# Influence of Optimization of Energy Consumption on Indoor Air Quality (Case Study: Educational Building)

**Farzaneh Mahlab[1*], Majid Shafiepoor[2]**

1. Graduatein Environmental Engineering, Department of Environmental Engineering, University of Tehran, Iran
2. Assistant Professor, Environmental Engineering, Department of Environmental Engineering University of Tehran, Iran (shafiepourm@yahoo.com)

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## Expanded Abstract

### Introduction
Reduction and optimization of energy consumption and consequently environmental pollution reductions, besides improving building performance, can provide occupants with comfort conditions. This makes the concept building closer to the concept of green sustainable building. Once the decision has been made to build green structure, one of the first steps in the green design process is establishment of firm environmental goals for the project.

In the recent years, much research has been carried out in the field of energy efficiency in buildings. Indoor air quality issues are also on debate these days due to its direct effect on the health of the people.

The sources of indoor pollution that release gases or particles into the air are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutants by not bringing enough outdoor fresh air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants. Carbon dioxide is often measured in indoor environments to assess quickly but indirectly the amount of outdoor air entering a room in relation to the number of occupants. Replaces of oxygen in the blood-exposure to concentrations of 40,000 parts per million (ppm) are immediately dangerous to life and health. $CO_2$ poisoning, however, is very rare.

In this research, a building as a case study is selected. One of the most characteristic energy audit software is modeled to estimate the amount of its energy consumption. It is estimated with calculating building heating and cooling loads in different seasons. The ventilation rate of the building as one of the factors in energy consumption is assessed. The concentration of gases in closed environments will be reviewed since all these standards are directly and indirectly trying to improve the human's life condition. Then, some optimization strategies were applied on the building to investigate the relationship between energy consumption and indoor air quality.

### Materials and Methods
**Energy Modeling**
At first, the educational building was modeled in the DesignBuilder Software and its energy consumption was calculated. Building characteristics such as occupancy, number of persons living in each sector, heating and cooling systems, fuel type, materials used in the construction of the building, and openings and its typewas imported into the software as input to the model. As seen, the highest rate of heat dissipation through the air in the building is from ventilation.

Indoor air quality modeling

Contam software is used for indoor air quality modeling. This program does not fully draw a geometric model, it can just draw external walls and partitions as a general plan. It can define airflow and show the location of doors and windows. The environmental factors such as air temperature outside and inside, wind speed and direction, wind speed ratio and outside pollutants can be introduced as an input to the model.

General characteristics of building

The case study is an educational building. Various parameters including U values of external walls, window to wall ratios, and orientations are investigated in this parametric study. Different U values of external walls (U=1.798[W/$m^2$.k], U=1.976[W/$m^2$.k]) and U value of roof (U=1.256[W/$m^2$.k]) are employed to analyze heating

* Corresponding Author: Tel: +98 09113321476 E-mail: F_mahlab@ut.ac.ir

and cooling loads for the educational building. In the simulation, the heating setpoint is 21 C and cooling setpoint is 25 C. The energy consumption of the house is taken as the criterion for the optimal sustainable facade design. Building heating is served by the central system and cooling system of the building is independent. The building's lighting system is served by fluorescent light bulbs. Geometry is drawn in the model space. Doors and windows and all openings in accordance with their actual proportions in the same location and orientation of the main building were drawn in the software.

## Results and Discussion

To assess the efficiency of buildings ventilation, carbon dioxide concentration is evaluated in the simulated building. Carbon dioxide is a byproduct of respiration. When breathing, people inhale oxygen into the lungs and exhale carbon dioxide. This will increase the carbon dioxide levels in buildings over the next several hours to reach a maximum value. In the model Carbon dioxide content in fresh air is approximately 400 ppm and human inspiration rates is equal to 0.1m3/h. According to the Figure 1, the class was supposed to start at 8 AM and finished in noon. Time period is considered from 8 AM to 14 PM.

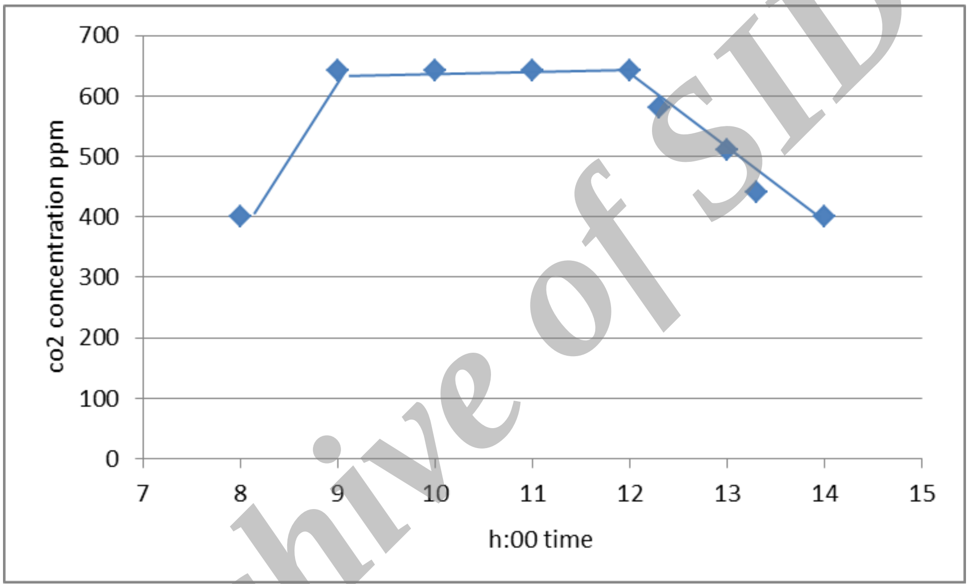


**Fig. 1. Carbon dioxide concentration changes over time**

The results clearly indicate that the $CO_2$ concentrations can give an indication of the indoor air quality in these indoor and enclosed environments. At the start of the class, $CO_2$ concentration was 400 ppm. It is clear that the $CO_2$ concentration increased immediately at 8 AM until it reached a steady state condition at 9 AM, as shown in Figure 1. The maximum $CO_2$ concentration was constant at 642 ppm for the entire duration until 12 AM. The maximum concentration of carbon dioxide is 642 ppm which is consistent with the existing standard allowance. But the increase in number of individuals in the model to 30 people, it increases nearly up to 800 ppm. The situation will require increasing ventilation within the class.

Building ventilation rates were 2.4 hours and the heat load of the building is estimated at 64,508 kWh. To investigate the effect of air changes in energy consumption, all the parameters affecting energy consumption are assumed to be constant at any given stage. The amount of air changes in the building start from 0.2 to 3 times at the time ended. We can see that the building heat load carrier ratio increased linearly. Thus, the amount of air changes is one of the most important factors affecting energy consumption of heating in the building. But the behavior of the building cooling load is different from the heating load and the effect of air changes and it is limited over time. Increasing the ventilation rate reduces the amount of carbon dioxide in the building. This is essential to improve indoor conditions. The amount of air changes vary in the studied buildings. For example, in the corridors and rooms air change rate per hour is high, and this matter will increase energy dissipation.

In order to optimize building energy consumption, a set of optimizing actions including wall insulation, roof insulation, replacing windows are applied in the model. It can be seen that heating and cooling load are decreased. However, the concentration of Co2 is increased due to decrease in ventilation rate. To solve these problems, air conditioning systems can be used.

## Conclusions

Evaluation of carbon dioxide as an indicator of indoor air quality was assessed. It is found that with the

increasing number of people in the class with the rates of air change is equal to 2.4 times per hour. The amount of carbon dioxide from respiration is increased to 800ppm. To solve this problem, it is necessary to increase the rate of air changes. It was observed that increase in the rate of air changes can greatly increase the building heating loads. It will increase energy consumption in the building. Performance of cooling loads is different and the rate of air changes has very little impact on the building cooling loads. Then, some optimization strategies are applied to the building and 67% of building heating loads and 39% of cooling loads are reduced. After these actions, leakage and penetration rate will be reduced. This can increase the amount of carbon dioxide in stable condition and breathing through people. Therefore, reduction in the rate of air changes should consider the measures to ensure indoor air quality.

**Keywords**: energy saving, indoor air quality, ventilation rate.