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The evolution of air temperature and energy consumption in a region of the Wilaya of Nouakchott using the TRANSYS program

El Mokhtar AHMED; Mohamed EL YAACOUBY; Mohamed Lemine FAGEL
Doctoral School of Science and Technology
Department of physics; University of Nouakchott; Mauritania

Abstract

Global energy demand in the building sector has continued to grow rapidly in recent years, making it one of the main contributors to reducing energy expenditures and greenhouse gas emissions, this leads to uncomfortable and energy-intensive buildings, and the excessive energy consumption is a reality in buildings. The following work aims to reduce this energy consumption and improve the energy efficiency of buildings. Optimizing thermal insulation is the only way to ensure this efficiency. Building energy performance simulation is becoming increasingly important in the design and analysis processes of buildings worldwide, which is why TRANSY simulation software was chosen because of its various advantages.

The results of the simulation showed after studying the variation of air temperature in an area of the Wilaya of Nouakchott for three different cases, in the absence of heating and air conditioning, the temperature is very high in summer and very low in winter.
Temperature changes in heating and air conditioning systems according to human needs to provide thermal comfort. Temperatures are reduced and maintained appropriately inside buildings in summer and winter to achieve a moderate atmosphere and thermal comfort thermal analysis is used. It has also been shown that the application of thermal insulation in buildings reduces energy consumption.

Keywords: Energy efficiency, Thermal insulation, TRANSY simulation, Energy demand, Heating & Air conditioning

1. Introduction

Energy efficiency has rapidly emerged as one of the major global challenges of our era, particularly in the context of accelerating climate change and increasing pressure on energy resources. Among all sectors, buildings represent one of the largest energy consumers, accounting for a significant share of total energy demand worldwide. This high consumption makes the building sector a critical field of action for mitigating greenhouse gas emissions. In this regard, improving thermal insulation constitutes one of the most effective strategies for reducing energy losses and achieving substantial gains in energy performance [1].

However, assessing the thermal behavior of buildings under real conditions is often costly, time consuming, and difficult to generalize. For this reason, numerical simulation has become an indispensable tool for analyzing energy performance and predicting the dynamic thermal response of buildings across varying climatic conditions. Simulation makes it possible to explore multiple design scenarios, optimize architectural components, and evaluate energy needs without the constraints of physical experimentation.

Among the different simulation environments, TRNSYS has proven to be particularly well-suited for dynamic building performance studies due to its modular structure, flexibility, and ability to model both simple and highly complex thermal systems [2]. It has been widely used in recent research covering cooling systems in arid regions [1], energy assessment of HVAC units in tropical climates [2], peak load analysis in single-zone buildings [3], evaluation of thermal inertia effects [4], desalination systems powered by renewable sources [5], and passive strategies for thermal comfort in desert areas [6, 7].

In this study, a self-built residential dwelling located in Nouakchott a city characterized by a hot desert climate is selected as the case study. The analysis relies on a full-year simulation, from January to December, in order to capture the seasonal variability of external conditions and their impact on the building's indoor energy requirements.

The parametric study is conducted on a virtual model representing a typical room with interior dimensions of 3 m height, 5 m length, and 4 m width. The objective is to evaluate the building's energy performance by estimating its cooling and heating demand under the climatic conditions of Nouakchott. Simulations are performed using TRNSYS 16, which allows a detailed analysis of thermal exchanges, climatic impacts, and system behavior throughout the annual cycle.

2. Material and method

The methodological approach adopted in this study is based on a dynamic thermal simulation carried out using TRNSYS 16, a widely validated simulation environment for modelling building energy performance. TRNSYS was selected due to its modular architecture, its ability to handle transient thermal phenomena, and its extensive library of components dedicated to building physics and HVAC systems.

The simulation was performed on a virtual single-zone model representing a typical residential room. The geometric characteristics of the model correspond to a room with a ceiling height of 3 m, a length of 5 m, and a width of 4 m, resulting in a total internal volume of 60 m³. These dimensions were chosen as they reflect common residential construction practices in the region and allow for a representative assessment of energy needs.

To analyze the building's thermal behavior realistically, the virtual model was subjected to the actual climatic conditions of Nouakchott, characterized by a hot desert climate with high solar radiation, elevated temperatures, and low humidity. The climatic data typically including hourly values of ambient temperature, solar radiation, wind speed, and relative humidity were integrated into TRNSYS using standard meteorological weather files.

The simulation covered a full annual cycle, from January to December, enabling the evaluation of seasonal variations in cooling and heating demand and the overall impact of insulation across different periods of the year. This long-term analysis ensures that the results capture both peak load conditions and typical operating conditions, providing a comprehensive understanding of the building's energy performance throughout the year [3].

By comparing the simulation results with and without insulation, the methodology allows quantitative assessment of energy savings, thermal comfort improvements, and the influence of material properties on the building's energy behavior.

3. Result and Discussion

3.1. Evolution of temperature :

Figure 1 shows the temperature variation in the studied area for a year (from January to December), under climatic conditions of Nouakchott.

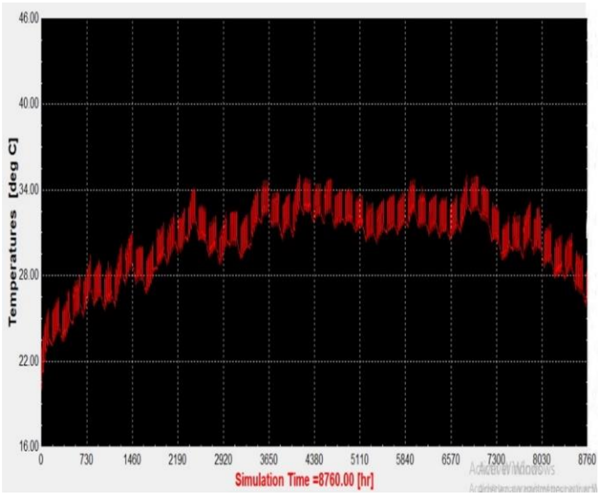

Figure 1: The annual temperature change (from January to December) in the studied area (without heating and air conditioning).

Four seasons make up the year, each extending over a specific time.

Each season differs from the others due to its climatic conditions, especially its temperature.

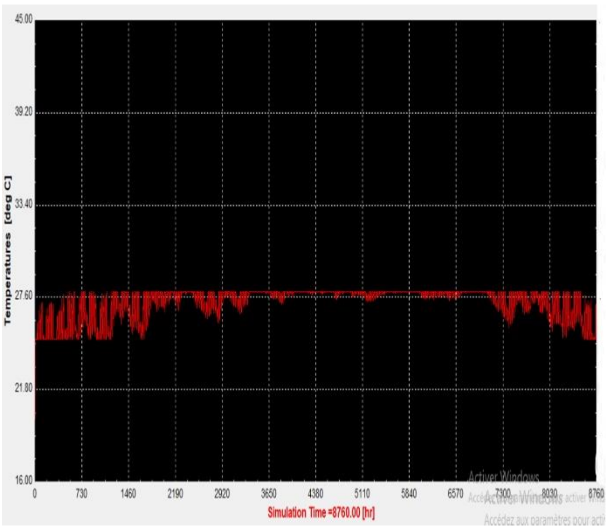

Figure 2: The annual temperature variation of the studied area (with heating and air conditioning)

The night temperature is 25°C, which increases during the day until it stabilizes at 28°C [4].

The reason for these changes in the use of air conditioning and heating is that air conditioning is a voluntary measure to control temperature and/or humidity to satisfy the thermal comfort of users. Therefore, the objective is to heat and/or cool the amount of air in the room throughout the day [5].

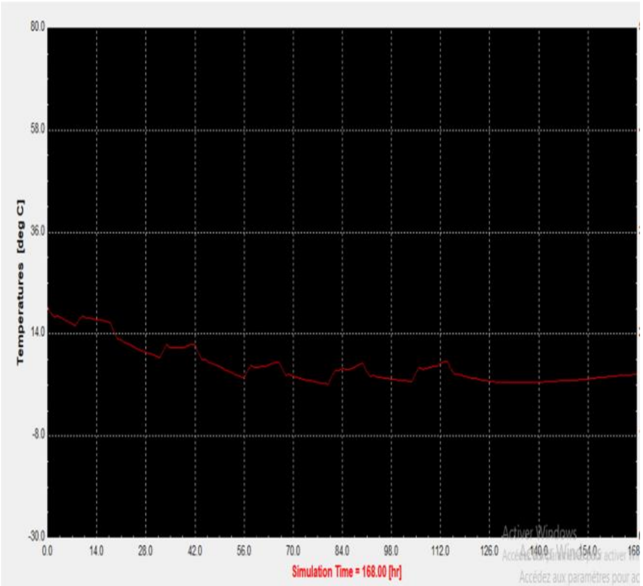

Figure 3: temperature variation of the studied area for January (with MFPD insulation).

Air conditioning is a convenient mode of thermal comfort when the outside temperature is high. When MFPD insulation is added, we notice that the day's temperature reaches 21.05 degrees Celsius [10].

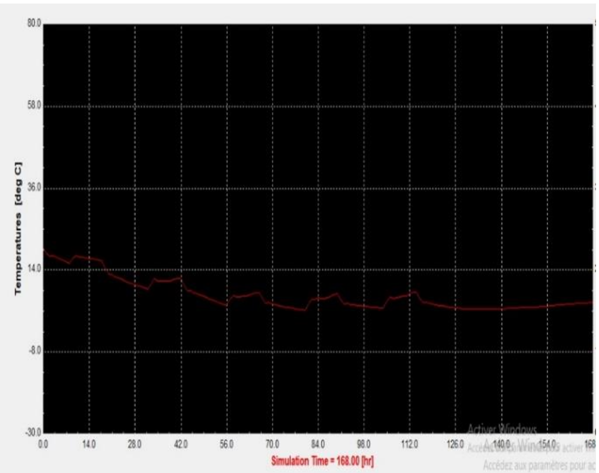

Figure 4: variation in the temperature of the studied area for the month of January (with BDV insulation)

On the other hand, when adding BDV insulation, we notice that the temperature reaches the highest value of 21.03°C during the day [13].

Comparing the values of the curves, we can see that there is a small difference between the interior temperatures corresponding to BDV and MFPD insulation, which indicates that these materials are good insulators This is due to its thermal properties, The lower the thermal conductivity, the more insulating the material, which means that choosing a good insulation depends on the thermal conductivity. Its thickness is also affected, the higher the resistance, the more effective the insulation, thermal insulation reduces the temperature differences caused by high sun temperatures during the day and low temperatures at night, as well as in summer and winter, which protects the building from climate change and weather fluctuations [12].

3.2. Evolution of energy consumption:

3.2.1. Energy consumption without MFPD insulation

The energy consumption is high before insulation use, up to 4944 kJ/h. Consumption reached 4,944 KJ/h in January and February, and decreased slightly in March, April and May to 3,410 KJ/h. Energy consumption reaches 3127 KJ/h in June, July, August and September and continues to increase rapidly during the months of October and November until energy consumption reaches a value of 3685 KJ/h and continues to increase in December at a value of 4568 KJ/h [6].

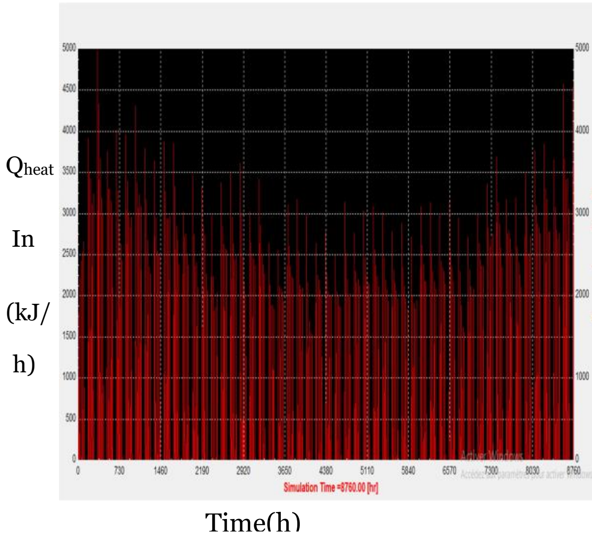

Figure 5: Annual energy consumption without MFPD insulation

3.2.2. Energy consumption with MFPD insulation

After using insulation, energy consumption is reduced during the year and energy consumption reaches 4274 KJ/h [14].

It is noted that there is a reduction in the annual energy consumption of 4944 KJ/h up to 4274kJ/h. After adding insulation, we saved 670 KJ/h.

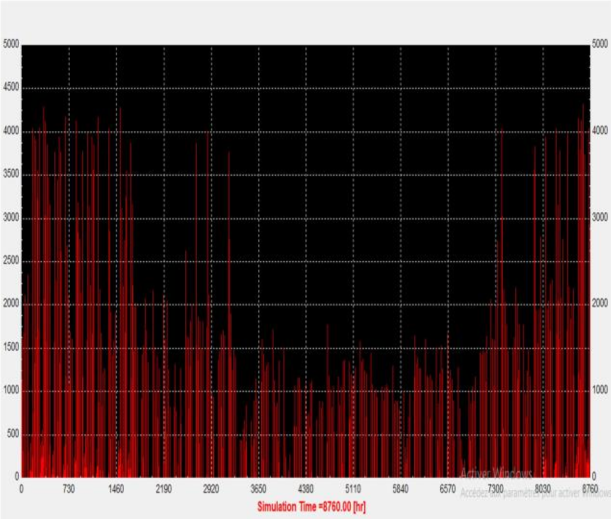

Figure 6: Annual energy consumption with MFPD insulation [15]

3.2.3. Energy consumption for the month of January without MFPD

The energy consumption (heating) in January, as reported before using "insulation" (without insulation), the energy consumption (heating) is high, up to 4973 kJ/h.

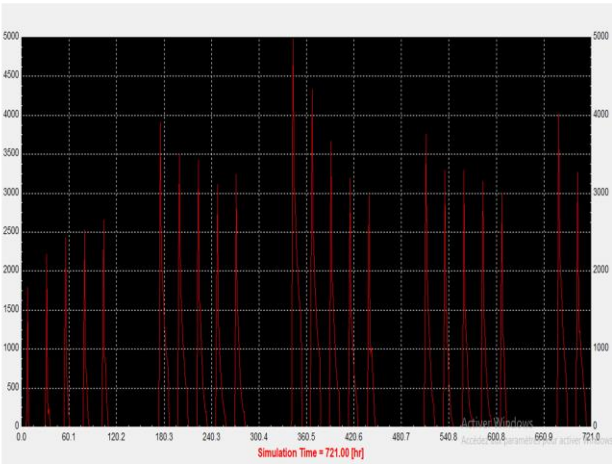

Figure 7: Energy consumption for the month of January without MFPD insulation [16]

3.2.4. Energy consumption for the month of January without MFPD

After using the insulation, energy consumption is reduced during the month of January and energy consumption reaches 4295 KJ/h

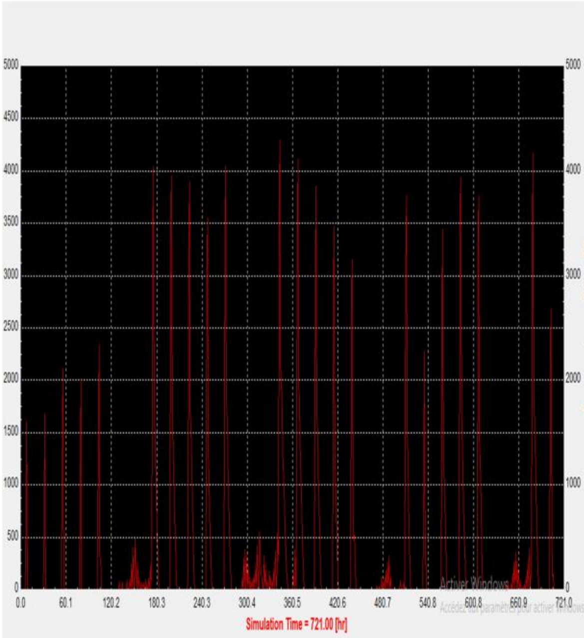

Figure 8: Energy consumption for the month of January with MFPD insulation

The energy consumed in the case "with insulation" is less than the energy consumed for the case "without insulation".

Therefore, the choice of insulation material reduces energy consumption for heating and increases comfort because it reduces the need for heating in other words saves energy.

In summer, insulation prevents external heating and solar radiation. A good insulation eliminates the "cold wall effect" in winter.

Table 1: Annual Indoor Temperature Comparison

Condition	**Max Temperature**	**Comment**
Without HVAC	Highly variable	Fully dependent on outdoor climate
With HVAC	25°C (night) → 28°C (day)	Temperature controlled for comfort

Table 2: Temperature and Energy Effects

Aspect	Without Insulation	With Insulation	Conclusion
Indoor Temperature	Highly variable	Stabilized (~21°C)	Comfort improved
Energy Consumption	High	Reduced	Energy savings achieved
Material Comparison	—	MFPD ≈ BDV	Both are effective

Table 3: Temperature in January with Different Insulation

Insulation	Max Temperature (Jan)	Comment
MFPD	21.05°C	Good thermal stability
BDV	21.03°C	Very similar to MFPD
Conclusion	—	Both materials are effective insulators

Table 4: Annual Energy Consumption Comparison

Condition	Energy Consumption (kJ/h)	Savings
Without insulation	4944	—
With MFPD insulation	4274	≈ 670 kJ/h

Table 5: January Energy Consumption Comparison

Condition	Energy Consumption (kJ/h)	Savings
Without insulation	4973	—
With MFPD insulation	4295	≈ 678 kJ/h

4. CONCLUSIONS

Based on the results obtained from the TRNSYS simulation, several important conclusions can be drawn regarding the impact of thermal insulation on the energy behavior of buildings. The simulation clearly demonstrates that improving the insulation of the building envelope significantly reduces heat losses, particularly through walls, roofs, and glazing surfaces. By limiting unwanted thermal exchanges with the outside environment, insulation contributes directly to lowering the building's overall energy demand, especially during periods of high temperature fluctuations [17].

Enhanced insulation not only reduces the load on cooling and heating systems but also improves thermal comfort inside the dwelling by maintaining a more stable indoor temperature. This leads to a noticeable reduction in energy costs, making thermal insulation an economically advantageous solution for households, especially in regions where climate conditions impose high cooling demand, such as Nouakchott [8].

Materials with low thermal conductivity act as better insulators, as they slow down the transfer of heat between the interior and exterior.

Therefore, selecting a suitable insulating material requires careful examination and comparison of its thermal conductivity value, as it directly determines the material's insulating capacity and, consequently, its impact on energy consumption [9].

The numerical results obtained from the TRNSYS simulation confirm these theoretical principles. The energy demand of the building when insulation is applied is significantly reduced, reaching 4295 kJ/h, whereas without insulation, the energy consumption rises to 4973 kJ/h [7]. This corresponds to a substantial reduction in energy needs, demonstrating the decisive role of insulation in improving building energy efficiency.

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