ENERGY SAVING AND INDOOR AIR QUALITY IN OFFICE BUILDINGS

E. Provata[1], D. Kolokotsa [1]

[1] *Technical University of Crete, Environmental Engineering Department, 73100 Chania, Greece*

ABSTRACT

Air quality in the office room areas, as well as their energy demands for heating and cooling are directly depended on the ventilation levels in those rooms. Specifically, high internal air quality requires high levels of ventilation and therefore high energy demands. On the other hand, high energy savings can be accomplished by full building impermeability, which means low to none ventilation and at the same time low air quality. Those observations were determined from studying the effect of natural air flow in energy preservation at an extant building with office complexes, specifically the K_2 building which is part of the Environmental Engineering Department at the Technical University of Crete. The building's thermal behaviour was examined using a modelling program called TRNsys, whereas the use of a tool named COMIS allowed the modelling of air flow inside the building as well as estimating the inner pollution derived from the employees.

KEYWORDS

Energy Saving, Ventilation, Infiltration, Indoor air quality

1 INTRODUCTION

According to the European Commission, the building sector is responsible for the 40% of the final energy consumption and the 36% of carbon dioxide emissions (European Commission 2013). For this reason, the energy savings from this sector is a concern for several decades.

Since the '80s, the first draft guidelines had been set in order to reduce the energy requirements of buildings. The full insulated constructions were considered as the first improvement action for that scope because these buildings don't allow the infiltration of fresh air into the building. After that, other improvement techniques were applied that were related to the technology and the operation of the HVAC systems, as are described by Olesen et al. (Olesen, Seppanen, and Boerstra 2006)

The consequences of these actions were the energy saving from the building sector and the degradation of the indoor air quality. The lack of fresh air in the internal environment of the buildings had negative effects to the human health.

Thus were established the first actions to ensuring good indoor air quality and the prevalence of a healthy internal environment. These actions were related to the ventilation levels, the lighting level, and acoustic level etc. (Olesen 2004)

The objective of this paper is the study of the infiltration / ventilation air rates as the critical parameter which affects the most to the energy demands and the internal pollution of a building. Several studies have examined the building's energy demands and propose energy saving measures without considering the air flow or the pollutant transport (Boyer et al. 1998), (Alemu, Saman, and Belusko 2012). In this paper, the energy saving is coupled with the indoor air quality.

2 METHOLOGY

The methodology proposed in this paper is based on computer simulations using TRNsys and COMIS. TRNsys (TRaNsient SYstems Simulation program) (Solar Energy LaboratoryUniversity of Wisconsin-Madison 2010) software is used in order to provide information on the dynamics of the thermal behaviour of both the whole building, as well as for individual components (Khandelwal, Talukdar, and Jain 2011), (Al-ajmi and Hanby 2008). It can calculate a number of variables, such as the internal temperature, humidity, airflow, the power consumption, the thermal comfort etc., solving a series of differential equations that describe mass and heat transfer in buildings. COMIS (Conjunction of Multizone Infiltration Specialists) (Comis 2005) simulates multizone air flow (Li and Heiselberg 2002) and pollutant transport in buildings (Viktor Dorer, Anne Haas, Werner Keilholz, Roger Pelletret 2001). These computer simulations can be coupled by type 157 in which the COMIS gives the air flow as input to TRNsys and then the last calculates different parameters considering the infiltration or ventilation rates.

2.1 Building Description

TRNsys and COMIS were used to calculate the energy demands and the pollution levels of a building located in the area of Chania in Greece. Specifically, this building called K_2 (Figure 1) belongs to the Department of Environmental Engineering of Technical University of Crete. It's located just a few kilometres from the sea, stands at an altitude of 137 m and is orientated 45^o northwest.

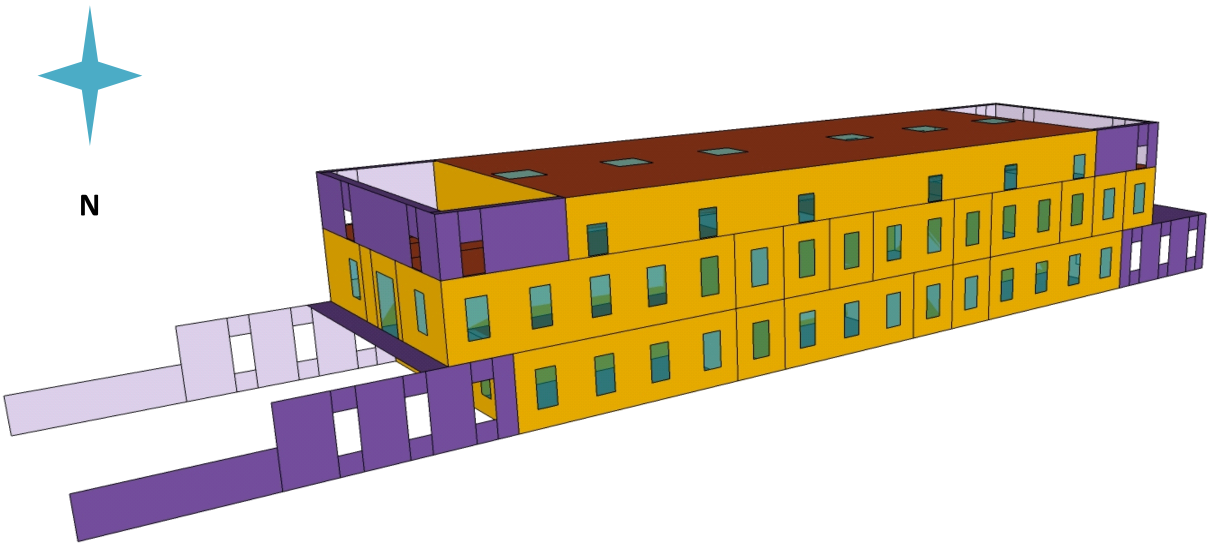

Figure 1: 3D model building

The studied building consists of a ground floor, a first floor and a second floor. At the ground floor, the computer center, a space for printings, toilets and laboratories are situated, while the first floor accommodates only offices. The last floor has no office or laboratory operation because the mechanical equipment of the building is there.

The dimensions of the building are the following: length = 42m, height = 12m and width = 14.4 m. It was separated into zones, in order to simulate and study. Specifically, thirty zones were created based on the using and the orientation of each zone. For the ground floor, 12 zones were created, 17 for the first floor, while the second floor was a single zone.

2.2 Characteristics of the building

In order to simulate the building using TRNsys, the constructive and the operating characteristics are needed.

The constructive characteristics of the building are presenting at the following table.

Table 1: Constructive characteristics

External walls	Gypsum board, Cement board, Concrete, Cement board type of Aquapanel
Internal walls	Gypsum board
Roof	Armed concrete, insulation panels
Ground Floor	Armed concrete, marble
Ceilings / Internal floors	Armed concrete, marble, Gypsum board tapes
Glazing	Aluminum frame and doubled layer

The operating characteristics that are required as inputs to each building zone include the occupants, the lights, the HVAC systems, the electronic computers, the printers and the operating schedules of all these.
The average power density of the installed lighting is 13 W/m^2 for the building under consideration. The heating system operates at 20 ° C and the cooling at 26 ° C. Computers operate at a power of 230 W and printers at 220 W. These data were entered in the modeling program considering weekly operating schedule which was a five-day work for 8 hours a day, from 8:00 until 16:00. Regarding, the occupants, it was estimated that 1 or 2 people work at each office zone doing light work and using 1 or 2 computers. At the computer center, it was set that 10 people visit this space using 10 computers from 9:00 to 15:00 daily.

3 PRESENTATION OF RESULTS

3.1 Validation of TRNsys simulation

Firstly, the validation of the simulated results was necessary. This, was achieved by comparing the measured internal air temperature with the calculated by TRNsys, at the zones which had no operation at the measuring period. The results are presented at the following figures.

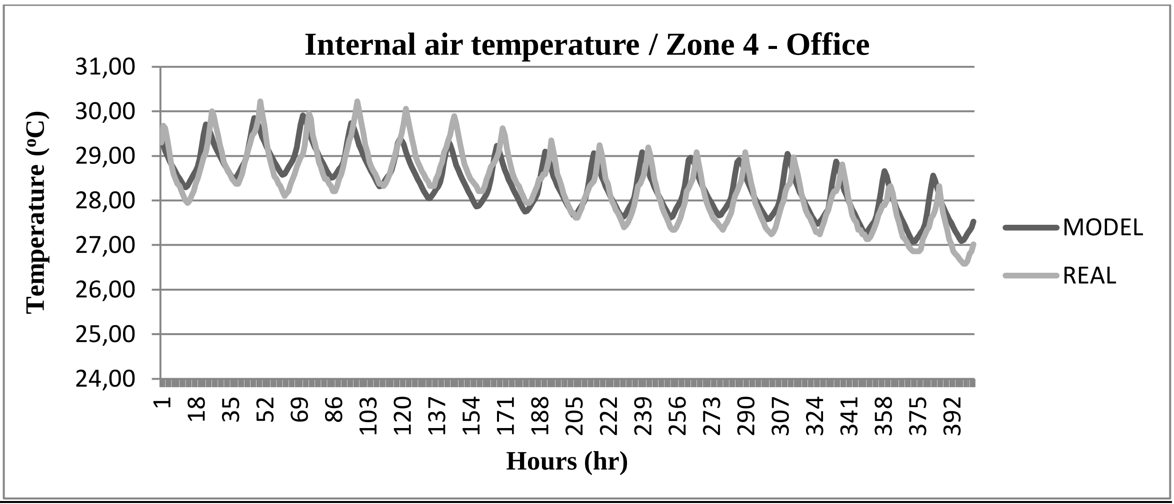

Figure 2: Comparison of internal air temperature at zone 4

Zone 4 includes one office of the building which is situated at the North West sight of the 1st floor. The internal air temperature was measured from 04/08/2012 to 21/08/2012 and its variance is shown at the figure above.

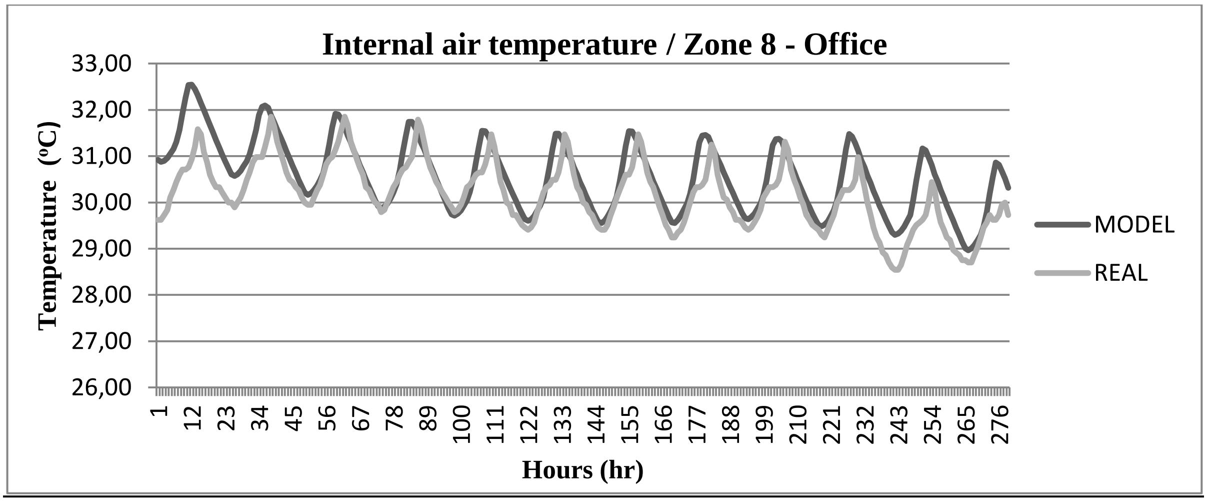

Figure 3: Comparison of internal air temperature at zone 8

At zone 8, which represents a North East office space of the 1st floor of the building, the measuring period of the internal temperature was from 08/08/2012 to 19/08/2012. The comparison between the simulated results and the measurements are shown at Figure 3.

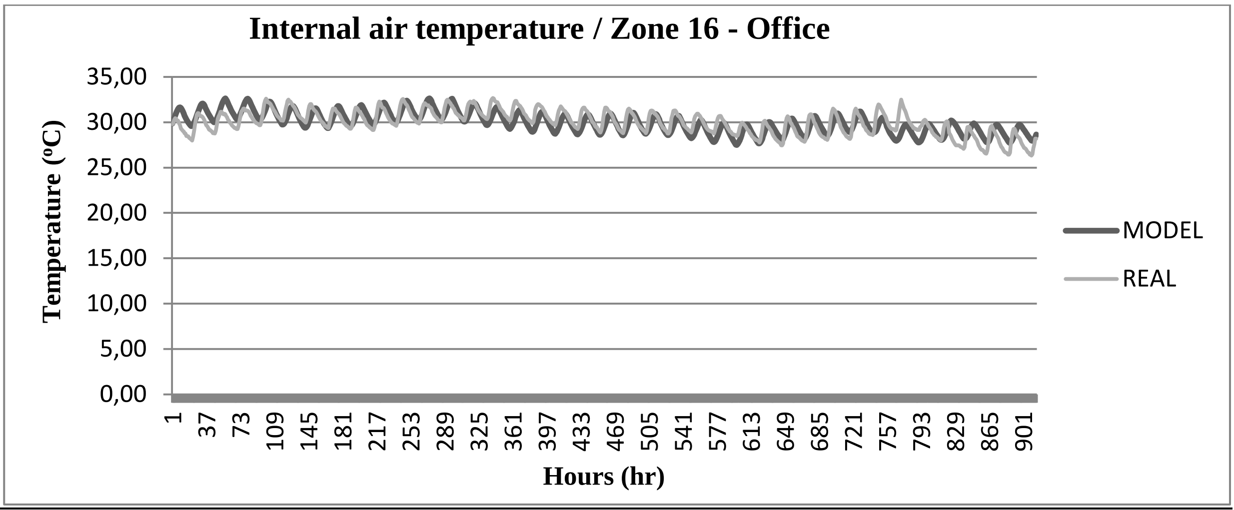

Figure 4: Comparison of internal air temperature at zone 16

The last validation was that at zone 16 which is situated at the south east corner of the 1st floor of the building. The measuring period was from 27/07/2012 to 30/08/2012 and the results are shown at Figure 4.

Regarding the three validations that were presented above, it is understandable that the building's simulation is close to the reality because of the declination between the measurements and the calculated values by the model that it was too small.

The model that was designed at TRNsys environment was validated and the next step was to calculate the energy demands of the building considering two study cases that are presented below, at the next section.

3.2 Building's energy demands

The building's energy demands were calculated considering two scenarios. At the first scenario, it was set that the building is full insulated and at the second the infiltration air rate that was calculated by COMIS for each zone is considered as an input parameter at TRNsys in order to estimate the heating and the cooling demands. The results of both scenarios are presented at the figure below.

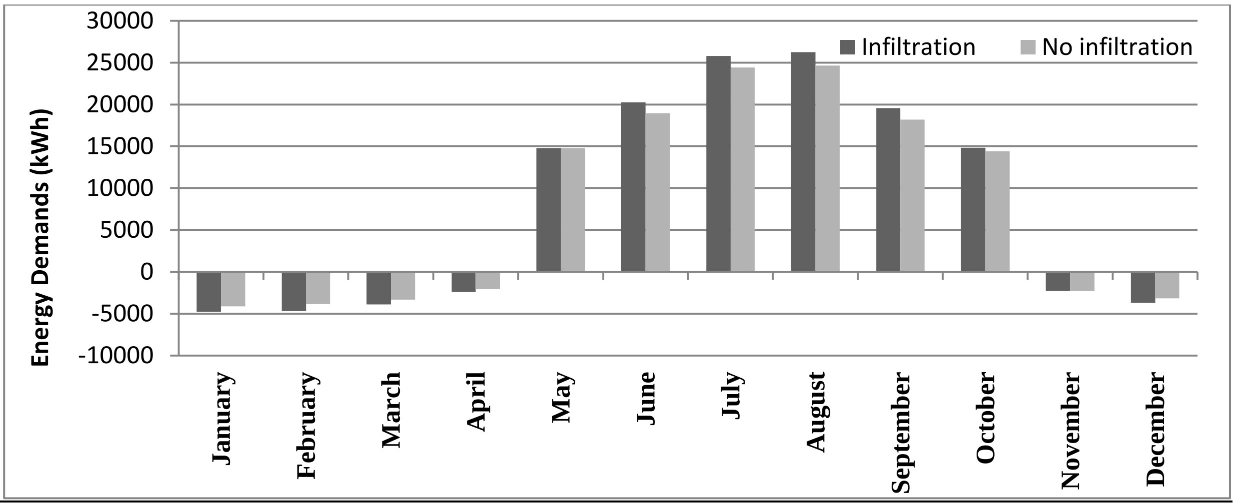

Figure 5: Building's energy demands considering infiltration and no infiltration air rates

At figure 5, the negative values represent the energy demands for heating, while the positive values show the energy demands for cooling. It is obvious that the cooling loads seems to be quite larger than the heating loads, which makes sense, as the building's geographical location is characterized by summers with intense sunshine and high temperatures, while winters are mild with median ambient temperatures. The infiltration air rate is a significant parameter for the energy saving. Regarding the results, if the building is full insulated the building needs 2947.5 kWh less for heating and 6080.1 kWh less for cooling.

In addition to energy saving, the indoor air quality should be examined in relation to the infiltration – ventilation rates, as this parameter directly affects at the health of employees in a building. As it mentioned at the beginning of this paper, the indoor air quality is depended of many pollutants and their concentrations.

In this paper only CO_2 levels were examined and calculated by using COMIS at zone 9 which represents an office space with one employee.

3.3 CO_2 levels in zone 9

Zone 9 represents an office, which is situated at the north west corner of the building at the 1st floor. In this zone, was placed equipment in order to measure the concentration of CO_2 which is produced by the human metabolism. The measuring period was from 19/08/2012 to 21/08/2012 and the measurements are presented below. The pollutant rates also were calculated by COMIS, considering that zone 9 is visited by one person who works there every day from 8:00 to 18:00. The person's characteristics that were set to COMIS are presented at Table 2.

Table 2: Person's characteristics

Sex	Male
Age	26
Height	1.80 m
Weight	80 kg
Metabolic rate	1.1 MET

The calculated concentration during the operating schedule of the office and the measurements are shown at figure 6.

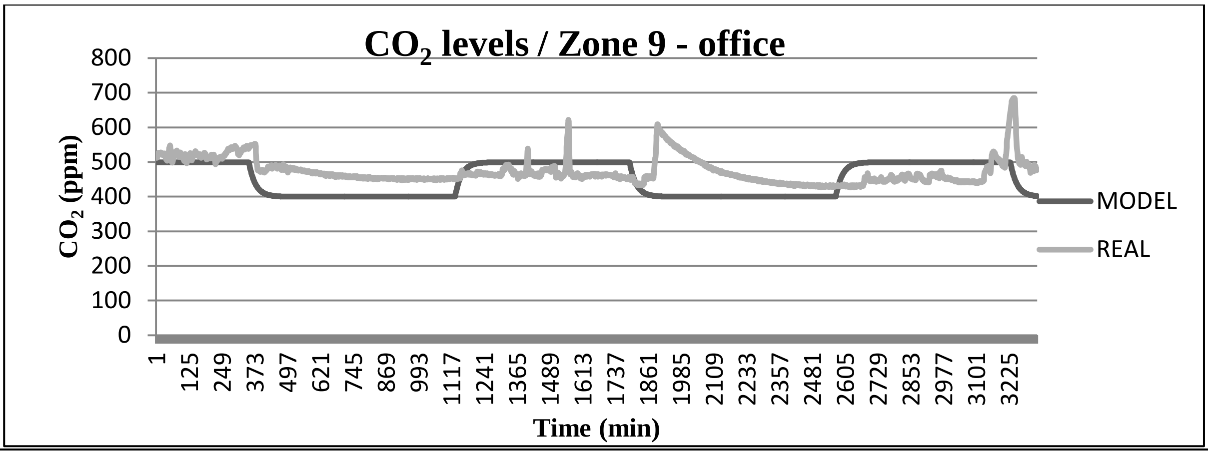

Figure 6: Comparison of calculated and measured CO_2 at zone 9

It is obvious from the figure that the calculated values are not close enough to the real measurements. However, it was estimated that the simulation represents the reality because the levels of CO_2 follows exponential increase during the time when the occupant is there, while its concentration decreases when the building is not operated.

Regarding the COMIS model is validated, the CO_2 levels was calculated at zone 9 considering 3 scenarios. The scenarios were the following:

i. The zone is full insulated
ii. The zone has not infiltration air rates
iii. The zone is ventilated every day from 11:00 to 12:00

The results are shown at the following figure. It should be noted here that the results considering the pollutant were calculated only for the period from 18/08/2012 to 26/08/2012 which includes the measuring period. That was chosen because the calculated time step was set at 60 sec in order to validate the results with the measurements and COMIS export files have capacitance limit.

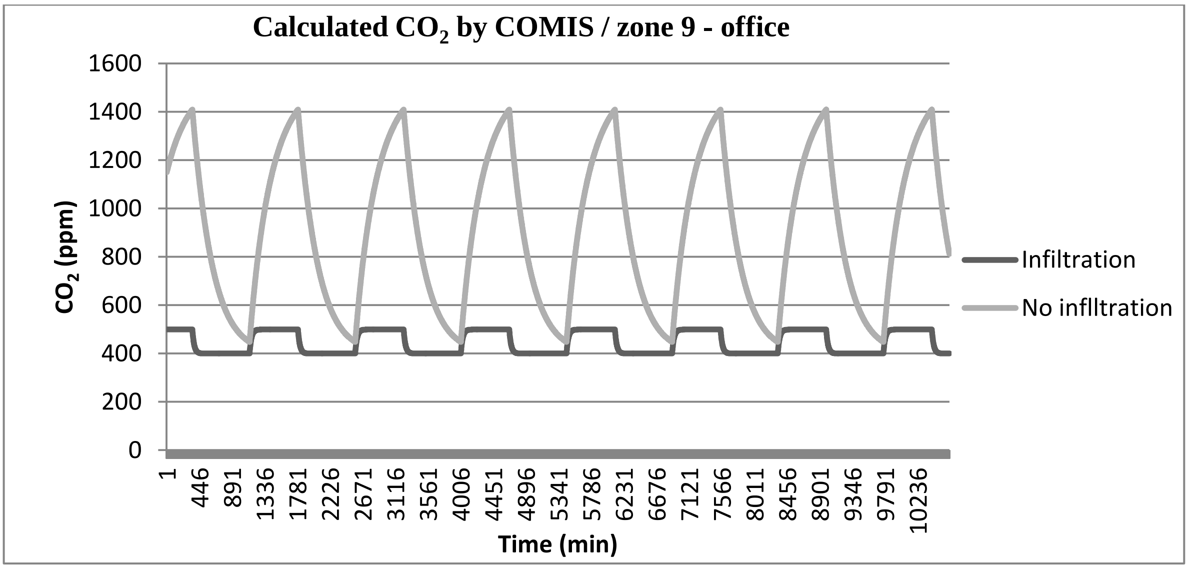

Figure 7: The variance of CO_2 concentration considering infiltration and no infiltration rates

Figure 7 shows the difference at CO_2 levels in zone 9 if the zone is infiltrated or not. At the second case, as it is obvious, the concentration increases excessively by reaching the value of 1400 ppm during the occupancy schedule.

Furthermore, as mentioned above, the natural ventilation of the zone 9 was examined. It was set at COMIS a time schedule that opens the window one hour a day daily for the simulation period. The variance of the concentration is shown below.

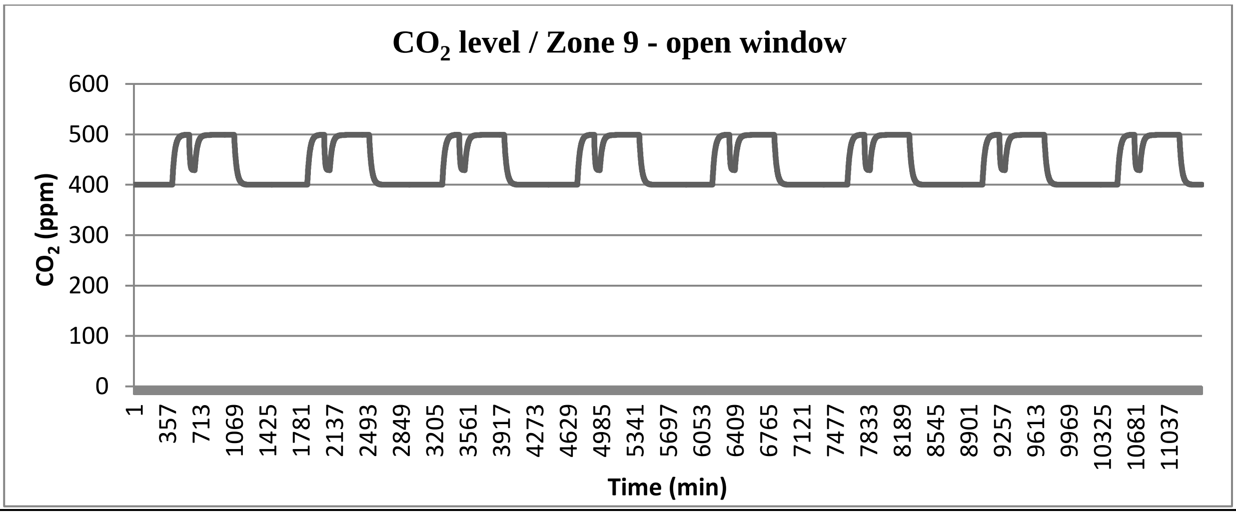

Figure 8: The concentration of CO_2 when the window is opened

As it is shown from figure 8, the CO_2 decreases when the window is opened because the air is refreshed and the concentration is diluted.

For these case studies, the energy demands of the zone also were calculated by coupling TRNsys and COMIS. The results are presented at the following figure.

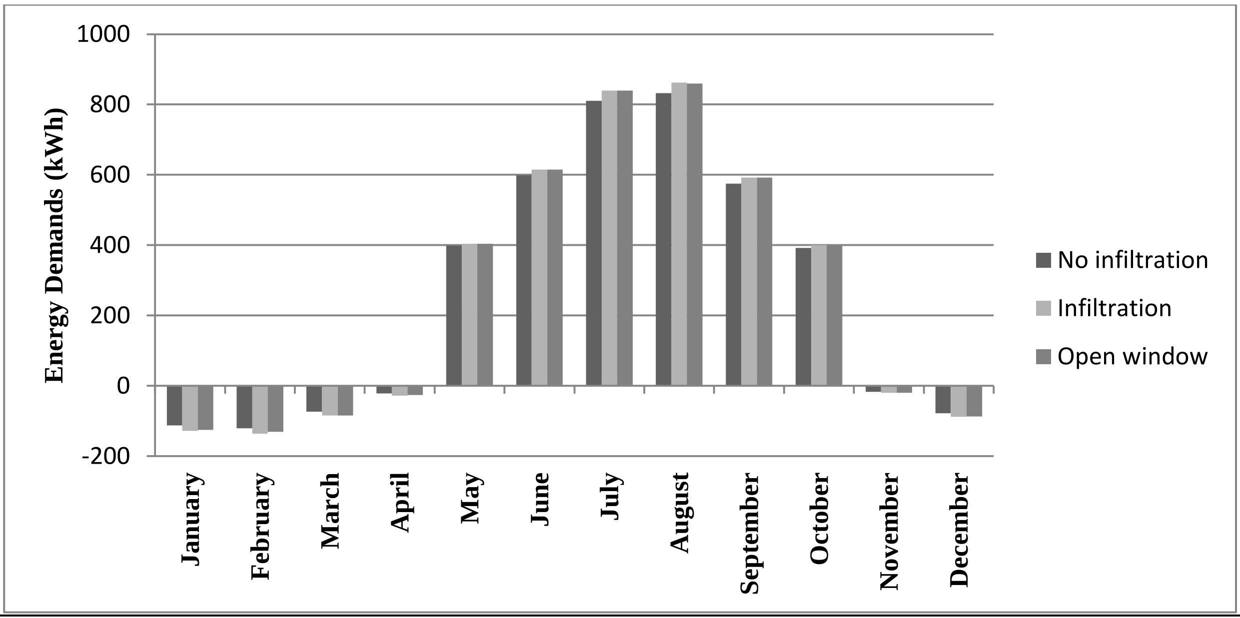

Figure 9: Energy demands of zone 9 of all the examined scenarios

Comparing the results of the three scenarios, it is concluded that the less energy consuming scenario is that it considers a full insulated building. Opening the window, the energy demands are the same as in the case of considering infiltration air rates from cracks and frames. This wasn't expected, but it was assumed that the ambient temperatures helped at the heating and the cooling of the zone.

4 CONCLUSIONS

The main objective of this report is to examine the effect of the infiltration / ventilation air rates on the energy requirements of the building and its indoor air quality. For that reason a building located at Chania of Greece was simulated by using TRNsys and COMIS software.

The calculated energy demands by TRNsys shows that the building needs more heating or cooling when it's not full insulated. However regarding the internal pollution it is obvious that low infiltration / ventilation rates create an unhealthy environment for the occupants.

At office buildings, it is important to achieve a balance between the energy demands and the quality of indoor environment, in order to minimize the consumption rates without the working conditions being unpleasant.

Finally, it would be interesting to study the case of mechanical ventilation and how this impacts on indoor pollution, the energy needs of the building and the energy cost, considering more parameters than CO_2 concentration.

5 REFERENCES

Al-ajmi, Farraj F., and V. I. Hanby. 2008. “Simulation of energy consumption for Kuwaiti domestic buildings.” *Energy and Buildings* 40(6):1101–9. Retrieved August 18, 2013 (http://linkinghub.elsevier.com/retrieve/pii/S0378778807002368).

Alemu, Alemu T., Wasim Saman, and Martin Belusko. 2012. “A model for integrating passive and low energy airflow components into low rise buildings.” *Energy and Buildings* 49:148–57.

Boyer, H., F. Garde, J. C. Gatina, and J. Brau. 1998. “A multimodel approach to building thermal simulation for design and research purposes.” 28:71–78.

Comis, Tutorial. 2005. “Comis 3.2.” 1–29.

European Commission. 2013. “Financial support for energy efficiency in buildings.”

Khandelwal, Ankur, Prabal Talukdar, and Sanjeev Jain. 2011. “Energy savings in a building using regenerative evaporative cooling.” *Energy and Buildings* 43(2-3):581–91.

Li, Yuguo, and Per Heiselberg. 2002. “Analysis Methods for Natural and Hybrid Ventilation – a Critical Literature Review and Recent Developments.” 1.

Olesen, B. W. 2004. “International standards for the indoor environment.” *Indoor air* 14 Suppl 7(Suppl 7):18–26.

Olesen, Bjarne W., Olli Seppanen, and Atze Boerstra. 2006. “Criteria for the indoor environment for energy performance of buildings: A new European standard.” *Facilities* 24(11/12):445–57.

Solar Energy LaboratoryUniversity of Wisconsin-Madison. 2010. “Trnsys 17.” 3.

Viktor Dorer, Anne Haas, Werner Keilholz, Roger Pelletret, Andreas Weber. 2001. “Rio de Janeiro, Brazil August 13-15, 2001.” 403–10.