The Impact of the Window Orientation on Natural Ventilation and Energy Consumption (Case of Collective Housing in Laghouat City)

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Abstract

Natural ventilation still one of the most basic elements of thermal comfort in the building to ensure cooling and air renewal of internal spaces, especially in the residential sector. With the concern for the unsustainability of fossil and non-renewable energies and the gradual rise of housing demand in Algeria, energy conservation has become a major issue, especially in the arid regions of the country such as Laghouat City. This motivated us to study the ventilation and its correlation with the window orientation, so we hypothesized that the orientation of the window has an important effect on natural ventilation and energy consumption. In order to verify our hypothesis, we used the computational analysis with Energyplus 8.4 software for obtaining the interior space temperatures for each orientation as well as the energy consumption of electricity and gas, and then comparing them to determine the most advantageous orientation to have a well-ventilated space with a low energetic consumption.

Keywords: Natural Ventilation; Energy Conservation; Energyplus; Thermal Comfort; Window Orientation.

1. Introduction

Algeria faces enormous climatic constraints. Four-fifths of the country's territory has a hot and dry climate, hence the importance of the climate aspect in choosing an energy saving strategy. The large-scale integration of this aspect seems to be ignored by the designers. Berghout & Al. (2014) Buildings consume more than 40% of the world's energy and generate nearly a third of the world's emissions of GHG's. International Energy Agency (2010) The structure of final consumption in Algeria remains dominated by the residential sector (44%). Bilan énérgetique national 2017 (2018) For this reason, the energy problem arises particularly in this sector, especially when we talk about hot and arid areas in Algeria where mechanical ventilation, especially air conditioning in summer, consumes a large amount of electricity. Dohsi (2017) The essential function of a home is to ensure an interior atmosphere that is well suited to our needs and comfort. The inhabitant often puts his comfort before energy savings. Errebai & Al (2012) In general, ventilation is used to maintain an acceptable level of indoor air quality (hygienic ventilation) and cooling (ventilation or ventilation for cooling), in order to reduce or eliminate the need for active air conditioning. Marcello Caciol (2010Natural ventilation is only addressed in relation to the effects of wind. It is therefore important to know the behaviour of air flows in buildings, so that they can be integrated into a global approach aimed at making buildings efficient and comfortable. The link between the effects of wind and the distribution of air within the building is made through openings (air links), which will channel the fluid flow. Depending on the size of the openings, the airflow, especially its direction. Hamdani & Al (2018) This leads us to the following question: The objective is to test the thermal and airflow behaviour of the living rooms and the energy consumption of electricity and gas in the dwellings located in Laghouat city against external climatic conditions. This concerns the study of the effect of the orientation of the openings of habitable rooms on indoor temperature and energy consumption in homes.

2. Methodology

2. 1. Presentation of case study

The city of Laghouat is located in Algeria at the foothills of the Saharan Atlas on the north side, it extends over the Saharan plateau on the south side, Laghouat is directed between 830m altitude in the west and 790m altitude in the north separated by a deep notch. It has a latitude of 33°46° and a longitude of 2°56°. Dohsi (2017)

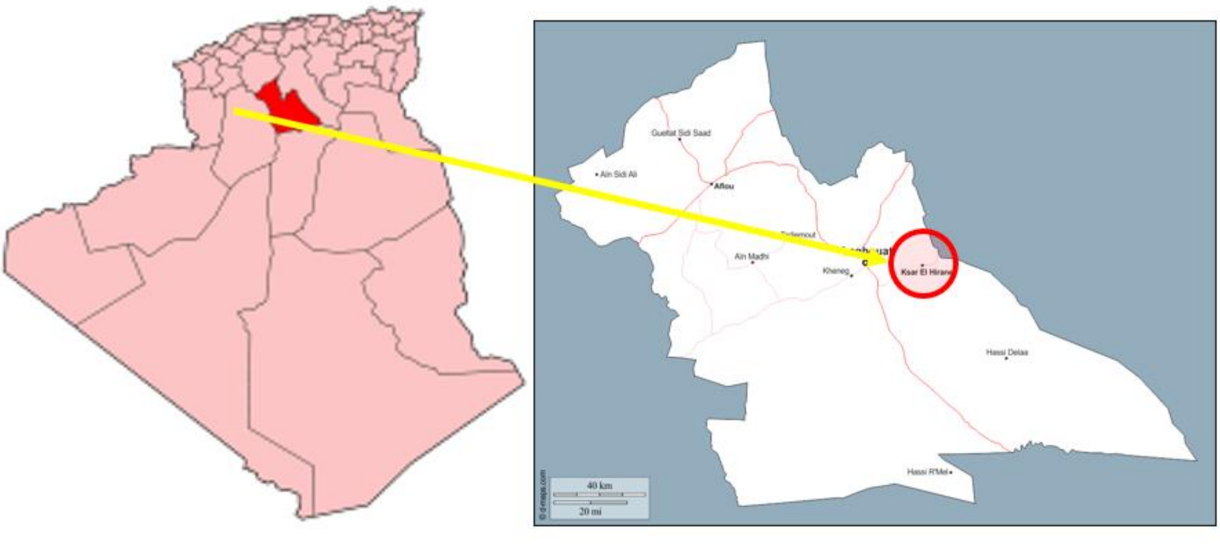


Figure 1. The situation of Laghouat city. Map.dz (2019)

Summers in Laghouat are scorching and arid; winters are long, chilly, dry and windy; and the climate is generally clear throughout the year. During the year, the temperature generally varies from 2°C to 39°C and is rarely below -1°C or above 42°C. Weatherspark (2019).

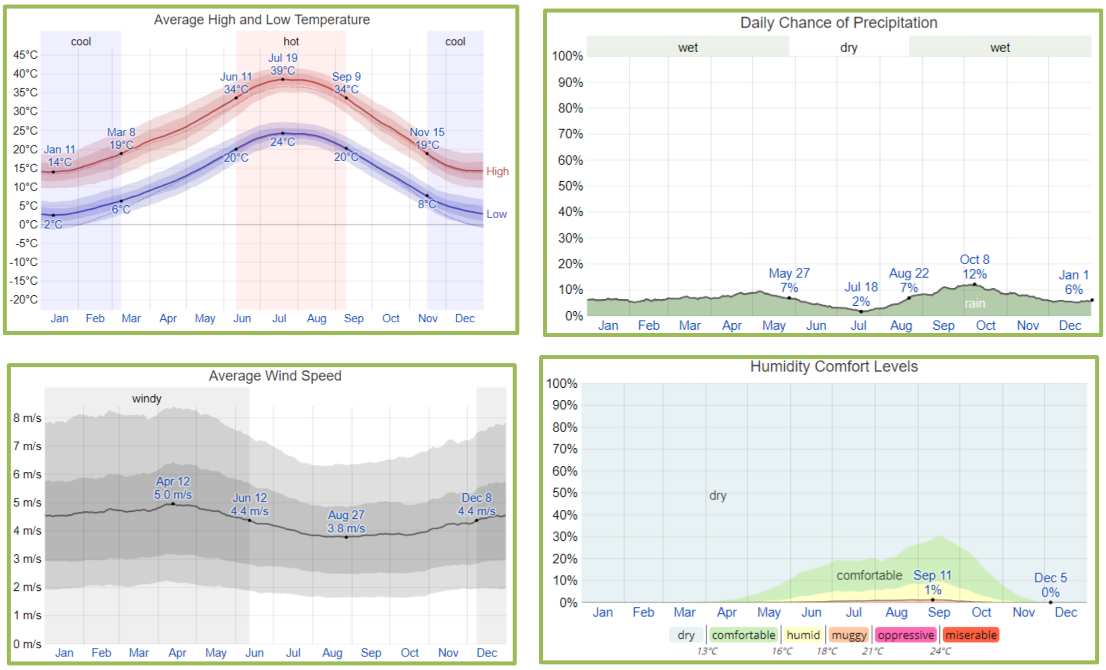


Figure 2. The typical weather in Laghouat during the year (1980-2016). Weatherspark (2019)

For the case study, we chose a collective housing already built in the city of Laghouat (152logs). This habitat chosen for the study is of the LSL type, it is located in the southwestern part of the city of Laghouat in the M'hafir district. The chosen habitat is in the form of two bar-shaped blocks connected by an urban gate, each of the blocks is composed of five straight blocks R+3. Dohsi (2017)

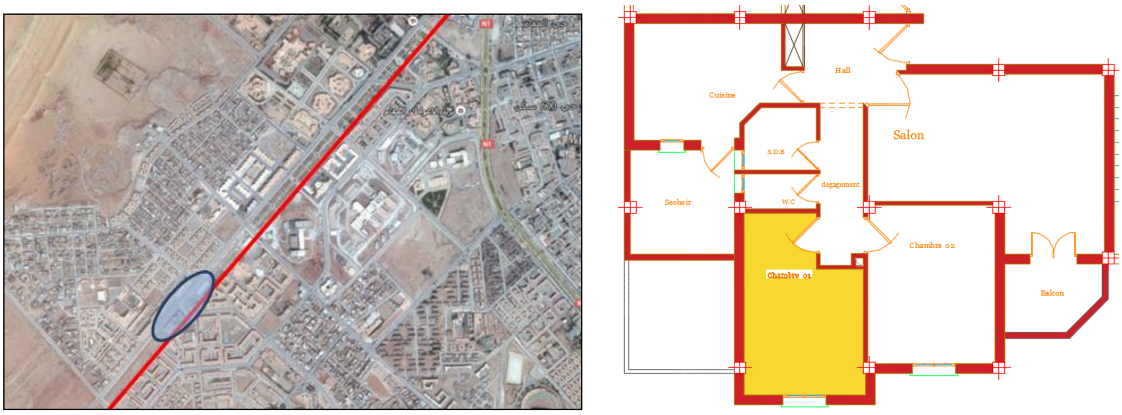


Figure 3. Plan of the block studied, specifying the room. (Author).

2.2. Simulation with EnergyPlus

Our study is based on the impact of the window orientation on natural ventilation and energy consumption, under the real climatic conditions of the external environment of Laghouat City. This will be studied in the winter case (month of January) and in the summer case (month of June), in the form of several scenarios to verify the effect of the orientation of the bedroom window.

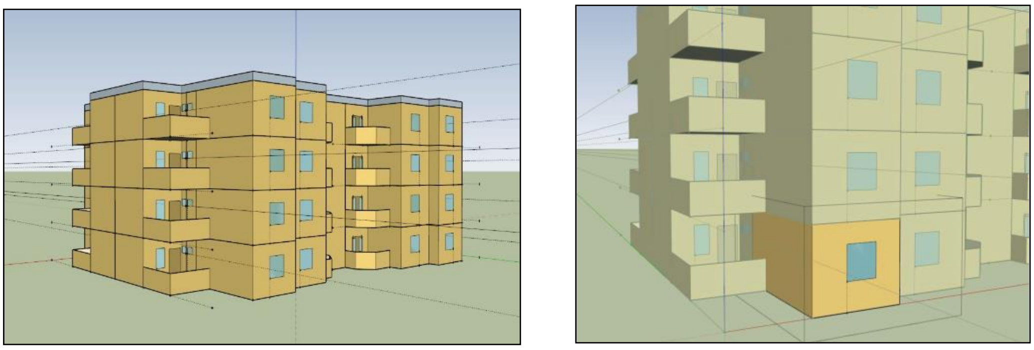


Figure 4. Zone étudiée du bâtiment choisi modélisé avec sketch up 16. (Author).

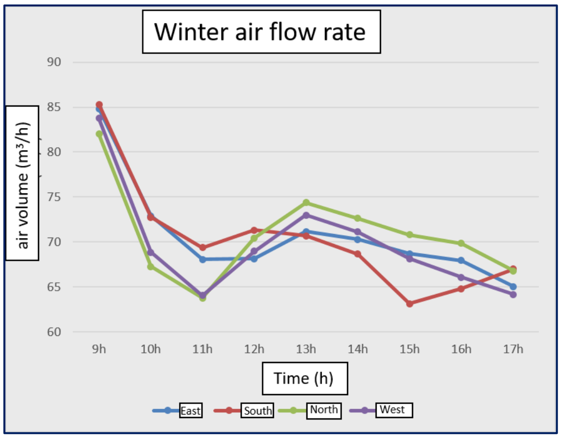
The thermal and energy performance of the room space will be tested by comparing the obtained indoor temperatures and the energy consumed, using ventilation. In order to verify this parameter, we will study the four main orientations (North, East, West and South).

3. Results and Discussion:

3.1 Natural Ventilation:

Winter Case:

Looking at Figure (5), we notice that the flow of each orientation follows a different curve from the other, where we see that the flow is at most at 09:00 in the morning for the four orientations studied where the south orientation exceeds 85m3/h. In the morning from 9am to 12pm the south orientation offers a higher air flow rate than the other cases, which increases the temperature from the first hours, while it is lower in the afternoon from 1pm to 5pm.



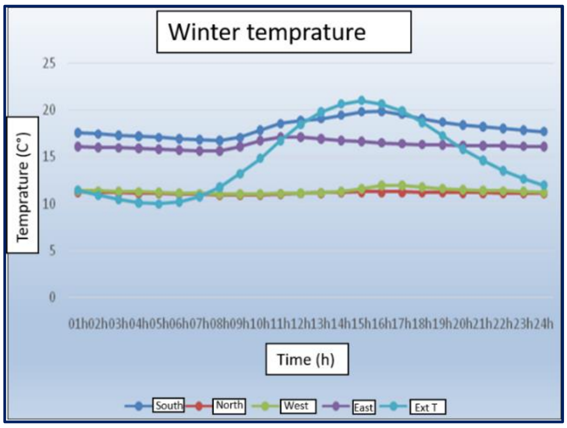


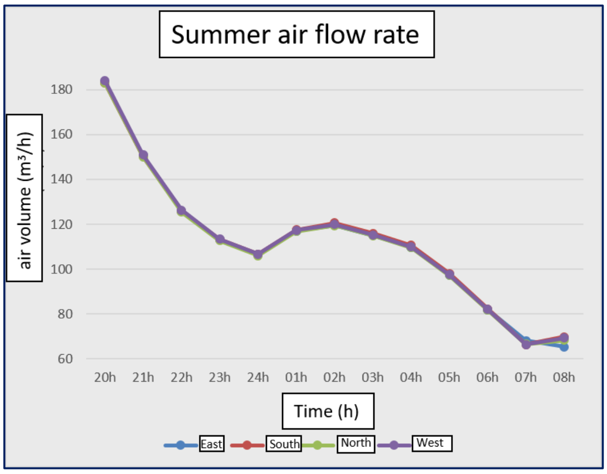
Figure 5: Comparison between the indoor air flows in the four cases in winter, with daytime ventilation. (Author)

Figure 6: Comparison between indoor temperatures in all four cases in winter, with daytime ventilation. (Author)

Figure (6) represents the variations in the interior temperature of the chamber for the four cases studied, we notice that the temperatures in the room oriented West and North we have a negligible difference except in the afternoon when it arrives at 1°C at 17h. However, comparing them with the case of East and South the difference is very clear and large where it exceeds 6°C at noon (12h and 11h) between the North and East, and 8°C between North and South in the afternoon from 13h to 18h.

Summer Case:

According to Figure (7), the difference in flow between the different cases is almost negligible. At the beginning of the night, the air volume exceeds 183m3/h, and it starts to decrease and reaches 65m3/h for the East and 69m3/h for the other cases at 8am.



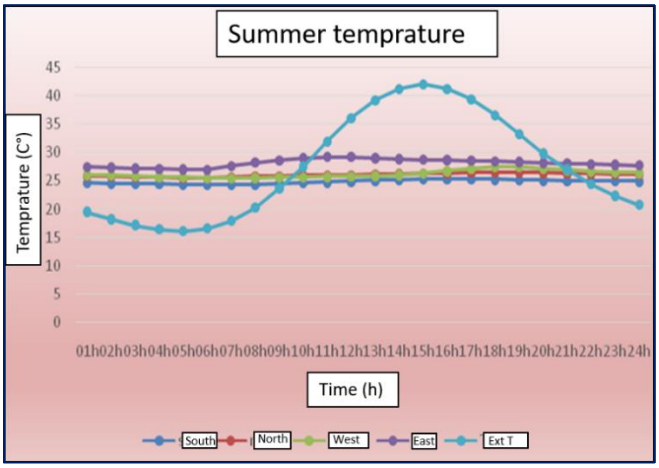


Figure 7: Comparison between the indoor air flows in all four cases in summer, with night ventilation. (Author).

Figure 8: Comparison between indoor temperatures in all four cases in summer, with night ventilation. (Author).

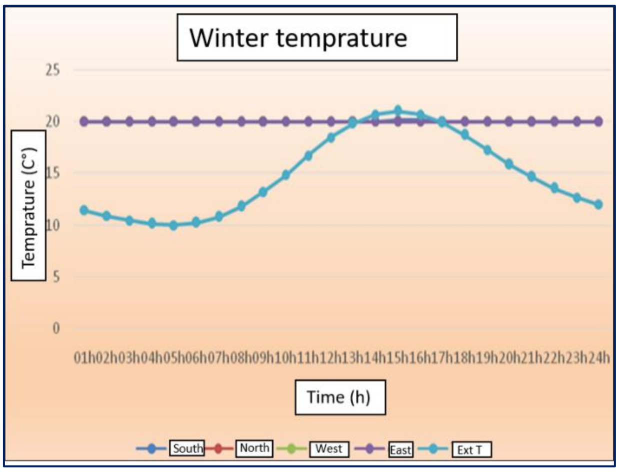
From the curves shown in Figure (8), the temperature in the east-facing case is the highest compared to the other three cases, and in the south-facing case, the temperature is lower than the others are where the difference between east and south reaches 4.5°C.

This check shows that the temperature in the case of a south-facing chamber is the most favorable.

3.2 Active system

Winter Case: Heating

Referring to figure (9), the desired temperature was verifying after adding a heating system for the four simulated cases.



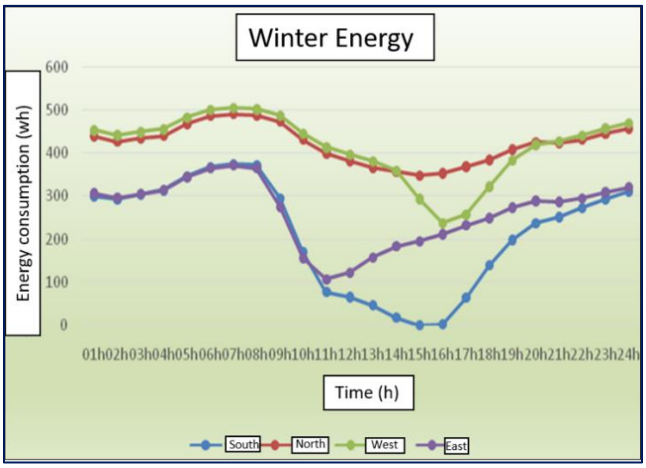


Figure 9: Comparison between indoor temperatures in the four cases in winter, with heating system. (Author)

Figure 10: Comparison between the energy consumption in the four cases in winter, with heating system. (Author)

Figure (10), represents the energy consumption of the heating system for each case studied, the energy consumed in the North is the highest while comparing it with the consumption in the south facing case where it is lower than the other cases, the difference exceeds 350w/h at 16h. From this, we can consider that in case of winter the favorable orientation is the south orientation.

Summer Case: Cooling

With the air conditioning system used, we have achieved the desired temperature in all four cases of our test where it varies between [23-25°C] and this is the satisfactory range.

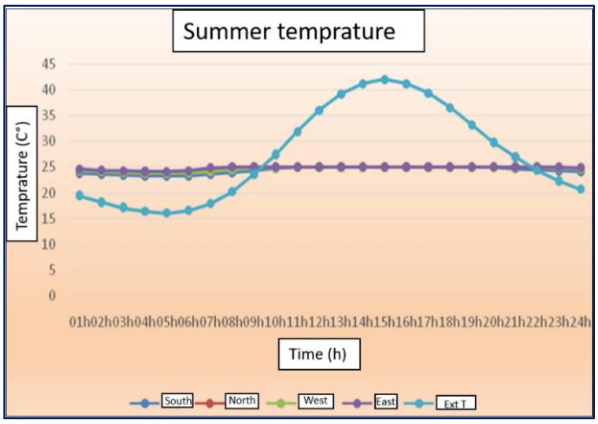


Figure 11: Comparison between indoor temperatures in all four cases in summer, with air conditioning system. (Author).

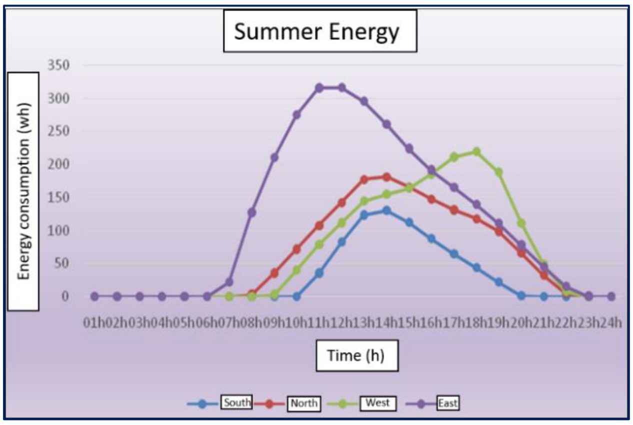


Figure 12: Comparison between the energy consumption in all four cases in summer, with air conditioning system. (Author).

In Figure (12), we see that there is a clear variation between each case, the east-facing case is characterized by the highest consumption and reaches its peak in the morning period (when the room is exposed to the sun). While the west-facing case reaches its peak in the afternoon period (when the space is sunny), and we see that the south-facing case is the case that consumes less energy compared to the other cases and the difference between the energy consumed in the east and that consumed in the south exceeds 280w/h at 11am in the morning. The difference noticed is not only in the energy flow but also in the time when the air conditioning is activate. in the East case the air conditioning is activated from 7am to 11pm while in the South case it is activated from 11am to 8pm. From the results of this study on the different orientations, we can see that the south orientation is the most favourable in winter and summer in order to have a good thermal comfort while ensuring a reduced energy consumption.

Conclusion

This research led us to conclude that the orientation of the window is a very influential factor on the potential of natural ventilation, which is one of the principles of bioclimatic architecture. In our problem, energy consumption was considered as the major problem of our study and our goal was the conservation of non-renewable energy especially in the residential sector especially when talking about the city of Laghouat and arid areas in general.

According to our study for the most appropriate window orientation, we can retain that the south orientation is the preferred orientation to optimize a more adequate internal thermal quality compared to the orientations and even the conservation of non-renewable energy is achieved based on the reduced energy consumption in the case of the south orientation. So in order to have a thermal and energetic gain in the room space the south orientation is the most suitable.

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