Analysis of the application of ventilative cooling in different regions of Turkey

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Abstract. Energy efficiency practices have gained momentum in recent years and continue to invest. The main motivation of this study is whether an effect can be achieved with ventilative cooling in terms of energy efficiency in buildings with mechanical ventilation, especially in transition seasons. In this context, the potential of ventilative cooling in different provinces of Turkey, where hourly average temperature values are taken, has been examined. According to the results obtained, ventilative cooling can be considered as an energy efficienct application.

Keywords. Ventilative Cooling, energy efficiency, mechanical ventilation
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1. Introduction

Energy efficiency applications have become one of the current research topics around the world, especially after the Paris Climate Change Agreement. Reducing energy intensity on a country-by-country basis and the amount of greenhouse gas emissions that need to be provided will also bring sanctions. Emissions trading and energy efficiency practices are supported by many different subsidy mechanisms. Although studies on this subject in Turkey have shifted to rooftop photovoltaic system applications in recent years, there is an important potential in buildings that has not been evaluated until now. While insulation applications come to the fore in new buildings, there are many buildings that do not even have insulation.

The use of natural ventilation in buildings has come to the fore again with increasing energy costs and the research for natural ventilation opportunities in new building designs has come to the fore. Considering that the energy consumption of fans in mechanical ventilation is around 5-15 W/m^2, there is a significant energy saving with natural ventilation. In addition, improvements to be made in heating or cooling systems, especially in the transition seasons, reveal a significant potential [1]. Examples of windows consists of phase-change materials in buildings also emphasize ventilation in order to reduce energy consumption [2]. Besides, the combination of phase change materials with night ventilation has shown that an energy saving of around 73% can be achieved [3]. Kigawata et al. [4] investigated the potential of ventilation cooling with radiant floor cooling systems in hot and humid regions. The results showed that horizontal pivot windows improve thermal comfort due to ventilation cooling. Increasing insulation thicknesses and airtight designs due to energy efficiency in buildings cause a continuous cooling load, especially in office buildings. Yu et al. [5], reviewed novel system solutions for cooling and ventilation in office buildings.

Belleri et al. [6], analyzed the ventilative cooling potential tool (VC tool) to assess the potential effectiveness of ventilative cooling strategies by considering also building envelope thermal properties, occupancy patterns, internal gains and ventilation needs. Grosso et al. [7], simulated ventilative cooling effectiveness in an office building. O'Sullivan et al. [8], also analyzed ventilative cooling potential for 14 international cases. Brambilla et al., [9] offered a performance indicator for a life cycle driven approach to evaluate the potential of ventilative cooling and thermal inertia. Chiesa and Grosso [10], analyzed the applicability of the natural ventilative cooling in the Mediterranean area. Simulations were performed for 50 cities in Design Builder and Energy Plus. The results showed that controlled natural ventilation as a heat dissipation technique has a fairly high potential in all Mediterranean region.

Overheating, on the other hand, is an important problem encountered in the cooling season due to the increased internal heat loads in well-insulated buildings. To overcome this problem, ventilative cooling is recommended by Annex 62 in the standards. In this context, although overheating will not be expected due to excess insulation in Turkey, it was investigated whether the thermal comfort conditions are provided by increased air flow rates before the cooling groups are activated, especially in buildings with mechanical ventilation during the transition seasons.

2. Ventilative Cooling Method

Ventilative cooling is a method for taking advantage of the cooling capacity of outdoor air through ventilation, that provides fresh air to the indoor environment [11]. According to the report, published by Annex 62 working group of International Energy Agency, five different cooling modes are recommended for ventilative cooling evaluations [12]:

- *Ventilative Cooling Mode 0:*

When the outdoor air temperature is lower than the heating temperature for the indoor environment, there is no need for cooling.

- *Ventilative Cooling Mode 1:*

The indoor environment is ventilated with the minimum air flow rate determined depending on the comfort conditions. At this point, if the outdoor temperature exceeds the indoor comfort temperature, the required minimum air flow rate is used in the calculations.

- *Ventilative Cooling Mode 2:*

If the outdoor environment has a temperature compatible with the indoor comfort temperatures, In the ventilative cooling system, the required fresh air can be given to the indoor environment by increasing its flow rate. In this case, the required air flow rate is calculated to keep the indoor temperature comfort stable.

- *Ventilative Cooling Mode 3:*

If the outdoor temperature is above the upper temperature limit, indoor comfort is provided by including direct evaporative cooling.

- *Ventilative Cooling Mode 4:*

If the outdoor temperature is above the upper temperature limit and the direct evaporative cooling outlet temperature exceeds the comfort conditions, the indoor environment becomes unfavorable. Therefore, the air change rate for night ventilation needs to be balanced.

2.1 Sample Designs for Ventilative Cooling

In this study, ventilative cooling requirements were determined for a hospital room with an area of 40 m^2 and a height of 3.5 m. It is accepted that there are 3 occupants in the hospital room. Ventilative cooling designs of the sample hospital room in the study were evaluated depending on the climatic characteristics of 5 different cities in Turkey. In terms of climate data diversity, Ankara from Central Anatolia region, Istanbul from Marmara region, Izmir from Aegean region, Erzurum from Eastern Anatolia region and Antalya from Mediterranean region were preferred for this study. Considering the general climatic characteristics of the regions:

- The Central Anatolia region has a cold and semi-arid continental climate.
- Marmara region has a moderate climate. In addition, intense humidity in summers and strong winds in winters are among the effective climate characteristics in the region.
- The Aegean region has a climate with mild and rainy winters and hot and dry summers.
- Eastern Anatolia region has a harsh continental climate.
- The Mediterranean region has a climate that is hot and dry in summers, mild and rainy in winters.

Ventilative cooling requirements are designed for each selected city through the ventilative cooling potential analysis tool developed by Annex 62. In the analysis, many parameters were calculated in detail, especially important parameters such as location, indoor volume, occupancy density per square meter, and minimum required ventilation rate.
The required minimum air flow rate was determined by choosing the 2nd category (normal level of expectation) given in standard EN 15251 or the revised standard EN 16798. The recommended air flow rates in the standard for the 2nd category can be selected in the tool prepared by the Annex62 working group.

3. Results

In this study, according to the data obtained from hourly temperature profile, the monthly average diurnal temperature swings are higher in Ankara and Erzurum, and lower in İzmir, Antalya, and Istanbul.
Additionally, internal heat gains that can be offset for night-time ventilation vary depending on the months for each city.

- In Ankara, an average of 13 W/m^2-ACH internal heat is gained between April and October.
- In Istanbul, an average of 9 W/m^2-ACH internal heat is gained between May and September.
- In İzmir, an average of 6 W/m^2-ACH internal heat is gained in July and August.
- In Erzurum, an average of 15 W/m^2-ACH internal heat is gained between June and September.
- In Antalya, an average of 5 W/m^2-ACH internal heat is gained between May and November.

The modes proposed by Annex 62 are studied in a ventilative cooling design for five different cities. In the graphs below for each city, red represents Mode 0, yellow represents Mode 1, medium dark blue represents Mode 2, light blue represents Mode 3, and very dark blue represents Mode 4.
According to the findings of the study:

– For the hospital room in Ankara climate conditions, Mode 2 was determined as the most suitable ventilative cooling design with a percentage of 59% annually (Figure2). Mode 2 has a high rate in all months of the year except December. In December and January, it is seen that Mode 0 and Mode 2 have very close percentage values (Figure 1). In summers, Mod 2 and Mod 3 usage time percentages are close to each other.

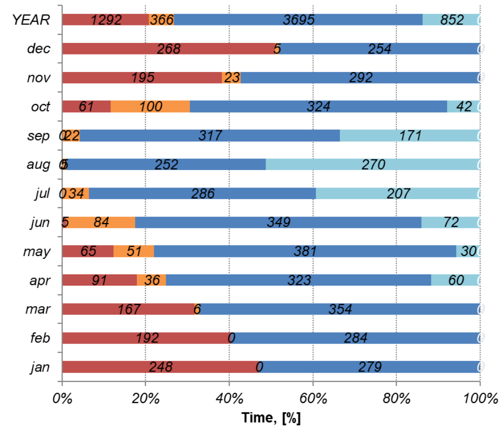

Fig. 1- Usage period of ventilative cooling design depending on months for Ankara climate conditions

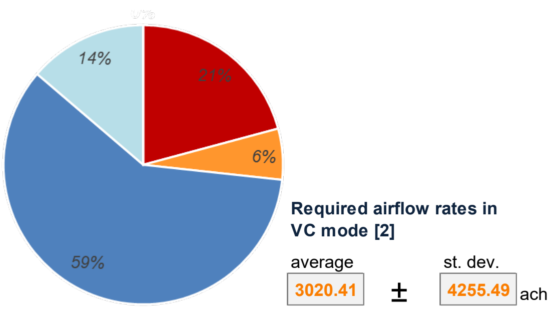

Fig. 2- Annually percentage diagram of the evaluated ventilative cooling modes for Ankara climate conditions

– For the hospital room in İstanbul climate conditions, Ventilative Cooling Mode 2 seems to be suitable with a high rate in all months of the year. As in the design in Ankara, it is seen that the terms of use for Mode 0 and Mode 2 in December and January are close to each other in percentages (Figure 3 and Figure 4).

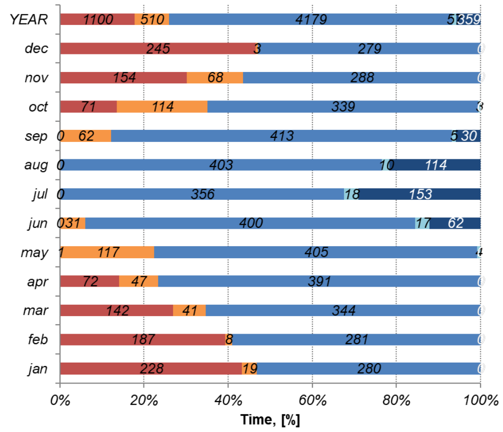

Fig. 3- Usage period of ventilative cooling design depending on months for İstanbul climate conditions

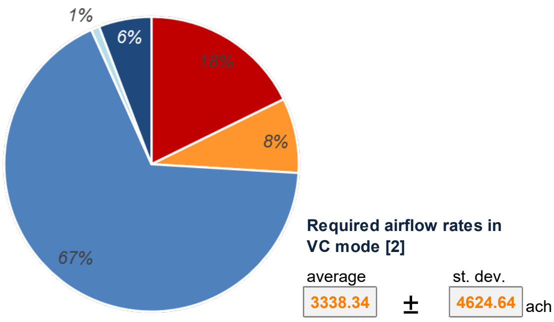

Fig. 4- Annually percentage diagram of the evaluated ventilative cooling modes for İstanbul climate conditions

– For the hospital room in İzmir climate conditions, it is seen that Mode 2 has the highest rates in all months of the year, and Mode 2 is 100% suitable for the design in summer months (Figure5). On an annual basis, the Mode 2 usage time is given in Figure 6 with a percentage of 73%.

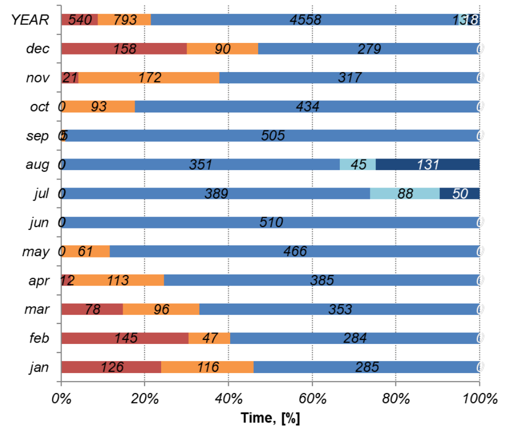

Fig. 5- Usage period of ventilative cooling design depending on months for İzmir climate conditions

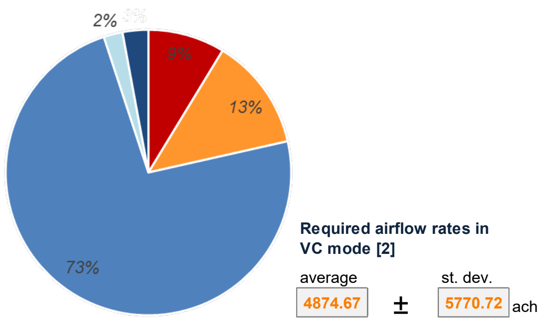

Fig. 6- Annually percentage diagram of the evaluated ventilative cooling modes for İzmir climate conditions

– For the hospital room in Erzurum climate conditions, it is seen that Mod 2 has a high percentage compared to other Mods in all months of the year. In addition, it is understood that Mode 0 has the second highest significant usage percentages in all months except summer (Figure 7).

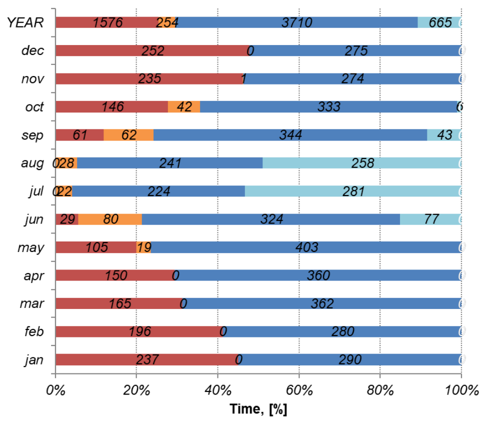

Fig. 7- Usage period of ventilative cooling design depending on months for Erzurum climate conditions

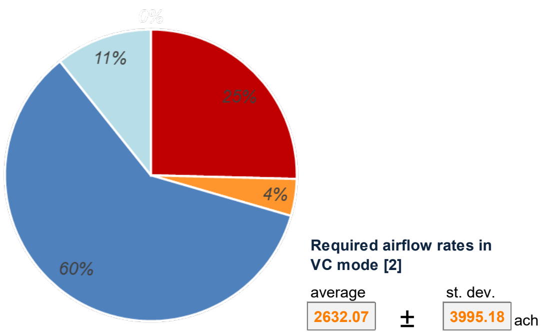

Fig. 8- Annually percentage diagram of the evaluated ventilative cooling modes for Erzurum climate conditions

– For the hospital room design in Antalya climate conditions, it is understood that Mode 2 has by far the highest percentage of usage time and the most suitable ventilative cooling design in all months except summer. In July and August, Mode 3 has much higher percentages than any other mode (Figure 9).

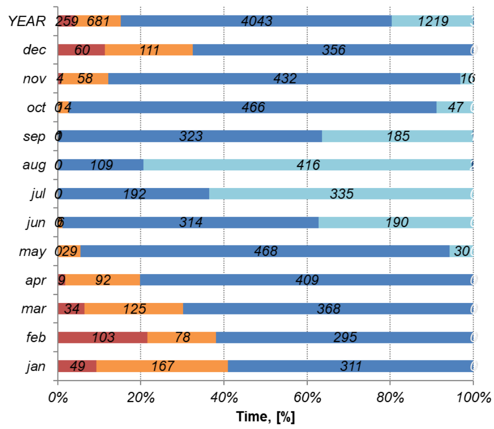

Fig. 9- Usage period of ventilative cooling design depending on months for Antalya climate conditions

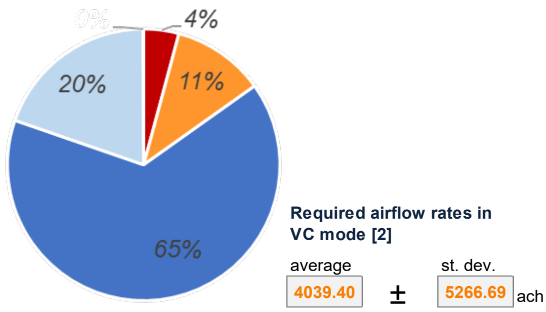

Fig. 10- Annually percentage diagram of the evaluated ventilative cooling modes for Antalya climate conditions

4. Conclusion

Within the scope of the study, hourly climatic data was taken as a basis for each city. Based on climatic data, it was analyzed using the ventilative cooling calculation tool developed by Annex 62. This calculation tool defines the useful time using ventilative cooling as a percentage based on months. At the same time, ventilation rates for day and night can be determined to benefit from the capacity of the heat in the building mass.

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