

Retrofit of the High Educational Buildings in a Hot Climate by applying the Thermal Nano-Coatings to Improve the Energy Efficiency

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ABSTRACT: Recent times have seen high educational buildings face challenges when it comes to high energy consumption in comparison to relatively low performance, which affects the interior of the building by reducing the comfort level of the area and this is because it contains many devices, equipment, labs, voids, and classes, and also as a result for its infrastructure, construction conditions and functional requirements to meet the needs of its users as it consumes of the total energy consumption of all building sectors in Egypt.

Therefore, this paper aims to retrofit the facades of high educational buildings to improve energy efficiency as retrofitting of existing buildings is a critical goal.

Unlike solutions for new design buildings that would take much time to show results, working on existing buildings would reflect immediately on the current energy consumption situation, and reach better levels of comfort. This will be done through the measures of the process of retrofitting Using nano-coatings as thermal insulation on the walls of the facades, and this is done into the selection of thermal performance and its reflection on the energy consumption in the building by using design-builder simulation program, which will be on Modern Academy For Engineering and Technology in East Cairo.

The research summarizes that using aerogel coating on the wall; it reduce the energy consumption 8% .

KEYWORDS: Higher education Building, Energy Efficiency, Aerogel coating, Thermal insulation coating material.

I. INTRODUCTION

Energy consumption in high educational buildings is one of the highest related to another building sector; with an annual consumption that ranges between 100 and 1000kWh/m² depending on geographic location, use, type of office equipment and its energy consumption as shown in figure (a,b) ,

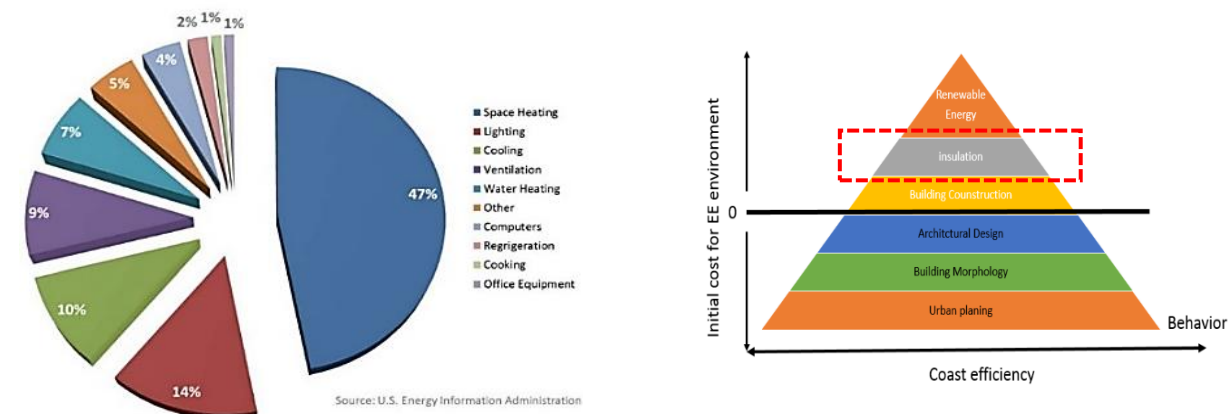


Figure (1):Key areas of energy consumption in educational facilities [1]

Figure (2): design level from urban planning to architectural design and it is cost effective energy efficient buildings.

Principle building activity	Consumption per sq. ft (BTU)	Number of building	Total sq. ft	Total energy consumption (BTU)
EDUCATION	83.046	386	9874000000	820000000000000

Table1: Table of energy consumption (BTU) per square foot Administration

Improving energy consumption rates and the appended greenhouse gas emissions are considered one of the world’s most pressing interests recently. The total energy contracted in Egypt in the year 2017 reached 180 terra watt-hours with an annual average growth rate of 8.2%. The building sector only including all building types-contributes with 43% of total energy consumption and one-third of greenhouse gas emissions globally and the characters are even higher in Egypt giving 54% of total energy sold in 2017[2].

The building facade is the main connector involving the indoor and outdoor environment and responsible for more than 50% of the building’s total energy consumption. Upgrading buildings can consume energy by applying effective methods and techniques as shown as figure (b) it designs level from urban planning to architectural design and it is cost effective energy efficient buildings.

Therefore, it was directed to retrofit it by using types of nanotechnology-based thermal insulation coating materials such as aerogel coating as these materials are generally considered to have better thermal insulation quality than traditional materials. That is why they can reduce the heat transfer coefficient.

Enough thermal insulation is achieved by applying building materials of low thermal conductivity, high thermal resistance, and by avoiding thermal joints. Thermal improvement of existing buildings represents a challenge in the construction sector, and it is usually the only way to improve their energy performance. Whereas aerogel is below 0.025W/(MK), a tenth of the respective value for traditional coatings [3].

II. RELATED WORK

A latterly patented nano insulating coating based on the (super) - insulating materials silica aerogels has been developed. The originality is a light mortar that can be used to the outer surface of a building to devise a thermally insulating coating. It consists of water, a mineral and organic hydraulic binder, an insulating filler including a powder or granules of hydrophobic silica aerogel, a structuralizing filler (optional), and additives (optional). This coating has a thermal conductivity of 0.027 W/(M.K), a density of 200 kg/m³, and a specific heat of 1100 J/(Kg.k). The new aerogel-based coating simple, easy to install, and compatible with the popular masonry facades techniques. It is flexible concerning unevenness, allows continuous thermal insulation, and can fill gaps or other difficult access areas[5].

Silica aerogels to variable compositions of Plaster mixtures for different thicknesses of insulation. The development of an aerogel coating with a thickness between 3 and 12mm purposed for mitigation of thermal bridges and a slight increase in the wall performance in terms of the surface temperature of the known insulated wall [6].To produce energy conservation.

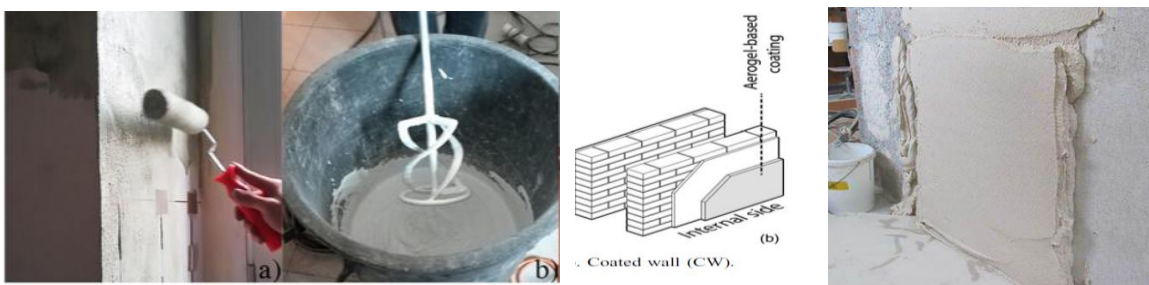


Figure (3) : Nano aerogel-based coating worked [7]

The higher the percentage of aerogel in the mixture, the lower the thermal conductivity achieved. The thermal conductivity of regular plaster represents about 0.50 W / (MK), but by making the mixture consisting of 90% granular

aerogel, the thermal conductivity of the insulating coating falls to 0.05 W / (MK). After much development, researchers have given values as low 0.015 W / (MK) [8].

Advantage of aerogel coating

1. High insulation efficiency, energy saving and environmental protection.
2. Excellent anti-scalding and anti-corrosion.
3. Easy to construct and free from the restriction of base material shape.
4. Convenient maintenance of equipment.
5. High volume solid content, low VOC.
6. Hydrophobic and dew-proof.

Other possible solutions aimed at reducing the final cost are based on minimization of the thickness. In a previous study by the authors (Fantucci. 2018), the development of an aerogel coating with a thickness between 3 and 12 mm was proposed for mitigation of thermal bridges and for a slight improvement in the wall performance in terms of surface temperature of the no insulated wall[10].

III. METHODOLOGY

This part describes the methodology used to achieve the objectives of the research through the applied approach which uses the Design-Builder simulation tool to study the case of a higher education building in Cairo which is Modern Academy for Engineering building in the ElMokattam city in Cairo.

First, the current study will examine the reduction in energy consumption resulting from the thermal insulation coating on a facade in two cases. Also, the study will examine the effect of nano-coating and the simulation results for each case. Following that, the results will be discussed.

The research methodology follows Literature, Analytical and Comparative/analytical reviews:

- **Analytical review:**the paper identifies and classifies the different design parameters of Nano thermal insulation coating in the wall on High educational building Facades
- **Comparative/Analytical review:** through using the "Base-case" Modern Academy model vs (nano thermal insulation coating) in the model to study and compare the impact of applying the technique of nano coating by using the "design builder" simulation tool.
- **The research summarizes**that using aerogel coating on the internal wall is better than using it on the external wall.

The research summarizes and classifies the results by the best placement of the nano aerogel for application in the Greater Cairo region regarding the following: [facade materials]. Through simulation models, the research has found that ((nano-aerogel thermal insulation coating) may reduce energy consumption by about (8%) from the same facades.

These resultswill assist architects and owners to make decisions related to enhancing energy efficiency in educational buildings.

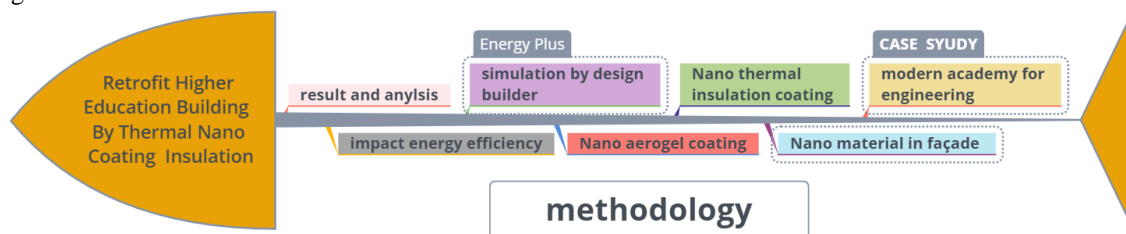


Figure (4): Diagram of the research methodology

IV. EXPERIMENTAL RESULTS

The Design - Builder software for building modelling uses various design aspects of a building such as building science (building materials), building architecture, cooling and heating systems, lighting systems. It simulates various ways of energy consumption in a building such as heating, cooling, lighting, household devices, hot water consumption. The Egyptian Typical Meteorological Year (ETMY), the International Weather for Energy Calculations (IWEC) and Köppen tagged Cairo climate as a hot semi-arid climate including a hot to humid, dry summer and mild to warm

wet winter [11].

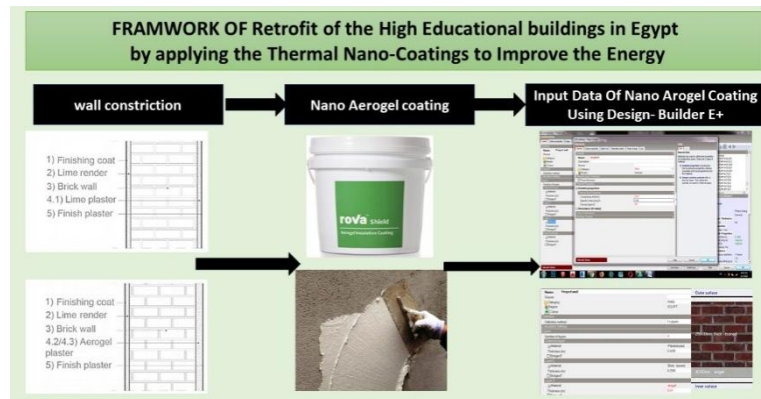


Figure (5) the Methodological Framework for the Applied Study

Modelling and Analyses were performed for the same selected academy, at which previous measurements had been performed. Fig. (7) shows Modern Academy for Engineering building model with the same construction and finishing materials. It also shows the case study location from the southern elevation view; presents the academy visualization model made by Design Builder software. It presents a high rate of solar radiation onto the southern elevation at the mid of the Academy daytime.

A higher education building consisting of 5 levels including an area in level of 16010.9 m² and chosen in the social-environmental climate of Egypt.



The case study as shown in figure 7. The building is located in Elmokattam city, Cairo ,Egypt

Building external walls measuring 25 cm with an internal and external design of the structure with a thickness of 12 cm. The chosen design designer inserts the specifications of the building materials and enters all the data on the materials in the base case condition and measures the energy consumption and compares it with the actual consumption, and then makes an improvement on the wall using the aerogel coating material, and then measures the actual consumption and compares the two cases with each other with energy savings.

Input parameters and materials thermal properties:

For efficient modelling and simulation of the academy building, one should consider the existing construction materials and real parameters of the building to apply to computer modelling. As the thermo-physical properties of wall materials can affect the building’s energy performance .The Simulation input parameters and limitations based on the onsite data collected shown in detail in Tables 3 and 4. It assumed that the properties of the material are constant during the simulation time.

Activities and schedule

Table 2 of energy consumption was used in the simulation and served on the standard way of Academy Student of Egypt (vacations, hours of work, etc.). For each set of parameters tested.



Element	Data
Occupancy pattern	occupancy rate is about 0.118 person/m ²
Working time	Sunday to Thursday day, between 8:00 am until 4:00 pm
Metabolic rate	0.90
Clothing	Winter 1.0 summer 0.5
Holiday	2 days / week
HVAC	cooling systems

Table 2. Simulation input parameters in Design Builder E+ tool

Building envelop component	Material	Cross section	Thick. cm	Density kg/m ³	Conductivity W/m.K	Specific heat J/kg.K
External wall from outside to inside (U-value=2.19W/m ² .K)	Plasterboard		2.0	2300	0.72	840
	Brick		25	1500	0.850	840
	Plasterboard		2.0	2300	0.72	840
Internal partitions (U-value=2.4 W/m ² .K)	Plaster		2.0	2300	0.72	840
	Mortar		2	2800	0.88	896
	Brick		12	1500	0.85	840
	Mortar		2	2800	0.88	896
	Plaster		2.0	2300	0.72	840
Intermediate floors (U-value=2.3W/m ² .K)	marbale tiles		2.5	2600	2.2	2563
	Mortar		2	2800	0.88	896
	Sand		6	2200	1.83	712
	Reinforced concert		12	2300	1.9	840
	Air gap		50	-	0.18	
	Gypsum board		0.7	1033	0.27	990
Roof without insulation (U-value=2.6 W/m ² .K)	roof tiles		3.0	1900	0.840	800
	Mortar		2.0	2800	0.88	896
	Sand		6.0	2200	1.83	712
	Reinforced concert		25.0	2300	1.9	840
	Air gap		50		0.18	
	Gypsum board		0.7	1033	0.27	990

Table 3. Existing construction materials thermal properties in Design Builder E+



Property	Density (kg/m ³)	Specific heat (J/kg K)	Thermal Conductivity (W/m K)	Thickness cm
Nano Aerogel coating	200	1100	0.027	4

Table 4: NANO aerogel coating properties for the simulation.

The results of what has been studied and tested are discussed in two significant aspects. First, energy consumption indices are compared, second thermal comfort is indicated.

Comparison between simulation results
Total Energy Consumption for building

To validate the simulation results, a comparison between the base case building and two affected to coating (aerogel exterior wall -aerogel interior) in retrofit by using the software.

Results of the comparison are shown in Figure (8)

The simulation shows that the total energy consumption of the aerogel coating compared to the base-case without insulation, It has achieved energy savings of more than 8% of the total energy consumed, and the most significant part of the savings was in the months from April to October.

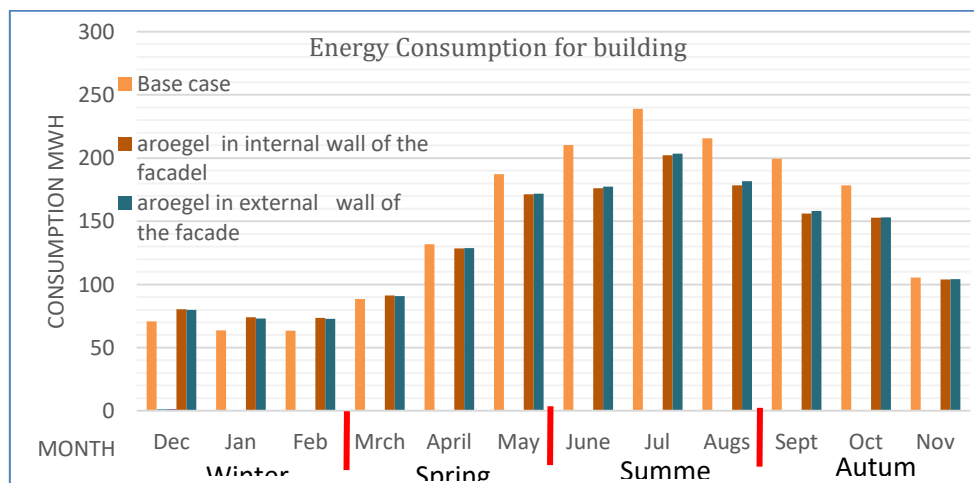


Figure 8 Monthly total energy consumption results

The simulation shows that by using the aerogel coating in the internal wall, there is a reduction of the total energy consumption by 8% and it is the idea that it is placed in the internal wall of the facade to reach the best results.

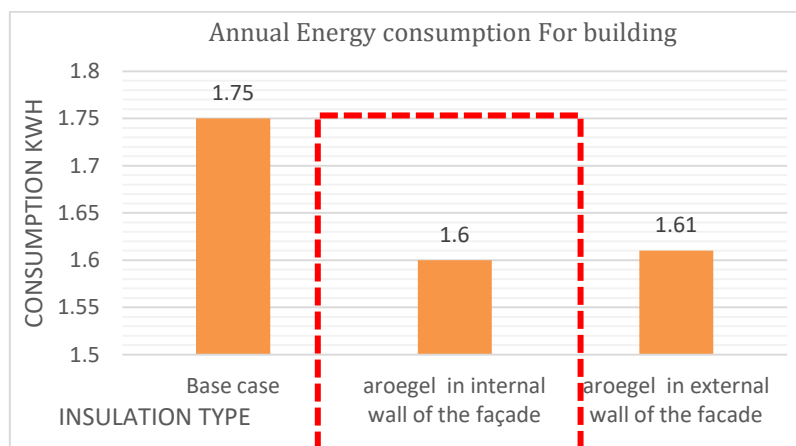


Figure 9 total energy consumption results for whole building per year

- Cooling Energy Consumption for building

It can be seen from Figure 10, illustrating the monthly cooling energy consumption, that the cooling energy consumption savings accruing from adding (aerogel coating in an internal wall) 4 cm reduced loads by (8)%; the bulk of the cooling energy savings is from April to November, with the maximum energy consumption reduction occurring in August and July, around the peak of the summer.

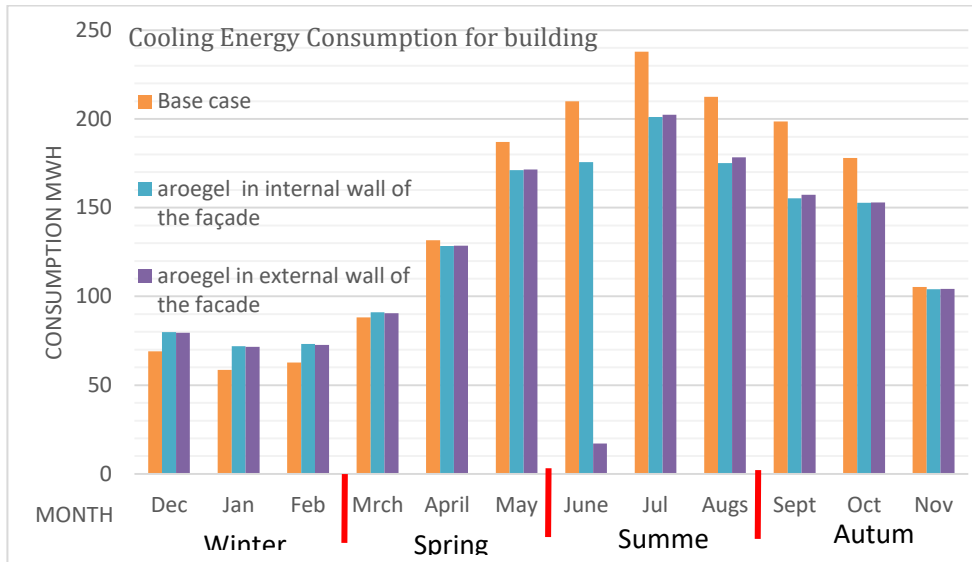


Figure10 Monthly cooling energy consumption for different cases

Figure (11), displaying the annual cooling energy consumption. The figure shows that there is a reduction in cooling energy consumption across the year if applied (Aerogel coating in an internal wall) 4cm on a wall to 1.59 GWH. In contrast, base case 1.74 GWH.

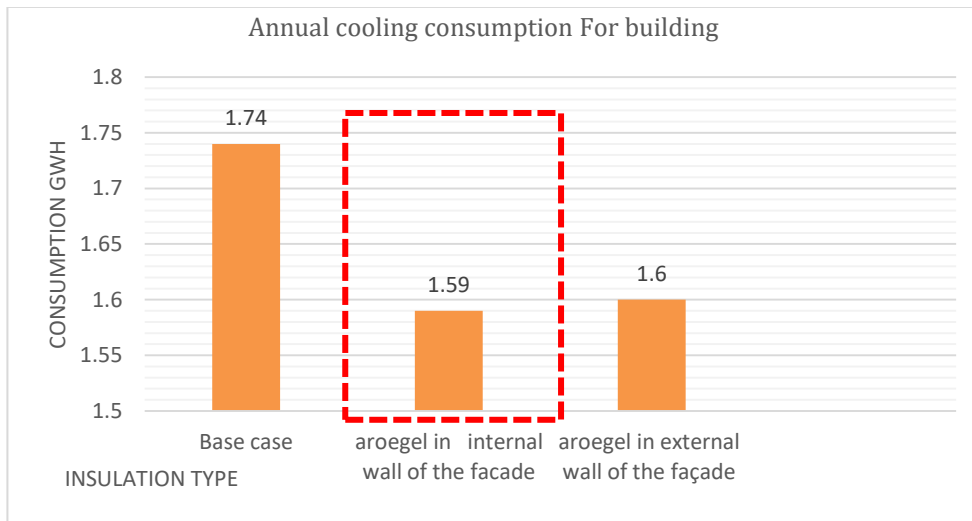


Figure11 Annual cooling energy consumption for different cases

Annual thermal comfort simulation results

Among the aims of this paper is to estimate the thermal performance of space over the school year. Input simulation coefficients are fixed based on real yearly aspects. Results:

PMV from the annual simulation results and data made, which will be explained in the following sections.

In Figure (12) the average thermal comfort is all close to the number to zero (-0.9 to 0.9), so the thermal comfort feeling is better, then adding the air-coating material in the case to the inner wall improves the thermal comfort rate, especially in Seasons of summer. We see that the best result in most months is the presence of an inner wall with nano

and the improvement is very noticeable except in May and March due to changing people's clothes, making it difficult to change the number in the program by specifying the months, which is one of the criteria for thermal comfort.

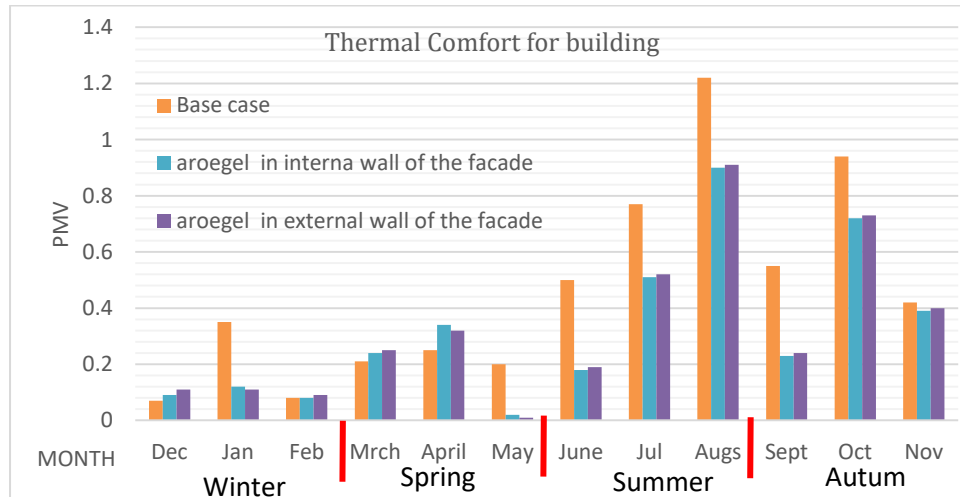


Figure12 Thermal Comfort for different cases per year

V. CONCLUSION

The concept of energy-efficient retrofit and its primary stages are discussed in this paper. Energy efficiency with a retrofit focused on reducing the building's energy use, extending its life cycle, and reducing its long-term impact on the environment in the future.

In this paper, the application of dielectric nanotechnology in antenna coating insulation materials was evaluated.

The analysis shows that the use of dielectric nanotechnology to rehabilitate higher education buildings is a suitable solution to improve the thermal performance of the building by allowing the matching of goals to reduce energy consumption. The combined use of opaque elements (surrounding walls) using nanotechnology insulation can allow for improved thermal comfort, to reduce energy consumption, and thermal inertia, to reduce air temperature fluctuations and reduce temperature rise during summer.

Nanotechnology insulation products are suitable for any building but are ideal for the internal regeneration interventions needed to increase energy efficiency and comfort with minimal space loss to allow for a complete application and an energy efficiency solution.

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