | Long-sleeve long gown (thick) | 0.46 |
| Walking shorts | 0.08 | Long-sleeve short wrap robe (thick) | 0.48 |
| Straight trousers (thin) | 0.15 | Long-sleeve pajamas (thick) | 0.57 |
| Straight trousers (thick) | 0.24 | Long-sleeve long wrap robe (thick) | 0.69 |
| Sweatpants | 0.28 | | |
| Overalls | 0.30 | | |
| Coveralls | 0.49 | | |

Table 2: garment insulation [3]

### 1.1.2 The current models of thermal comfort

Considering the above conclusions and the tendencies that dominate in the field of science of thermal comfort it could be said that the models of thermal comfort ISO7730 and ASHRAE55 are found permanently under revision. The new revised model ISO7730: 2005 [5], just like and AHRAE55-2004 (ASHRAE, 2004b), place as criteria for acceptable thermic indoor climate the requirements for total thermal discomfort (indicators PMV-PPD, temperature of operation, speed of air, humidity) and the local thermal discomfort (current of air - medium speed, turbulence, temperature, vertical difference of temperature, temperature of surface of floor), as determine also the previous models. The differentiation of the revised ISO7730:2005 concerning the previous model ISO7730:1994 consists in the categorization of buildings in 3 classes, as it happens also in CR1752 (CENCR1752, 1998), so that is possible the formulation of different objectives for the levels of thermal discomfort with likely economic, technical, energy and environmental base, criteria that are placed in the countries of application of model. Also, is proposed the estimate of thermic conditions of indoor environment for one entire year and the differentiation of criteria in air-conditioned and naturally ventilated buildings.

In more details the buildings are separated in 3 classes A, B and C. Regarding the natural ventilated buildings in the revised model ISO7730:2005 is imported the significance of the phenomenon of adaptation and its described the way they can be combined the results of the relative model in the standard model. However, it does not provide explicit instructions on the way of dealing with the differences between air-conditioned and ventilated buildings. In regard to the relative humidity in the previous model ISO7730:1994 its proposed to maintain her prices between 30-70%, for reasons of quality of internal air, however in the new model it does not exist more inferior limit, while it only constitutes criterion, when exist system of humidification or dehumidification. Regarding the speed of air, the current of air can lead to discomfort and also to improvement of thermal comfort in cases where the environment is hot. [15]

### 1.1.3 The social dimension of energy consumption

The energy consumption of buildings is related immediately with socio-economic factors. Research that was realized recently by the University of Athens, offered important elements as for the social dimension that is related with the buildings and the built environment. Concretely, it was realized that the medium surface of residence in the higher incoming order is at 115% bigger than that in the low incomes.

It was realized that exists an important differentiation of the percentage of families that live in insulated buildings with double glazing. The percentage in the high incoming order is at 800% bigger than that in the poorer class. Concretely, only the 8% of citizens of low income live in completely protected buildings with double sun parlors and insulation, while in the high incomes the corresponding percentage reaches the 64%. Simultaneously was realized an important differentiation of the air that escapes from the building per incoming order. This has important consequences so much in the consumption of energy but also in the thermic comfort inside the buildings. [51]

As result of differentiation in the quality of buildings, it was realized that the distribution of energy consumption for heating per square meter, concerning the income presents the form of U shape, with big consumption in the two utmost. Big thermic consumption per square meter is presented in very low and in the very high incomes. The cost of heating per individual and unit of surface is 127% bigger in the low incoming classes concerning the high incomes. In absolute prices, the medium consumption of energy for heating oscillates from 107 until 130 kWh/m$^2$/year. These levels are exceptionally high, and almost correspond in the medium thermic consumption of residences in Austria.

At medium price the use of air conditioning increases the cost of family at 100€, at 0.6 € per m$^2$, or at 12.5 € per individual. The increase is by far bigger in the low incomes, where the increase are 195 € per family, 1.2 € per m$^2$, 87 € per individual. In 2004, the medium percentage of income that represents the heating and the electric energy was 2.4 and 3.1% respectively. The heating represented the 6.2% of income of low incoming order.

The corresponding percentage in the high class was 0,6% For the same time period, roughly the 1,63% suffered from poverty of fuels and 0,35% from serious poverty of fuels. In the low incomes the percentage of households in poverty of fuels was 16%, while 4% it was in serious poverty of fuels. [52]

With given the increase of price of fuels that is realized from 2006, the medium percentage of income that is spent for heating it was increased by 2,4% in 4,5%, while the medium percentage that is spent for energy was increased from 5,5 in 7,4%. In the low incoming order the percentage that is spent for heating was increased by 6.2% in 11.6%. At the same time, the expenses of energy were increased by 12.1% in 17.6%.

With the data 2006, the percentage of population that suffers from poverty of fuels was increased by 1.6% in 8,4%. For the lower incoming orders the poverty of fuels was increased from 16 in 36%. The medium percentage of households in energy poverty was increased from 11.3 in 21.1%. The corresponding percentage in the low incoming orders was increased by 40% in 60%.

The important energy and thermic problem that face the low incomes, can lead to important problems of survival. Measurements of internal temperature in 60 residences of low income without insulation, double panes and air conditioning, which was realized in Athens during the summertime of 2007, showed that for the 50% of roughly time, the internal temperature was beyond the 34°C, while the temperature reached up to the 42°C. Was measured spaces of 145 successive hours beyond the 34°C. At the duration of each period of heat wave, the medium temperature of buildings is increased at 1-1.5°C. In the end of each heat wave the internal temperature reached almost 38°C. Given increase of appearance of heat waves, as well as because the increase of temperature that causes the thermal island, the population of low income constitutes the first victim of climatic changes will be supposed to be taken immediately providence so that is improved the quality of buildings.

## 1.2 The factors that influence the thermal comfort

As it has already reported and above, Fanger (1970) proposed that the most important parameters that influence the conditions of thermal comfort are: the activity of person (production of heat from the body), the thermic resistance of clothing (the price clo), the temperature of air, the medium radiative temperature, the relative speed of air and the humidity.

### 1.2.1 Temperature

The temperature of air is undeniably a decisive parameter when we report in the internal environment of the building. It influences the comfort with a lot of ways and in combination with other factors it constitutes the key of our energy balance, the sense of thermal environment, the comfort, the discomfort and sense of quality of internal air. The parameters that influence the temperature in the interior of buildings can categorized in three categories: the exterior environment, the designing of the building and the system of heating, cooling and ventilation.

The temperature of air can be measured with a simple thermometer of dry bulb which should not is influenced by any radiative heat and constitutes one from the most important parameters of thermal comfort, creating the sense of "heat" or "cold" in a specific indoor space. [14] Besides, the bigger percentage of heat that is removed by the human body is transferred in the environment, depending on the temperature that prevails in it.

The problem that is found in the study of temperature as a parameter of thermal comfort lies in the fact that does not exist a standard price of temperature that would constitute the most optimal solution, but a field of prices as interrelation of many other factors. Our body conceives the temperature of air (and the other parameters of thermic environment) from the sensory organs of skin and hypothalamus regulating its temperature.

In more details, the temperature influences the human body and the operations of exchange of energy under the form of heat with the environment. The increase of temperature of air tends it decreases the losses of heat with conduction and radiation, while the losses of heat because of perspiration are increased. The temperature of air influences also the average temperature of the skin. This natural size has been imported for the more complete evaluation of thermal comfort. Researches of P.Hoppe that took place with the help of the mathematic model M.E.M.I., led to the cross-correlation of temperature of air and the average temperature of the skin.

### 1.2.2 Humidity

The humidity can be defined as relative and absolute humidity (ISO 7730 2005). It is fixed as "the reason of partial pressure (or density) of the steam in air as for the partial pressure (or density) of the saturated steam, in the same temperature and total pressure" (ASHRAE Standard 55 2004). The humidity influences the general thermic comfort of the body that is required in the thermic balance of model of thermal comfort. Each 10% increase of the relative humidity it is considered that it counterbalances with a increase of order 0.3°C in the temperature of operation (ISO 7730 2005). This influence is decreased in intermediate temperatures (<26°C) and mediocre level of activity (<2 met), however in higher temperatures and activities the influence is bigger (ISO 7730 2005). "The small relative humidity increases the process of cooling with evaporation, for this reason a hot environment with low levels of humidity is more comfortable than another one with the same temperature but with higher humidity". [6] In the revised model ASHRAE 55(2004) do not exist more inferior level of humidity and the "on" limit is fixed as the reason of humidity 12g/kg.

The humidity, in general, determines the faculty of storage of water vapors from air. The low relative humidity of air strengthens the expulsion of water from the human body (under the form of sweat that it is evaporated), causing thus a sense of cooling.

Experimental studies that became in a university in Denmark [7], showed that in transient conditions (for instance, when a person comes outside from the building or is moved by a space in another with different humidity), the thermic effect of humidity in the feeling of comfort is 2-3 times bigger concerning her effect in conditions of extended stay in a space in which the humidity is maintained constant.

In general, the relative humidity in an internal space should oscillate between 30-70%. Relative humidity below the 30%, causes dryness of mucous, the neck, even problems in the sight, while relative humidity beyond the 70% can cause mold in the space. In the usual calculations, in any case, the relative humidity is taken round the 50%.

### 1.2.3 Air speed

It is "a medium price of instant speed of air in a time period" [3].

The movement of air round the human body can influence the feeling of thermal comfort determining, on one side the exchange of heat, with "transfer" (convection), between the human body and the environment, and on the other side the content of air in water vapors. Thus, the loss of heat with convection from the human body depends from the intensity of air and the temperature difference between the skin and the environment.

When, therefore, the temperature of air is lower than the temperature of body, the creation of a breeze causes a sense of cold and it creates discomfort in the tenants. On the contrary, when the temperature of air is higher than the temperature of body, the high speed of air increase the rhythms of perspiration, and in consequence, they improve the sense of cooling, neutralizing, and the negative effect of plausible high humidity.

The degree, in which feels somebody the movement of air depends, moreover, from the type of clothing, the type of employment, even from the part of body in which accepts the breeze of air. As an example, when a person accepts breeze of air in the back, it feels usually discomfort, because the back part of body senses the changes of temperature in a more intense way.

### 1.2.4 Average radiation temperature

The average radiation temperature of a space it is defined as that temperature of compact black surface for which is observed the same loss of heat through radiation, concerning the examined surface.

The calculation of medium temperature of radiation is particularly laborious (is required the complete calculation of corner factor between the individual and the examined surface) and resort in use PC and tables of models ASHRAE 55 – 92 and ISO 7730 for the corner factors.

While the internal surfaces of the exterior walls of a bad insulated building are usually colder at the winter from those of similar well insulated building, can be maintained lower from those of bad insulated building, for the same level of comfort.

The medium temperature of radiation plays sovereign role in the exchange of heat because of radiation between the body and the environment. In low speeds of air near the 0,1 m/s, her increase temperature of air at $1^0$C causes the same thermic result with the increase of medium temperature of radiation at the $1^0$C. The medium temperature of radiation is differentiated by the temperature of air, because she is mainly responsible for the land-planning differences of temperature in a space and the creation of discomfort.

## 1.3 Predicted Mean Vote

Big part of the research on the thermal comfort as that of ASHRAE Standand55 (2004) took place in internally checked environments. These researches were based on laboratorial experiments in which the all the natural characteristics of the environment were checked. These laboratorial experiments were used in order to develop indicators of thermal comfort as the PMV (predicted mean vote) that developed Fanger in 1970.

The Predicted Mean Vote (PMV) alludes to a thermal scale that runs from Cold (-3) to Hot (+3), initially created by Fanger and later adopted as an ISO standard. The original information was gathered by subjecting an extensive number of people (reputedly many thousands of Israeli soldiers) to different conditions inside a climate chamber and having them select a position on the scale the best portrayed their comfort sensation. A mathematical model of the connection between all the environmental and physiological components considered was then derived from the data. The outcome relates the size thermal comfort factors to each other through heat balance standards and produces the following sensation scale. [40]

Predicted Mean Vote sensation scale

| Value | Sensation |
|---|---|
| -3 | Cold |
| -2 | Cool |
| -1 | Slightly cool |
| 0 | Neutral |
| 1 | Slightly warm |
| 2 | Warm |
| 3 | Hot |

Table 3: Predicted mean vote [40]

The recommended acceptable PMV range for thermal comfort from ASHRAE 55 is between -0.5 and +0.5 for an interior space.

The PMV indicator and the PPD indicator that is the percentage of individuals that feel thermic comfortable in a space concerning the aggregate number of individuals that they are in this space, are used in this respect in the same time.

The PPD Indicator (Predicted Percentage of Dissatisfied) forecasts the medium price of the thermic disappointed people who it is likely to feel very hot or a lot cold in a big team of people. The PPD indicator can easily be found it has been preceded the measurement of PMV from the diagram 3.17 that is given in model ISO7730 (2005). The people that feel thermal discomfort are those that vote that they feel very hot, hot, and cold or a lot of cold in the seven-grade scale of model.

There are many standards that use models of calculation of thermal comfort in which are applied the theory of Fanger and the equations of PMV and PPD, as for example the American model ASHRAE 55 and the international model ISO 7730.

Various researchers, via the inquiring work on the spot, showed people with different culture consider their self-comfortable in a different breadth of temperatures. Employees of office in Thailand felt comfortably in internal temperatures bigger than those that work in more mild climates. [8] Pakistanis employees of office felt thermal comfort in temperatures between 17 and 31$^0$C and the preference in the internal temperature vary with the climate and the season. [10,11] Existed also some differences in the thermic perception and in the practices among the workers in naturally and artificially air-conditioned buildings that were indicated by this inquiring work and were connected with the culture and the climatic conditions. [11] The de Dear and Auliciems found important difference in the perception of thermic comfort between people that was found in air-conditioned and naturally air-conditioned buildings.

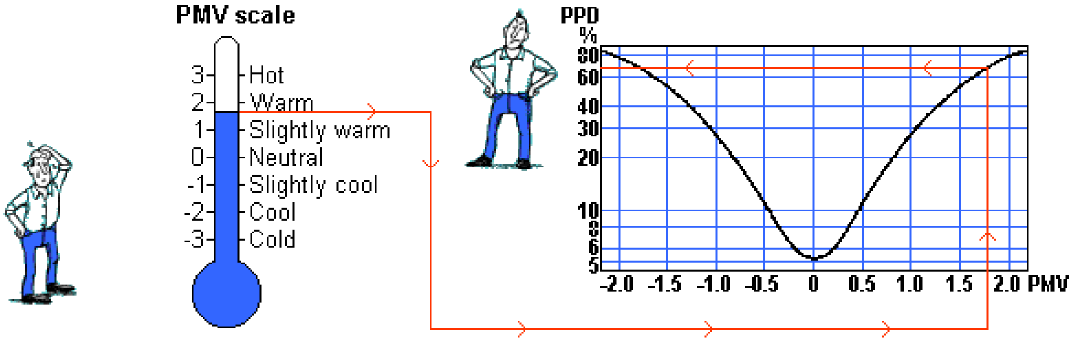


Figure 2: Predicted mean vote and diagram [43]

There were existed also papers that showed that the thermal comfort can be determined partially from the behavior of the people. [12] Au contraire to the method of PMV indicator, the thermal comfort is not based only on the six known parameters, but also by the fact that people tend to make their selves thermal comfortable by changing their clothes, their activity and their position-space.

Other research papers showed that in naturally ventilated buildings (free running) people can be adapted in higher indoor temperatures from those that forecast model PMV but exist the uncertainty that "it needs further examination, if the people will have again the same level of performance in higher temperatures". [13] Also it has been written that in office buildings without air conditioning "between 25 and 280C, more and more people will feel heat, discomfort and will present less productivity". [14]

# 2. Indoor Air Quality (IAQ)

The indoor air quality in the buildings constitutes essential factor that it should it is taken under consideration in the estimate of danger for the safety and the health of employees as well as other assistants that may find themselves in this buildings.

A lot of residents or workers in buildings express complaints for the quality of air that breathes, creating the need for further investigation of the situation. The internal atmospheric quality began to be reported as problem in the end of '60 decade, even if the first studies were presented roughly ten years later. From 1984 the World Health Organization-WHO led to the conclusion that up to the 30% of the new and reconstructed buildings worldwide they can be the subject of excessive charges relative with the internal atmospheric quality.


Figure 3: Symptoms of indoor air pollution [44]

Even if would appear reasonable to be considered that the high atmospheric quality is based on the presence of essential components in the suitable proportions in air, actually the user, via the breathing, is the best critic of atmospheric quality. This happens because the inhaled air becomes immediately perceptible via the senses, since the person is sensitive in the olfactory and irritant results of roughly half of the chemical unions. Consequently, if the users of building are in its entirety satisfied with air, it is considered that it is the high quality, while if they are unsatisfied, bad quality. Correct quality of air in an internal space means conditions of health and comfort for the individuals that live and work in this space. This mean it is possible to be forecasted because of his composition air, but only partly. This method functions well in the environment of industrial buildings, where the particular chemical unions relative with the production are known, and their concentrations in air are measured and compared with the marginal prices of most minimum limits. In the not industrial buildings, however, where they can exist a large number of chemical substances and in very low concentrations in air, the situation is different.

In working places in which prevail continuous noise, insufficient lighting, inadequate thermic environment and/or ergonomic problems, it is possible to be caused discomfort that is often attributed erroneously in concentrations of chemical or biological factors in air. In the past, the symptoms that were usually reported by the employees in a building they were considered psychological, because these were variable and subjective and because their precise cause it was not possible to be located.

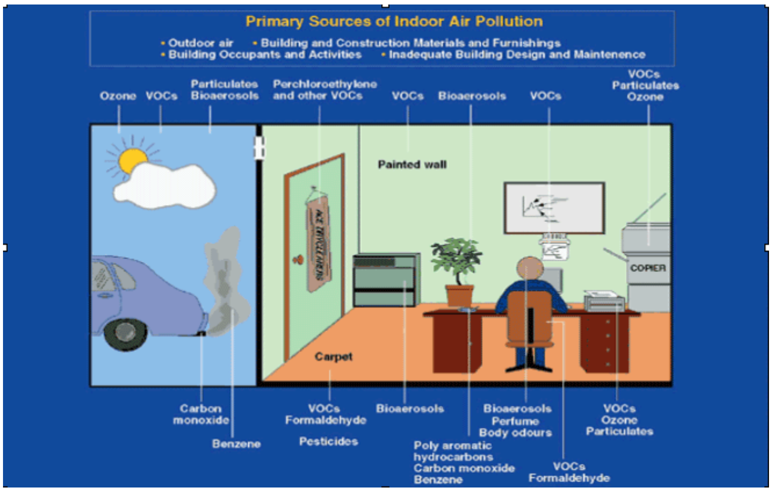


Figure 4: Primary sources of indoor air pollution [45]

The exterior environment in the big cities is also polluted, but is fact that often the air in the buildings can be more polluted from the outdoor air (sometimes even in the bigger and more industrialized cities) and consequently the danger for the health can be bigger when the people are exposed in the internal atmospheric pollution that in outdoor. [39]

The problem is increased with the construction of buildings that are drawn in a way so that they are more airtight and they recycle air with a smaller percentage of the new from abroad environment, so that they are energetically more efficient. The use of increased rates of ventilation finds, in most cases, contrary to the energy output while the energy charge of fresh air can constitute important part of consumption of energy of the entire building. Consequently it is important to be checked the percentages of ventilation in a building achieving at the same moment the acceptable levels of quality of internal air. Often, the problems with regard to the quality of internal air are presented when a building is used or is maintained with a way, which is not conforming to its initial planning or suitable functional processes. Naturally the problems of quality of air can be also result of poor planning or activities of residents.

Today, the problem of quality of internal air in the residences, the office buildings and the public buildings have assembled everyone's attention, because the potential negative repercussions in the human health, comfort and productivity. The importance of quality of internal air is obvious, if someone thinks the fact: a) that the levels of concentration of certain pollutants are higher in the interior of buildings rather than in the environment and in particular in certain cases they exceed the limits of report in the pollutants at the national standards, b) that the urban population is usually found in the buildings for more than 90% of a year and c) that the most time inside the buildings pass the vulnerable groups of population, as are the old people, the children and the weak individuals.

Thus, the EPA (Environmental Protection Agency) claims that the pollution of internal air constitutes one from the five serious environmental dangers for the public health. [33] It was calculated that the new-construction or renovated buildings, in percentage up to 30% in world scale, will be candidate for the appearance of immoderate complaints that are related with the quality of internal air. [34]

## 2.1 The role of airing for the Internal Air Quality

Internal atmospheric quality (IAQ) is an important parameter that characterizes the internal environment and is related intensely with the health of the residents of buildings. Besides, the operation of system of ventilation of building it is also important, since the fundamental role of ventilation is improving the internal climate of building. Consequently, the attribution of a ventilation system determines immediately the quality of air of the internal space. Also the flow of air and his course in the building have important influence in the thermic comfort of holders, specifically at the duration of aestival period.

The ventilation is essential in order to dilute and exhausts the internal pollutants as dioxide of coal and the volatile organic unions. Exist two different forms of ventilation, the natural and the mechanic airing. [42]

The natural ventilation is supported or in the air that is imported via the rabbets of openings in the file of construction (infiltration) or the direct and extensive ventilation because the open windows and other points of entries and exits (passive ventilation) in order to import fresh air in the interior of the building.

The mechanic ventilation requires the use of fans in order to import fresh air from outdoor environment in the interior and to remove the over-used air from the interior of building to the exterior environment.

## 2.2 Sick Building Syndrome

Definition of «sick building»

The term «Sick Building Syndrome (SBS)» generally it is accounted for the conditions in which the inhabitants of buildings have usually problems of health and/or discomfort that is associated obviously with the time they spend in a building, while the same time no specific illness or cause of these results cannot be determined. The charges can be located in a specific room or an area, or they can be engendered all over the building. [47]

The term «Building Related Illness» (BRI) it is used when is determined the symptoms of illness that can be diagnosed and is possible to be connected immediately to the airborne contagious factors of building.

### 2.2.1 Symptomatology for the «Sick Building»

In a global level do not exist some clinical definition of the syndrome of sick building and no sufficient theory for the medical incidents that are related with this. Its characteristics are not specific symptoms, which are presented in the users of building and are not caused by a specific illness.

The symptoms of eye irritation, respiratory, the headache and the drowsiness are usually present in all cases of syndrome. However the types and the severity of these symptoms vary a lot between the individuals, even these that are in the same building, potentially because different conditions in the various spaces of building, or the different sensitivity of individuals. Certain individuals can present symptoms, or present different symptoms from certain other users of same the building. [48]


Figure 5: Sick Building syndrome [54]

### 2.2.2 Asbestos

Asbestos is the total fibrillose mining silicates and presents chemical and thermic stability as well as high resistance in tensile strength, important properties for a lot of applications. The asbestos is constituted by microscopic beams of fibers that can be transported with air. These fibers pass in air and can be imported in the lungs causing, potentially, important problems of health. The researchers have still not determined a level of sure exposure but are known that as long as bigger the level of concentration and the time duration of exposure increases even more the danger of appearance of illness that is related with asbestos. The asbestos is usually used in the soundproofing, heat insulation and fire safety and in the structural manufactures. Its fibers are exceptionally durable in the heating.

The asbestos is not always dangerous. Actually, if it is maintained in good condition and is checked periodically so that to be checked the cohesion then does not exist reason of concern. Dangerous it is only when it is disturbed or when its components suffer deterioration. In the case where its components are destroyed, the fibers are separated and they can be transported with air. Afterwards are reported the repercussions in the human health from the exposure in asbestos. [49]

More specifically, asbestos can cause:

- Irritation of skin.
- Irritation sensory organs (nose, eyes, neck).
- Respiratory problems.
- Bronchitis and crises of asthma.
- Pneumonococcosis of asbestos.
- Mesothelial tissue volume
- Cancer of lungs.
- Problems in the gestation of pregnant women

# 3. Literature review

The bulk of bibliography in the field of building renovation to minimize energy consumption and reduce $CO_2$ emissions focuses mainly on setting economic and cost-effectiveness scenarios for residential and office buildings.

In the Santamouris & Daskalaki (2002) study, 10 buildings were housed and housed in different climatic zones in Europe. For each building an energy audit was carried out, observations were made by monitoring bodies, specific experiments were carried out and then all possible proposed refurbishment scenarios were evaluated. The final deliverables from this study include: case studies showing representative high-quality office renovations in various European countries, an assessment methodology that classifies office buildings based on their energy efficiency, CO2 production and indoor thermal and optical attitude, the Atlas, which describes the technical and economic prospects for energy savings from selected scenarios for certain office types in different climatic zones. rules in Europe, Design Guide, performance criteria and best practice methodologies giving emphasis on the integration of renewable energy in office buildings.

After analyzing and refurbishing the Delphic Archaeological Museum, Tombazis & Preuss (2001) published a study that generalizes the application of this innovative architectural design to the other 16 archaeological museums studied and facing similar problems. For the renovation of the museum they focused mainly on the improvement of the natural lighting and ventilation, the reduction of thermal losses and the improvement of the acoustics in the interior of the museum. They concluded that with these corrective interventions the total energy consumption of the museum was reduced by about 70%, while the comfort conditions exceeded the desired levels.

In a publication by Triantis, Morck, Erhorn, & Kluttig, there is a comparative analysis of 25 study cases related to the environmental renovation of educational buildings in 10 different countries in Europe and the United States. The analysis includes cost factors, environmental benefits, energy-saving factors, design guidelines, user feedback, and beneficial conclusions from any conversion that occurred during the renovation in the selected study cases. The data collected was used to develop an "energy concept adviser" tool. One of the most important aspects of this analysis is related to the architectural dimensions of the renovation process. The conclusions drawn from this analysis are that the integration of the architectural features of the building to be renovated, both in terms of space and materials, is essential for the successful integration of environmental renovation strategies into educational buildings. In addition to energy saving, reduced environmental impacts and upgraded intrusion, integrated projects include better use and appreciation of improved or expanded spaces in or around the building and increase the participation of students and teachers in the operation of the system in order to achieve high environmental standards.

In the publication of Asadi, Silva, Antunes, & Dias (2011), a mathematical multi-criteria optimization model is presented, which provides assistance in the process of assessing technological options for building renovation. The goal is to minimize energy use in a cost-effective way, while meeting the needs and requirements of the users. The results from applying the model to an existing home have demonstrated the potentiality of this methodology to indicate the right strategies for building renovation and enhance the applicability of this approach.

The publication of Dorizas, Assimakopoulos, Helmis & Santamouris (2013) investigates the indoor thermal comfort perceived by students through a questionnaire survey conducted during spring 2013 in naturally ventilated primary schools in Athens. Various parameters of the thermal environment, such as air temperature, relative humidity, air velocity, etc. were measured simultaneously. The Fangers Index of Predicted Average Voting (PMV) and the percentage of people not satisfied (PPD) were then calculated using clothes and metabolic rates. The main purpose of this work is to evaluate the thermal environment of the classes. Possible correlations between subjective thermal sensing votes and objective measurements are examined by comparing students' responses based on the seven-point thermal sensing range and the results of the calculated PMV and PPD.

Rey (2004) introduces in his publication a multi-criteria methodology for evaluating strategies for building renovation. Within the framework of this methodology, three key renovation strategies are identified: "the stabilization strategy", "substitution strategy" and "the double-shell facade strategy". The assessment is based on specific criteria that are directly linked to the three pillars of sustainability: environmental, socio-cultural and economic criteria. The applicability of this approach has been verified in three study cases involving offices representative of three different architectural periods. As demonstrated by the results of these three study cases, the method developed can be a tool for strengthening the decision-making process. In addition, it offers an efficient chance of comparing the degree of performance of the different renovation strategies.

The study of C.A. Balaras et al. (1994) includes an overview of the residential building stock in the EU with particular reference to Greek buildings. The purpose of the study was to quantify the benefits and set the priorities of energy saving strategies in buildings to reduce $CO_2$ emissions. In particular, 14 ECMs (energy conservation measures) have been implemented in existing buildings of different climatic zones, which need to be refurbished to reduce $CO_2$ emissions. The 14 ECMs include: thermal insulation of exterior walls, thermal insulation of the roof, sealing of openings, double glazing, central heating maintenance, replacement of inefficient boilers with efficient liquid fuel burner, replacement of inefficient boilers with efficient gas burner, installation of temperature control systems for central heating, installation of external shades, installation of ceiling fans, replacement of old non-efficient air conditioners, installation of solar panels for domestic hot water heating, installation of energy saving lamps. These scenarios, as well as their impact on $CO_2$ emissions, have been evaluated and the best ECMs have emerged. These are: masonry thermal insulation (with 33-66% energy savings and 3573,6 kt reduction of $CO_2$ emissions), sealing of openings (16-21%, 1712,2 kt), installation of double glazing (14-20%, 1539,2 kt ), maintenance of central heating boilers (10-12%, 951,4 kt) and installation of solar panels for production of DHW (50-80%, 2709,7 kt).

In the study published by Stourna Trianti, Santamouris, & Vallindras (1986), the results of the passive solar renovation of a historic building in Athens are reported. The simulation results from the analysis of passive solar systems showed that the average annual coverage of the heating load is satisfactory (36%). They concluded that passive solar renovations are quite important for the Mediterranean region, both architecturally and energetically.

Krstic (1998) reports in an article that bioclimatic rehabilitation of existing buildings can bring significant amounts of energy savings. The study looks at some rehabilitation measures in apartments in Belgrade. By closing balconies and building lofts for residential purposes, an efficient and cost-effective increase in the living space results and living conditions improve.

In their study, CABRAL & CHALFOUN (1998) are examining the case of renovating an old building in Portugal, within a framework that approaches sustainable building. They tried to improve the exterior microclimate of the building in order to reduce the cooling load required during the summer period in the interior of the building. At the same time, they adopted strategies for the interior of the building, which included the application of double glazing and the design of skylights by taking measures for their night protection as well as their solar protection by extension of the roof. From the implementation of these strategies, they calculated with the help of a simulation program that the cooling load can be reduced by 71% while the heating load by 9%. For the exterior of the building, they recommended the installation of a passive cooling system to modify the conditions of the outdoor space and thus to improve the conditions inside the building. Specifically, they installed a special cooling tower as well as a shading system that provides solar protection to the outdoor paved courtyard that functions as a restaurant in the summer. According to the calculations made, the decrease of the temperature in the outdoor yard from the presence of the cooling tower reaches 8 °C.

The aim of the Calderaro & Agnoli (2007) study was to improve the energy efficiency of the structure of a building that functions as a library to ensure comfort conditions, reduce energy consumption by adopting appropriate design, promote the use of solar and at the same time to reduce air pollution. For this purpose, they installed a solar chimney near thermal storage building elements, which is supported by passive cooling technologies, through evaporation, capable of mitigating high temperatures during the summer period. As regards the winter season, a heat collection and storage system was implemented, allowing the use of thermal storage and heat transfer through contours. With the help of simulation software it was found that the winter period will save energy of 10,306,033 kWh, while in the summer period the energy to be saved will reach 12,954,860 kWh. At the same time, $CO_2$ emissions will be reduced by 2,623 kg $CO_2$ / year.

The study by Zain-Ahmed, Sayigh, Surendran, & Othman (1998) deals with the implementation of the bioclimatic map, the bioclimatic psychometric map, the Mahoney tables and the possible control zones, with the aim of defining the appropriate strategies for achieving internal comfort conditions. The area studied was the Valley of Kang in Malaysia, while the most appropriate strategies they came up with concerned with natural ventilation, shading and dehumidification.

# 4. Office Buildings – Description of the building

## 4.1 Historical data

From the antiquity until today the buildings of offices they have changed radically. With the constitution of first democracy in Greece, new institutions (councils, you will assemble citizens, supervising committees, courts) were created in Athens and in her colonies. Their administration was accommodated in multifunctional rooms supported in columns or in newer goods of buildings. The chamber of deputies, the prytaneum, the headquarters and the dome in order to we report few of the goods of buildings, were placed mainly in the ancient market, the political and social center of ancient Greek cities. The immediately next period of city of Rome it was elected in the world scene with her developed public sector and the well-developed system of administration of state.

Afterwards the collapse of ancient Rome in the western world, with the exception of Byzantium and administrative beginnings in Istanbul, was not realized no important development in the planning of office buildings. The 18th century however was developed the architectural base of current office buildings. With the foundation of private banks and actuarial companies, they were created group of professionals which the activities of were connected with the work of office. Finally was realized the segregation of working place by the space in which somebody lives in (which later was accelerated with the creation of railways), which followed the growth of commercial enterprises in the start of 19th century.

In Chicago in 1880 the big demand for offices fired a wave of building speculation. Because did not exist restrictions in the height, neither legislation on the depth of rooms, the economic reasons and the wish of achievement of biggest profit they determined the form of ground plans of office buildings. In the initial stages of manufacture of towers, the exploitation the natural and artificial lighting was not enough for works of office as typing, setting in this way natural restriction in the greed of speculators. These eight with ten meters depth of rooms were enough bigger than these in Europe. As long as for Europe were developed similar ground plans with two lines of offices in each side that because the big depth of offices, allowed other land-planning regulations. The floors of office buildings were often subdivided in a different model of offices, which was constituted by two small offices behind an office of one common secretary.

In Northern Europe the tradition of offices is different almost from each opinion from that of Northern America "tend to be low instead of tall, suburban than in the center of city, narrow instead of deeply, with natural ventilation instead of air-conditioned and influenced from the needs of usual employees of offices rather than from the style of company". [26] The planning of offices in Northern Europe reflects the preferences and the requirements of employees with different ways and often it is very narrow in order to provide direct access in exterior view, with layout as a beehive because the requirement on encompassed offices and environmentally careful, because of the attention that is given in the health and in the safety of employees. [26]

## 4.2 The office studied

The building examined is a block of offices in a building constructed in 2010. We examined the engineering office, the orientation of which is southeast and the number of users is two. The area of the office is 68,13m$^2$ but the air-conditioned room is 55, 18 m$^2$ and also the office is 0,50m above the ground. The offices operating hours are 8am-3pm and 5pm-8pm daily.

Once we look at the office as an energy inspection, we need to use as much information as we can find. The orientation of the office is south-eastern and the altitude from the sea is at 36m. On the horizon in approximately 15m from the office we have a church with a height of almost 17m while the neighborhood around the building has rich green spaces with tall trees and low vegetation that help the microclimate.

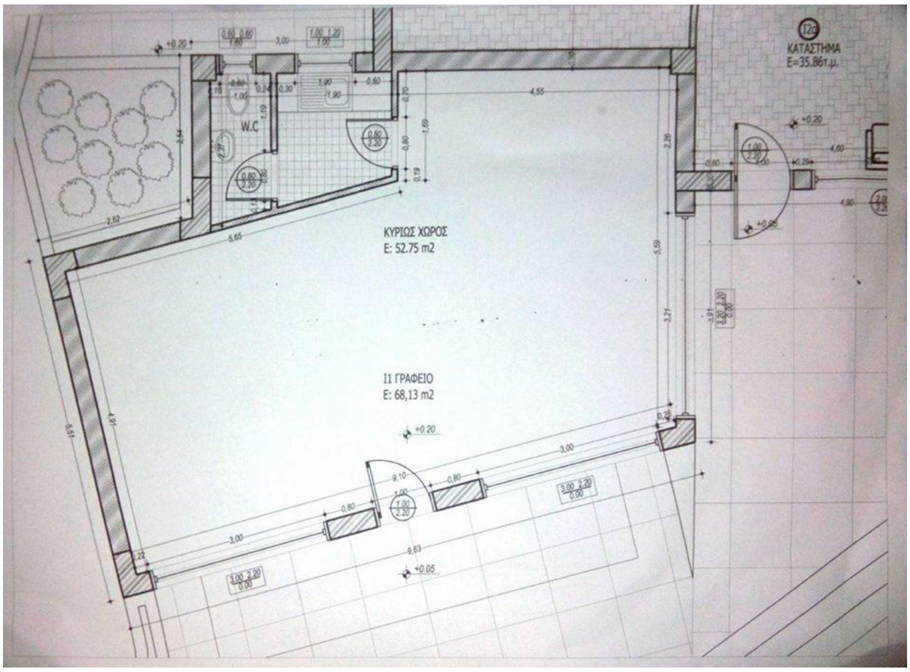


Figure 6: Floor plan of the examined office

It should be useful to refer to the general characteristics of the building; the envelope is constructed from brickwork, with rock wool (5cm) for thermal and acoustic insulation. Also, reinforced concrete without insulation has been used for the walls. The exterior surface of the office is made of beige-colored plaster while the roof of the building consists of a sloping four-sided roof with tiles. The windows - openings have aluminum frames without insulation, double glazing with stratification (6mm – 19mm – 4mm). The main entrance is a classic glass door.

Air conditioning installations are constructed using **cooling ceiling** while the energy consumption for heating is 750Kwh for four (4) months with operational equipment drywall roof and heat pump. The office doesn't need domestic hot water that's why there is no installation for this purpose. There are five pairs of "tl" lamps for lighting and because of the big openings; we take advantage of the natural lighting for many hours but we need some shading during summertime. There are some external venetian blinds for shade which are not permanent but very modern with automation control systems.

Figure 7: Façade of the examined office

## Questionnaire – Analysis

The first step in order to estimate the "character" of the building concerning the existing situation of conditions of thermal comfort and the quality of indoor air is the recording of sense of conditions of internal environment of tenants and their behavior in regard with the way of airing of spaces and with the energies of influence of quality of internal air, the evaluation of the internal environment from the same users of building with the help of suitably "shaped" questionnaire.

Because in the office work only two people, it's going to be useful in order to have better results if questionnaires were given and to others. For this reason the questionnaires was answered from two collaborators engineers that come almost daily in the office. The average age of the people that answered the questionnaire is 39 years old and there are three men and a woman. As it is already mentioned, the office building is a new constructed building, so it would be useful to collect more questionnaires also from another office nearby. The **second office** is an old constructed (built in 1994), with not the proper insulation and generally modern systems for heating and cooling. The average age of the people that answered the questionnaire is 48, 5 years old and there are two men and two women. The second office's operating hours are almost the same with office no1.

The orientation of the second office is northern and the altitude from the sea is again at 36m. On the horizon of this office, we have in a small distance (5m) another house with a height of almost 3.5m and the office is ground floor. The neighborhood around the building in this case does not have any green areas because we are talking about building in the center of the town (near the square) with a dense construction. There are few trees and low vegetation, mainly ornamental plants that act as decorations in the square.

Again we should refer to the general characteristics of the building; the envelope is constructed from brickwork without any insulation. Also, reinforced concrete without insulation has been used for the walls. The frontage of the office has windows - openings with metal frames without insulation and single glazing. The main entrance is also metal frame with single glazing while the roof is terrace without insulation.

There is an air conditioning installation for cooling and heating, and for the needs of domestic hot water there is an electric water heater installation for this purpose. There are four common lamps for lighting and because of the big openings, the office takes advantage of the natural lighting for many hours but there is the need for shading during summertime.

The questionnaires results will be discussed and compared based mainly on the way the construction year affects the employees' attitude and productivity.

When distributing the questionnaires were given all the essential information and detailed instructions on the way of its completion, so as to minimize likely misunderstandings and their erroneous completion. The questionnaires were collected one day from the day of distribution. Were in total supplemented 8 questionnaires (4 for each office) but once again our sample is not representative enough for statistic reasons but hope that the relative conclusions that resulted will portray at the most representative way the conditions that experience the users of buildings.

The first part of the questionnaire concerns the assessment of the conditions of the internal environment in which the respondents work. Space users were asked questions about air temperature, air quality, lighting adequacy, surface reflection problems, noise, and the general feeling of comfort in the room. Space users were asked to record the exact conditions of the above queries on a seven-step scale from "unsatisfactory" to "satisfactory". The assessment of indoor climatic conditions was divided into two periods, the heating season (autumn and winter) and the cooling season (spring and summer). It should be noted here that the assessment was not based on the PMV scale because the purpose of the survey is not only to capture the thermal envelope, but more generally the indoor environment and, in particular, indoor air quality. If the building users were asked to respond to two different scales, they were likely to have difficulty either not completing the questionnaire or filling it up incorrectly.

The second section of the questionnaire concerns the assessment of the basic characteristics of indoor climate in terms of air temperature (heating-cooling), ventilation, humidity and shading. In this case, a seven-step scale was used from "unsatisfactory" to "satisfactory". In addition to this assessment, the questionnaire includes the investigation of possible building-related problems where the respondents recorded symptoms such as dry eyes, runny nose and headache on a seven-step scale from "never" to "always" and whether the building users believe that these problems are related to the office they are working in.

From now on our office, what I'm working in will be defined as " office 1 " and the other office we are looking for, as a benchmark will be defined as " office 2 ".

## 4.3 Results analysis

### 4.3.1 First part

Since in the first part of the questionnaire the answers are in scale from 1 to 7 It felt right for ease of interpretation, to make charts with average prices in order to compare the two offices and of course separate winter and summer.

## Winter

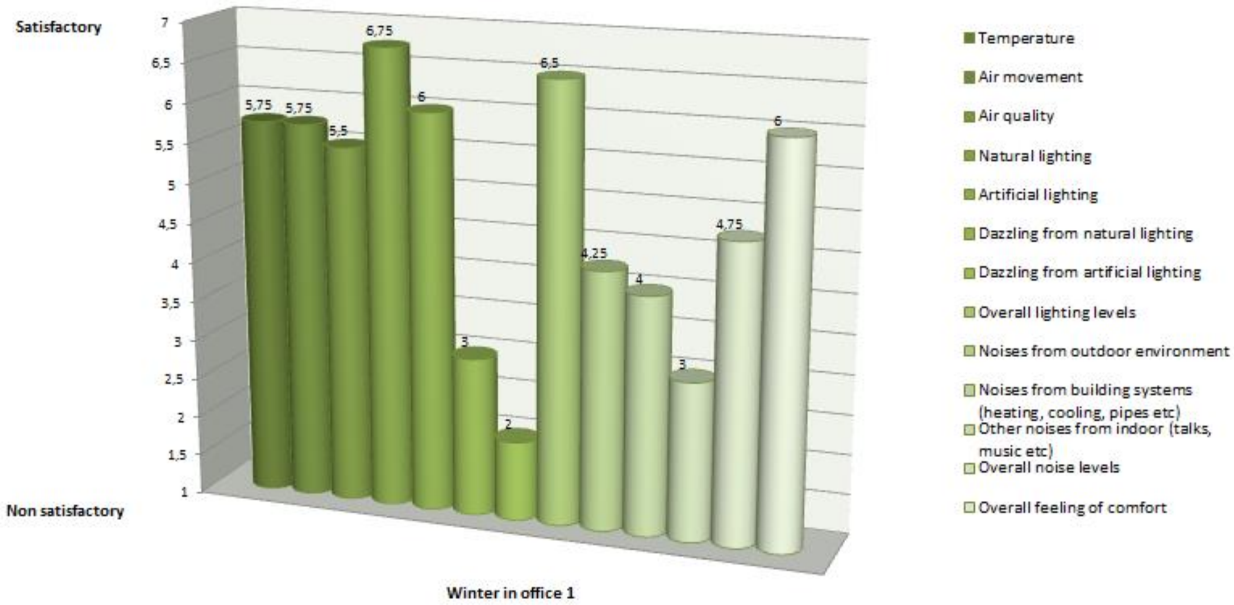


Figure 8: Seven scale diagram with the answers for winter in office 1

In the above diagram the results for the winter of office 1 are presented. We have the seven scale, while in the memorandum appear characteristic the questions that the respondents had to answer. From the analysis results is defined that natural lighting is almost entirely satisfactory as well as overall lighting levels. On the contrary low levels of glare from artificial lighting are observed which means that we will be supposed to see again the lights we use.

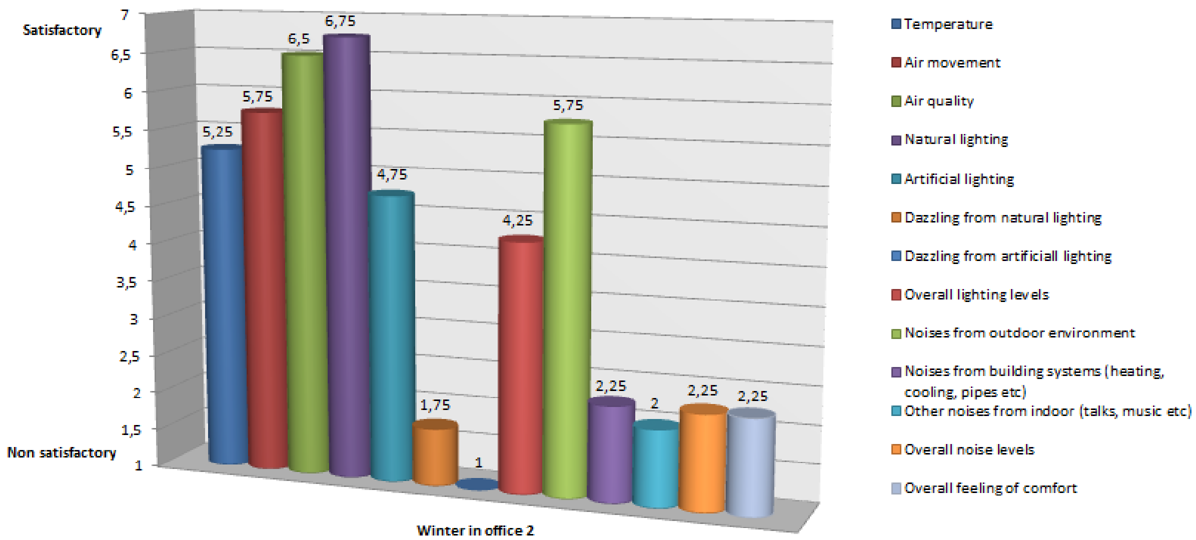


Figure 9: Seven scale diagram with the answers for winter in office 2

In the above diagram the results are depicted for winter for office 2. The scale once again is the same while in the memorandum appear the questions as before. As it is shown in the diagram the natural lighting is almost completely satisfactory as well as the air quality. Instead, we see low levels of glare from both artificial and natural lighting which means we should look again at the lights we use and perhaps use shades.

It is better to do a comparison of the two offices. As it is depicted from the diagram there is a small precedence in the temperature of the first office against the second. And the two offices have big openings therefore they are justified by the exceptional natural lighting. We observe glare in both offices although we must emphasize that the first office has shades of the latest technology but may not be used properly, they work from the wrong time, etc.  In general, we notice very good results about the general lighting elements in the office 1 rather than in the office 2.

Something very important is the noise levels in the two office buildings. Whether these noises comes from the inside or from the outside, we notice that in the oldest office the noise levels are almost unsatisfactory, which may be linked to the poor sound insulation of the office due to age. In the most critical of the results, the final question about the general feeling of comfort, the difference between the two offices is very large and this is certainly related to the obsolete systems of the second office, to the bad orientation and to its old construction.

**Summer**

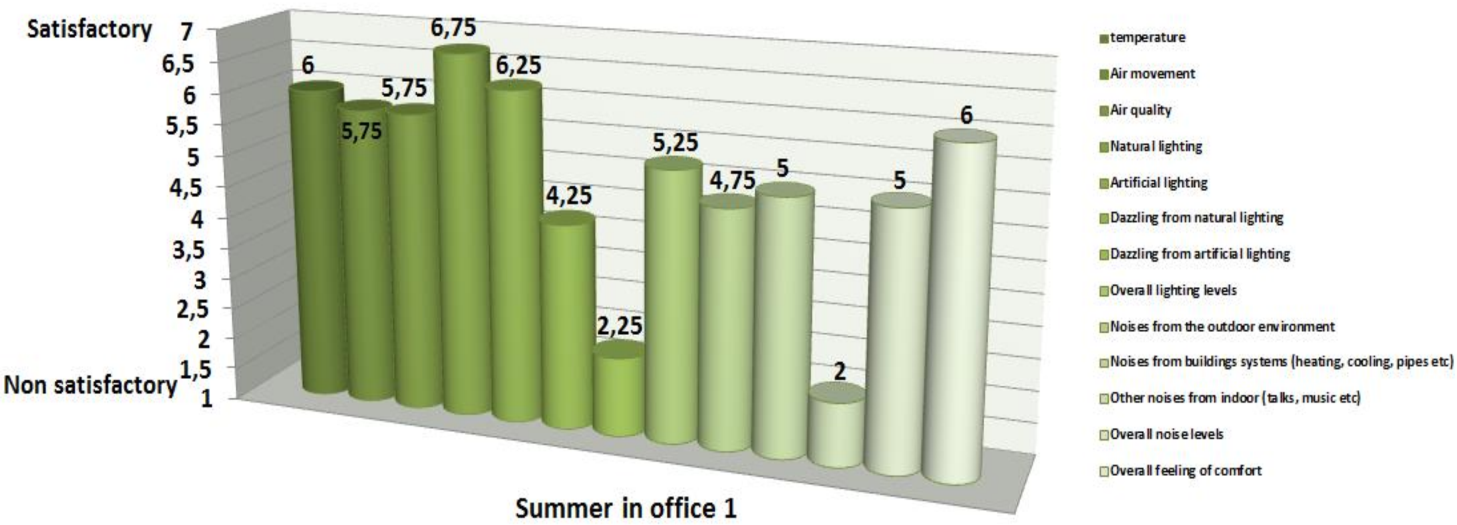


Figure 10: Seven scale diagram with the answers for summer in office 1

In the figure above, the office 1 result are presented in summer conditions. The scale is seven-scale, while in the memorandum the questions that the respondents had to answer are again typical. Again as it is showed on the diagram the natural lighting is almost entirely satisfactory just as it was for winter in the same office while the levels of artificial lighting are satisfactory. On the contrary, we see low levels of glare from artificial lighting, which confirms that we may use illumination, poor lamp quality etc, which means we should see the lights we use again and the noise from the interior of the office.

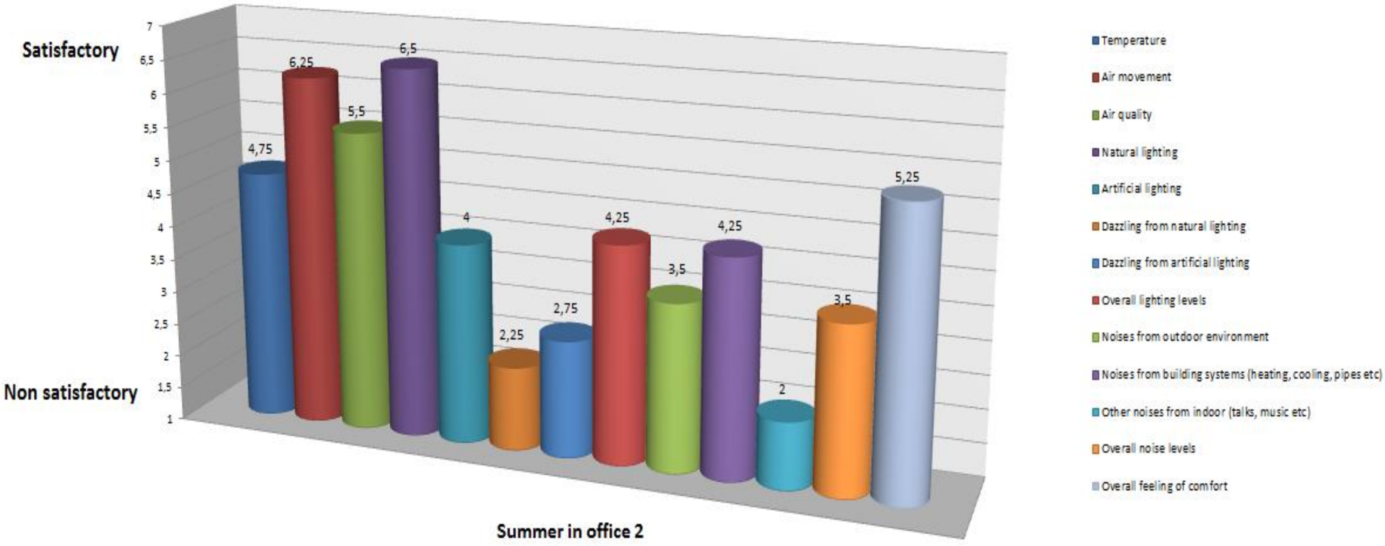


Figure 11: Seven scale diagram with the answers for summer in office 2

In the figure above, the office 2 results are presented again in summer conditions. The scale is again seven-digit, while in the memo the questions looks like before.as it is observed on the diagram the natural lighting is almost completely satisfactory, as is the air movement. Instead, we see low levels of glare from both artificial and natural lighting which means we should look again at the lights we use and perhaps use shades as well as other noises in the interior that is worth exploring.

The office results are compared in detail. It is observed that the temperature of the first office versus the second. Both offices have large openings, so exceptional natural lighting is justified. We observe glare in both offices, although we have to emphasize that in the first office there are shades of the latest technology but maybe they are not used properly, they work from the wrong time, etc. In general we observe very good results about the general lighting clues in the office, rather than in the office two.

Something very important is the noise levels in the two office buildings. Whether these sounds come from the inside or outside, we notice that in the oldest office the noise levels from the inside seem almost unsatisfactory, which can be related to the poor soundproofing of the office due to age as all the questions with noises are at average score. In the most critical of the results perhaps, the last question, about the general feeling of comfort, the difference between the two offices is small.

At first it is worthwhile to look at the most important elements of the two offices and then evaluate them as a whole. In terms of temperature, office 1 is more efficient, its rating is quite satisfactory, although office 2 does not make much difference. Impressively, the results of the questionnaire on the natural lighting of both offices are quite satisfactory. Office 1, however, is good from artificial lighting, while office 2 is considered neutral and may need to change its lighting.

The part of glare as well as the part of noise in both offices is quite modest and needs to be changed very carefully. In glare, office 1 makes a mean of around 3.5, but in my opinion it is due to the misuse of its latest shielding shades. In office 2 the glare is in the middle at 2 and certainly does not have any means of shading so it is not protected and it is difficult for the employees to work. Almost the same results we have for noise levels in both offices. Office 1 makes a mean of around 2.5, perhaps due to the fact that the office is on the ground floor and on a busy road. In office 2, the noise levels are around 2 and the same reasons apply to the office 1.

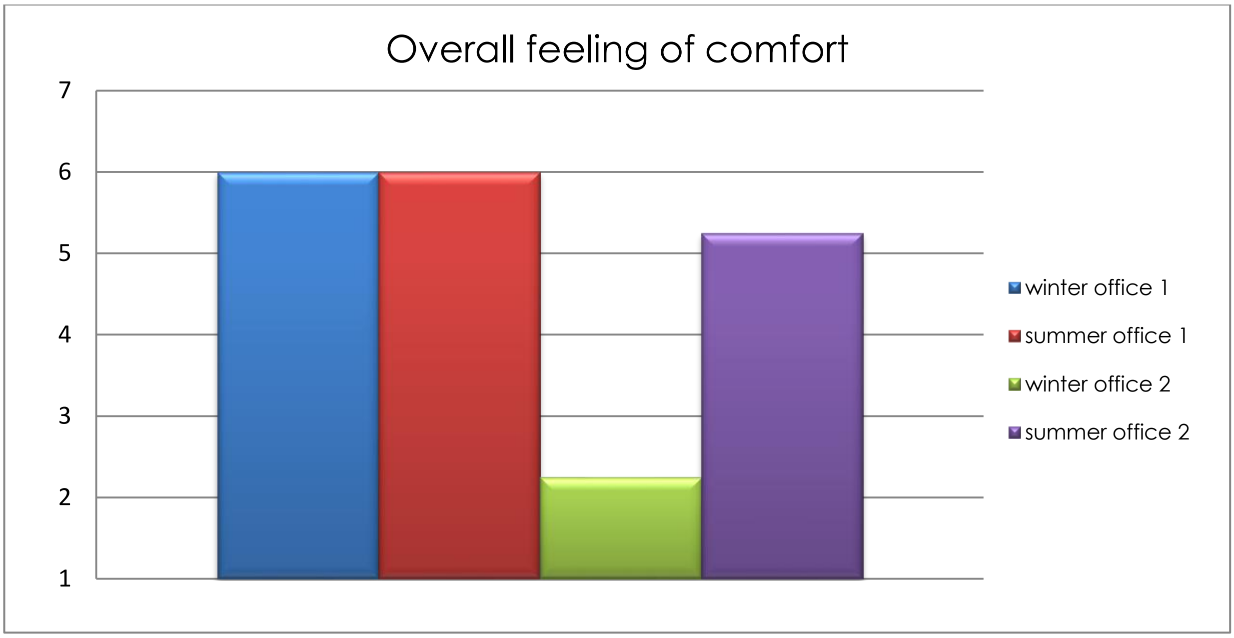


Figure 12: Seven scale diagram with the answers for summer-winter in both offices

Both offices have poor soundproofing indoors, from room to room that's why both offices were rated from the respondents with scores of less than 3 so not so satisfactorily. Last but not least on the general comfort conditions of each office, the results are pretty clear. Office 1 is judged to be very satisfactory by its employees. Office 2, on the other hand, was rated medically below average and judged to be moderately satisfactory.

As is logical, office 2, being more than a decade older than office 1, is definitely lagging behind and this also appears in the questionnaires. Cooling and heating systems, poor insulation and lack of shades make office 2 almost unsatisfactory for workers.

### 4.3.2 Second part

In the second part (Other Parameters), the users were asked to investigate the connection of the thermal comfort with typical personal factors such as, gender, age etc. In addition, the thermal comfort develops through certain mental processes before it leads to the expression of judgment or preference some of the questions that have been asked seek correlations with subconsciously established beliefs. [7] When referring to the subconscious, we refer to that cerebral mental process that takes place in the right hemisphere of the brain and is characterized by vague data memorization and processing speeds multiple times of those on the left hemisphere. In fact, our questions in this second part of the questionnaire become a little more subjective-personal and it may be useful to make an correlation with the ages of the users.

We have the classic seven scales, with the answers: ''1=never" and of course "7=always", while in the memorandum appear characteristically the colors of the two offices.

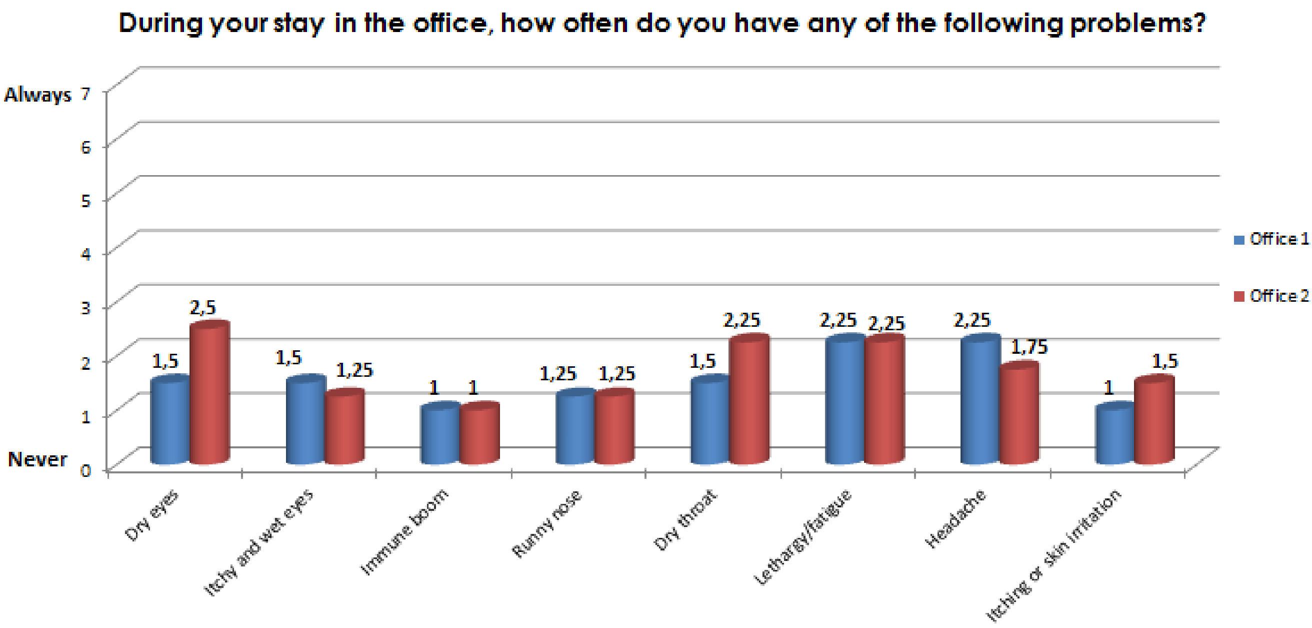


Figure 13: Seven scale diagram with some of the answers in both offices

In our first chart, we ask how often some symptoms are presented to office users. We preferred to present the results on mutual tables with average price again, with both offices so we can compare directly. We can see that in the office 2 we have more frequent symptoms than in office 1. More specifically, office 2 users have more dry eyes and dry throat, symptoms that are probably related to poor indoor air quality.

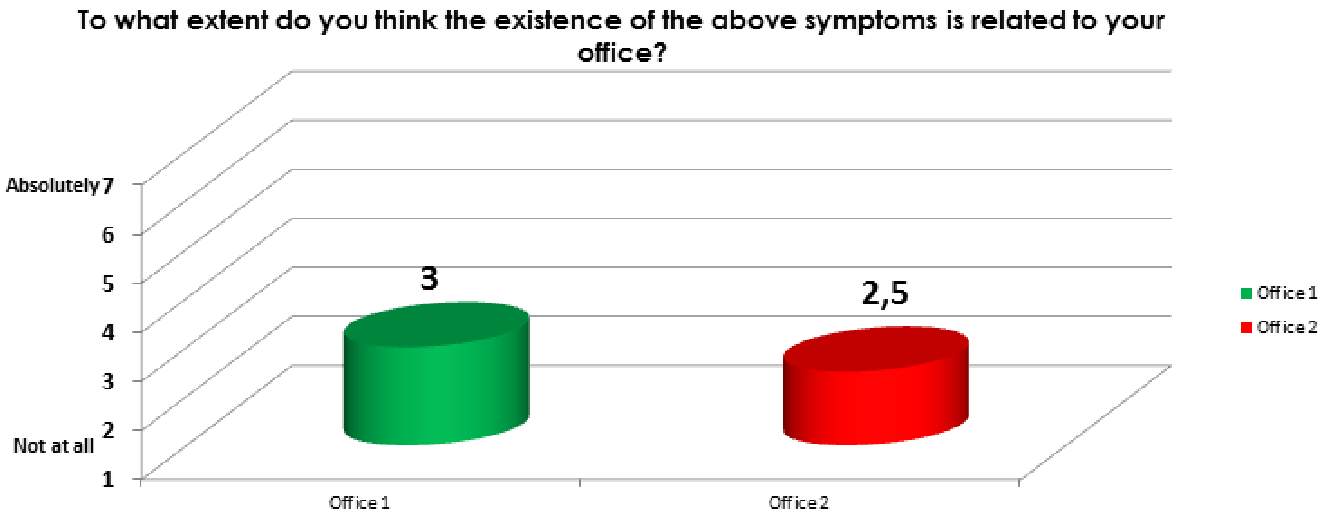


Figure 14: Diagram on if the symptoms are related with the office

In the second diagram, the question is to what extent you think the existence of the above symptoms is related to your office. Our results are once again in a mutual table with average prices, with both offices in order to be able to compare directly. We can see that our results are a similar fact, which means that in both offices the employees connect their symptoms to their working environment this requires further research for both offices.

# 5. Suggestions for reducing energy consumption as well as improving thermal comfort and air quality in the study areas

## 5.1 Thermal insulation

Thermal insulation is a necessary element of the building shell as it prevents the thermal energy from escaping from a space to another unheated space. [27]

In recent decades, there has been a lot of effort to improve the energy performance of buildings, particularly with regard to the thermal insulation of the building shell. The example of the evolution of legislation, for example in Germany, where the minimum thickness of thermal insulation of 5cm in 1972, has grown to 20cm today. [28] In America, it is estimated that thermal insulation of buildings is responsible for reducing carbon dioxide emissions by 780 million tons per year. [29]

In order to reduce the energy consumption in the building sector through the thermal protection of the shell, thermal insulation materials with low conductivity values (less than 0.04 W / mK) have been developed in recent years. The most widely used categories of heat insulating materials are inorganic fibrous (fiberglass and mineral wool) and organic foam (expanded and extruded polystyrene and, to a lesser extent, polyurethane extruded), while all other materials cover the remaining 10% of the market. [30]

In existing buildings (homes, hospitals, etc.) in which we are interested in improving their energy efficiency, it is desirable to have a constant temperature and are more interested in maintaining heat after heating, rather than in direct performance of the heating system, so the external thermal insulation of the masonry is preferred. [31]

The insulation in tile roof has as a result the reduction of the temperature up to 50%. In the same time the internal temperature of house is decreased up to 25%.

We have examined a lot of different materials, we spoke with technicians that are specialized in the heat insulation in order to take the best decision and in order to find out what they prefer to use. We found out that the most optimal solution is the extruded polystyrene of thickness 50mm of Dow. [37] The process to make extruded polystyrene foam has as a result an insulating material with uniform, small and closed cerumen and an incomparable combination of attributes that makes the specialists to select the product for a wide range of exigent applications of heat insulation.

- The low factor of thermic conductivity, which minimizes the thickness of plate that is required in order to be achieved a specific price k (U), giving thus in the scholar a bigger flexibility (λ=0,033).
- The high resistance in the compression. In applications of high charges, the structure of closed cerumen gives in the foam bigger rigidity and makes him exceptionally durable in the compression.
- Low Hydro absorbance. Dow products have natural resistance in rain, snow, ice and the water vapors, so as to be exceptionally stable materials that maintain their initial insulated performance and their natural integrity for big chronicle time lap. This extraordinary attribute gave the possibility of concretization of Inverted insulation in which Dow existed pioneer.
- The Dow thermal-insulate plates have small liability in the erosion, therefore are minimized the growth of mold or fungi. They are clean, odorless and do not contain irritant dust.
- The insulate materials of Dow, are friendly in environment (GWP<5, ODP=0), after they are produced with inflation by recycled dioxide of coal ($CO_2$) without the use of HFCS.

Some features of this particular material are:

- Thermic Conductivity coefficient L 90 days in the 10 °C = 0,033W/mk
- Resistance in the Compression (price in the limit of escape or 10% deformation) = 0,25N/mm2
- Hydro absorb = 1,5 max % at volume
- Resistance of Penetrability of Water Vapors m (Air m=1) = 100 min
- Dimensions
  LENGTH =1250mm WIDTH =600mm

We selected to make heat insulation in the tile roof since in the rest cell of the building exists already insulation. The area of our roof is 59.08$m^2$ hence according to the offers that we took from the technicians, and the predicted price 12€/$m^2$ (cost of insulation and placement together) it will cost us **708.96€**.

## 5.2 Improving lighting conditions

As it has already mentioned, the natural lighting is pretty good, the matter is mainly during the winter months when artificial lighting is required in the afternoon hours for office operation. The existing light bulbs are technically sufficient, but for energy saving reasons, it would not be unreasonable to replace them. For example, in office buildings and stores in general, electricity consumption for lighting is 50% of the total.

Figure 15: Characteristic sample of LED lighting in office building [46]

LED LIGHT is a revolutionary product that, although old on the market, has recently become more useful because of the need for reduced power consumption, in line with the recommendations of the European Community, as well as the increased efficiency and fidelity of the light it emits, compared to other light sources, a few years ago. [32]

LEDs replace conventional lighting modes in a variety of high reliability applications, both in the architectural and industrial sectors, as well as in street, park lighting, etc. They are made of tiny chips. These chips directly convert electricity into light without the use of a yarn. Instead, chips are included in various shells, glass or plastic with great potential and variety of shapes and sizes. Since LEDs generate energy in the above manner, this also requires extra heat and CO2. In addition, they have a life span of over 100,000 hours of life, compared to conventional lamps that have 2,000-4,000 hours of life.

# 6. The effect of energy saving on heating, cooling and ventilation systems in the IAQ

Buildings are a major energy consumer and therefore, efforts to reduce energy consumption in these buildings are, in particular, today intensive. The EU has set itself the objective of reducing energy consumption as part of its strategy of separating itself from imported resources and the strategy of protecting the environment. As the energy required to heat and cool the buildings is a significant share of total energy consumption in buildings, efforts focus, in addition to insulated building shielding and bioclimatic design, on the more efficient operation of mechanical heating, cooling and ventilation systems.

Within this logic, many energy-saving tactics have been developed and implemented so far. However, recently, and because of the importance of the IAQ in buildings, energy-saving tactics are being revised. The above is due to the fact that the application of energy saving techniques to heating, cooling and ventilation systems can influence positively or negatively the IAQ. Therefore, the IAQ is now a new parameter in the selection and adoption of energy saving measures. [38]

More generally, energy-saving techniques can be divided into those relating to the design of the heating, cooling and ventilation system, the use of control devices and energy recovery methods. Others protect or improve the IAQ and others again degrade.

## Measures of improving IAQ and save energy in office buildings

- Reduce internal loads. The interior loads of a building include lights, office equipment and household equipment. The reduction of internal loads leads to a reduction in the thermal load and hence the requirements that the mechanical system must cover in air. But this also means a reduction in the rate of ventilation. Therefore, care must be taken to achieve the minimum ventilation levels as defined by the IAQ standards. Reducing internal loads leads to a reduction in the refrigerant load but an increase in the thermal load. However, the energy benefit from reducing the refrigerant load is higher compared to energy consumption due to the increase in thermal load [36]
- Cooling cycle with air. The economic cooling cycle is based on the use of outside air for cooling without the need for energy consumption. In general, it helps to improve the IAQ since it works by providing air, thus increasing the average ventilation, while reducing the annual energy costs of a heating, cooling and ventilation system, especially in cold or

mild climates. Particular attention should be paid to the calibration of its operating points

- Night ventilation. Night ventilation is called the technique whereby cold ambient air is introduced into the building during the night to reduce the refrigerant load and hence energy consumption. According to EPA studies in commercial buildings, night ventilation can produce 5% -18% energy savings. [33] This technique improves the IAQ, because during night ventilation the concentration of indoor pollutants decreases. However, if the dew point of the outside air is sufficiently high and there is a risk of condensation and an environment conducive to the development of microbiological organisms.
- Preventive maintenance of the heating, cooling and ventilation system. Preventive maintenance ensures proper calibration and efficient operation of mechanical parts of the heating, cooling and ventilation system, thus providing not only energy savings but also improved IAQ. Preventive maintenance measures concern calibration of temperature and humidity sensors, periodic replacement of air filters, maintenance of pressure and air flow control systems, air flow balancing to ensure proper distribution and cleaning of cooling elements or / And heating and other subsystems to reduce the resistance displayed in the flow and the sources of pollutants in the system.
- Reducing the power of the central equipment. According to EPA studies, reducing the power of 73% -77% office refrigerators and school buildings (by 86% -90%) leads to energy savings of 13% and 17%, respectively [34]. The effort to reduce the power of the equipment focuses mainly on boilers (cast iron boilers that increase heat transfer, improved burners and reduction of combustion chambers) and the use of energy recovery systems. However, this reduction should be such as to meet the thermal comfort conditions at peak periods and moisture control to avoid microbiological contamination.

**Other measures for improving IAQ which are not strictly connected to energy consumption are also mentioned below:**

## Mechanical Ventilation

Mechanical systems can provide controlled ventilation and are usually combined with temperature control and air filtration. These systems have two main methodologies: Mixers that reduce concentration of contamination by providing "clean" air and removing the same volume of contaminated air or displacement mode that remove the contamination near their source before being mixed with air. [41]

## Air cleaning

Air purification is accomplished with so-called air cleaning devices. These devices remove small airborne particles, liquid or solid (dust, droplets and gaseous pollutants) from the indoor air. It is still questionable whether these devices can reduce the allergic reactions caused by larger particles such as pollen, mold, etc., which are mainly deposited on surfaces rather than suspended in the air. However, it is considered likely that these substances can be effectively removed from the space as long as they are re-dispersed in the air. [36]

**i.** Mechanical filters

Mechanically called filters, whose filtration function is based on mechanical mechanisms (diffusion, inhibition and inertia). The particles themselves, as they are deposited on the filter, are converted into collectors of other particles.

As the airflow is obstructed, the pressure drops, while the performance of the filter increases. Filters combined with ventilation systems can be of three types: prefilters, HEPA filters or ULPA filters. Profilers typically have a yield ranging from 70-90% for particles less than 1 μm from the air.

HEPA (High Efficiency Particulate Air) filters are high performance filters (99.97%) for particles> 0.3 μm. These filters are dry-type and large-area filters and are often found in hospitals, industries, etc., in places with high concentrations. Great influence on filter performance has both the manufacturer's quality standards, installation, operation and maintenance of the appliances, actual airflow and humidity conditions, and possible leakage of contaminated air from gaps or crevices between Filters and their context.

**ii.** Ionisation of air

The ionizer is a device that produces negative or positively charged ions and diffuses them into the air. Air ionization removes suspended particles and dust from room air by depositing on horizontal main surfaces around the ionizer (often walls, furniture, etc.). This method is likely to reduce the concentration of aerobic micro-organisms as they are often transported through dust and particulates. The deposited particles accumulate, form together compounds and form larger particles, thereby increasing the rate of deposition of new particles. As with electrostatic precipitators, both ionizers require a high level of electricity consumption and high to dangerous levels of ozone.

## System maintenance

Maintenance of Ventilation-Heating-Air-Conditioning Systems By definition, the indoor air quality depends on the supply and distribution of fresh air, the thermal comfort conditions and the concentration of pollutants. Good air quality implies health, well-being, comfort and hence increased productivity of people who live in, live or work within. [35]

Recent research has shown that in most of the cases where we encounter indoor air quality problems, the main responsibility is the incorrect design and malfunction or maintenance of mechanical ventilation, heating, air-conditioning and refrigeration systems.

Proper design, rational operation and regular control and maintenance of HVAC systems are a prerequisite for maintaining indoor air quality. In any case, in order to have the right results in terms of quality of indoor environment and thermal comfort, at least the following conditions must exist:

- **i.** A properly designed and installed heating / cooling system.
- **ii.** The HVAC system must be proactively controlled, regularly maintained and continuously adapted to the needs and characteristics of the building (use, number of users, materials, equipment, etc.)
- **iii.** Have a person skilled in operating and managing the HVAC system.
- **iv.** Keep records of any activities, actions, repairs, checks, damages, complaints, etc. that are related to the system or are performed in the system.
- **v.** An open network of communication between users and system administrators. [35]

## Maintenance and cleanliness

Generally people appreciate cleanliness in particular. In fact, they appreciate cleanliness, especially for reasons of good aesthetics rather than hygiene, as they often ignore the existence of micro-organisms, allergens and other dangers, even in obviously unpalatable spaces. In particular, the knowledge on the subject "how the quality of cleaning can affect man" is very limited.

Sources of pollution are found in almost every area. Pollutants can also be transported from outside to inward through penetration, openings, ventilation systems, etc. There is a constant exchange between the interior and exterior environment: external dirt is conveyed inwards and backwards. This process also greatly contributes to the cleanliness that can either be part of the solution, eliminating the sources of microorganisms and allergens in the space, or, in some cases, being the cause of transport of pollutants from one place to another, or even the source of pollution itself.

Cleanliness is directly linked to system and material maintenance, since the use of incorrect cleaning products or faulty cleaning techniques can cause surface corrosion, and a lack of cleanliness can reduce the efficiency of operating devices and machines. Special cleaning is required for heating, air conditioning, fire extinguishing systems, etc. where, in addition to the operational aspect, cleanliness in the quality of indoor air and the elimination of sources of indoor pollution.

# 7. Bibliography


1. Brill,M, Margulis,S.T και BOSTI,(1985), Using offices design to increase productivity,vol 2,Buffalo.

2. Gaitani N. , (2003) Bioclimatic assessment of open spaces, diploma thesis, University of Athens

3. ASHRAE Standard 55, 1995

4. McCullough,E,A, Olesen,B,W and Hong,S,W, (1994) thermal insulation provided by chairs, ASHRAE Transactions 100(1).

5. ISO 7730 Standard (2005), Ergonomics of the thermal environment analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. London, UK.

6. Aronoff, S and Kaplan, A (1995), Total workplace performance, Ottawa, WDL, Canada

7. Santamouris M. , Asimakopoulos, D, (1996) Editors, PASSIVE COOLING OF BUILDINGS, University of Athens, Greece,.

8. Busch, J (1992), A tale of two populations: thermal comfort in air conditioned and naturally ventilated offices in Thailand, Energy and Buildings, 18 (3-4), pp.235-249

9. Nicol, F and Roaf, S (1996), Pioneering new indoor temperature standards: the Pakistan project, Energy and Buildings, 23, pp. 169-174.

10. Nicol, J.F, Raja, LA, et al (1999), Climatic variations in comfortable temperatures: the Pakistan project, Energy and Buildings, 30, pp.261-279.

11. de Dear, R and Auliciems, A (1988), Air conditioning in Australia I I: User attitudes, Architectural Science Review, 3, pp. 19-27.

12. Humphreys,M.A and Nicol,F (1998), Understanding the adaptive approach to thermal comfort, ASHRAE Technical Data Bulletin,14 (1),1-14.
13. Olesen, B.W and Brager, G.S (2004), A better way to predict comfort, ASHRAE Journal, pp.20-26.

14. CIBSE Guide A, (2006), Enviromental design, London, The Chartered Institution of Building Services Engineers.

15. Daskalaki E and M. Santamouris: 'On the potential of retrofitting scenarios for offices' J. Buildings Environment, 37,6,557-567,2002 Tombazis & Preuss (2001)

16. Triantis, E., Morck, O., Erhorn, H., & Kluttig, H.Environmental retrofitting of educational buildings-architectural aspects of an international research project

17. Asadi, E., Silva, M. G., Antunes, C. H., & Dias, L. (2011). "MULTI-OBJECTIVE OPTIMIZATION FOR BUILDING RETROFIT STRATEGIES: A MODEL AND AN APPLICATION". Energy and Buildings

18. Dorizas, Assimakopoulos, Helmis & Santamouris (2013), A STUDY ON THE THERMAL ENVIRONMENT IN GREEK PRIMARY SCHOOLS BASED ON QUESTIONNAIRES AND CONCURENT MEASUREMENTS

19. Rey, E. (2004). Office building retrofitting strategies: Multicriteria approach of an architectural and technical issue. Energy and Buildings, 36(4), 367-372.

20. Balaras C., (1994). A guide for Energy Conservation in School Buildings. C.I.E.N.E., Department of Applied Physics, University of Athens

21. Stourna Trianti, E., Santamouris, M., & Vallindras, M. (1986). Passive solar strategies in retrofitting design—the case of a historic building in athens, greece. Solar & Wind Technology, 3(1), 1-11.

22. Krstic, A. D. (1998). Bioclimatic rehabilitation of existing building stock. Renewable Energy, 15(1), 337-342.

23. CABRAL, M. I., & CHALFOUN, N. (1998). Microclimate control and passive cooling in a rural house for tourism in cova da beira

24. Calderaro, V., & Agnoli, S. (2007). Passive heating and cooling strategies in an approaches of retrofit in rome. Energy and Buildings, 39(8), 875-885.

25. Zain-Ahmed, A., Sayigh, A., Surendran, P., & Othman, M. (1998). The bioclimatic design approach to low-energy buildings in the klang valley, malaysia. Renewable Energy, 15(1), 437-440

26. Duffy, F (1997), The new office, Conran Octopus Limited, London.hum

27. CRES, (1995). Instructions for thermal-optical comfort and energy saving in public schools. http://www.cres.gr/kape/pdf/download/thermal_visual_comfort_in_schools_s.pdf

28. Papadopoulos A.M. & Papadopoulos M.A. (2001), Insulation Materials for Buildings' design, First National Conference for the Building and the Environment, Athens

29. Crane, A.E. & Ware, D.W. (2002), Insulation Products Environmental Comparison – A Life – Cycle Approach. http://calc.naima.org/lifecycle.asp

30. Papadopoulos, A.M., (2005). State of the art in thermal insulation materials and aims for future developments. Energy and Buildings 37, pp 77-86.

31. Aravantinos D. (2009), Constructional interventions in the building shell of new and existing buildings to improve their thermal behavior, Notes on the short-term seminar of the Central Macedonia Department of the Technical Chamber of Greece, Thessaloniki, January

32. Aravantinos D. (Ed.). (2011). ENERGY DESIGN GUIDE: BIOCLIMATIC ARCHITECTURE & ENERGY SAVING. Thessaloniki: BUILDING

33. EPA, "Stage Three-Other Load Reductions", Energy Star Buildings Manual, Ιούνιος 1998

34. EPA, «Energy cost and IAQ performance of ventilation systems and controls-The impact of energy efficiency strategies on energy usage, thermal comfort and outdoor air flow rates in commercial uildings,Project#7», Indoor Environments Division (6609J), Office of air and Radiation, EPA-402-S-01-001F, Ιανουάριος 2000

35. Methods for control of indoor air quality, Charles E. Billings, Sandra F. Vanderslice, Environment International, Vol. 8, pp. 501, 1982

36. Indoor air Pollution Control, Godish T. Lewis Publishers Inc., Michigan, USA 1989

37. Everyday Ecology, Small Guide to Changing our Daily Traditions, Stavros Yfantis, Stefano Generali

38. Santamouris M, A. Argiriou, E. Daskalaki, C. Balaras and A. Gaglia : Energy Characteristics and Savings Potential in Office Buildings. Solar Energy, Vol. 52, 1,p.p.59-66, 1994.

39. Synnefa A, E. Polichronaki, E. Papagiannopoulou, M. Santamouris, G. Mihalakakou, P. Doukas, P.A. Siskos, E. Bakeas, A. Dremetsika, A. Geranios, A. Delakou : An experimental investigation of the indoor air quality in fifteen school buildings in Athens, Greece. J. Ventilation, Vol.2,No3,p.p.185-202, 2004

40. Autodesk sustainability workshop https://sustainabilityworkshop.autodesk.com/

41. http://www.openarchives.gr/

42. Technical Chamber of Greece (2011). Bioclimatic building design. (Technical Instruction No. 20702-5 / 2010). Athens

43. Dr. Sam C M Hui, Air Conditioning and Refrigeration, Thermal Comfort

44. http://theairqualityexperts.ca/

45. http://nptel.ac.in/courses/105102089/air%20pollution%20(Civil)/Module-6/1.htm

46. https://www.alconlighting.com/shop-by-application/led-office-lighting.html

47. Argyro Lagoudi, Maria Loizidou, Mat Santamouris, Demosthenes Asimakopoulos, 1996, Symptoms experienced, environmental factors and energy consumption in office buildings

48. A. ARGIRIOU, D. ASIMAKOPOULOS, C. BALARAS, E. DASCALAKI, A. LAGOUDI, M. LOIZIDOU, M. SANTAMOURIS and I. TSELEPIDAKI, 1994, ON THE ENERGY CONSUMPTION AND INDOOR AIR QUALITY IN OFFICE AND HOSPITAL BUILDINGS IN ATHENS, HELLAS

49. http://www.domisikat.gr/index.php?option=com_content&view=article&id=46:asvestis-2011&catid=118:2012-11-22-15-41-56&Itemid=151

50. E. Gossauer, A. Wagner, Post-occupancy evaluation and thermal comfort state of the art and new approaches, Adv. Build. Energy Res. 1 (2007)151–175, http://dx.doi.org/10.1080/17512549.2007.9687273.

51. R.J. De Dear, T. Akimoto, E.A. Arens, G. Brager, C. Candido, K.W.D. Cheong, B.Li, N. Nishihara, S.C. Sekhar, S. Tanabe, J. Toftum, H. Zhang, Y. Zhu, Progressin thermal comfort research over the last twenty years, Indoor Air 23 (2013)442–461, http://dx.doi.org/10.1111/ina.12046.

52. I.A. Meir, E.L. Kr, L. Morhayim, S. Fundaminsky, Towards a comprehensive methodology for Post Occupancy Evaluation (POE): A hot dry climate case study, in: 2nd PALENC Conf. 28th AIVC Conf. Build. Low Energy Cool. Adv.Vent. Technol. 21st Century, Crete island, 2007, pp. 644–653.

53. P. Antoniadou and A.M. Papadopoulos AUTh, Process Equipment Design Laboratory, Dept. of Mechanical Engineering, Aristotle University of Thessaloniki, 2017

54. https://ecohealthsolutions.com.au/blog/sick-building-syndrome-in-the-workplace/

# 8. Appendix

The questionnaire which the employees called to answer. [53]

Γραφείο:

Ημερομηνία:

Αριθμός Ερωτηματολογίου:

**<u>Α. Συνθήκες Άνεσης</u>**

Πώς θα περιγράφατε τις συνθήκες άνεσης στο χώρο γραφείου σας τον ***ΧΕΙΜΩΝΑ*** και το ***ΚΑΛΟΚΑΙΡΙ*** με βάση τις ακόλουθες συνθήκες; ***(Απαντήστε τόσο για το χειμώνα όσο και για το καλοκαίρι)***

| | ΧΕΙΜΩΝΑΣ | ΚΑΛΟΚΑΙΡΙ |
|---|---|---|
| **Α.1.Θερμοκρασία** | Μη Ικανοποιητική 1 2 3 4 5 6 7 Ικανοποιητική | Μη Ικανοποιητική 1 2 3 4 5 6 7 Ικανοποιητική |
| **Α.2. Κίνηση αέρα** | Έντονη 1 2 3 4 5 6 7 Άπνοια | Έντονη 1 2 3 4 5 6 7 Άπνοια |
| **Α.3. Ποιότητα αέρα** | Μη Ικανοποιητική 1 2 3 4 5 6 7 Ικανοποιητική | Μη Ικανοποιητική 1 2 3 4 5 6 7 Ικανοποιητική |
| **Α.4. Φυσικός φωτισμός** | Μη Ικανοποιητικός 1 2 3 4 5 6 7 Ικανοποιητικός | Μη Ικανοποιητικός 1 2 3 4 5 6 7 Ικανοποιητικός |
| **Α.5. Τεχνητός φωτισμός** | Μη Ικανοποιητικός 1 2 3 4 5 6 7 Ικανοποιητικός | Μη Ικανοποιητικός 1 2 3 4 5 6 7 Ικανοποιητικός |
| **Α.6. Θάμβωση από Φυσικό φωτισμό** | Καθόλου 1 2 3 4 5 6 7 Έντονη | Καθόλου 1 2 3 4 5 6 7 Έντονη |
| **Α.7. Θάμβωση από Τεχνητό φωτισμό** | Καθόλου 1 2 3 4 5 6 7 Έντονη | Καθόλου 1 2 3 4 5 6 7 Έντονη |
| **Α.8. Συνολικά Επίπεδα φωτισμού** | Μη Ικανοποιητικά 1 2 3 4 5 6 7 Ικανοποιητικά | Μη Ικανοποιητικά 1 2 3 4 5 6 7 Ικανοποιητικά |
| **Α.9. Θόρυβοι που προέρχονται από το εξωτερικό περιβάλλον** | Καθόλου 1 2 3 4 5 6 7 Έντονοι | Καθόλου 1 2 3 4 5 6 7 Έντονοι |
| **Α.10. Θόρυβοι που οφείλονται σε συστήματα του κτιρίου (θέρμανσης, ψύξη, αερισμός, φωτισμός, σωληνώσεις)** | Καθόλου 1 2 3 4 5 6 7 Έντονοι | Καθόλου 1 2 3 4 5 6 7 Έντονοι |
| **Α.11. Άλλοι ήχοι από το εσωτερικό του κτιρίου (ομιλίες, μουσική κ.λπ.)** | Καθόλου 1 2 3 4 5 6 7 Έντονοι | Καθόλου 1 2 3 4 5 6 7 Έντονοι |
| **Α.12. Συνολικά επίπεδα θορύβου** | Μη Ικανοποιητικά 1 2 3 4 5 6 7 Ικανοποιητικά | Μη Ικανοποιητικά 1 2 3 4 5 6 7 Ικανοποιητικά |
| **Α.13. Αίσθημα άνεσης συνολικά** | Μη Ικανοποιητικό 1 2 3 4 5 6 7 Ικανοποιητικό | Μη Ικανοποιητικό 1 2 3 4 5 6 7 Ικανοποιητικό |

## Β. Λοιπές Παράμετροι

**Β.1. Πώς θα αξιολογούσατε τα ακόλουθα χαρακτηριστικά του γραφείου σας, συνολικά:**

| Μη Ικανοποιητικά | 1 | 2 | 3 | 4 | 5 | 6 | 7 Ικανοποιητικά |
|---|---|---|---|---|---|---|---|
| Θέρμανση | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ψύξη | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Αερισμός | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Επίπεδα Υγρασίας στο χώρο | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Σκιασμός λόγω ηλιακής ακτινοβολίας | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Β.2. Κατά την παραμονή σας στο χώρου του γραφείου πόσο συχνά αντιμετωπίζετε κάποιο από τα ακόλουθα προβλήματα;**

| Ποτέ | 1 | 2 | 3 | 4 | 5 | 6 | 7 Πάντα |
|---|---|---|---|---|---|---|---|
| Στεγνά Μάτια | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Φαγούρα &Υγρά μάτια | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Μπούκωμα | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Καταρροή | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ξηρός λαιμός | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Λήθαργος ή/και κούραση | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Πονοκέφαλος | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Φαγούρα ή ερεθισμός Επιδερμίδας | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Β.3. Σε τι βαθμό πιστεύετε πως η ύπαρξη των παραπάνω συμπτωμάτων σχετίζεται με το γραφείο σας;**

| Καθόλου | 1 | 2 | 3 | 4 | 5 | 6 | 7 Απόλυτα |
|---|---|---|---|---|---|---|---|
| | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Β.4. Έχετε ποτέ είτε εσείς είτε οι συνάδελφοί σας εκφράσει παράπονο σχετικά με:** *(σημειώστε 1 ή περισσότερα)*

| | | |
|---|---|---|
| ☐ Θέρμανση | ☐ Φυσικός Φωτισμός | ☐ Εργασιακό Περιβάλλον |
| ☐ Αερισμός | ☐ Τεχνητός Φωτισμός | ☐ Άλλο ____________ |
| ☐ Κλιματισμός | ☐ Θόρυβος | ☐ Τίποτα |

**Β.5. Φύλο:** Άντρας ☐ Γυναίκα ☐

**Β.5. Ηλικία:** ……………………………………………………………………………

**Β.6. Μορφωτικό επίπεδο:**

☐ Δημοτικό
☐ Γυμνάσιο/Λύκειο
☐ ΑΕΙ/ΤΕΙ
☐ Μεταπτυχιακό/ Διδακτορικό
☐ Άλλο ____________