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Ensuring sustainability of thermal energy conservation in traditional houses in the Republic of Moldova

Asigurarea sustenabilității conservării energiei termice la casele tradiționale din Republica Moldova

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Abstract

The conservation of thermal energy in traditional winter homes in rural areas of the Republic of Moldova represents a current challenge due to the sustained increase in the prices of thermal energy resources. The construction industry is witnessing a shift towards greater energy efficiency, with minimal or even near-zero consumption. The main aim of this study is to conduct a comprehensive examination of current technologies and methodologies designed to enhance the energy efficiency of traditional residential structures while adhering to sustainability principles. The authors aim to carry out the analysis of thermal insulation materials for walls and to recommend practical solutions to help promote traditional energy-efficient housing.

Rezumat

Asigurarea conservării energiei termice în casele tradiționale de locuit pe timp de iarnă în localitățile rurale din Republica Moldova constituie o problemă actuală pe motiv ce prețurile la resursele de creare a energiei termice sunt în permanentă creștere. Progresele din industria construcțiilor indică o schimbare spre eficiență energetică cu consum minim sau chiar aproape de zero. Autorii își propun să efectueze o analiză amănunțită a tehnologiilor și metodelor actuale care vizează sporirea eficienței energetice a caselor tradiționale de locuit, respectând principiile de sustenabilitate. Studiul își propune analiza materialelor de izolare termică a pereților și recomandarea de soluții practice, care să contribuie la promovarea locuințelor tradiționale eficiente din punct de vedere energetic.

Keywords: *thermal energy, traditional house, sustainability*

Cuvinte cheie: *energie termală, casă tradițională, sustenabilitate*

1. Introduction

In the context of mounting concerns about the environment and energy efficiency, the conservation and optimisation of heat consumption in traditional houses

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is a topic of significant interest. [1, 2, 3, 4]. It is evident that traditional houses, in particular those constructed from adobe bricks, have significant cultural and historical value. However, it is also apparent that these structures frequently encounter difficulties with thermal insulation and excessive energy consumption. It is of paramount importance to enhance the energy efficiency of these dwellings if they are to remain viable in the long term. The utilisation of appropriate materials and technologies enables the optimisation of the thermal insulation of traditional houses, thereby reducing energy consumption and enhancing the comfort of residents.

The concept of sustainability is of paramount importance, particularly in light of the pressing issues of climate change and our dependence on finite energy sources. The term 'sustainability' is defined as the capacity to maintain an action or system over an extended period of time. In the field of construction, energy efficiency is of paramount importance. The traditional adobe house is a pertinent topic in this context.

The Republic of Moldova Ministry of Energy, the Consolidated Unit for the Implementation and Monitoring of Energy Projects (UCIPE), and the United Nations Development Programme (UNDP) are currently conducting an investigation into the potential of new approaches to thermal energy conservation in modern [5] and traditional residential buildings. This initiative, which has the support of international partnerships and recent legislative changes, has the potential to make a significant contribution to local energy efficiency and sustainable community development in the Republic of Moldova.

The Republic of Moldova has a long tradition of building houses from natural materials, but faces significant challenges in terms of sustainability and energy efficiency of traditional housing [6]. Traditional houses, constructed from adobe bricks, stone or wood, have a relatively low environmental impact. However, they are prone to significant heat loss, which results in high heating and cooling costs.

The study addresses the question of ensuring sustainability of thermal energy conservation in traditional houses in the Republic of Moldova. The study analyses the main characteristics of traditional houses in terms of energy performance, identifying potential solutions for sustainable thermal insulation of the envelope of traditional houses.

The objective of this study is to provide a comprehensive analysis of existing technologies and methodologies to improve the energy performance of traditional houses while respecting the principles of sustainability. Furthermore, the study will present effective solutions that will contribute to the promotion of more energy-efficient traditional housing, thus contributing to a more sustainable future for the Republic of Moldova.

2. Brief history

The construction of adobe houses in the Republic of Moldova has a long history, spanning centuries. The construction technique has been influenced by historical, geographical, and cultural factors, becoming an integral part of the architectural identity of the area.

Archaeological evidence indicates that the use of clay in combination with straw or straw in construction has been identified since the Bronze Age (3rd millennium BC). This evidence demonstrates a long tradition of the use of this material in construction.

The construction of adobe houses became more widespread in the 13th-16th centuries, coinciding with the emergence of urban centres and more developed rural communities.

In the 19th and 20th centuries, the construction of adobe houses continued to be a widespread practice, influenced by the architectural trends of the time. The construction of traditional adobe houses was adapted to the specific characteristics of each region, reflecting the distinct geographical and cultural characteristics of the area in question.

In terms of architectural design, traditional adobe houses were divided into three categories. The first was a one-room house, which was usually found in more remote villages or as a secondary summer accommodation. The second was the two-chambered house, which consisted of a truss and a pantry, with a four-sided hipped roof. The third was the three-chamber house, which was characterised by the addition of a new living room to the central space, with the aim of creating a clean room with valuables (Figure 1) [7]. They were perfectly adapted to the climatic conditions of the Republic of Moldova, providing protection against the cold and excessive heat.

The external appearance of the houses was created by plastering the walls with lime, which gave the impression that they were built of stone [8].

Patio, a platform in front of the house, was a common architectural element. The purpose of the patio was twofold: first, to protect the foundation from rain and second, to serve as a resting place.

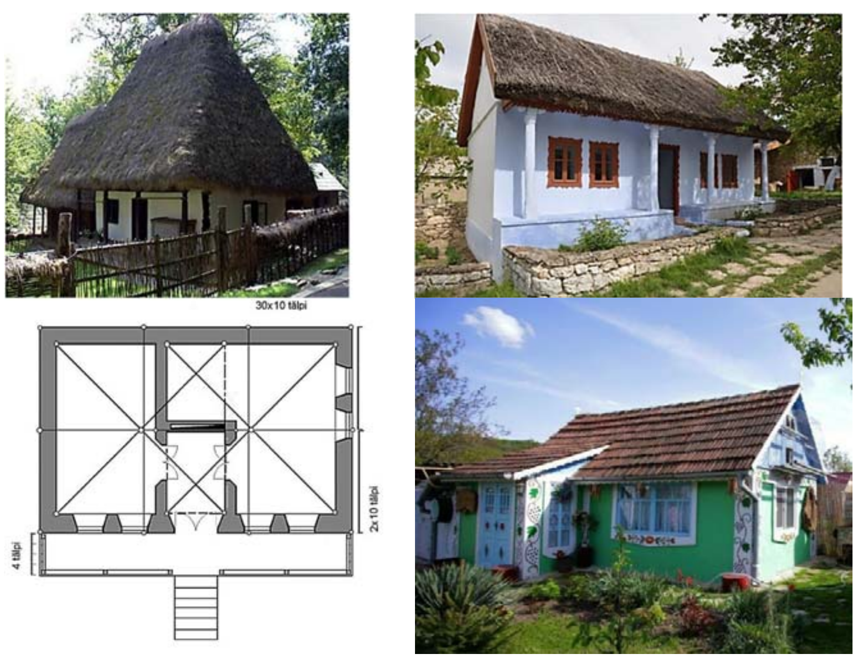

Figure 1. Traditional houses in the Republic of Moldova

The construction of the adobe houses was achieved using a straightforward and cost-effective methodology. Wall construction was carried out manually, with adobe bricks laid in layers and glued together with clay mortar (Figure 2). The clay, which was mixed with straw, was readily available and could be easily handled. The incorporation of straw into the composition imparted strength and elasticity to the material. Once the walls were erected, they were improved by applying a layer of clay plaster with horse chaff or baleen and glazing. This not only added a smooth and visually appealing finish, but also served as a protective barrier against moisture, ultimately contributing to the strength and longevity of the walls [9].

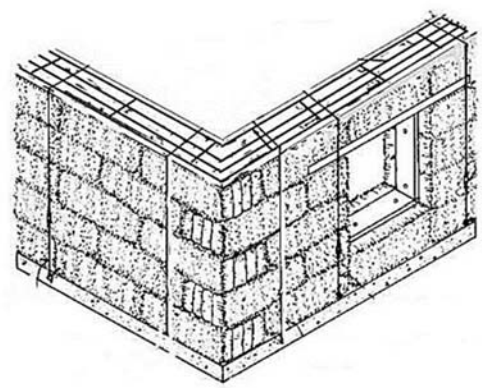

Figure 2. The structure of adobe walls [9]

The traditional adobe houses of the Republic of Moldova are imbued with a profound cultural significance, symbolising a rich heritage and a profound connection with nature. Such structures exemplify an ingenious adaptation to local resources, a respect for local traditions, and a sense of community.

3. Material and technology

In the present era, traditional adobe houses are confronted with a multitude of challenges, including those pertaining to energy efficiency and the adaptation of these structures to the prevailing standards of modern construction. Modernisation of these houses necessitates the implementation of intelligent solutions with the objective of improving thermal insulation and reducing energy losses, whilst simultaneously preserving the authentic characteristics of traditional construction.

In order to maintain the architectural integrity of the facade, an investigation was conducted to ascertain the suitability of natural materials for insulating the interior walls (Figure 3).

Figure 3. Types of sustainable insulation materials

In order to identify suitable insulation materials for traditional houses in the Republic of Moldova, a comparative analysis (Table 1) of the six materials shown in Figure 3 was carried out.

Table 1

Analysis of sustainable insulation materials

No.	Insulating material	Criteria: Breathability	Biodegradable	Fire resistance	Toxicity	Sound insulation	Cost	Country of production	Others
1	Sheep wool board	The material allows water vapour to pass through it, thereby preventing condensation and mould formation in the walls.	The material in question decomposes naturally, thereby reducing the environmental impact.	Sheep wool is fire resistant, contributing to a safe home.	The product does not emit any harmful chemicals into the atmosphere.	The material serves to absorb sound, thereby reducing noise from external sources.	12.50-13.00 euro/sqm	Romania	Sheep wool is a suitable choice for people with allergies as it is natural and hypoallergenic.
2	Cellulose board			Treated with mineral salts, cellulose is non-combustible, contributing to the safety of the home.			10.60 euro/sqm	Finland	
							38 euro/sqm	Moldova	

No.	Insulating material	Criteria							
		Breathability	Biodegradable	Fire resistance	Toxicity	Sound insulation	Cost	Country of production	Others
3	Wood fibre board			Wood fibres are treated with fire retardant to reduce the risk of fire.			12.50-44.50 euro/sqm	Germany	Wood fibres are a suitable choice for people with allergies as they are natural and hypoallergenic.
4	Hemp board			Hemp boards are flame retardant treated to reduce the risk of fire.			14 euro/sqm	Netherlands - Romania	Hemp absorbs CO_2 from the atmosphere, helping to combat climate change.
5	Cork board			Cork is fire resistant, contributing to the safety of the home.			29.00-42.80 euro/sqm	Portugal	Cork is a suitable choice for people with allergies as it is natural and hypoallergenic. Cork is a durable material that can last for decades.
6	Microfibre straw board			Microfibre straw is flame retardant treated to reduce the risk of fire.			10.65 euro/sqm	Poland	Straw microfibres are a suitable choice for people with allergies as they are natural and hypoallergenic. Straw absorbs CO_2 from the atmosphere, helping to combat climate change.

The utilisation of sustainable insulation materials in the construction of adobe-walled houses confers a plethora of advantages, both in terms of environmental impact and the well-being of those who reside therein. These natural materials are environmentally friendly, biodegradable, non-toxic, and have the capacity to regulate humidity and temperature within the home. Furthermore, the use of these materials can help reduce the energy expenditure required for the heating and cooling of buildings, thus reducing the environmental impact. The utilisation of these sustainable insulation materials facilitates the construction of a healthier and more balanced environment, with long-term sustainable benefits.

Figure 4 shows the fundamental technology utilised to implement interior thermal insulation utilising environmentally friendly materials. The process begins with the attachment of OSB plywood to the adobe wall, followed by the attachment of the wooden casing. Subsequently, the insulation material is installed in conjunction with a vapour barrier and plasterboard. The final step in the process is the application of decorative plaster to complete the wall.

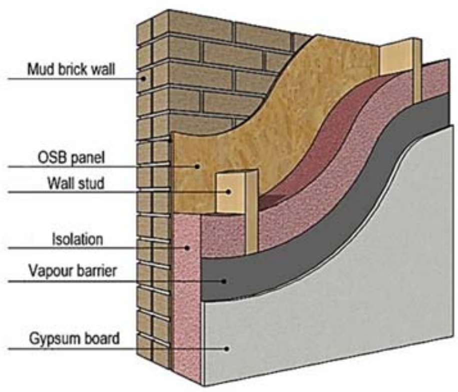

Figure 4. Technology of thermal insulation of adobe walls

The advantages of such insulation include the reduction of energy consumption, an improvement in the thermal efficiency of the home, and a reduction in the carbon footprint.

4. Improving wall energy efficiency

There is a growing focus on energy efficiency in buildings, with a shift towards near zero energy buildings (NZEB) and a strong emphasis on promoting environmental sustainability and resource efficiency. This trend reflects a wider move towards more sustainable and greener practices in the construction industry. In order to bring traditional houses up to the new requirements by incorporating modern technologies and sustainable materials, calculations on thermal resistance and thermal transmittance were proposed and are presented in Table 2.

Given that the typical thickness of adobe walls is 40 cm, and that the thermal conductivity of clay blocks with straw is 0.40 W/mK, the thermal resistance [10] was calculated to be 1.00 m^2K/W, while the thermal transmittance was found to be 1.00 W/m^2K. In accordance with European standards, houses should aspire to achieve NZEB [11], where the thermal resistance should be a minimum of 4 m^2K/W and the thermal transmittance a maximum of 0.25 W/m^2K.[12].

Table 2

Energy efficiency of sustainable solutions for thermal insulation of adobe walls

No	Type of thermal insulation	Input data Thermal conductivity (λ), W/mK	Thickness, cm	Thermal resistance (R), m^2K/W	Thermal transmittance (U), W/m^2K
1	*Thermal insulation with wool boards*			**4.687**	**0.213**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667
	Wool board	0.038	10.00	2.632	0.380
	Vapour barrier	0.400	0.02	0.001	1818.182
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.028	2.00	0.714	1.400
2	*Thermal insulation with cellulose boards*			**4.619**	**0.216**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667
	Cellulose board	0.039	10.00	2.564	0.390
	Vapour barrier	0.400	0.02	0.001	1818.182
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.028	2.00	0.714	1.400
3	*Thermal insulation with wood fibre boards*			**4.121**	**0.243**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667
	Wood fibre board	0.040	8.00	2.000	0.500
	Vapour barrier	0.400	0.02	0.001	1818.182
	OSB board	0.130	1.50	0.115	8.667
	Aerogel plaster	0.028	2.00	0.714	1.400
4	*Thermal insulation with hemp boards*			**4.107**	**0.244**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667
	Hemp board	0.039	8.00	2.051	0.488
	Vapour barrier	0.400	0.02	0.001	1818.182
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.028	2.00	0.714	1.400
5	*Thermal insulation with cork boards*			**4.643**	**0.215**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	Cork board	0.037	10.00	2.703	0.370
	Vapour barrier	0.400	0.02	0.001	1818.182
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.028	2.00	0.714	1.400
6	*Thermal insulation with microfibre straw boards*			**4.217**	**0.237**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667
	Microfibre straw board	0.037	8.00	2.162	0.463
	Vapour barrier	0.400	0.02	0.001	1818.182
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.028	2.00	0.714	1.400

A summary of the findings is presented in Figure 5, which illustrates that the use of thermal insulation materials, including sheep wool boards, cellulose boards, and cork boards, results in enhanced energy performance of traditional houses in the Republic of Moldova.

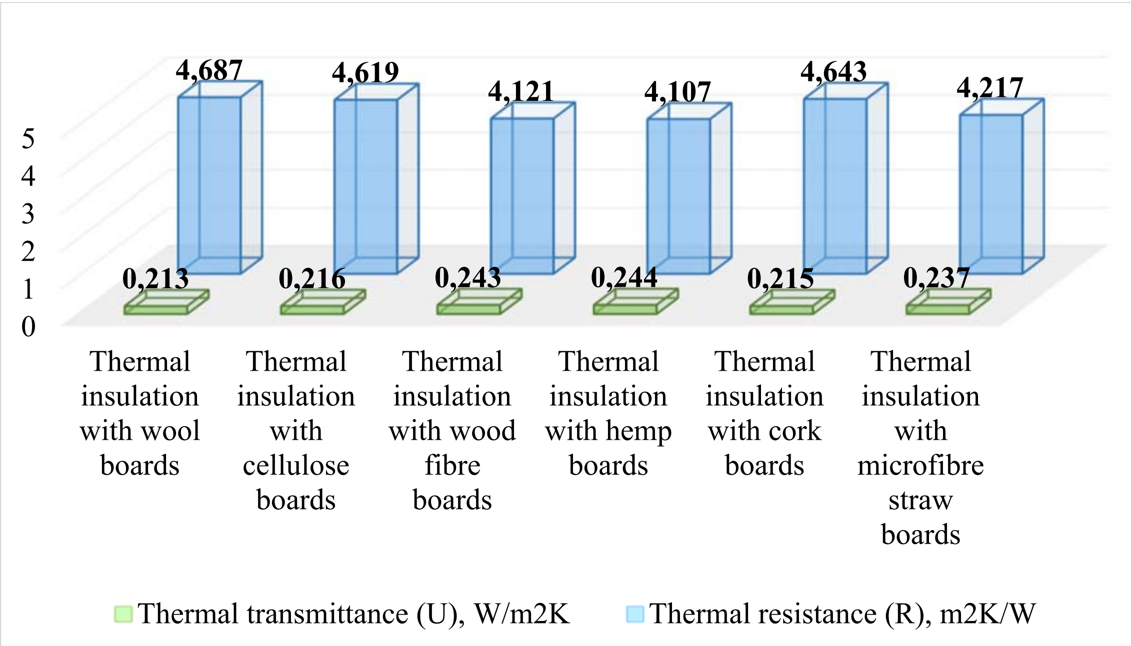

Figure 5. Presentation of data on the energy efficiency of thermal insulation for adobe walls

To gain a more comprehensive understanding, calculations were carried out on the energy efficiency of adobe walls with thermal insulation using the most common materials, including mineral wool, expanded polystyrene and polyurethane foam.

Table 3

Energy efficiency of solutions for thermal insulation of adobe walls

No.	Type of thermal insulation	Input data Thermal conductivity (λ), W/mK	Thickness, cm	Thermal resistance (R), m^2K/W	Thermal transmittance (U), W/m^2K
1	*Thermal insulation with expanded polystyrene*			**4.367**	**0.229**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	Adhesive	0.080	2.00	0.250	4.000
	Expanded polystyrene EPS100	0.034	10.00	2.941	0.340
	Aerogel plaster	0.400	0.02	0.001	1818.182
2	*Thermal insulation with mineral wool*			**4.199**	**0.238**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667

No.	Type of thermal insulation	Input data: Thermal conductivity (λ), W/mK	Input data: Thickness, cm	Thermal resistance (R), m^2K/W	Thermal transmittance (U), W/m^2K
	Mineral wool	0.035	10.00	2.857	0.350
	Vapour barrier	0.400	0.02	0.001	1818.182
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.400	0.02	0.001	1818.182
3	*Thermal insulation with polyurethane foam*			**4.198**	**0.238**
	with αe + αi			0.175	
	Adobe wall	0.400	40.00	1.000	1.000
	OSB board	0.130	1.50	0.115	8.667
	Polyurethane foam (closed-cell)	0.021	6.00	2.857	0.350
	Gypsum board	0.250	1.25	0.050	20.000
	Aerogel plaster	0.400	0.02	0.001	1818.182

The insulation of adobe walls with expanded polystyrene or mineral wool will require a thickness of 10 cm to achieve the necessary energy efficiency requirements, whereas the use of closed-cell polyurethane foam will necessitate a thickness of 6 cm.

5. Conclusion

The research presents potential technologies for thermal insulation of adobe walls of traditional houses in the Republic of Moldova, with a focus on energy performance analysis.

A critical analysis of the six types of sustainable solutions for thermal insulation of adobe walls reveals the following conclusions:

- The proposed solutions permit the passage of water vapour, thereby preventing condensation and mould formation in the walls. Furthermore, they are composed of biodegradable materials that do not emit toxic substances into the environment and provide effective sound insulation;
- The proposed solutions are fire-resistant, having undergone a flame retardant treatment;
- Sheep wool board, wood fibre board, cork board and microfibre straw board solutions are suitable for allergy sufferers as they are manufactured from hypoallergenic materials;
- The analysis of the energy efficiency of sheep wool, cellulose and cork solutions indicates a thermal resistance of greater than 4.6 W/m^2K and a thermal transmittance of less than 0.22 m^2K/W. In comparison to the most commonly utilised materials, the proposed solutions demonstrate superior energy performance with a thickness of 10 cm;
- From a financial perspective, the thermal insulation solution comprising cellulose boards imported from Finland is likely to be more cost-effective than the other proposed solutions.

In conclusion, it is of paramount importance to prioritize the sustainability of thermal energy conservation in traditional houses in the Republic of Moldova. This will facilitate a reduction in energy consumption, the conservation of natural resources, and the protection of the environment. The study demonstrated that there is a wide range of practical and effective solutions to improve thermal energy conservation in traditional houses without affecting their authenticity. The implementation of the sustainable solutions presented will result in traditional homes becoming more energy efficient, thereby reducing heating costs, carbon emissions and negative environmental impacts. Furthermore, it will ensure the comfort of residents and contribute to the preservation of cultural heritage.

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