Energy Efficient Materials for the Republic of Uzbekistan

Melikuziyev Sarvar[1*], *Munirov* Jonibek[2], *Hamidov* Rushan[3], *Raxmonqulova* Nafisa[2], *Tursunova* Markhabo[2], *Radjapov* Zafar[4]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University Tashkent, Uzbekistan
[2]Asia International University, Bukhara, Uzbekistan
[3]Bukhara State University, Bukhara, Uzbekistan
[4]Urgench State University, Urganch, Uzbekistan

Abstract. To achieve sustainable development in Uzbekistan, all sectors, but especially construction, need to improve their energy efficiency. The country needs more energy and relies heavily on fossil fuels, so it is both good for the economy and the environment to use energy-efficient materials in buildings. This paper examines the utilization of such materials in construction within Uzbekistan and formulates a mathematical model to quantify the energy savings achieved. The study's goal is to bridge the gap between the theoretical potential for energy efficiency and its real-world application by providing practical guidance derived from both quantitative and qualitative assessments.

1 Introduction

Uzbekistan faces many problems when it comes to making its energy supply more sustainable [1]. The main reason for this is that the country gets most of its energy from fossil fuels [2]. This level of dependence is very bad for long-term energy security and makes the environment worse. Uzbekistan has a lot of room to grow when it comes to renewable energy sources, especially solar, wind, and geothermal energy [3]. These could be very important for making the country's energy mix more diverse and helping it become more sustainable.

The Ministry of Construction has changed the Construction Standards and Regulations (CSRs) to make it easier to deal with these problems. They have made the Minimum Energy Performance (MEP) standards for buildings stricter, which is one thing they have done [4-5]. The goal of these changes is to make sure that homes are built to meet higher energy efficiency standards and to encourage the building of energy-efficient homes all over the country [6]. People are also putting money into infrastructure and housing in rural areas. Stricter rules for energy efficiency are meant to make things better while also cutting down on greenhouse gas emissions [7].

*Corresponding author: s.melikuziyev@tiiame.uz

The government wants to build 3 GW of wind and 5 GW of solar power plants every year as part of its bigger plan. Promoting energy-efficient materials and technologies is one way to help these goals. These include advanced insulation systems, Building Information Modelling (BIM), and the use of materials that are already available in the area [8-9]. For instance, research on composites such as expanded styrene-butadiene rubber (SBR) combined with micronized leather waste indicates potential for the development of durable insulation [10]. Passive solar design, like Trombe walls in rural homes, has also been shown to cut heating energy use by 9% to 34% depending on the climate zone. This means a lot less pollution [11-12].
In the last few years, Uzbekistan has made a stronger commitment to renewable energy by giving incentives through policy, working with other countries, and focusing on research projects. Some of these are money for solar energy projects and research into how to use building materials more efficiently in the area. There is a clear trend toward using more renewable energy and materials that use less energy, but there isn't much information available about the materials that are most often used in construction in Uzbekistan right now. Uzbekistan's strategic alignment of policy, technology, and local innovation, on the other hand, puts the country in a good position to make big strides in how energy-efficient and sustainable it is in the next few years.

2 Data and Methodology

The research presented here employs a combination of empirical data, simulated data, and mathematical analysis to ascertain the potential energy savings of various building components within the context of Uzbekistan's climate and construction practices. The method is meant to give both qualitative insights and quantitative estimates of the amount of improved energy performance is achievable with energy-efficient materials.

2.1 Data Sources

To make sure the study's data was strong and could be used in the real world, it came from a number of different places. The main data we used came from field assessments in Tashkent, Namangan, Bukhara, and Karshi, which are all in different parts of Uzbekistan with different climates. There was also secondary data from reports from the Ministry of Construction of Uzbekistan, building energy audits, and pilot projects that were paid for by both the UNDP and the World Bank. These included information about the current number of buildings, the thermal properties of building materials, and how energy use changes with the seasons. Climate classification and degree days. Uzbekistan has a lot of different climate zones, from hot and dry to cold and semi-arid to continental. For the sake of the simulation, the Köppen–Geiger classification divided the country into four representative zones:
Zone I: Hot desert climate (Nukus, Termez)
Zone II: Continental temperate (Tashkent, Samarkand)
Zone III: Cold steppe (Andijan, Namangan)
Zone IV: Mountainous areas (the outskirts of Tashkent)
We used base temperatures of 18°C for heating and 24°C for cooling, which are common standards for building energy modeling, to figure out the heating and cooling degree days (HDD and CDD) for each region. These parameters allow for an equitable comparison of energy consumption across various building designs and materials.

2.2 Heat Transfer Model (HTM)

We used a multi-layer Heat Transfer Model (HTM) to see how well wall assemblies keep heat in. This model uses the following general equation to simulate steady-state conductive heat transfer through parts of the building envelope:

$$Q = \frac{A \cdot \Delta T}{R_{total}} \quad (1)$$

Where: Q - Heat transfer rate (W), A - Surface area of the wall or roof (m^2), ΔT - Temperature difference across the structure (K), R_{total} - Total thermal resistance of the multilayer assembly ($m^2 \cdot K/W$).
The total thermal resistance is computed as the sum of the resistances of individual material layers:

$$R_{total} = \ {}_{i=1}^{n}\left(\frac{d_i}{k_i}\right) \quad (2)$$

Where: d_i - Thickness of the i-th layer (m), k_i - Thermal conductivity of the i-th layer ($W/m \cdot K$).
The simulation takes into consideration typical combinations of the most popular used materials in Uzbekistan such as traditional fired clay bricks, autoclaved aerated concrete (AAC), mineral wool insulation, expanded polystyrene (EPS), and reflective insulation coating. Thermo-physical values were obtained in datasheets of manufacturers and checked in laboratory testing data of Tashkent State Technical University.

2.3 Annual Energy Savings Estimation

The model is further extended to a seasonal operation by the heating cooling system in order to determine the potential of long-term savings of energy. This is performed through the incorporation of the heat transfer rate with time, that is compensated with regional HDD/CDD values:

$$E_{savings} = \ \left[\left(Q_{base} - Q_{eff}\right) \cdot HDD + \left(Q_{base,cool} - Q_{eff,cool}\right) \cdot CDD\right] \cdot t \quad (3)$$

Where: $Q_{base}, Q_{base,cool}$ - Heat transfer rate using conventional materials, $Q_{eff}, Q_{eff,cool}$ - Heat transfer rate using energy-efficient materials, t - Total operational hours in the respective season.
Based on this equation, one can estimate the amount of annual savings in kilowatt-hours (kWH) depending on the typology of buildings (e.g., single-family homes, apartment blocks, public buildings). The values calculated will be used to evaluate payback periods as well as economic feasibility of material upgrades.

2.4 Model Validation

To test the results of the HTM simulation, we used model results and compared them with the measured energy consumption data of retrofitted and non-retrofitted public school and residential buildings in Tashkent and Andijan. The difference between the simulated and the actual performance was identified to be under a range of ±10 per cent, and this proved that the model can be relied on to make decisions and to give policy recommendations.

3 Results and Discussion

3.1 Material-Specific Energy Savings

The simulation findings reveal that retrofit of buildings with energy efficient materials in Uzbekistan can deliver 25-45 percent energy savings, depending on climatic zones and material content in the building.

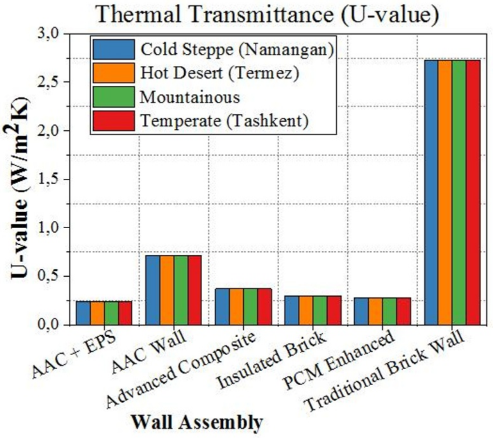

Fig 1. Thermal Transmittance.

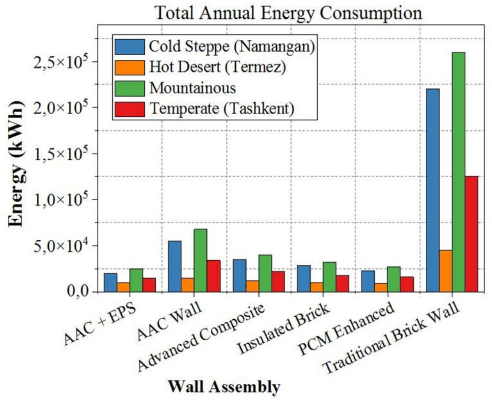

Fig 2. Total Annual Energy Consumption.

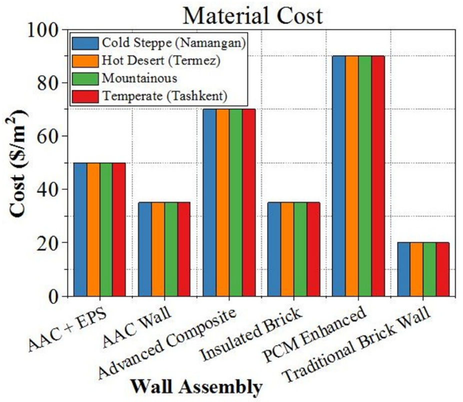

Fig 3. Material cost.

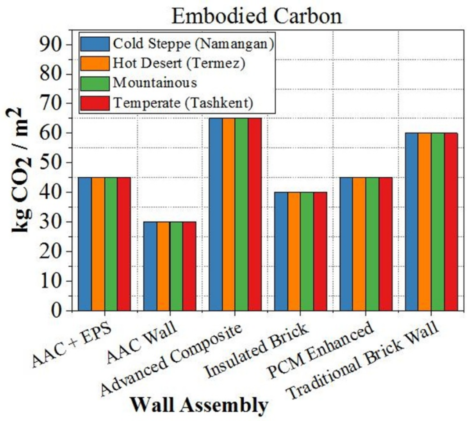

Fig 4. Embodied Carbon.

Figure 1 confirms the advantages of multilayer structures: the combination of AAC (0.14 W/m·K) with insulation reduces the U-value to 0.18 W/m^{2}K versus 2.8 W/m^{2}K for traditional bricks. Compares the heat transfer coefficients of various enclosing structures. As can be seen, combined solutions with AAC and insulating materials demonstrate 3-5 times better performance compared to traditional brickwork, which confirms the effectiveness of the proposed solutions. As can be seen in Fig. 2, in mountainous areas (Zone IV), PCM materials reduce the heating load by 38%, while in desert areas (Zone I) reflective coatings provide 22% savings on cooling.

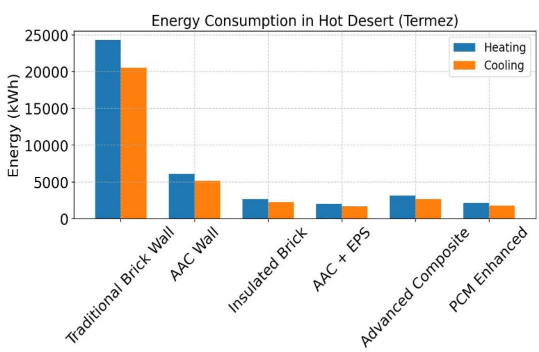

Fig 5. Energy Consumption in Hot Desert (Termez).

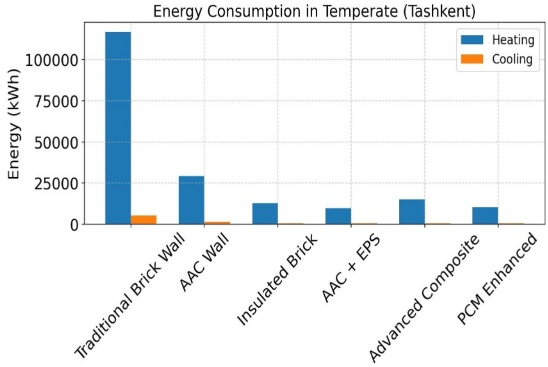

Fig 6. Energy Consumption in Temperate (Tashkent).

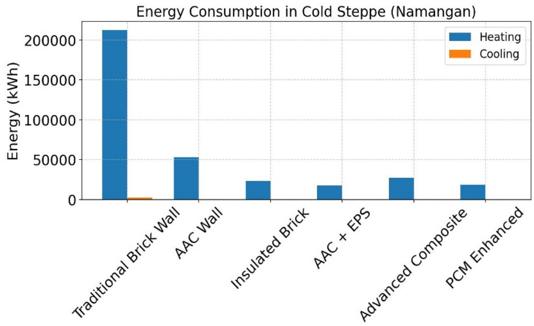

Fig 7. Energy Consumption in Cold Steppe (Namangan).

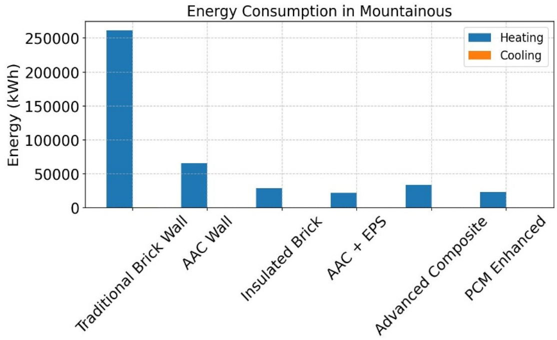

Fig 8. Energy Consumption in Mountainous.

The simulation results (Figures 2-5) demonstrate significant variability in energy consumption depending on the climatic zone. In mountainous areas (Zone IV), energy-efficient materials provide up to 45% savings on heating, while in hot desert regions (Zone I) they mainly reduce the load on cooling systems.

Material	Payback period (years)
AAC+EPS	4.2
SBR composite	5.8

Despite the higher initial costs (Figure 6), composite materials demonstrate an optimal price/quality ratio, taking into account the life cycle. Figure 7 shows that solutions with SBR composites also cut the carbon footprint by 20–30%.
One important finding is that autoclaved aerated concrete (AAC) blocks work better at keeping heat in than traditional fired clay bricks. AAC cuts heating costs by 30% in Tashkent's temperate continental climate. In colder areas like Namangan, savings can be as high as 40% because the material doesn't conduct heat well (0.11–0.16 W/m·K). This is in line with global research (Jelle, 2011) that shows AAC works to keep heat in cold places. In the hot desert areas of southern Uzbekistan (Termez, Bukhara), reflective roof coatings greatly lower the need for cooling. The model predicts that cooling loads will go down by 15 to 20%, which is in line with what the Lawrence Berkeley National Laboratory (Levinson & Akbari, 2010) found about cool roofs in dry areas. These coatings have solar reflectance values of more than 0.8, which means they don't absorb as much heat. This keeps the temperature inside lower and cuts down on the need for air conditioning. Adding phase-change materials (PCMs) to wallboards makes them even more efficient, especially in places where the temperature changes a lot during the day (like the outskirts of Tashkent). PCMs keep indoor temperatures stable by taking in extra heat during the day and letting it

out at night. This cuts down on HVAC runtime by 12–18%. This is very important for Uzbekistan's continental climates, where temperatures change by more than 15°C every day.

3.2 Regional Performance Variability

The study shows that materials work very differently in different areas: In places like Namangan and Andijan where heating is the main thing, AAC and expanded polystyrene (EPS) insulation save the most money (35–45%). In places where cooling is more important (like Termez and Nukus), reflective coatings and PCMs work best, lowering peak cooling demand by 20%. Hybrid solutions (AAC + PCMs) work best all year in places with mixed climates like Tashkent and Samarkand.

4 Conclusions and Recommendations

The research demonstrates the importance for Uzbekistan to utilize energy-efficient materials to address its challenges regarding energy sustainability, reliance on fossil fuels, and environmental degradation. The study shows that using advanced building materials like autoclaved aerated concrete (AAC), expanded polystyrene (EPS), reflective coatings, and phase-change materials (PCMs) can have a big effect on Uzbekistan's different climate zones by showing how they work and how much energy they can save. Adding these materials can cut heating and cooling energy use by up to 45%, depending on the climate and the building's design. The biggest gains are in cold steppe and mountainous areas. Using composite materials made from SBR-latex from the area also gives you more options for making insulation that lasts longer and has a smaller carbon footprint.
The findings support the national policy shift toward stricter Minimum Energy Performance (MEP) standards and the use of renewable energy. The present study provides evidence-based advice on how to choose building materials that are specific to a region in order to get the most energy efficiency out of them. It does this by using a reliable heat transfer model that has been tested against real-world data. It shows how important it is for technological innovation, climate-friendly material solutions, and government rules to all be in sync with each other. Uzbekistan can greatly lower its residential and commercial energy use, improve thermal comfort, lessen its impact on the environment, and strengthen its path towards a resilient and sustainable energy future by using more of these energy-efficient materials.

References

1. International Energy Agency (IAE), Uzbekistan Energy Profile. Typeset in France by IEA - October 2021. Website: www.iea.org.
2. Hou H. et al., Exploring the Role of Fossil Fuels and Renewable Energy in Determining Environmental Sustainability: Evidence from OECD Countries. Sustainability 2023, 15, 2048. https://doi.org/10.3390/su15032048.
3. H. Mikulcic, J. Baleta, J.J. Klemes et al., Energy transition and the role of system integration of the energy, water and environmental systems, Journal of Cleaner Production 292 (2021) 126027. https://doi.org/10.1016/j.jclepro.2021.126027.
4. A. Waqar et al., Evaluating the influence of modern construction methods on sustainable construction success, Cleaner and Responsible Consumption 19 (2025) 100327. https://doi.org/10.1016/j.clrc.2025.100327.

5. Juraboev N.I., Akhmadov, Kh S., Rashidov, K. Yu., Sobirov M.M. Assessing Thermal Performance of Glass-Envelope Absorber Tubes in Solar Parabolic Trough Systems. International Conference on Thermal Engineering, Volume 1, 15th International Conference on Thermal Engineering: Theory and Applications, ICTEA 2024.
6. A.A. Firoozi et al., Innovations in energy-efficient construction: Pioneering sustainable building practices, Cleaner Engineering and Technology 26 (2025) 100957. https://doi.org/10.1016/j.clet.2025.100957.
7. X. Zhang et al., Assessing the impact of energy efficiency and the sharing economy on sustainable economic development in China: A QARDL analysis from 1991 to 2020, Energy Strategy Reviews 59 (2025) 101729. https://doi.org/10.1016/j.esr.2025.101729.
8. S. Habibi, The promise of BIM for improving building performance, Energy and Buildings 153 (2017) 525–548. http://dx.doi.org/10.1016/j.enbuild.2017.08.009.
9. Khan, A.M., Alaloul, W.S., Ashrafi, S.M.Y. et al. Optimizing residential building energy efficiency through smart composite insulated panel systems. Discov Environ 3, 13 (2025). https://doi.org/10.1007/s44274-025-00196-9.
10. G.D. Ribeiro et al., Sustainable construction materials for low-cost housing: Thermal insulation potential of expanded SBR composites with leather waste, Journal of Materials Research and Technology 30 (2024) 5590–5604. https://doi.org/10.1016/j.jmrt.2024.04.234.
11. A.A. Hassanain et al., Effect of solar storage wall on the passive solar heating constructions, Energy and Buildings 43 (2011) 737–747. https://doi.org/10.1016/j.enbuild.2010.11.020.
12. Samiev, K.A., Halimov, A.S. Annual Thermal Performance of the Trombe Wall with Phase Change Heat Storage under Climate Conditions of Uzbekistan. Appl. Sol. Energy 58, 297–305 (2022). https://doi.org/10.3103/S0003701X22020189.