SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Application Efficiency Measures Through TRNSYS Software on Algerian Building to Save Energy

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ARTICLE INFO

Article history:
Received 24 November 2021
Received in revised form 20 February 2022
Accepted 22 February 2022
Available online 28 March 2022

Keywords:
Energy Efficiency; Energy in Buildings; Trnsys simulation; Energy Saving; Thermal Regulation

ABSTRACT

In Algeria, the building sector is the biggest energy consumer. In 2020, the total final energy consumption absorbed by the building is near 42%, the shares of the residential and tertiary sectors are 36% and 7%, respectively. This high consumption argued the Algerian government to put the building sector in the first priority target in terms of energy efficiency action. Add to this, the Algerian authorities set a goal of reducing energy consumption by 15% by 2030. To concretize this goal, the government concentrates its efforts to develop thermal insulation and ameliorate the quality of windows. Moreover, several attempts are assumed to create new versions of Thermal Regulation (RT) for building RT2016, which should be revised in 2022. To this end, the present work aims to evaluate the thermal regulation of building RT2016, and to identify the weaknesses point of this RT. Simulations are fulfilled using TRNSYS for a building that conforms to the requirement of this RT.

1. Introduction

The Algerian building sector constitutes a significant share of finale energy consumption which is around 40%. In recent decades, the rapid growth in energy demand is due to the development shown in different domains, the increase in population and economy, and the dependence of daily activities on the energy consumption. For these reasons, it is important to adapt new codes to satisfy the increasing energy demand [1].

To fulfill high energy-efficient of buildings, and reduce energy consumption by preventing heat gain and loss through the envelope, it is important to design the best insulation material in order to reduce energy consumption by preventing heat gain and loss through the envelope. In fact, this insulation refers to an energy measure. Several kinds of insulation against heat loss are studied and developed in clod and heat gain in summer [2]. It is important to note that; each kind has its own technical characteristics and financial investment costs and benefits best insulation measures, and can be considered as one of the most effective savings measures [3].

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https://doi.org/10.37934/arfmts.93.2.160172

The windows configurations have a big effect on energy consumption. They represent the weakest thermal parts of the building envelope for the heat gain in summer and heat loss in winter. So, the thermal performance of a window is very important to consider by the research area, since the best window configuration is the main key to saving energy [4]. In order to achieve an efficient energy measurement, the development of new and adequate residential energy code with proven approaches is essential (insulation in buildings, windows configuration, air leakage ...).

Several pieces of research provided updates on energy savings in the building sector. For example, Shin *et al*., [5] used measured data to evaluate the net zero energy performance of the office building at the Fort Hood army base, the analysis approaches applied to the building include: unadjusted measured energy use comparison of both rations of the building; a weather-normalized, change-point linear regression to approximate the annual energy savings; and regulated building energy simulations with thermostat schedules and occupancy conditions of both percentages in the building. The results show savings of 37% to 50% for the renovated portion of the building (i.e., NZEB) compared to the un-renovated portion depending on the method of analysis.

Sudhakar *et al*., [6] studied the latest ideas dealing with building performances, and reviewed the net-zero building design projects. The results show that the cooling is responsible for the biggest share of energy consumption. By applying new measurement, it has been shown that Net Zero energy performances can be extended. Besides, to achieve the energy independent and to provide energy performance goal, buildings require different design solutions and policies.

Abdul-Zahra and Jubori [7] developed a solution based on combining different scenarios for residential buildings with an area of 240 m^2 to reduce energy consumption. The results indicate that the maximum reduction rate in energy demand for cooling demand of 33.9% was attained by changing the construction, ventilation, and control systems. The scenarios of using double glaze and insulating the building reveal the most significant impact on reducing the energy demand with a total reduction rate ratio of 34.40% compared to the other scenarios. From economic analysis, it can be concluded that the increase in the energy price led to an increase in the yearly energy cost for the preliminary building without solar PV panels. The results highlighted that the effects of key investigated scenarios should be considered in combination through a parametric investigation.

Ahmed *et al*., [8] discussed the contributions of renewable energy generation hydropower, wind energy, solar, heat pumps, and bioenergy to the development of net-zero energy buildings.

Naserabad *et al*., [9] combined the heating, the cooling and the power (CCHP) generations systems that are integrated with PVT panels to meet the demand of a building. The results also confirmed that the system has the maximum and minimum efficiency in July and January, respectively. The exergy efficiency in these two months is 46.67% and 19.33%, respectively. Indeed, the economic objective function is considered as the main priority for the design and one-year operation of the integrated system.

Muhieldeen *et al*., [10] evaluated the cooling load based on different types of wall thermal insulation like polyethylene, polystyrene, and Rockwool. The results show that Rockwool fulfilled the best potential in terms of energy saving.

Ifran and Ramlie [11] considered the relationship between the input/ output variables and their role in the form of heating and cooling load. The result demonstrated that the orientation did not influence the energy demand. While, the effect of overall height, wall area, and surface area impacted considerably on the energy yield.

Jamaludin *et al*., [12] presented three years of energy consumption data of a building, to ensure that it is able to meet the standards of energy requirement, and suggested a recommendation to improve energy saving.

In Algeria, Imessad *et al*., [13] implemented new Algerian thermal regulations for buildings. The authors discussed the potential of energy savings in a building by applying the RT 2016.

Unfortunately, these studies did not provide a depth analysis on the weakness of the adapted RT, where the majority of researchers considered just its advantages. For that, the present paper provided a depth analysis of the RT 2016 thermal regulation with TRNSYS simulation scenario. The weaknesses of the RT are well analyzed and some recommendation to update theme are suggested. Moreover, the thermal insulation material design effect on the total energy and the influence of the window configuration are also considered and analyzed. In fact, other parameters influence on energy consumption in building such as lighting consumption, water heat consumption, heating in winter, cooling in summer. But the present research selected the important ones due to their high importance and to show their significant impact on energy load.

2. Case Study: Description of the Building

In order to assess the impact of the Algerian thermal regulations' application on the reduction of energy demand for heating and cooling, a thermal study of the building with 104 m2 area, located in Dar-elbeida Algiers (latitude 36 ° 24N, longitude 03.12N) is carried out. In fact, the building is a home office use with an occupancy rate of 5 people.

In Dar-elbeida the warmest month of the year is august; with average temperature around 26.9°C. In other side the coldest month of the year is January with average temperature 11.0°C. Two cases are considered in the present study:

i. In the first case, we consider that the building meets the requirements of Algerian regulations. The Thermal transmittance coefficients 'U' for each wall are given in Table 1.
ii. Whereas, in the second case we consider that the building meets the new insulation materials. The Thermal transmittance coefficients 'U' for each wall are given in Table 2.

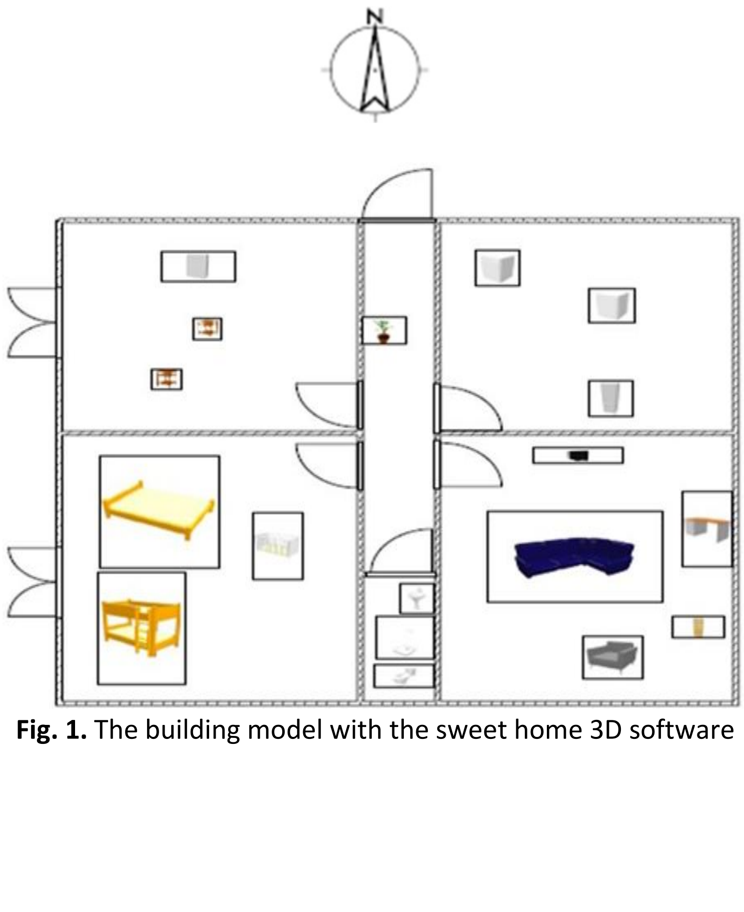

Fig. 1. The building model with the sweet home 3D software

3. TRNSYS Simulation Software

The world reference in the field of dynamic simulation of buildings and systems, TRNSYS (Transient System Simulation) software version 16 allows dynamic thermal simulation applied to buildings [14]. The software makes it possible to integrate all the characteristics of a building and its equipment (HVAC equipment) for the detailed study of the thermal behavior of this building. According to its location, the construction materials used, of the global design, the selected energy concept, etc. Mainly intended for engineering offices, manufacturers and suppliers of gas and electricity, the TRNSYS software is also highly acclaimed by researchers [15].

TRNSYS is software for the numerical simulation of the thermal behavior of buildings and their equipment developed by the Scientific and Technical Center for Building a (CSTB). TRNSYS is useful studying system whose thermal behavior varies strongly with time. TRNSYS makes it possible, for example, to accurately calculate energy load, to evaluate the thermal performance of building, to perform sensitivity analyzes and to optimize the design of an energy system [16].

"Type 56" used in TRNSYS represents the geometrical concept of building, the "Type 56" can be generated with TRNBUILD, indeed, it contains the descriptions of: zones, walls, windows, internal gains, infiltration and other parameters [17].

3.1 Modeling

The dynamic behavior of the building is simulated through a multi-zone transient modeling by TRNSYS with a time step of 1h. The building is divided into six thermal zones. The simulation consists of calculating the cooling and heating requirements according to the standards applied in Algeria, the temperature of thermal comfort for heating is 18°C and for air conditioning of 27°C. The climatic data of the dar-elbeida region are taken from the METEONORM.

The figure below presents the modeling of the building studied in the software "TRNSYS simulation Studio".

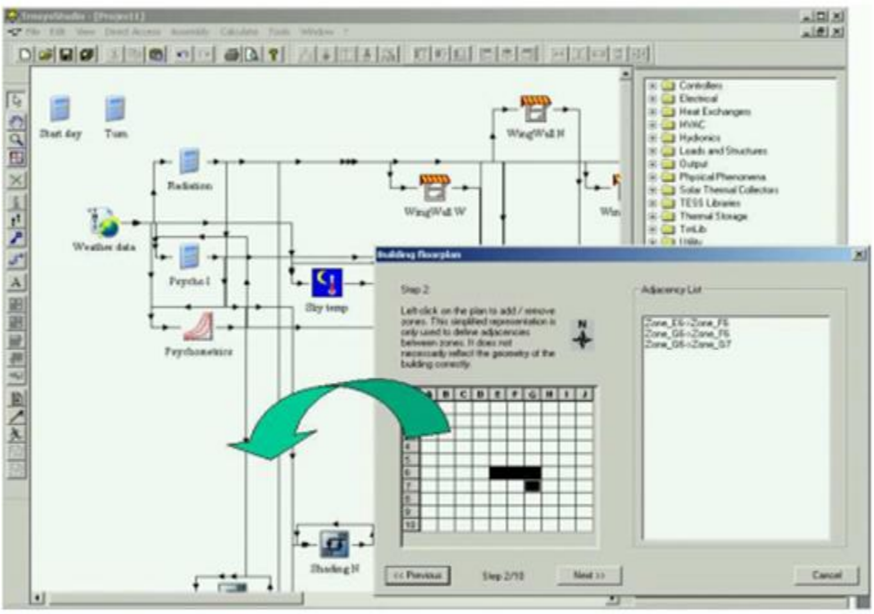

Fig. 2. Creation of a building simulation project with TRNSYS

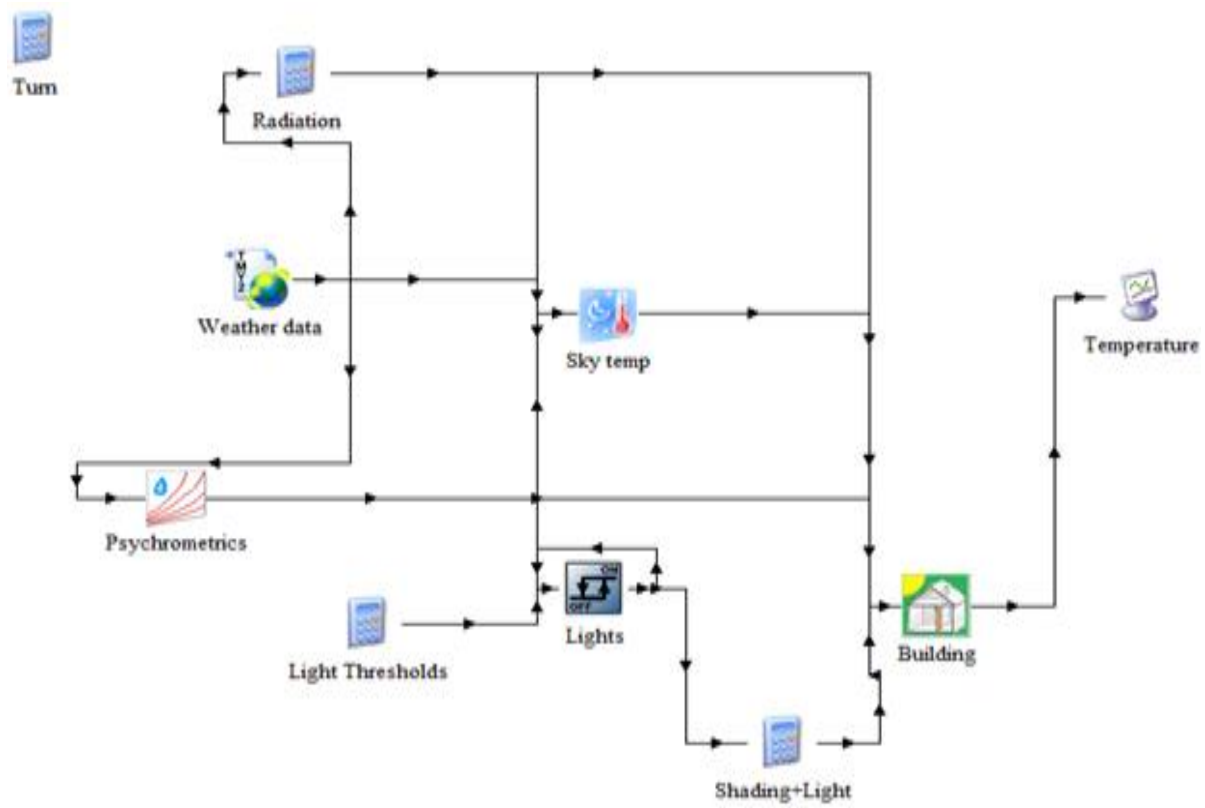

Fig. 3. Trnsys simulation studio

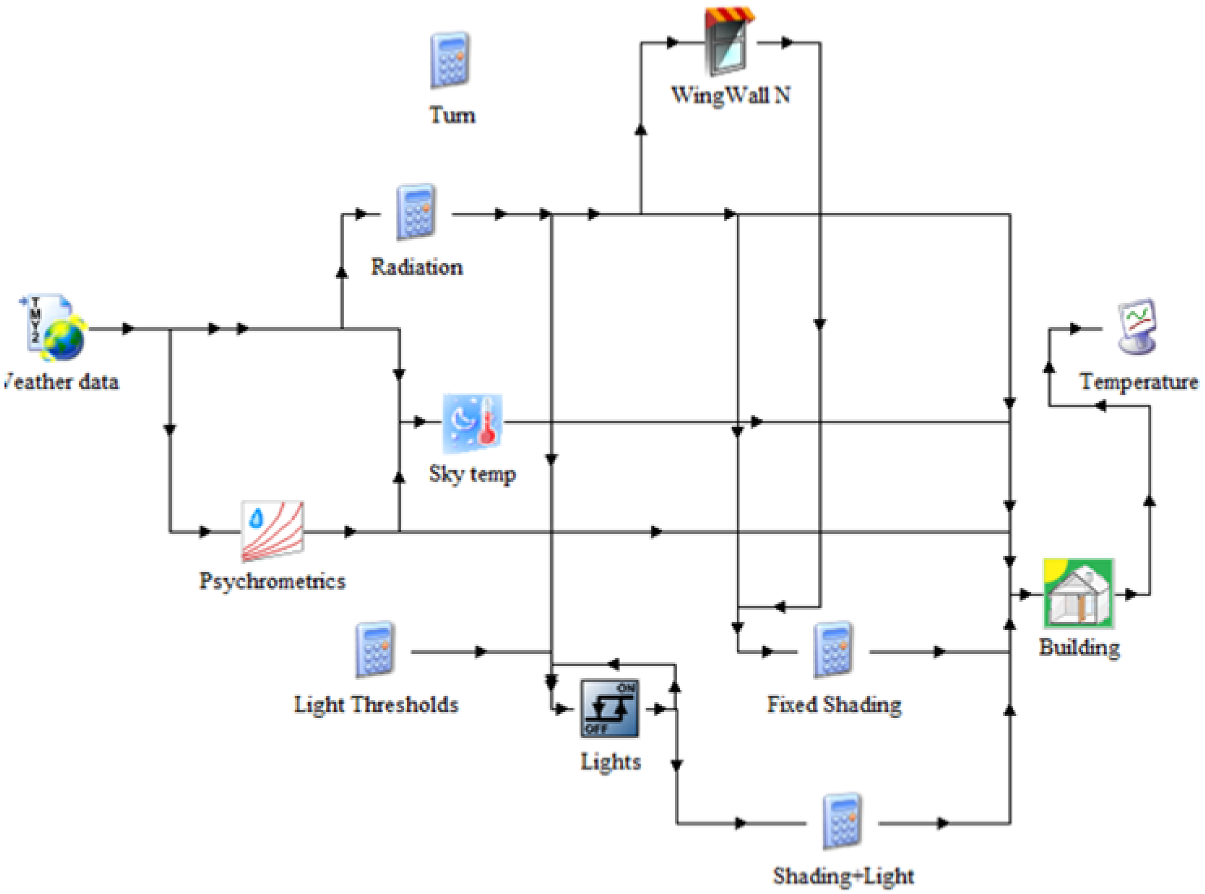

Fig. 4. Trnsys simulation studio with window configuration

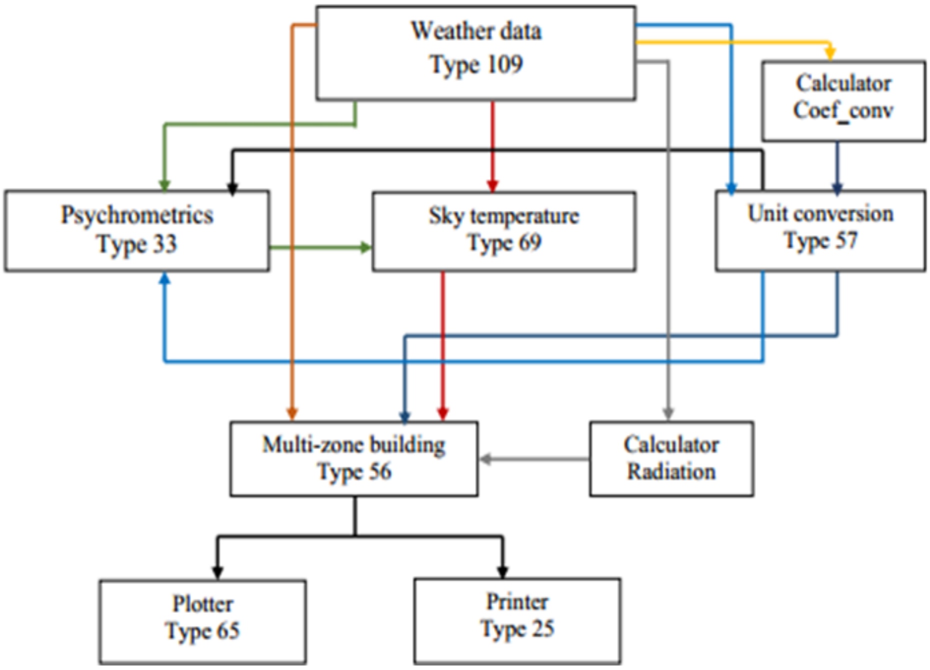

Fig. 5. Modeling of the building in the software "TRNSYS simulation Studio"

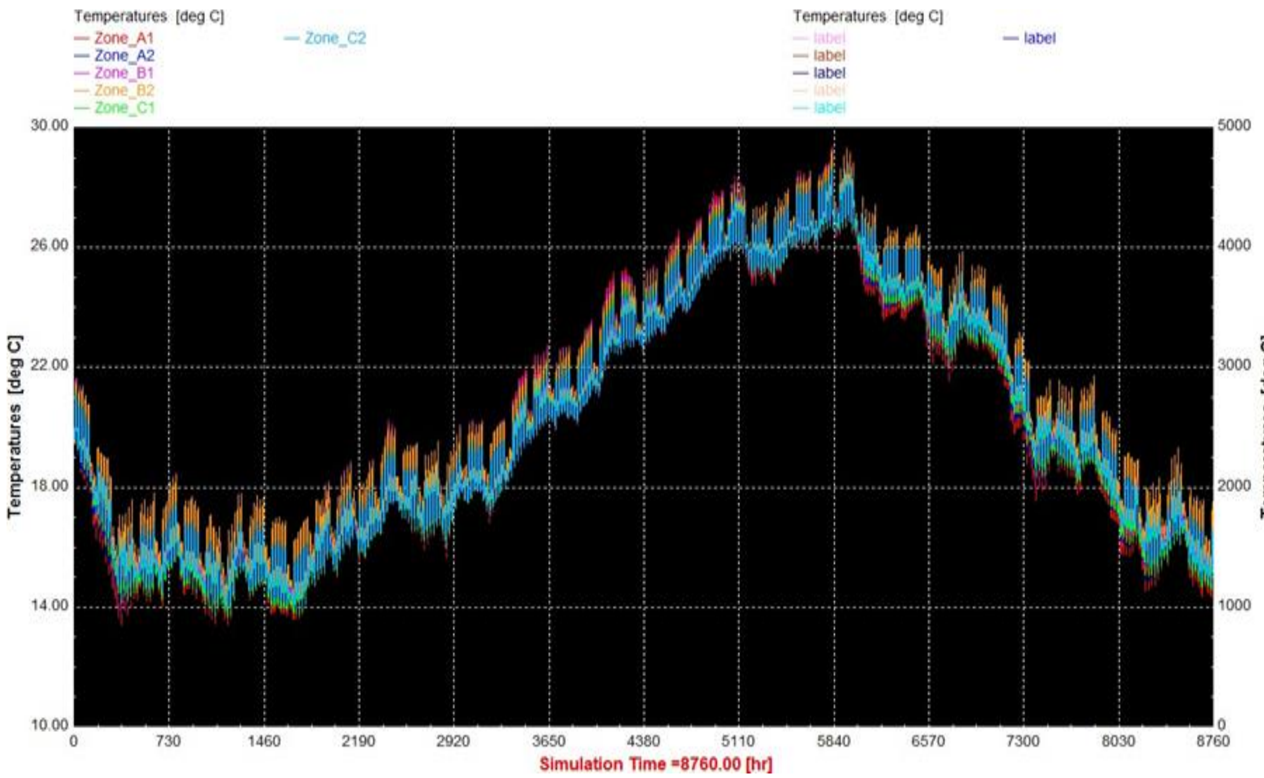

Fig. 6. Average annual variation of temperature in dar- elbaida

4. Verification of Thermal Regulations for Algerian Building 2016

i. Summer check

The DTR 2016 required that the heat loses transmission through walls must be inferior to a reference value, as in Eq. (1).

$$DT \leq 1.05\ D_{ref} \tag{1}$$

ii. Winter check

It is important to note that, the DTR 2016 required a heat gains inferior to the reference value through opaque walls (APO) and glass, as in Eq. (2).

$$A_{po}\,(15h) + Av\,(15h) \leq 1.05\, A_{ref} \tag{2}$$

Figure 7 illustrates the heating and cooling demand compared to the requirement values in the DTR 2016. From the analyses of the results, it can be concluded that the adapted building complies with this DTR.

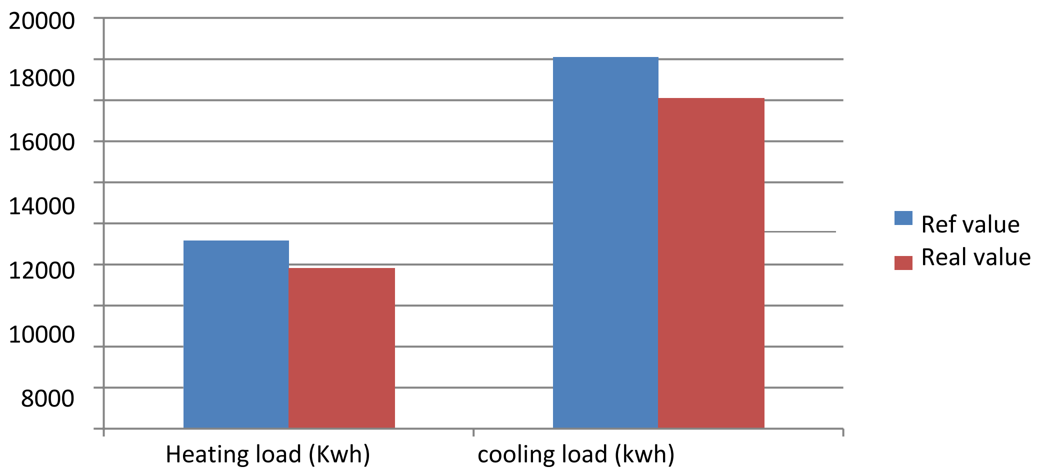

Fig. 7. Heating/cooling load

5. Comparative Study: Choice of the Best Insulation Materials

In this simulation part, two types of insulation for the walls and the roof are chosen: the polystyrene and the aerogel. Then, a comparison to the total energy consumption is done to show the improvement reported.

In fact, the effect of insulation on energy efficiency using extruded Polystyrene and aerogel is studied. The insulation was used by thickness of 0.02 cm, for the wall and the roof, in order to determine the part which must be isolated as a priority.

The components of the adapted building with some features are given in Table 1. Whereas, the characteristics of the materials are done in the Table 2 below.

Aerogel is a Nano insulation material with the structure composed of spherical particles connected by thin links. The aerogel can reduce energy loss, and it is typically applied for coverage walls, floors, roofs, and windows.

The polystyrene has a high thermal resistance, made from chemical that come from oil and gazes, and a stable R value, unfortunately, the major drawbacks of this latter are that the exposure to sun deteriorate the material, flammable, and requires proper placement in the considered utilization.

Table 1
Building envelop component

	Composition	Thickness (m)	Density kj/hmk	U value (w/m^{2}k)
walls	Cement mortar	0.02	4.152	
	brick	0.1	3.2	
	Air blade	0.1	0.216	
	brick	0.1	3.2	
	plaster mortar	0.02	1.264	
				0.468
Roof	Terrazzo tiles	0.02	1.227	
	Laying mortar	0.02	4.152	
	concrete	0.04	1.191	
	slabs	0.04	0.433	
	Plaster mortar	0.02	1.264	
				0.895
windows	Single glazing			5 W/m^{2}k^{-1}

Table 2
Characteristics of the insulating material

Materials	Thickness (m)	Conductivity (kj/hmk)	Capacity (kj/kg.)	Density (kg/m^3)
polystyrene	0.02	0.027	1.9	200
Aerogel	0.02	0.141	1.38	25

6. Results and Discussion

From Figure 8, it can be observed that the energy consumption (cooling and heating) achieves its lowest value when simulating a building with aerogel insulation. This latter, shows a difference of about 30% compared to the use of a building conform to RT2016.Whereas; a polystyrene insulation building shows an intermediate value between the aforementioned cases.

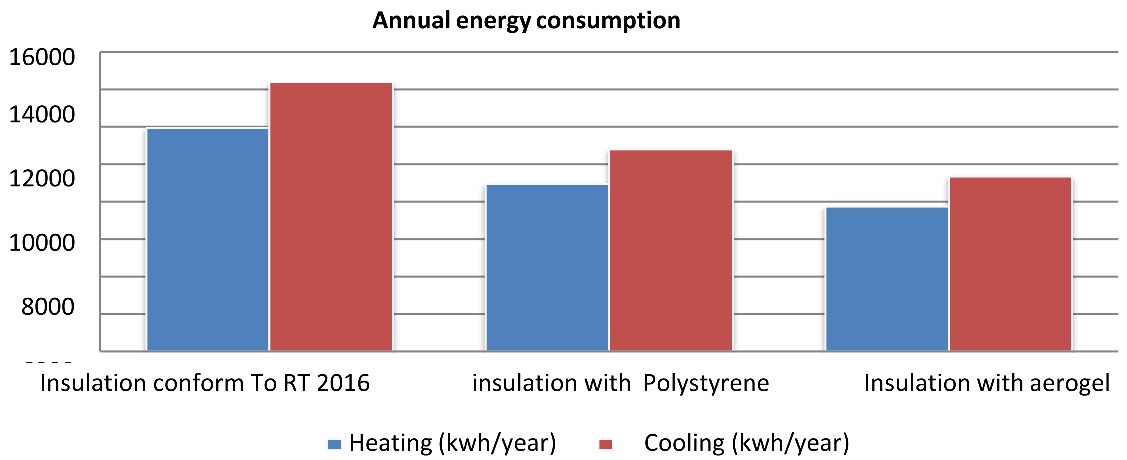

Fig. 8. Annual energy consumption according to the choice of insulation material

The energy efficiency in buildings depends on the characteristics of its envelope; therefore, the thermal performance in walls, roof and ground represents the key to increase the energy efficiency.

Thermal insulation is the best mean adapted to reduce the energy consumption in Algerian buildings. In this scenario the selection of the aerogel and polystyrene, and the thickness allow to obtain a good results andadequate energy savings potential.

A series of simulations are carried out to study the type of double glazing windows, and the orientation facades impact for energy consumption, also to show the influence of opening ratio on the energy demand in heating and cooling, and find the optimal point.

Several scenarios are considered and compared to the needed of cooling and heating energy for a set temperature of 27°C and 18°C for cooling and heating, respectively, according to the new version of Algerian thermal regulation 2016 for building.

It can be noted from Figure 9 that, the double glazing window is the best solution to optimize the energy consumption. This is fulfilled through the high reduction shown in the heating energy consumption. In fact, this type of windows can reduce the amount of energy consumption from 10% to 14% in heating demand.

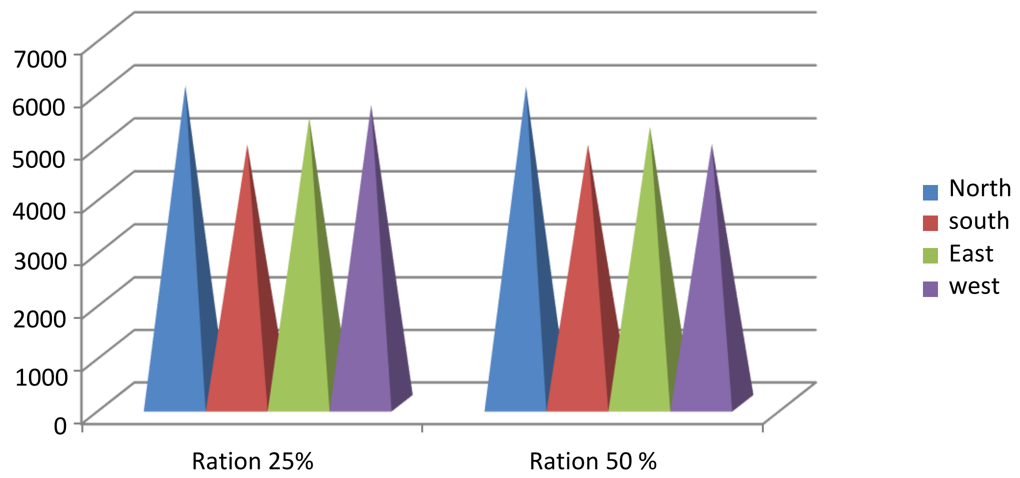

Fig. 9. Heating loads in KWh double glazing

Furthermore, the same figure shows that the high value of heating loads in the double glazing is obtained in the north façade with 25% opening ratio.

From Figure 10, it can be noted that the cooling loads is the highest in the west facing.

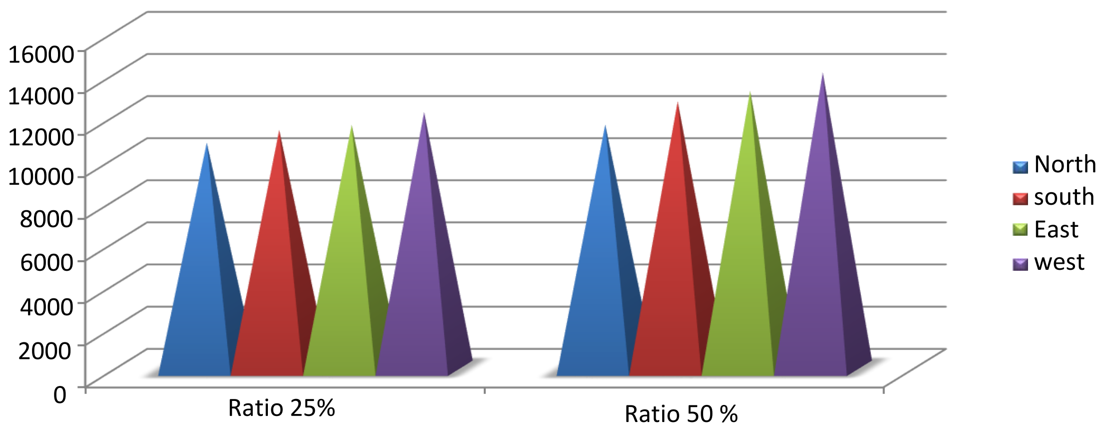

Fig. 10. Cooling loads in KWh double glazing

From Figure 11, the highest value of cooling is fulfilled in west side.

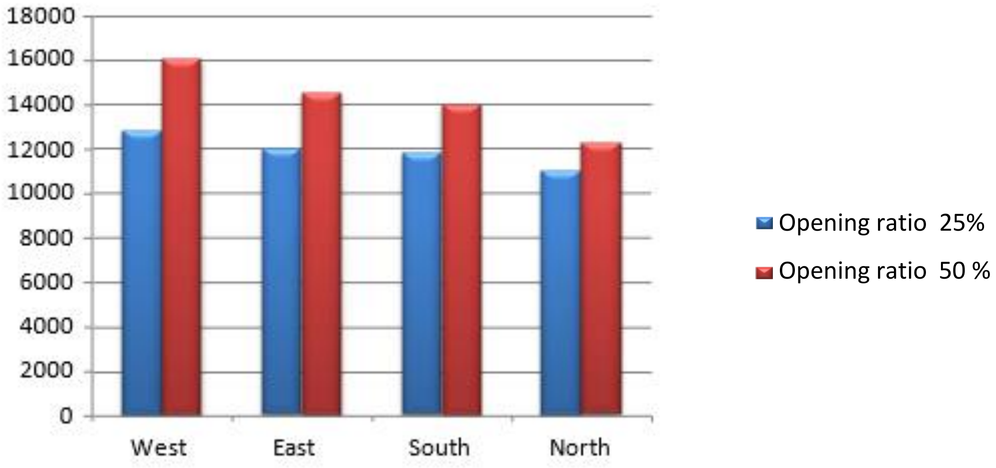

Fig. 11. Cooling loads in KWh according to opening ratio

From Figure 12, the heating load increases with low opening ratio, and decrease with high opening ratio, at the same time the heat loads decrease from the north, east, and west to the south side.

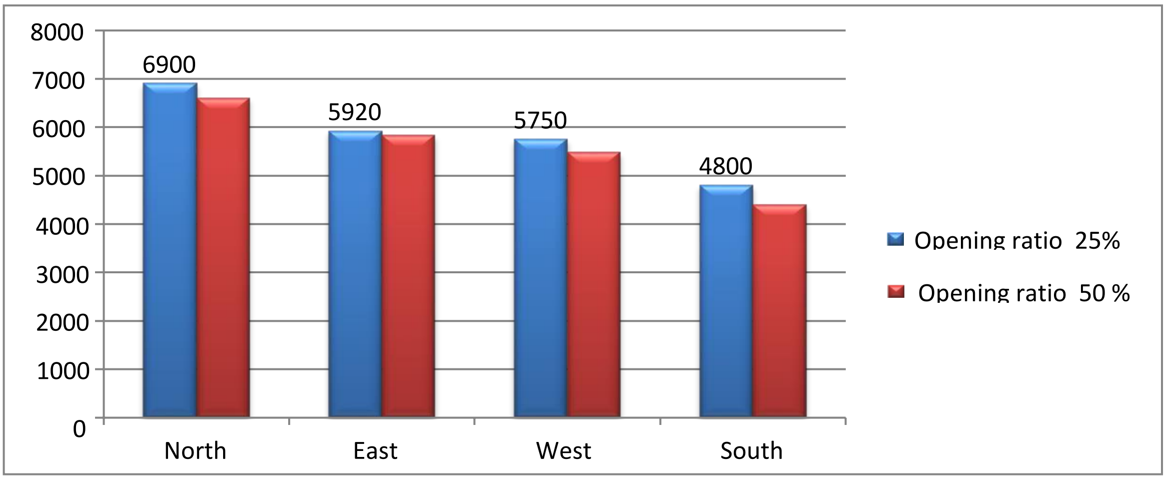

Fig. 12. Heating loads in KWh according to opening ratio

In this paper, the relationship between the heating and cooling loads with glazing types, orientation and opening ration are examined and simulated under different cases.

It can be noted from the obtained results that, when the opening increases, the annual energy load increases too, regardless the different conditions considered such as, the window types, the openingratio and the orientation. Indeed, the lowest total energy of the load is equal to 5806 kWh in the triple glazing, whereas, the biggest load is around 6014 kWh in double glazing. So, the gap between the loads value is equal to 208 KWh. For these reasons, the designers must take in consideration the impact of window type to ameliorate the quality of the energy transferred to loads.

The annual energy load increases as the opening gets bigger, regardless of the window types and opening ratio and orientation. The lowest total energy load is equal to 5806 kWh in the triple glazing, and the biggest load is 6014 kWh in double glazing. The gap between the two loads is around 208 kWh. Therefore, designers should carefully consider the impact of the window type.

Now, taken into consideration the opening ration which shows a cooling value equals to 16034 kWhin the west, and equals to 12204 kWh in the north. In this case, the gap is 3830 KWh. In the north side, the lowest load value is around 10956 KWh with 25% of the opening ratio.

Consequently, the installation of adequate windows will reduce the heat loss and ameliorate the quality, efficiency and performances of energy in the building. Indeed, an energy efficient window carries out a break to thermal bridges and reinforces insulation in the envelope and the walls. To do that, double and triple glazing is adequate solutions to improve energy efficiency, depending on the window orientation.

For the opening ratio, the high value of cooling is equals to 16034 kWh in the west, and 12204 kWh in the north, the gap is 3830 kWh. The lowest value is 10956 Kwh in north side with 25% of opening ratio. It is clear that the heat loss can be reduced and more energy yield will be obtained in this building by installing the best windows, an energy efficient window imposes a break to thermal bridges and reinforced insulation in the walls and envelope. Double and triple glazing are the most important solutions to get a high energy efficiency, and depending on the orientation of the window:

i. Heating energy demand

When the building faces almost south, the heating energy demand shows it lowest value. In other hand, if the building is oriented to another direction (east or west), it can be observed that the heating energy demand is increasing. Where, this value is higher at the north side.

According to the different orientations, the variation of the heating energy demand of the building is around 22%.

The lowest heating energy demand occurs when the building faces almost south, if the building is turned away from this orientation, either east or west, the heating energy demand increases. The building achieves its highest heating energy consumption on the north side. The heating energy demandof the building varies by about 22% according to the different orientations.

ii. Cooling energy demand

When the building is oriented to the north, it can be observed that the cooling energy demand showsits lowest value. Whereas, the highest value is obtained when the building faces the north side.

The cooling energy demand is at its lowest when the building is set out in a north orientation. Thehighest cooling energy demand occurs when the building faces the north side.

Due to the sun's course throughout the day and year, the cooling energy demand increases whenturning the building from the east-west to a north–south direction, and vice versa.

By turning the building from an east-west to a north–south direction, and vice versa, the cooling energy demand decreases. The described behaviour is due to the sun's course throughout the day and year.

During the summer period, the sun rises from the north-east and sets in north-west, while reaching high altitude in the south where it can prevent a highest heat gain. On summer morning (from sunrises to around 10am), the sun travels the north-east to the south-east parts of the building. In this case, a low attitude is fulfilled, because the solar radiation incident on the walls (vertical surfaces) is greater than that touching the roofs (horizontal surfaces). However, a high solar heat gains are obtained via the windows and cooling energy demand when orienting the building in east, north east or south-east.

It is necessary to verify and validate the results of simulation. To do this, the present results compared with the experimental studies obtained from Elshazli *et al*., [18]. According to the obtained results the present work outperforms the previous ones in reducing energy consumption (about 23%) in the aerogel insulation material.

Moreover, Brdnik [19] studied the Thermal Performance Optimization of Double and Triple glazing systems, the comparison shows good agreement between the simulations results and experimental studies.

7. Conclusion

The work has been devoted to the study the conformity of building situated in dar-elbeida to the Algerian thermal regulation, then, simulations via Trnsys are performed to improve their energy performance.

The simulation results showed the following synthesis

i. The annual energy load significantly decreases as the best insulation material used.
ii. The energy gain reach to 30 % using aerogel, and 27% using polystyrene demand compared to the requirement values in the DTR 2016.
iii. The window orientation and position have a big influence on energy load, while, the variation from single to double have a slight impact, with only 3.8%, and from single to triple with 5.4%, respectively. In addition, the load variation depends on the window orientation.
iv. The position of the window has the biggest influence on energy load. In this case, the variation has insignificant impact; form single to double around 3.8%, and from single to triple 5.4% of energy loss.

Furthermore, various solutions were presented to improve energy efficiency in an Algerian building. This study was carried out with the TRNSYS 16 simulation environment, using the multizone model (type56), the energy saving was obtained Through the insulation of the envelope using the most efficient materials (polystyrene, aerogel), the design of a correct configuration of the windows is an important factor to consider so as reducing the excessive consumption.

Finally, from an economic perspective, it is necessary to accompany this study through a techno-economic evaluation that will make the work very important at a time when the country is considering various attempts, improve energy efficiency in the housing sector. Further aspects of optimizing energy consumption are recommended for future studies.

Acknowledgement
This research was not funded by any grant.

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