ISSN:
2181-3906
2025

International scientific journal
«MODERN SCIENCE AND RESEARCH»
VOLUME 4 / ISSUE 12 / UIF:8.2 / MODERNSCIENCE.UZ

EVALUATION OF THE ECONOMIC FEASIBILITY OF USING COMMON THERMAL INSULATION MATERIALS IN THE EXTERNAL WALLS OF A BUILDING IN THE CLIMATE OF HERAT

Abdul Karim Pouya

Lecturer at Engineering Faculty, Jami University

Associate Professor Ahmad Temory, Lecturer at Education Faculty, Herat University.

https://doi.org/10.5281/zenodo.18084825

Abstract. *In this study, a sample building was simulated in order to simultaneously examine energy savings and the economic aspects resulting from thermal insulation. By modeling the sample space under the climatic conditions of Herat, characterized by cold winters and hot summers, the annual heating and cooling energy consumption of the building was calculated using common insulation materials widely used in Afghanistan for external walls. In addition, the amount of heating and cooling energy saved through insulation was determined.*

The cost of insulating the walls, including the cost of the insulation material, labor, transportation, and other related expenses, was also estimated. Finally, by calculating the break-even point, the payback period for the insulation investment based on the achieved energy savings was obtained. The results indicate that the initial cost of insulating the building walls is recovered after approximately six years. Furthermore, the most economical wall for insulation was found to be the southern wall with the recommended Preen concrete block insulation, which had a payback period of about 41 months. This payback duration is reasonable and fully justifies the application of wall insulation from an economic standpoint.

Keywords: *cooling energy, heating energy, economic feasibility, energy savings, break-even point, thermal insulation.*

1. Introduction

In principle, one of the indicators of economic growth is the increase in energy consumption. Economic assessments carried out in recent years show that global energy consumption has been consistently rising, and forecasts indicate that it will continue to grow in the coming years. Therefore, energy has become a valuable commodity in the global market, and for countries that possess significant energy resources, it is a major source of financial income.

Energy resources enable producing countries to use the resulting revenue for rapid development and industrialization.

For this reason, in today’s world, all countries striving for growth and seeking to overcome economic, industrial, and social underdevelopment, aim to access greater energy resources at the lowest possible cost. However, countries vary significantly in terms of energy resource availability. A general look at the geographical distribution of energy in the modern world shows that different types of energy are unevenly dispersed across the globe. Some forms of energy are found only in specific regions, while others, such as natural energy resources, although present almost everywhere, differ greatly in terms of quality, accessibility, and efficiency of utilization.

The high environmental pollution costs caused by such energy sources, along with the failure to discover effective substitutes for fossil fuels, have encouraged specialists to explore strategies for reducing energy consumption in various sectors.

Buildings are among the major consumers of energy carriers and account for a significant share of total energy consumption. The upward trend in energy use, the high per-capita consumption compared to global averages, and the large energy losses in the residential sector of Afghanistan clearly highlight the necessity of effective planning for energy management as the most suitable solution for preventing the current crisis and avoiding further escalation.

Effective and practical planning regarding the application of thermal insulation in construction practices in Herat has not yet been implemented. Buildings are often constructed without considering the required standards. The importance and advantages of thermal insulation, especially in reducing heating and cooling energy costs in winter and summer, remain largely neglected by most building owners, engineers, and contractors. From a geographical perspective, Herat is located in a region with cold winters and hot summers; average winter temperatures drop to around -10°C, while summer temperatures rise to about 45°C. Therefore, the four-month cold season and four-month hot season significantly increase the energy demand of buildings in the city.

Dessel and Foubert (2010; pp. 1156–1164) conducted a study to maximize the performance coefficient of active thermal insulation as a heating and cooling system for buildings.

Using the Lumped Element Model as a finite-element-based method, they concluded that this insulation model performs better in heating mode.

Lewis and colleagues (2012; pp. 7–15) carried out a feasibility study based on the optimization of an active thermal insulation system. Through a preliminary optimization study, they assessed the potential effectiveness of active thermal insulation. They also designed this insulation for a specific window in order to compensate for heat transfer through it.

Whiffen and Riffat (2013) The authors classify various PCM types, including organic (e.g. paraffins), inorganic (e.g. hydrated salts), and eutectic mixtures, and discuss their advantages and limitations: organic PCMs tend to be stable and safe, but may suffer from low thermal conductivity; inorganic PCMs often have higher heat storage capacity, but may face issues like supercooling, chemical stability, or corrosion. To address limitations such as poor thermal conductivity and leakage during phase change, the review describes several encapsulation and design methods: macro-encapsulation, micro-encapsulation (MPCM), shape-stabilized PCMs, and slurry systems. Each method has trade-offs regarding stability, thermal performance, and suitability for building integration.

Fokaides and Papadopoulos (2014; pp. 203–212) investigated the optimal thickness and cost of insulation in arid climates. Their objective was to develop a method for determining the cost-optimal insulation thickness for building elements. They conducted a detailed study on the ideal insulation thickness to provide more reliable results and eventually introduced a model that balances simplicity with accuracy, using materials with low thermal conductivity to enhance building energy efficiency.

Neyris and colleagues (2015; pp. 268–274) proposed a mathematical model based on investment–savings analysis to optimize both the energy and economic aspects of thermal insulation for exterior walls. They selected polystyrene insulation and used the minimum payback period as the optimization criterion. Based on the economic conditions of Serbia, they calculated a break-even period of approximately 1.5 years.

Aksapoulos and colleagues (2018; pp. 939–959) studied the economic evaluation of optimal insulation thickness for exterior walls in different orientations, taking wind direction into account, in Cyprus.

Villasmil et al. (2019) Among the tested materials, vacuum insulation panels and silica aerogels provided the most effective thermal insulation due to their very low thermal conductivity and also the research highlights that the cost-effectiveness of using high-performance insulation materials is largely determined by a careful balance between the higher upfront cost of advanced materials and the benefits gained through reduced spatial requirements or improved energy savings.

Mitran et al. (2021) Despite these limitations, composite PCMs using porous silica can still achieve substantial latent heat storage (often in the range of 100–200 J/g) and maintain good stability over many heating, cooling cycles, making them promising candidates for applications in thermal energy storage, building climate control, waste-heat recovery, and beyond.

In the present study, commonly used insulation materials in Afghanistan as well as the specific climate of Herat have been considered. These choices make the results more localized and realistic. Moreover, previous studies have rarely addressed the simultaneous impact of price, initial cost, and wall orientation on thermal insulation performance. This research examines these parameters concurrently.

2. Sample Space and Solution Conditions

In the present study, the ASHRAE Standard 140-2017 was used to define the sample space for the simulations. The sample space, shown in *Figure 1*, has a height of 2.7 meters, a width of 8 meters along the south-facing direction, and a length of 10 meters along the east-west direction.

The sample space contains two windows with dimensions of 1.8 × 2 meters, without any shading devices, both installed on the southern façade. For the selected sample space, the infrared emissivity (e) of both interior and exterior walls is taken as 0.9, and the solar absorptivity (α) of the interior and exterior walls is assumed to be 0.6.

In this research, the building energy model was simulated under the assumption that the building is located in Zone 5 of Herat city, with window openings oriented toward the north and south. Using the thermal transmittance coefficients (U-values) of the materials used in the walls, the effects of parameters such as variations in wall construction materials, thermal insulation of exterior walls, heat and moisture loads, and the monthly energy consumption of the sample building were analyzed under the climatic conditions of Herat.

The objective of this study is to investigate the impact of thermal insulation on exterior walls and to evaluate its economic feasibility. For this purpose, three different types of insulation materials were considered. Although the walls consist of composite layers, the average thermal transmittance values are presented in *Table 1*. The baseline for insulation comparison was assumed to be a conventional clay bake brick wall.

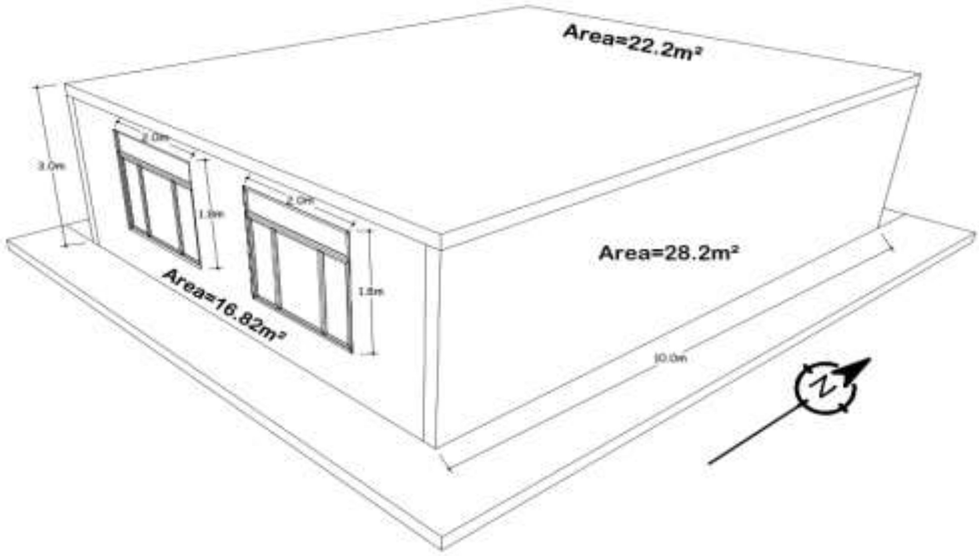

Figure (1) illustrates the configuration of the sample space.

In the initial stage, the reference insulation was applied to all four sides of the building. In the subsequent modeling processes, each type of insulation was placed individually on the four geographical orientations in order to determine the amount of energy savings resulting from the use of each insulation material. For the economic evaluation of this study, the cost that must be paid per kilowatt-hour of cooling (summer) and heating (winter) energy was estimated based on electricity bills and the average coal consumption of households. These values are presented in Table 2. Although the market price of coal is generally given per ton, in this research the cost is calculated based on kilograms. On average, power plants generate 2 kWh of electricity per kilogram of coal. For energy-consuming equipment, it is assumed that during winter a gas heater is used, and during summer an evaporative cooler (Water Cooler) is employed.

To determine the initial cost of insulation, the total cost of each insulation material is required, including the price of the insulation itself, labor cost, transportation to the construction site, and other related expenses. These total costs are presented separately for each type of insulation in Table 3. Clearly, these figures, similar to the energy prices, are proposed values. In the table of proposed insulation costs, all prices are calculated per square meter of the corresponding insulation material.

Table (1): Thermal Conductivity Coefficient of the Proposed Insulation Materials.

S/No	Proposed Insulation	(U) Thermal Transmission Coefficient of the Proposed Insulation (W/m²·K) *
1	Standard Baked Brick	2.05
2	Concrete Perin Block	0.09
3	Hollow Clay Block	0.1

* Source: ASHRAE Standard 140-2017

Table (2): Energy Cost Data

S/No	Type of Energy	Price per kWh (USD)*
1	Heating per kilowatt-hour using coal	0.16
2	Cooling per kilowatt-hour using electricity	0.22

* Source: Based on household coal consumption survey and average electricity bills Herat Province. (Authors 2025).

Table (3): Cost of Proposed Insulation (per m²)

S/No	Proposed Insulation	Price per Square Meter (USD)*
1	Standard Baked Brick	8
2	Concrete Perin Block	16.47
3	Hollow Clay Block	15.80

* Source: Based on Herat Province Markets, (Authors, 2025).

3. Analysis and Discussion

The climate of Herat city was selected, and the components and thermal conductivity coefficients of the proposed insulation materials were applied to the walls. The outputs of the calculations were obtained as annual heating and cooling energy consumption, indicating the average energy consumption (heating or cooling) per year when the respective insulation is applied.

In Table 4, the first row corresponds to the case where all four walls are made of standard Baked bricks (baseline case), while the subsequent rows correspond to scenarios where insulation is applied in one geographical orientation, and the remaining three walls remain as standard baked bricks. By obtaining the heating and cooling loads with insulation applied in all four orientations, the annual energy savings can be calculated as the difference in energy consumption (heating and cooling) between the baseline case (all walls with standard baked bricks) and the eight alternative scenarios (insulation applied in different directions). The results are reported in MWh.

In Table 5, the winter heating load savings and summer cooling load savings resulting from the application of insulation on the four walls are presented in MWh. The analysis of these outputs shows that applying insulation to a single wall of the building saves approximately 8.1 MWh of cooling load in summer and 1.62 MWh of heating load in winter.

After evaluating the energy savings achieved by the insulation, the study proceeds to the economic analysis, which is more understandable and relevant for building owners and contractors. This information is particularly important for paying electricity bills and purchasing coal. As energy prices in Afghanistan rise, building owners are increasingly motivated to reduce energy consumption. Notably, higher energy prices combined with reduced consumption allow consumers to benefit from significant cost savings. Using these results, contractors can be encouraged to adopt insulation measures. Table 6 presents the cost savings resulting from applying insulation in different directions, broken down by cooling and heating loads, expressed in United state dollar (USD).

Table 4. Annual Heating and Cooling Energy Consumption with Insulation Applied

Insulation Type	Orientation	Heating (MWh)*	Cooling (MWh)**
Ordinary Baked Brick	All 4 sides	2.513	13.2
Precast Concrete Block	North	1.064	4.69
Clay Hollow Block	North	0.96	5.344
Precast Concrete Block	East	1.071	4.84
Clay Hollow Block	East	0.746	6.25
Precast Concrete Block	West	0.56	6.29
Clay Hollow Block	West	0.73	6.23
Precast Concrete Block	South	0.862	4.81

*MWh: Megawatt Hour

** Source: Based on the research calculations, (Authors, 2025)

Table (5). Amount of Annual Heating and Cooling Energy Saved Compared to the Base Year

Type of Insulation	Orientation of Insulation	Heating Energy Saved (MWh)**	Cooling Energy Saved (MWh)**
Ordinary Baked Brick	All four orientations	0	0
Concrete Prin Block	North	1.449	8.51
Clay Hollow Block	North	1.553	7.856
Concrete Prin Block	East	1.442	8.36
Clay Hollow Block	East	1.767	6.95
Concrete Prin Block	West	1.953	6.91
Clay Hollow Block	West	1.783	6.97
Concrete Prin Block	South	1.651	8.39
Clay Hollow Block	South	2.363	6.03

**Source: Based on the research calculations, (Authors,2025).

Table (6). Amount of Annual Energy Cost Savings (in Afghani)

Type of Insulation	Orientation of Insulation	Heating Savings (USD)*	Cooling Savings (USD)*	Total (USD)
Ordinary Baked Brick	All four orientations	0	0	0
Concrete Prin Block	North	1.10	43.24	44.33
Hollow Clay (Sofali) Block	North	1.26	36.85	38.11
Concrete Prin Block	East	1.09	41.73	42.81
Hollow Clay (Sofali) Block	East	1.63	28.84	30.47
Concrete Prin Block	West	1.99	28.51	30.50
Hollow Clay (Sofali) Block	West	1.66	29.00	30.66
Concrete Prin Block	South	1.42	42.03	43.45
Hollow Clay (Sofali) Block	South	2.92	21.71	24.63

* Source: Based on the Herat Market prices and research calculations, (Authors, 2025)

In the last column, the total saved costs (heating and cooling) in the USD are included.

This means that by using any of these insulation materials on one side of the building wall, the amount of money saved in one year is shown. Next, the initial cost of insulation is calculated.

If insulation is applied on one side, there is no need to construct a mud baked-brick wall on that side. This initial cost is provided in Table 7. A zero cost refers to the cost of constructing the wall with ordinary baked bricks on all four sides and subtracting the cost of insulation and wall construction together. It is noteworthy that in this research, the south-facing windows of the sample space were removed, because the focus of the study is on wall insulation. In Table 7, since the areas of the east and west walls are equal, the insulation cost is therefore the same for both. As an example, to insulate the northern wall using clay bricks (clay hollow blocks), the initial cost is calculated as follows:

Table (7): Initial Cost of Wall Insulation

Type of Brick/Block	**Direction**	**Cost (USD)***
Ordinary Baked Brick	North	215.37
Concrete Prin Block`	North	155.73
Concrete Prin Block	East/West	273.58
Hollow Clay (Sofali) Block	East/West	197.82
Concrete Prin Block	South	266.87
Hollow Clay (Sofali) Block	South	287.31

* Source: Based on the Herat Market prices and research calculations, (Authors, 2025)

According to the dimensions of the sample space, the area of the north wall is 22.2 m², and as mentioned, the cost of insulation per square meter is 16.42 USD. Therefore, the total insulation cost for the north wall is 364.52 USD. By subtracting the construction cost of a wall made with regular baked bricks (215.37 USD), the net savings can be determined.

After calculating the amount of cost savings and the insulation cost, the Break-Even Point (B.E.P) can be determined. The break-even point refers to the time after which the profit from the insulation equals the investment cost.

In other words, until this time, the insulation does not generate any profit for the user, and after this point, the financial benefit of insulation is observed.

The B.E.P can be calculated using the following formula:

$$\text{B.E.P} = \frac{C.I\ (\text{USD})}{C.S\ (\text{USD/year})} \qquad (1)$$

Where:

- $C.I$= Cost of insulation (USD)
- $C.S$= Annual energy cost savings (USD/year)

By dividing the insulation cost by the annual cost savings, the B.E.P is obtained in years, indicating how many years it will take for the insulation investment to pay off. The calculated break-even points in this study are presented in Table 8.

Table 8: Break-Even Point (B.E.P) in Years

Type of Insulation	Direction	Insulation Cost (USD)*	Energy Savings (USD/year) *	Break-Even Point (Years)*
Regular Baked Brick	All directions	0	0	0
Concrete Prin Block	North	215.37	44.33	4.86
Clay Hollow (Sofali) Block	North	155.73	38.11	4.09
Concrete Prin Block	East	273.58	42.81	6.39
Clay Hollow (Sofali) Block	East	197.82	30.47	6.49
Concrete Prin Block	West	266.87	30.50	8.75
Clay Hollow (Sofali) Block	West	287.31	30.66	9.37
Concrete Prin Block	South	162.99	43.45	3.75
Clay Hollow (Sofali) Block	South	117.85	24.63	4.79

* Source: Based on the Herat Market prices and research calculations, (Authors, 2025)

Figure 1 illustrates the break-even point (BEP), measured in years, for investments across four primary directions (North, South, East, and West). Each direction appears twice, likely representing two scenarios, two corridors, or two sets of data within the same direction. The BEP represents the amount of time required for the investment to recover its initial cost through generated returns.

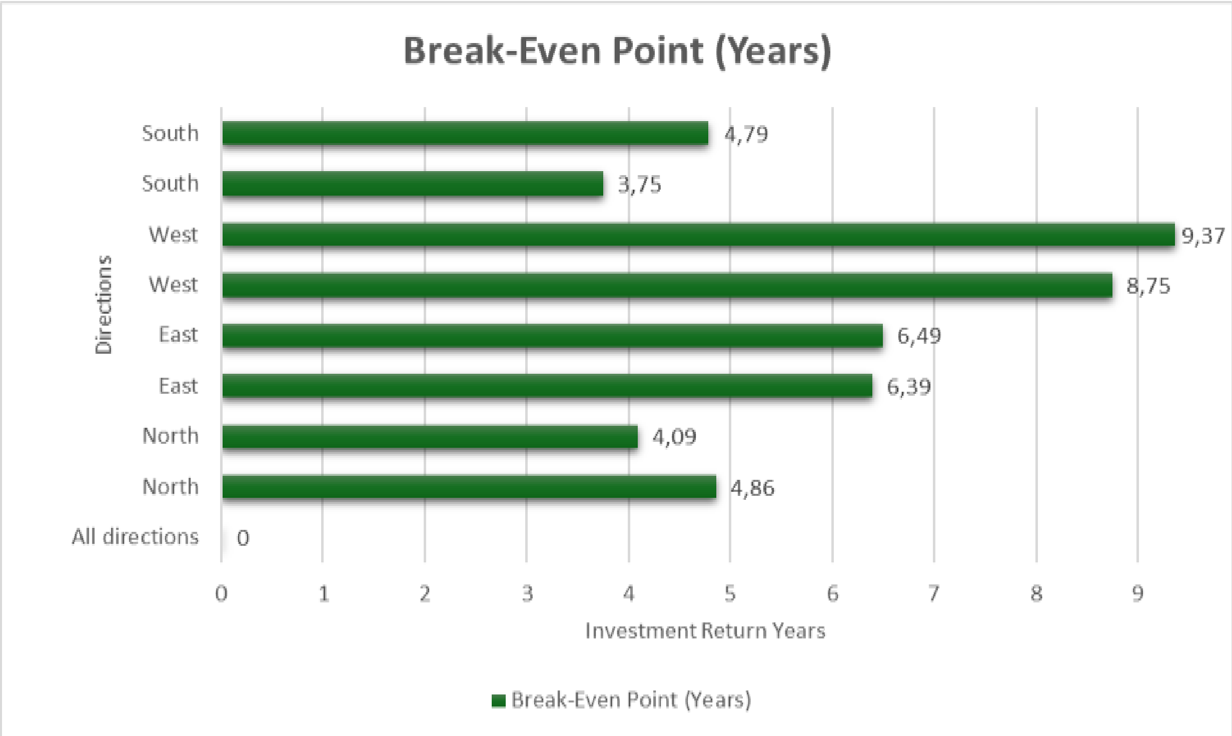

Figure (2): Break-even point for four geographic directions and two different thermal insulation

Observations:

East Wall**:** Clay Hollow block has a slightly higher B.E.P (~9.3 years) compared to Concrete Prin block (~8.8 years).

West Wall**:** Clay Hollow block B.E.P is higher than Concrete Prin block (~4.6 vs ~3.8 years).

North Wall**:** B.E.P is lower for Concrete Prin block (~4.9 years) than Clay block (~6.0 years).

South Wall**:** Concrete Prin block reaches break-even faster (~5.6 years) than Clay Hollow block (~6.0 years). In most directions, Concrete Prin blocks reach break-even faster than Clay hollow blocks, meaning they provide a quicker return on insulation investment. East and West walls require the longest time to reach B.E.P for both types.

4. Conclusion

The present research examined the influence of various thermal insulation materials on the external walls of a prototype building across four geographical orientations in the climatic context of Herat Province. Subsequently, the economic justification and feasibility of employing these insulation systems were evaluated. The results demonstrate that, considering both the heat transfer coefficient and the overall cost of procurement and implementation, Perin Concrete Blocks represent the most efficient thermal insulation option for buildings in Herat.

According to the computational analysis, the thermal transmittance (U-value) of this material is 0.09 W/m²K, indicating a high level of thermal resistance and a strong capacity to reduce energy loss through building walls. The estimated cost of installing Perin Concrete Block insulation with a thickness of 20 cm is approximately 16.42 USD per square meter. Moreover, the economic assessment suggests that the initial investment in insulation is recoverable in nearly six years, making it financially viable in the long term.

Despite the proven benefits, the application of thermal insulation in Herat remains limited and unsystematic. Nevertheless, in cases where insulation has been utilized, *Perin Concrete Blocks* have been the predominant choice due to their favorable thermal properties. Heating demand in the region is largely met through electricity, firewood, coal, and gas-based appliances.

However, a considerable proportion of building owners and contractors still regard thermal insulation as a non-essential expense and lack sufficient awareness of its energy-saving potential and economic payback.

References

1. S. Van Dessel and B. Foubert, "Active thermal insulators: Finite elements modeling and parametric study of thermoelectric modules integrated into a double pane glazing system," *Energy and Buildings*, vol. 42, pp. 1156–1164, 2010.
2. T. Harren-Lewis, S. Rangavajhala, A. Messac, and J. Zhang, "Optimization-based feasibility study of an active thermal insulator," *Building and Environment*, vol. 53, pp. 7–15, 2012.
3. T. R. Whiffen and S. B. Riffat, "A review of PCM technology for thermal energy storage in the built environment: Part I," *International Journal of Low-Carbon Technologies*, vol. 8, no. 3, p. 147, 2013.
4. P. A. Fokaides and A. M. Papadopoulos, "Cost-optimal insulation thickness in dry and mesothermal climates: Existing models and their improvement," *Energy and Buildings*, vol. 68, pp. 203–212, 2014.

5. J. Nyers, L. Kajtar, S. Tomić, and A. Nyers, "Investment-savings method for energy-economic optimization of external wall thermal insulation thickness," *Energy and Buildings*, vol. 86, pp. 268–274, 2015.
6. I. Axaopoulos, P. Axaopoulos, G. Panayiotou, S. Kalogirou, and J. Gelegenis, "Optimal economic thickness of various insulation materials for different orientations of external walls considering the wind characteristics," *Energy*, vol. 90, pp. 939–952, 2018.
7. W. Villasmil, L. J. Fischer, and J. Worlitschek, "A review and evaluation of thermal insulation materials and methods for thermal energy storage systems," *Renewable and Sustainable Energy Reviews*, vol. 103, pp. 71–84, 2019, doi: 10.1016/j.rser.2018.12.040.
8. R.-A. Mitran, S. Ioniţă, D. Lincu, D. Berger, and C. Matei, "A Review of Composite Phase Change Materials Based on Porous Silica Nanomaterials for Latent Heat Storage Applications," *Molecules*, vol. 26, no. 1, p. 241, 2021, doi:10.3390/molecules26010241.