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Energy efficient renovations and costs in existing building society houses

Mevcut kooperatif yapılarında enerji etkin yenilemeler ve maliyetleri

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Energy Efficient Renovations and Costs In Existing Building Society Houses

Highlights

- *Energy Efficient Renovation*
- *Housing Cooperatives*
- *Use of Local Materials*

Graphical Abstract

Considering that the energy problem is increasing day by day, the amount of energy consumed by existing buildings is too high to be ignored. In the studies conducted, it was observed that there was inadequacy in the use of local materials and cost. For this purpose, the energy efficient renovation costs in mass housing were examined through the selected building group and a contribution was made to the literatüre.

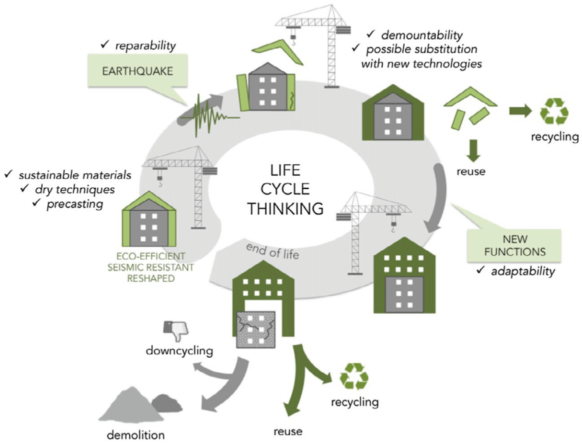

Figure. Building Life Cycle (Life Cycle Assessment, 2022)

Aim

A renovation approach was made through a Yapı Konut Kooperatif production selected as a study area in Avanos district of Nevşehir Province. It was aimed to contribute to energy efficient renovations by using local materials and making energy and cost calculations.

Design & Methodology

In the study, the Bep-TR regulation and the Bep-TR application, which is dependent on the regulation, were selected as the method. The current energy status of the selected residences and the energy consumption and carbon emission amounts after the proposed renovation approach were determined through the selected program.

Originality

Although many studies have been conducted on energy and cost, it has been seen that studies on the use of local materials and cost in renovations are insufficient and this study has contributed to the literature.

Findings

Within the scope of the study, the current status of the houses was evaluated and renovation suggestions were made in light of the legislation. Energy gains and cost calculations of the energy efficient renovation of the houses were made. In addition, the cost of using local materials and its effect on energy were revealed. As a result, 44% savings were achieved in energy and greenhouse gas emissions..

Conclusion

The energy consumption values of Insurance Houses in Avanos were discussed. The current energy consumption values of the houses were calculated with the Bep-BUY software. Renovation approaches were made to reduce energy consumption values and meet legal obligations. It was observed that approximately 44% energy and 43% carbon emission gains were achieved with the renovations.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Energy Efficient Renovations and Costs In Existing Building Society Houses

(This article is produced from Dilan Sarıkaya's Master's Thesis titled "Energy Efficient Renovation and Cost Analysis of Existing Buildings, The Example of Yapı Konut Cooperative in Avanos"..)

Araştırma Makalesi / Research Article

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ABSTRACT

The search for new resources has begun to meet the energy needs of the increasing world population, and the efficient use of existing resources has become important. In residences, which have a large share in the consumed energy, it is considered important to reduce the amount of energy used. Although many studies are conducted in this field, studies on the use of local materials and costs in renovations are insufficient. For this purpose, a renovation approach was made through a Yapı Konut Kooperatif production selected as a study area in Avanos district of Nevşehir Province. The Bep-TR regulation, which is mandatory in our country, and the Bep-TR application, which is dependent on the regulation, were selected as the method in the study. The current energy status of the determined residences and the energy consumption and carbon emission amounts after the proposed renovation approach were determined through the selected program. The current energy classes of the buildings were determined as F156. The proposed renovation approaches were planned in a way that would meet the legal obligations for the energy class of the building (C 99). In addition, the energy values and costs of the stone coating application, which is a local material, were evaluated in the renovation approaches.In the study, it was observed that 43% energy and 44% carbon emission savings were achieved in two different renovation proposals. It was observed that the cost was high in the case of using local materials. However, stone cladding was seen to be preferable due to its high durability and sustainability. The study is expected to guide energy-efficient renovations in mass housing.

Keywords: Energy Efficient Renovation, Housing Cooperatives, Use of Local Materials.

1. INTRODUCTION

With the industrial revolution, energy has become indispensable for human life. With the development of technology, energy has become necessary in every area of life [1]. The increasing world population, changing human needs and the differentiation of living standards continue to increase the need for energy. In order to obtain the required energy, existing resources must be operated or renewable energy sources must be used [2]. The fact that existing resources can be exhausted and the damage to the atmosphere caused by the gases produced while obtaining energy from these resources constitute another problem for the future of the world. For a livable world, the use of renewable energy sources and saving existing energy are considered important [3].

Buildings have a large share in the energy consumed. According to Peter Bakker, the president of the World Business Council for Sustainable Development (WBCSD); buildings are the largest energy consumers in the world economy, accounting for more than one-third of final energy use and approximately 30% of global carbon emissions [4]. Buildings consume energy throughout their entire life cycle, from construction to demolition (Figure 1). They continue to consume energy throughout the entire process, from the production of the building's structural elements to the construction phase, from the usage period to demolition and recycling phases [5].

Global problems such as the increasing need for energy, the decrease in energy resources, and the damage to nature during energy production have become problems for all countries [6]. In order to maintain the current situation and to encourage renewable resources, solution proposals are being produced on a national and global scale.

2. BEP-TR APPLICATION

Global The Ministry of Environment and Urbanization is making legal arrangements to provide solutions to factors such as environmental concerns, limited energy resources in the face of rapidly increasing energy consumption, climate crisis, and economic reasons. In this context, the "Regulation on Thermal Insulation in Buildings" was published in 2008 for buildings, which are a major source of energy consumption [7]. The regulation includes the necessary procedures, methods, standards, and methods to calculate the energy consumption value of buildings. With the prepared national calculation method (BEP-TR), the Energy Identity Certificate (EIC) is given, which includes the building's energy consumption value, CO_2 emission rate, heating, cooling, lighting, and renewable energy usage information [8]. EIC can be given to residential, office,

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hospital, education, hotel, and shopping mall buildings. In addition, the housing category is considered as detached, apartment, and residence. First made mandatory for new buildings constructed after 2010, EIC has become mandatory for all buildings as of 2020 [9]. Since it is mandatory to apply it in all buildings across the country, Bep-TR was selected as the energy calculation method within the scope of the study.

A national software program was created within the framework of the "Energy Efficiency Law" and the "Energy Performance Regulation in Buildings", which was established to reduce energy consumption and prevent air pollution. The Building Energy Performance Application First Version (BEP-TR 1) software, which will create the EIC document showing features such as energy consumption, CO_2 emissions, and insulation information of buildings, was published in 2011 [10]. With the application prepared by the Ministry of Environment and Urbanization, the parameters affecting the energy consumption of existing and new buildings are examined and the energy performance classes of the buildings are determined [11].

While preparing the software, the method detailed in the "Communiqué on the National Calculation Method for Energy Performance in Buildings" published on 05.12.2008 was used [10]. Basically, while making the calculation, if TS is insufficient for EU and national values, ASHRAE is used. The codes, names and the legislations from which they were taken are given below (Table 1) of the standards and documents used in the preparation of Bep-TR.

Table 1. Bep-TR standards used [12]

Standard number	Name (English)
EN 13790	Energy Performance of Buildings - Calculation of Energy Use for Space Heating and Cooling
EN 13789	Thermal Performance of Buildings - Transmission Heat Loss Coefficient - Calculation Method (ISO 13789: 1999)
EN 15251	Indoor Environment Criteria for Design and Calculation of Energy Performance of Buildings
TS 825	Rules of Thermal Insulation in Buildings
EN ISO 14683	Thermal Bridges in Building Construction- Linear Thermal Transmittance- Simplified Methods and Default Values (ISO 14683:2007)
EN 10456	Building Materials and Products - Hygrothermal Properties - Tabulated Design Values and Procedures for Determining Declared and Design Thermal
BS EN 12524	Building Materials and Products. Hygrothermal Properties. Tabulated Design Values
BS EN 12524	Conventions for U-Value Calculations
TS 2164	Project Guidelines - Central Heating Installations
DIN 18599	Energy Efficiency of Buildings - Calculation of the Net, Final and Primary Energy Demand for Heating, Cooling, Ventilation, Domestic Hot Water and Lighting
EN 13370	Thermal Performance of Buildings - Heat Transfer Via the Ground - Calculation Methods
2005 ASHRAE	Fundamentals Handbook

In this application, the simple hourly calculation method, which is a semi-dynamic calculation method, has been adopted [13]. The system determines the energy performance class by comparing the default building and the imaginary building [14]. The reference building is an imaginary building with the same location as the original building, the same dimensions, but providing minimum compliance with the regulations in terms of mechanical system and building component features. In other words; it is a digital twin with the minimum energy values that must be provided. The reference building is automatically defined by the system according to the project information [15].

The energy class of the building is determined by comparing the energy consumption per square meter and the CO_2 emission value of the original structure and the ghost structure. In order to calculate the energy consumption of the building; building location and title deed information, building geometry, heating, cooling, ventilation, lighting and building component information and building zones must be entered into the system (Figure 1) [10].

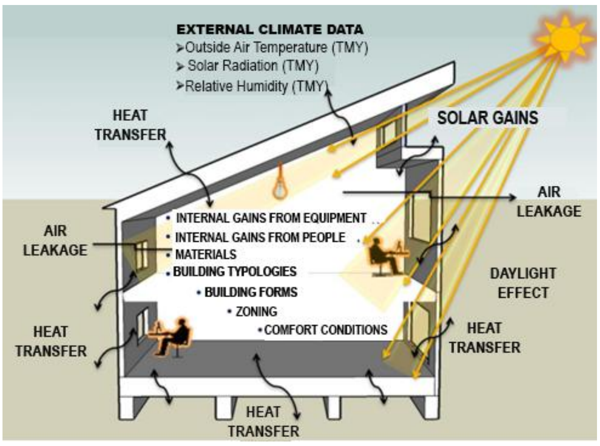

Figure 1. Bep-TR Inputs Determining EP Class [12]

The Energy Performance (EP) class D performance value of the reference building is 100. Energy classes are shown according to EP values and the same values are used for CO_2 emissions (Table 2) [10].

Table 2. Energy Classes According to EP Values

Energy Performance Ranges	Energy Class
0-36	A
40-79	B
80-99	C
100-119	D
120-139	E
140-174	F
175-	G

After the application was put into use, the second version was worked on to resolve the problems and deficiencies encountered, and in 2017, the Building Energy Performance Application Second Version (BEP-TR 2) was published and started to be used [14]. The Bep-TR 2 version consists of 2 basic parts that work online and offline on the desktop. The online system is the Ministry of Energy Performance in Buildings end software (Bep-BUY), and the internet-based server application is called Bep-IS [10]. In general, the system is seen to consist of two steps (Figure 2). The Bep-TR application can be downloaded from the Ministry of Environment, Urbanization and Climate Change website and used by authorized users.

With the Bep-BUY application, all data regarding the building can be uploaded to the system and preliminary calculations of greenhouse gas emissions can be made with the EP value [16]. The system can work online or offline, and calculations can be made automatically without any authorization. In this way, the current EICs of the houses and the EICs obtained after the proposed renovation were calculated through Bep-BUY within the scope of the study (Figure 2) [10].

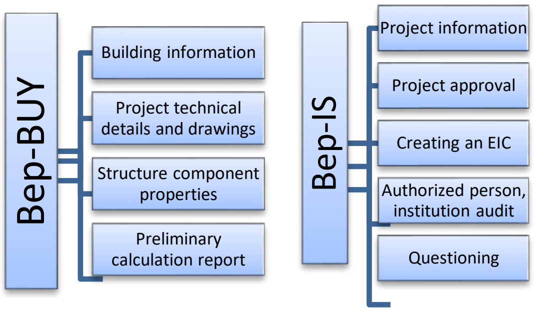

Figure 2. Scope of Bep-BUY and Bep-IS Study

All information entered on the building name via Bep-TR is also used in the creation of the reference building. The building energy performance value is determined by comparing the annual energy consumption per m² of the building with the annual energy consumption per m² of the reference building. The same approach is applied to CO_2 emissions. According to the calculation method; cities are divided into 4 different climate zones, and the highest U (Thermal Transmittance Coefficient) values that should be accepted for each zone are determined. U values are given separately for roof, floor, wall and window (TS825, 2008).

The recommended values are also considered as the U values of the reference building and the solar energy transmittance coefficients of the transparent component. The building energy performance, which determines the energy class, is calculated with the following formula for energy consumption:

$$E_p, EP = 100\ (EP_a\ /\ EPr) \quad (1)$$

Ep: Energy performance of the building
EP: Annual energy consumption amount per m² of the building, converted to primary energy (kWh/m2 -year),
r: Reference building,
a: The actual building.

The following formula is used for CO_2 emissions:

$$E_{p,SEG} = 100\ (SEG_a\ /\ SEG_r) \quad (2)$$

SEG: It expresses the annual CO_2 emission amount per m² of the building (kg-CO_2/m² -year) (Building Energy Performance Calculation Method, 2017; Yiğit, 2013).

The building energy class is defined according to the determined Ep value. The E_p value of the reference building is taken as 100 and the energy class is determined as D. The energy performance class and CO_2 emission classes are determined with the same evaluation system.

The study area is located in the 3rd Region of Avanos district of Nevşehir province. The external wall heat transmittance value to be presented in the renewal approach must be UD: 0.50, UT: 0.30 and below. While selecting the material in the renewal approach, the technical properties of the heat insulation material were decided using this calculation.

3. COOPERATIVE HOUSES

The role of construction cooperatives in housing production did not exceed 10% until the 1970s, but with the cooperation with municipalities in the 1970s, it increased to 15% by 1980 [17]. With the establishment of the cooperatives' upper organizations and the Mass Housing Law enacted in 1984, cooperative housing production increased and reached its highest level in 1986. While it was around 16% in 1980, it increased to 36% in 1986 [18]. Due to the legal regulations, restrictions on credit opportunities, and TOKİ and the private sector taking a more active role in housing production, cooperative housing production decreased after 2000. Today, this rate has dropped to 1% [19].

Within the framework of Law No. 3476, cooperative unions were established by the coming together of at least 7 cooperatives, and central unions were established by the coming together of cooperative unions. According to the data on the official website of the Ministry of Commerce, there are a total of 3 central unions, 338 sub-unions of these centers, 54,996 Housing Construction

Cooperatives affiliated to these unions and a total of 1,985,076 members [20].

In this context; the first established upper organization is the "Central Union of Turkish S.S. Construction Cooperatives" (TURKKONUT). The upper organization, established in 1985, was established with the aim of "producing policies for housing production, contributing to the country's economy, making the construction sector economical and rational, disciplining and supervising housing cooperatives, guaranteeing the savings of construction cooperative partners, and ensuring that they have a cheap, solid, reliable and high-quality home." There are 225,000 partners under the central union through 12 unions (Table 3) and 1347 cooperatives. Houses have been delivered to 200,000 of these partners and the construction of 25,000 houses is ongoing [21].

Table 3. TURKKONUT Sub-Unions

Affiliated Cooperatives
Altındağ Housing Production Building Cooperatives Union
Western Union Housing Construction Cooperatives Union
Berk-Ay Housing Construction Cooperatives Union
Beysan Workplace Building Cooperatives Union (Istanbul)
Fatih Housing Construction Cooperatives Union
Hasret Housing Cooperatives Union
Izmir Construction Cooperatives Regional Union
Kale Housing Production Building Cooperatives Union
Pazar Housing Cooperatives Union
Serhat Housing Construction Cooperatives Union
System Housing Cooperatives Union
New Zafertepe Construction Cooperatives Regional Union (Kütahya)

Another superstructure, the "Central Union of Turkish Urban Cooperatives (TÜRKKENT)" was established in Ankara in 1988. The union, which was formed by the merger of 14 sub-unions, today has 32 sub-unions, 790 active cooperatives affiliated to them and around 37,000 members. Within the scope of the central union, a total of 2200 Housing Construction Cooperatives affiliated to 45 housing construction cooperative unions have become members and more than 240,000 houses have been constructed. Today, there are 7 Housing Construction Cooperative Unions that continue to provide service (Table 4) [22]. Information on the 3rd superstructure could not be accessed.

3.1. Building Society Houses

Building Society Houses, a Yapı Konut Kooperatifi located in Avanos district of Nevşehir province, was selected as the study area. Building Society Houses is a housing community consisting of 54 blocks and 108 independent units, the construction of which started in 1975 (Figure 3).

Table 4. Active Housing Construction Cooperative Unions that are TÜRKKENT Members

Cooperative Unions	**City**
ADANA- COOP	ADANA
ANT- COOP	ANTALYA
DİCLE- COOP	DİYARBAKIR
ERYAMAN- COOP	ANKARA
KENT- COOP	ANKARA
HOUSING-UNITION	İSTANBUL
YESILKENT	İSTANBUL

The garden blocks consist of a ground floor and 1 normal floor. There is an independent section on each floor. The houses have a plan scheme consisting of 3 rooms, a living room, a kitchen, wet areas and 2 small balconies (Figure 4-5). The project and application information of the structure could not be found in official records. The necessary information was obtained by on-site measurements and interviews with the users [23].

Figure 3. Building Society Houses Location

Figure 4. Building Society Houses layout plans

Figure 5. Building Society Houses

The houses are built with 20 cm masonry load-bearing brick walls. Black plaster (cement-based plaster) and paint were applied to the outer and inner surfaces of the walls, and the inner parts were repaired with gypsum plaster over time. The stairs are reinforced concrete pillared carriers with mosaic casting on them. The windows, wooden frames and glasses are made of single glass. Since the wooden joinery was exposed to rain and air and wore out over time, heating problems increased and over time it was replaced with PVC joinery and double glass by the users. The main entrance door of the building was manufactured as a non-heat-insulated metal door (Figure 6).

Figure 6. Addition to the Garden

Since the houses were built before the "Heat Insulation Regulation", there is no thermal insulation application in any of the building components. Information on thermal insulation materials for the foundation, floor and roof could not be obtained. In the examination, the floor layers resting on the ground were determined as cast mosaic flooring on unreinforced lean concrete. The intermediate floor flooring was accepted as 4 cm cast mosaic on 15 cm reinforced concrete flooring in its original construction. The exterior and interior walls were calculated as black plaster on 20 cm brick. The roof covering material was tile flooring on a wooden structure.

Buildings heated with solid fuel stoves were converted to natural gas heating with the arrival of natural gas. Hot water needs were also converted to natural gas, and it was observed that some blocks used solar energy systems. However, since this application was seen very rarely, solar energy was not taken into account when calculating energy consumption. Since the majority of users used LED or energy saving bulbs for lighting elements, average values were taken into account.

4. CURRENT STATUS ENERGY CLASS

The Bep-TR application selected the building type with the location and construction information of the building and created a project. Floor plans were created with the program and details of the building components were selected. The heating, hot water and lighting information of the block with a total construction area of 220 m² were entered. Since photovoltaic system, cogeneration system, mechanical cooling and ventilation systems were not used in the houses, no data entry was made in these sections.

As a result of the information entered into the system, the Thermal Transmittance Coefficient (U Value) of the building components was calculated (Table 5). In line with these values, the system calculates the energy consumption and CO_2 emission amounts of the building. The energy and carbon class of a block belonging to Building Society Houses was determined as F156 (Table 6).

Table 5. Current Situation U Values

Building Components	U Values
Outer wall	1.63
Inner wall	1.45
Floor-Sit Flooring	1.80
Mezzanine Flooring	3.68
Attic Flooring	4.00
PVC Window	1.50
Roof Covering	0.98

The total energy consumption of the building was calculated as 375.67 kWh/m².year per m², and the carbon emission amount was 88.21 $kgCO_2/m^2$.year. When the total values were examined, it was observed that the most energy was used for heating needs. It constituted approximately 94% of the total energy used. 350.04 kWh/m².year of energy is used to meet the heating need for one m² area. The amount of CO_2 released while meeting this energy was revealed as 82,04 $kgCO_2/m^2$.year (Table 6).

It was observed that the largest share after heating belongs to Sanitary Hot Water with a rate of 5%. The

Table 6. Current Energy Consumption

	Annual energy consumption				Renewable energy				
	Final (kWh/year)	Primary(kWh/year)	(kWh/M2.year)	(kgCo2Wh/M2.year)	Primary(kWh/year)	(kWh/M2.year)	(kgCo2Wh/M2.year)	building class	Co2 class
	Final	Primary	M2	M2Co2	PrimaryRegen	M2Regen	M2Co2Gain	EkbClass	Co2Class
Total	71040,06	72327,39	375,67	88,21	0,00	0,00		F 156	F 156
Heating	66855,87	67393,61	350,04	82,04	0,00	0,00		F 160	
Sanitary Hot Water	3407,04	3459,53	17,97	4,22	0,00	0,00		D 101	
Cooling	14,27	27,07	0,14	0,04	0,00	0,00		A 29	
Ventilation	0,00	0,00	0,00	0,00				D 100	
Lighting	762,88	1447,18	7,52	1,92				G 233	
Photovoltaic					0,00	0,00	0,00		
Cogeneration									

Direct Greenhouse Gas Emission (m²): 84,6 amount of energy to be used to meet the need for sanitary hot water was calculated as 17.97 kWh/m².year per m², and the carbon emission of the consumed energy was calculated as 4.22 $kgCO_2$/ m².year (Table 6).

Another parameter, the amount of energy used for lighting, is less than other loads, but it accounts for 1% of the total energy. Lighting energy consumption is 7.52 kWh/m², and carbon emissions are calculated as 1.92 $kgCO_2$/m².year per m².

No mechanical system information regarding cooling was entered into the program. However, it was observed that calculations were made based on the system components of the building. Accordingly, while a total of 0.14 kWh/m² of energy was consumed for cooling in the building, the amount of CO_2 emissions was determined as 0.04 $kgCO_2$/m².year (Table 6).

When looking at the total values, the highest share in energy consumption is heating energy. While 94% of the total energy is heating loads, it accounts for approximately 93% of CO_2 emissions. After heating loads, the highest share of energy used in the building is sanitary hot water. The energy used to provide hot water accounts for 5% of the total energy, while it also has the same rates in carbon emissions. Lighting energy is responsible for 1% of the total energy and 2% of CO_2 emissions. It was observed that cooling loads are too small to affect the percentages (Table 7).

Table 7. Current Energy Consumption

	Energy consumption				**CO_2 Emission**	
	m² (kWh/ m².year)	**Primary (kWh/ year)**	**Energy Class**	**Rate**	**m² (kgCO₂/m². year)**	**Rate**
Heating	350,04	67.393,61	F 160	%93	82,04	%93
Sanitary Hot Water	17,97	3.459,53	D 101	%5	4,22	%5
Cooling	0,14	27,07	A 29		0,04	
Lighting	7,52	1.447,18	G 233	%2	1,92	%2
Total	375,67	72.327,39	F 156	%100	88,21	%100

4.1. Renewal Approaches

Existing houses need to be renewed due to reasons such as wear and tear during their use, inadequacy in meeting comfort conditions, and systems that are used falling behind technological developments. Especially buildings built before the 2000 "Heat Insulation Regulation" consume a lot of energy, especially for heating needs. With renovations, comfort conditions of users can be improved while energy consumption can be saved.

When the studies in the literature were examined, it was determined that the most effective renovation approaches were made through building facade and roof cladding. While Alveraz et al. [24] revealed that the most savings were made with facade and roof insulation in continental climates, Almedia and Ferreira. [25] determined that the most suitable option in terms of cost was the insulation on the building facade [24]. In addition, the studies showed that the most suitable insulation material for the facade was XPS and for the roof, stone wool was the thermal insulation material [26].

In this context, the renovation approaches in Avanos Sigorta houses selected as the study area were determined to cover the building facade and roof. In the renovation approaches, it was preferred to use suitable materials specified in the literature. While stone wool heat insulation material was selected for the building roof flooring, it was decided to use XPS on the facade. The thicknesses of the materials recommended to be used were determined in a way that would not meet legal obligations. After determining the current energy class of the building through the Bep-BUY program, a renovation approach was made in a way that would increase the energy class to level C. In addition, the stone coating application specific to the region, which is mandatory to be applied in the region, was also considered within the scope of the study and evaluated within the scope of cost and energy.

In order to increase the current energy class of insurance houses from F156 to C98, it was deemed appropriate to apply 4 cm of "Extruded Polystyrene Foam (XPS) with a thermal conductivity coefficient of 0.30" to the building facade and 2.5 cm of stone wool thermal insulation material with a thermal conductivity group of 0.035 to the roof deck (Table 8). In addition, a different renewal approach was made to evaluate the gains of using local and sustainable materials. In the second renewal approach, no change was made to the roof insulation material in order to reveal the effect of the stone coating used. On the other hand, the thickness of the XPS application to be made under the stone coating proposed to be applied to the building facade in order to achieve the same energy class in both options was determined as 3 cm.

Considering the cost of the proposed renovation approaches, economic fluctuations and their effects on costs, instead of evaluating them based on unit prices, calculations were made based on current market values. Since it was suggested to use local stone in particular, companies providing service in the region were consulted and an analyzed unit price list was prepared. During the price research, the prices of materials that would meet the heat conductivity values used in the calculations in the system were emphasized. In addition, transportation, loading and unloading, scaffolding, SSI, and general expense items were added to the cost (Table 8). Prices were taken on June 17, 2023 and the current dollar exchange rate was $23.62. According to the metering calculations, the total area where the facade application will be made was calculated by taking the window and door areas into account and a 5% loss share was given to the total metering. The total cost (X) is obtained by multiplying the unit price (y) and metering (z) formula.

$$X = y*z \quad (3)$$

X= Renewal Cost ($)

y= Unit price ($)

z= Quantity (m^2)

Table 8. Renovation Suggestions Wall Layers

	System Login	Thickness
Existing Wall Layers	L:1.000 – 04.01 – Lime mortar, lime cement mortar	3 cm
	"L:0.500 – 07.01.02.01 – Walls with solid or vertically perforated bricks in accordance with TS EN 771 – 1 - Brick walls"	30 cm
	L:1.400 – 04.06.01 – Cement mortar plaster	5 cm
1. Renewal Proposal Layers	L:0.070-04.10.01 – Thermal insulation plasters (in accordance with TS EN 998-1); Plasters with thermal conductivity group 070	1 cm
	Extruded Polystyrene Foam – in accordance with TS EN 11989 EN 13164; Thermal conductivity groups 030 - Extruded Polystyrene Foam (XPS) boards - synthetic foam materials	4 cm
2. Renewal Proposal Layers	L:0.070-04.10.01 - Thermal insulation plasters (in accordance with TS EN 998-1); Plasters with thermal conductivity group 070	0.8 cm
	Extruded Polystyrene Foam - in accordance with TS EN 11989 EN 13164; Thermal conductivity groups 030 - Extruded Polystyrene Foam (XPS) boards - synthetic foam materials	3 cm
	L:0,440-07.02.03 Lime sandstone walls (in accordance with TS 808 EN 771-2)	7cm

4.2. Post-Renovation Energy Classes

In the current situation, renewal proposals have been made to reduce heating loads, which are the biggest factor in energy consumption. With the renewal approaches suggested to be implemented, the energy class, which is F156, has increased to C98 in both options. While the total amount of energy consumed in the current situation is 375.61 kWh/m².year, it has been calculated as 214.46 kWh/m².year as a result of the first renewal proposal and 215.30 kWh/m².year after the second renewal proposal including stone cladding application. The heating load, which was 350 kWh/m².year, has decreased to 188.97 kWh/m².year in the first renewal approach and 190.35 kWh/m².year in the second renewal approach. While the amount of energy used for heating needs has decreased by 46%, the total amount of energy has decreased by 43% in both options. It has been observed that while the amount of energy used for hot water has decreased, the amount of energy spent for cooling has increased.

Table 9. Energy Consumption After Renovation

	Per Unit Area (kWh/m².year)					Energy Class		
	The current situation	After the First Renewal	Difference (%)	After the Second Renewal	Difference (%)	The current situation	After the First Renewal	After the Second Renewal
Heating	350,04	188,97	-%46	190,35	-%46	F 160	C 96	C 97
Sanitary Hot Water	17,97	17,6	-%2	17,18	-%4	D 101	C 99	C 97
Cooling	0,14	0,45	+ %221	0,45	+ %221	A 29	B 79	B 79
Lighting	7,52	7,43	-%1	7,32	-%2	G 233	G 233	G 233
Total	375,61	214,46	-%43	215,3	-%43	F 156	C 98	C 98

When the CO_2 emission amounts after the proposed renewal approach are compared, they are similar to the energy consumption values (Table 10). The amount of carbon released to obtain the energy used to meet the heating need, which has the largest share in greenhouse gas emissions, decreased by 44% per unit area per year after the first renewal proposal, from 88.21 kgCO₂/m².year to 43.14 kgCO₂/m².year. As a result of the second renewal proposal, a saving of 43% was achieved and the carbon emission, which is currently 82.04 kgCO₂/m².year, decreased to 50.63 kgCO₂/m².year after the renewal (Table 29). The amount of CO_2 released for

Table 10. Comparison of Greenhouse Gas Emissions Between Current Situation and Post-Renovation

	Per Unit Area (kgCO₂/m².year)				
	The current situation	After Renewal	Difference (%)	After Renewal	Difference (%)
Heating	82,04	43,09	-47%	44,62	-46%
Sanitary Hot Water	4,22	4,05	-4%	4,03	-5%
Cooling	0,04	0,13	+225%	0,12	+200%
Lighting	1,92	1,87	-3%	1,87	-3%
Total	88,21	49,14	-44%	50,63	-43%

hot water use was observed to decrease by 4% as a result of the first renovation proposal to be applied to the facade and roof, and by 5% after the second renovation proposal, from 4.22 kgCO_2/m².year to 4.05 kgCO_2/m².year and 4.03–43.09 kgCO_2/m².year, respectively (Table 10).

Unlike these, although there is no mechanical cooling system, it was observed that the carbon emission amount of the energy to be used for cooling increased by 225% for the first proposal and 200% for the second proposal. Despite the high increase rate, the emission amount is much lower compared to other factors. The greenhouse gas emission, which was 0.04 kgCO_2/m².year, increased to 0.13 kgCO_2/m².year as a result of the first renewal approach and to 0.12 43.09 kgCO_2/m².year as a result of the second renewal approach (Table 10).

Although the lighting data was not changed, the amount of CO_2 released to meet the energy consumed to meet the lighting need decreased from 1.92 kgCO_2/m².year per unit area to 1.87 kgCO_2/m².year for both proposals, resulting in a 3% gain (Table 10).

When the amount of carbon released per unit area of total consumption energy is examined, greenhouse gas emission, which is currently 88.21 kgCO_2/m².year, decreased by 44% to 49.14 kgCO_2/m².year after the first renewal proposal. Similar values were obtained as a result of the second renewal proposal, and it decreased to 50.63 43.09 kgCO_2/m².year with a 43% gain. While the CO_2 emission class is currently F156, it was observed that it increased to C 98 after the first renewal approach proposed to raise the energy class above C 99, and to C 99 after the second renewal (Table 10).

Comparing the results of the proposed renewal approach, it is observed that total energy consumption decreases by 43% in both options, while carbon emission decreases by 44% in the first renewal approach and 43% in the second renewal approach. While similar savings are achieved in both evaluation criteria, it is observed that the change in energy classes after renewal is similar. While the total energy gain of the insurance houses consisting of 54 blocks is 1,676,026.08 kW/m² for the first renewal proposal and 1,667,322.90 kW/m² for the second renewal proposal, the annual reduction in the amount of CO_2 released into the atmosphere is 2,109.78 kg CO_2/m².year per unit area in the first renewal approach and 2,029.32 kg CO_2/m².year after the second renewal approach.

Table 11. Renewal Cost Comparison

	Roof Cost	Wall Cost	Cost of a House	Cost of a Block	54 Block Cost
1. Renewal Proposal	419.136 $	6,729 $	3.574,84 $	7.149,68 $	386.083,15 $
2. Renewal Proposal	419.136 $	16.732,43$	8.575,78 $	17.151,56 $	926.184,58 $

When the cost evaluations of both renovation proposals are examined, the total cost for the first renovation after the application of thermal insulation to the building facade and roof is $7,149.68, while the cost of the stone coating application in addition to these insulations is calculated as $13,272.96 (Table 11). In the first renovation approach, the recommended thermal insulation thickness is 4 cm in order to achieve the desired energy level, while the second renovation proposal including the stone coating application uses 3 cm XPS by decreasing the thermal insulation thickness by 1 cm in order to obtain the same values. In addition, in the case of stone coating, the thermal insulation plaster and paint poses to be applied to the exterior facade are removed, while the mechanical system cost recommended for this coating is added.

In addition, the technical features of the thermal insulation material (XPS) used on the facade were kept the same, and their thicknesses were changed, and the energy gains in this case were evaluated. The same renovation approach was repeated with 6 cm XPS and 8 cm XPS. When the renovation was made with the 6 cm XPS application, it was observed that the energy class increased to C 94 and a total energy gain of 46% was achieved. It was observed that a gain of approximately 49% was achieved in the heating load energy, which has the largest share in the total energy (Table 12).

When the same process was repeated for 8 cm XPS, the building energy consumption class was calculated as C 91. While 47% of the total energy was saved, this rate reached 50% in the amount of energy used for heating.

When the amount of CO_2 emissions was compared, it was seen that similar gains were achieved. While the CO_2

Table 12. Energy Consumption After Renovation

	Per Unit Area (kWh/m².year)								
	The current situation	**After the First Renewal**	**Difference (%)**	**After the Second Renewal**	**Difference (%)**	**After the Third Renewal**	**Difference (%)**	**After the Fourth Renewal**	**Difference (%)**
Heating	350,04	188,97	-%46	190,35	-%46	179,78	-%49	174,19	-%50
Sanitary Hot Water	17,97	17,6	-%2	17,18	-%4	17,39	-%3	17,25	-%4
Cooling	0,14	0,45	+ %221	0,45	+ %221	0,41	+ %193	0,42	+ %200
Lighting	7,52	7,43	-%1	7,32	-%2	6,54	-%9	6,50	-%10
Total	375,61	214,46	-%43	215,3	-%43	204,12	-%46	198,36	-%47

class was calculated as C 94 for the 3rd Renewal approach, the CO_2 class increased to C 92 for the 4th Renewal approach (Table 13).

When the amount of CO_2 emission of the renovation approaches is examined, it is determined that the amount of gain provided increases with the increase in the thickness of the heat insulation material used. While the annual amount of CO_2 released decreased by approximately 45% from the 3rd renovation approach, this rate was calculated as 47% from the 4th renovation approach. Similar rates of gain were achieved in the amount of CO_2 released from the energy used for heating (Table 14).

As a result of the proposed renovation approaches, it has been determined that by increasing the thickness of the thermal insulation material used on the building facade, the building energy class increases and the amount of energy used by the building decreases (Table 15).

5. FINDING

The district of Avanos was chosen as the study area because of the long-term requirement of using local materials in building facade cladding. Avanos, which is a settlement on the northern and then southern shores of Kızılırmak, has had problems in creating a settlement area due to factors such as sloping terrain conditions, the impact of natural disasters on life, and the abundance of protected areas. Housing cooperatives, which were established with the aim of collaborating to produce solutions to these problems, play an active role in housing production in the region. The oldest housing cooperative with available data is Sigorta Evleri. While almost all of the housing cooperative houses built were in the southern part of the city where settlement later spread, “Sigorta

Table 13. Energy Consumption After Renovation

	The current situation	After the First Renewal	After the Second Renewal	After the Third Renewal	After the Fourth Renewal
Heating	F 160	C 96	C 97	C 92	C 89
Sanitary Hot Water	D 101	C 99	C 97	C 98	C 97
Cooling	A 29	B 79	B 79	C 82	C 83
Lighting	G 233	G 233	G 233	G 200	G 200
Total	F 156	C 98	C 98	C 94	C 91

Table 14. Energy Consumption After Renovation

Per Unit Area ($kgCO_2/m^2$.year)

	After Renewal	Difference (%)	Difference (%)	After Renewal	Difference (%)	After Renewal	Difference (%)	After Renewal	Difference (%)
Heating	82,04	43,09	-47%	44,62	-46%	42,23	-49%	40,92	-50%
Sanitary Hot Water	4,22	4,05	-4%	4,03	-5%	4,10	-3%	4,06	-4%
Cooling	0,04	0,13	+225%	0,12	+200%	0,12	+200%	0,12	+200%
Lighting	1,92	1,87	-3%	1,87	-3%	1,86	-3%	1,85	-4%
Total	88,21	49,14	-44%	50,63	-43%	48,30	-45%	46,95	-47%

Table 15. Comparison of Renewal Approaches

	The current situation	1. Renewal Approach	2. Renewal Approach	3. Renewal Approach	4. Renewal Approach
Wall U Value	1,635514	0,489054	0,540389	0,368809	0,296025
Roof U Value	4,000	1,037037	1,037037	1,037037	1,037037
Energy consumption	375,61 (kWh/m^2.year)	214,46 (kWh/m^2.year)	215,30 (kWh/m^2.year)	204,12 (kWh/m^2.year)	198,36 (kWh/m^2.year)
Energy Class	F 156	C 98	C 98	C 94	C 91
CO_2 Production	88,21 ($kgCO_2/m^2$.year)	49,14 ($kgCO_2/m^2$.year)	50,63 ($kgCO_2/m^2$.year)	48,30 ($kgCO_2/m^2$.year)	46,95 ($kgCO_2/m^2$.year)
CO_2 Class	F 160	C 98	C 99	C 94	C 92
Cost (m^2/dollar)		28,59 $	68,60 $		

Evleri" chose the northern part of the river as a settlement area. Due to these differences, "Sigorta Evleri" was selected as the study area and the application area.

Energy calculations were made using the architectural project created with on-site measurements of Sigorta Evleri and the Bep-BUY program, which is the software of the Bep-TR application. Two different renovation approaches were implemented to reduce the energy consumption value, and while calculating energy saving rates with these approaches, the effects of stone cladding applied in Avanos district on cost and energy consumption were evaluated. According to the data obtained, the primary energy consumption rate of the building was 72,327.39 kWh/m² per year, while the energy consumption per unit area was 375.67 kWh/m².year. The amount of carbon released while meeting this energy need was calculated as 88.21 $kgCO_2$/m².year per unit area. The energy and greenhouse gas emission class was determined as F156 (Table 16).

As a result of the studies carried out on the system; two different renovation proposals were made that would increase the total energy consumption class of the building above the C 99 level, and the insulation thicknesses to be used were calculated to provide this energy level. In the first renovation proposal, the building energy class could be increased to the C98 level by applying 4 cm 030 heat permeability coefficient XPS to the wall surface and 2 cm 035 heat permeability coefficient stone wool to the roof surface. With the second proposed renovation approach, no change was made to the stone layer laid on the roof, while the thermal insulation material (XPS) applied to the facade was reduced to 3 cm and it was assumed that stone coating was applied on it. With this application, the building energy class reached the C 98 level (Table 16).

With the proposed renovation approaches, the annual energy consumption value of the building decreased by 43%, reaching an average of 41,370.00 kWh/m², while the annual average per unit area was calculated as 215.00 kWh/m².year. Similarly, CO_2 emissions decreased by 44%, reaching an annual average of 50.00 $kgCO_2$/m².year per unit area (Table 16).

When looking at the individual energy consumption headings, the highest energy consumption is used for heating needs, while the lowest energy and carbon emissions are consumed for cooling needs. Therefore, the highest energy saving after the renovation occurs in heating energy. While a 46% decrease in heating energy is achieved, it is seen that cooling energy increases by 221% in both options (Table 16).

The cost of the renovation approach was calculated as $7,148,925 per building for the first renovation proposal and $16,732.43 for the second renovation proposal, according to current information received from companies implementing in the market. This cost is covered by $28,595, $68,606 per m² and $3,574,462, $8,575,783 for each residence, respectively (Table 12). It was observed that the cost of the applied stone coating was more than twice as much as the heat insulation application. One of the biggest factors for this was the mechanical system proposal. However, it should be kept in mind that the costs are short-term due to inflation differences and are constantly updated according to increasing inflation and changing exchange rates.

Generally speaking, the cost of the proposed thermal insulation renovation approach for the "Insurance Houses" consisting of a total of 54 blocks and 108 residences is $386,041.999, the total cost of the renovation approach including stone cladding application is $926,184.589, while the total energy gain to be achieved is determined as an annual average of 1,672,000.00 kW/m².

Table 16. Comparison of Renewal Approaches

	The current situation	**1.Renewal Approach**	**2.Renewal Approach**
Wall U Value	1,635514	0,489054	0,540389
Roof U Value	4,000	1,037037	1,037037
Energy consumption	375,61 (kWh/m².year)	214,46 (kWh/m².year)	215,30 (kWh/m².year)
Energy Class	F 156	C 98	C 98
CO_2 Production	88,21 ($kgCO_2$/m².year)	49,14 ($kgCO_2$/m².year)	50,63 ($kgCO_2$/m².year)
CO_2 Class	F 160	C 98	C 99
Cost (m²/dollar)		28,59 $	68,60 $

Within the scope of the section, the current status of the houses was evaluated and renovation suggestions were made in the light of the legislation. Energy gains and cost calculations of the energy efficient renovation of these houses were made. In addition, the cost of using local materials and its effect on energy were revealed. As a result, 44% savings were achieved in energy and greenhouse gas emissions.

5.1. Discussion and Result

Considering that the energy problem is increasing day by day, the amount of energy consumed by existing buildings is too high to be ignored [27]. The energy gain that can be achieved by energy efficient retrofitting of buildings constructed with traditional methods and in a time period when there are no legal obligations has been the subject of many studies in the literature.

Buildings that have a high share in energy consumption and are constructed with traditional methods, especially in periods when energy consumption is not limited by legislation, have much higher energy consumption rates. Considering the current building stock, reducing energy consumption with energy-efficient renovation becomes important [28]. Considering that energy consumption is intense at all hours of the day in residences, which account for one-third of energy consumption in our country, the renovations to be implemented will be effective in energy saving [29]. For this reason, energy-efficient renovation of existing residences and improvement of comfort conditions have been deemed important.

Within the scope of the Bep-TR application initiated under the control of Ministry of Environment, Urbanization and Climate Change in our country, as of 2011, the energy consumption values of all newly constructed buildings have been limited and the classification of energy consumption values has become mandatory for existing buildings. The Bep-TR certification calculation system has developed mandatory standards for heating, cooling, lighting and ventilation systems for new buildings [30].

Energy consumption is considered important in existing housing units built before 2000, when the legislation on energy efficiency had not yet developed and played an active role in energy consumption. Almost one third of the existing housing stock in our country was built between 1980 and 2000. During this period, housing cooperatives, which were mostly formed by low-income people, had a large share in order to provide the housing needed. Especially after 1980, due to their effectiveness reaching 40% in housing production, it was deemed essential to determine the energy consumption of housing units produced by housing cooperatives, the renovation approaches to be made for energy improvements and the costs of these approaches for users.

In this context; the energy consumption values of Building Society Houses, which is a housing construction cooperative product in Avanos and consists of 54 blocks and 108 housing units, were examined. The current energy consumption values of the housing blocks were calculated with the Bep-BUY software. Renewal approaches were made to reduce the energy consumption values of the current situation and to meet legal obligations. It was observed that approximately 44% energy and 43% carbon emission gains were achieved with the renewals. In the stone coating application on the facade, the thickness of the thermal insulation material was reduced to obtain similar data. While the amounts of gain in carbon emission were similar, it was observed that the greenhouse gas emission classes were C98 in the first proposal and C99 in the second renewal proposal.

The recommended thermal conductivity coefficient-U values for the 3rd Region, where the study area is located, are specified as 0.50 for the wall and 0.30 for the roof in the BEP regulation for the wall and roof layers where the renovations are made. While the renewal result U value recommended for the roof within the scope of the study is 1.037037, the wall U value as a result of the first renewal approach is 0.489054, and the wall U value as a result of the second renewal approach is 0.540389. Even if the recommended values are not met, the total energy class of the building is C99.

With the renovations, the highest gain was achieved in heating energy with a 46% decrease in both options. When the ratio of the heating load to the total energy is examined, it is seen that the gains obtained from heating energy are similar to the gains obtained from the total energy consumption of the building. Therefore, improvements in the heating load directly affect the building energy class. In line with the obtained data, it can be concluded that the thermal insulation applied to the building directly affects the natural gas consumption and the bills will decrease at the same rates. The same results were obtained in the second renovation proposal, the stone cladding option. The stone cladding application reveals that the reduction in the thermal insulation thickness used on the external wall is effective in meeting the thermal insulation function of the stone cladding.

The energy gain amounts obtained were calculated according to the renovation proposals prepared based on the energy level required for new buildings. The gains that can be obtained from the consumed energy will be much greater by increasing the thickness of the insulation materials used, replacing the lighting elements with energy-saving lighting elements, and using renewable energy sources.

When the costs of the energy gains obtained are examined, calculated with the current prices taken from the market, it is seen that the initial investment cost of the stone coating application is higher. The biggest factor in this is the selection of the mechanical system as the application system. It is thought that the cost will be reduced by selecting the adhesive system instead of this system. In addition, the natural stone material hardens as it is exposed to water and becomes more resistant to regional weather conditions. Its high resistance to abrasion, breakage and impacts also provides longer-term protection on the exterior. Thus, although the initial investment cost of the stone coating application is high, the maintenance and repair cost will be much lower than the cladding application. Since it will pay back the cost it creates for the users in the process, it is thought that stone coating is more suitable for the use of local materials, the protection of the urban texture and sustainability.

In addition to the 4 cm insulation material, the technical specifications of the thermal insulation material (XPS) used on the facade were kept the same and their thicknesses were changed, and the energy gains in this case were evaluated. The same renovation approach was repeated with 6 cm XPS and 8 cm XPS. When the renovation was made with the 6 cm XPS application, the energy class increased to C 94 and it was observed that 46% of the total energy was saved. In the 8 cm XPS, the building energy consumption class was calculated as C 91. While 47% of the total energy was saved, this rate reached 50% in the amount of energy used for heating. When the amount of CO_2 emission of the renovation approaches was examined, it was determined that the amount of gain provided increased with the increase in the thickness of the thermal insulation material used. As a result of the proposed renovation approaches, it was observed that the building energy class increased and the amount of energy used by the building decreased by increasing the thickness of the thermal insulation material used on the facade.

Avanos, located in the Central Anatolia Region, has a continental climate. Summers are hot and dry, and winters are cold and harsh. The city's annual average temperature is 10.6°C [30]. As in regions where the continental climate prevails, the temperature difference between day and night is high in Avanos. Since the temperature felt in the shade is lower than the sensible temperature, mechanical cooling is not used in the region. For this reason, a mechanical cooling system was not selected within the scope of the study and was excluded from the system.

Within the scope of the study, the energy gains and the reduction in CO_2 emissions that would be achieved if the minimum C energy class application, which is mandatory for newly constructed buildings, was implemented especially in buildings built with traditional methods before 2000, and the cost of this for the users were revealed. In addition, the costs and benefits of using local and natural materials, which are considered important in terms of sustainability and ecology, were evaluated. Considering the existing housing stock, especially those built by housing construction cooperatives, it was aimed for this study to be an example for the improvements that can be made and the studies in the field. In this direction, suggestions were developed for local governments, designers, construction cooperatives, producers and users.

Thermal insulation makes the indoor temperature of the building more balanced. This ensures that the interior remains cooler, especially in summer, thanks to insulation. Lighting fixtures (especially old-style ones) emit heat while operating. This reduces the indirect energy consumption related to lighting in total. The BEP-TR application evaluates the lighting load together with the indoor heat balance. Thermal insulation does not directly affect the lighting energy, but indirectly affects the energy performance and ambient temperature. This explains the reduction in the energy requirement of lighting systems.

Since the insulation was made outside the building, the condensation was released outside the building. Considering the vapor permeability properties of the materials used, it was predicted that this condensation amount was quite low and was excluded from the scope of the study.

Avanos is located in the 3rd earthquake zone in Turkey. Nevşehir and its region are among the provinces with the lowest earthquake risk within the borders of Turkey (Yıldırım, 2003; Bulhaz and Uğurlu, 2021). Earthquake is an important phenomenon in our country. Although the province where the study was conducted is located in the 3rd degree earthquake zone, this issue is a subject that needs to be examined in detail in another study. In this context, a new dimension can be added to the literature by including earthquake-related data in other studies to be conducted. In addition, it was deemed important to conduct condensation studies in addition to this study. The condensation issue will be addressed in different studies.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Dilan SARIKAYA: She conducted the research and writing of the article.

Z. Özlem PARLAK BİÇER: She conducted the research for the article.

Gamze Lütfiye ŞAHİN: She carried out the writing process of the article.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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REFERENCES

[1] Damgacı, E., Boran, K., Boran, F. E. "Sezgisel Bulanık TOPSIS Yöntemi Kullanarak Türkiye'nin Yenilenebilir Enerji Kaynaklarının Değerlendirilmesi". ***Politeknik Dergisi*** , 20 (3): 629-637, (2017).

[2] Demirsoy G., Sözen A., "Binalarda enerji verimliliğinin toplam faktör etkinliği". ***Politeknik Dergisi***, 1-1, (2024).

[3] Dikmen, Ç. B., "Enerji Etkin Yapı Tasarım Ölçütlerinin Örneklenmesi". ***Politeknik Dergisi,*** 14 (2): 121-134, (2011).

[4] WBCSD., EEB Manifesto magazine Energy Efficiency in Buildings. An insight from companies. ***WBCSD publications library,*** (2014).

[5] Karamanlıoğlu, Ş., Enerji Etkin Bina Cephe Sistemlerine Yönelik Yaklaşımların İrdelenmesi. Dokuz Eylül Üniversitesi, Yüksek Lisans Tezi. İzmir s. 182, (2011).

[6] Manav, A., "Değişen Mikro İklim Koşullarında Geleneksel Konutların Enerji Etkin Davranışları: Geleneksel Mut Evlerinin Karşılaştırmalı Değerlendirmesi". ***Politeknik Dergisi***, 24 (3): 1137-1149, (2021).

[7] Bulut, B., Yeşil Bina Sertifika Sistemleri: Türkiye İçin Bir Sistem Önerisi. Gazi Üniversitesi, Fen Bilimleri Fakültesi, Yüksek Lisans Tezi. Ankara, s. 215, (2014).

[8] Durmuş G., Önal S., "Assessment of energy performance of buildings constructed in different regions of turkey according to european specification". ***Politeknik Dergisi***, 21 (3): 581-586, (2018).

[9] BEPY., Binalarda Enerji Performansı Yönetmeliği. Mevzuat, (2010).

[10] Bep-TR Eğitim Kullanıcı Kılavuzu, Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, (2020).

[11] İslamoğlu, A. K., Konutlarda Enerji Tüketimini Etkileyen Tasarım Yöntemleri ve Bep-Tr Yöntemiyle Uygulama Örneklerinin İncelenmesi. Fatih Sultan Mehmet Vakıf Üniversitesi Mühendislik ve Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi. İstanbul, s. 126, (2017).

[12] ***Building Energy Performance Calculation Method***, 2017.

[13] Yılmaz, A. Z., Bina enerji performansı ulusal hesaplama yöntemi (Bep-Tr) ile ısıtma ve soğutma enerjisi ihtiyacının hesaplanması. s. 765-778, Binalarda Enerji Performansı Sempozyumu, İzmir, X. Ulusal Tesisat Mühendisliği Kongresi, (2011).

[14] Yiğit, K., Bep-Tr Yazılımı İle Konutlarda Enerji Kimlik Belgesi Uygulaması Ve Aydınlatmaya Yönelik Tüketilen Enerjinin Tasarruf Potansiyelinin Belirlenmesi. Yıldız Teknik Üniversitesi, Yüksek Lisans Tezi. İstanbul, s. 93 (2013).

[15] Yener, A. K., Binalarda Aydınlatma Enerjisi Performansının Belirlenmesi için Bir Yöntem : BEP-TR. s. 829-836, X. Ulusal Tesisat Mühendisliği Kongresi, İzmir (2011).

[16] Aydın, Ö., Saylam Canım, D., "Binalarda Enerji Performansı Hesaplama Yöntemi (BEP-TR1)'in Kullanılabilirliğinin ve EKB Uygulamasının Değerlendirilmesi". ***Mimarlık Ve Yaşam Dergisi,*** 2 (2), 265-277, (2017).

[17] Bilgin, N., Tanıyıcı, Ş., "Türkiye'de Kooperatif ve Devlet İlişkilerinin Tarihi Gelişimi". ***Karamanoğlu Mehmetbey Üniversitesi Sosyal Ve Ekonomik Araştırmalar Dergisi***, 2008 (2), 136-159, (2008).

[18] DPT., Konut ÖİK Raporu. Devlet Planlama Teşkilat. Ankara: Sekizinci BYKP, DPT Yayını, (1999).

[19] Koç, H., "Kentsel konut sunumunda giderek unutulan bir organizasyon: konut yapı kooperatifleri". ***İdealkent***, 13 (37): 53-65, (2022).

[20] https://ticaret.gov.tr/kooperatifcilik/bilgibankasi/kooperatiflerhakkinda/turkiyedekooperatifcilik, "Türkiyede Kooperatifçilik". T.C. Ticaret Bakanlığı, (2021).

[21] https://www.turkkonut.com.tr/hakkimizda.html, "TÜRKKONUT Kuruluş". Türkiye S.S. Yapı Kooperatifleri Merkez Birliği, (2023).

[22] http://www.turkkent.org.tr/index.php?option=com_content&view=article&id=48&Itemid=61, "TÜRKKENT, Tarihçe". Türkiye Kent Kooperatifleri Merkez Birliği, (2023).

[23] Álvarez, L., Muñoz, J. R., Domínguez, N. A., Ignacio, M. R., "The Effects of Roof and Wall Insulation on the Energy Costs of Low Income Housing in Mexico". ***Sustainabitiy***, 8 (590), (2016).

[24] Almeida, M., Ferreira, M., "Cost Effective Energy and Carbon Emissions Optimization in Building Renovation", ***Energy and Buildings*** (152), 718-738, (2017).

[25] Çetiner, İ., Metin, B., Enerji etkin konut yenilemelerinde enerji tüketimi ve yaşam dönemi maliyetlerinin değerlendirilmesi: İstanbul örneği. X. Ulusal Tesisat Mühendisliği Kongresi. İzmir, (2011).

[26] Yenioğlu, Z. A., Ateş, V., "Yenilenebilir Enerji Kullanımındaki Göreceli Etkinliklerin Veri Zarflama Analizi ile Değerlendirilmesi: Türkiye ve Yedi Avrupa Ülkesi Örneği". ***Politeknik Dergisi,*** 22 (4): 863-869, (2018).

[27] Yağcı, B. E., Sözen, A., "Türkiye'nin Enerji Verimliliği Etkinlik Analizi". ***Politeknik Dergisi***, 1-1, (2021).

[28] Söğüt, Z., "Binalarda Enerji Taraması ve Örnek Uygulama". ***Savunma Bilimleri Dergisi,*** 8 (2): 127–143, (2009).

[29] Zengin, B., Polat, H., Yurtcan, U. E., "Türkiye'de Enerji Verimliliği için BEP-TR Yöntemi Kullanımının Maliyet ve Malzeme Analizi: Örnek Bir Model Değerlendirmesi". ***Bingöl Üniversitesi Teknik Bilimler Dergisi***, 4 (2), 19-26, (2023).

[30] Akdere, S., Sürdürülebilir Kalkınma Ekseninde Sakin Şehir (Cittaslow) Hareketi: Avanos'un Sakin Şehir Olma(ma) Süreci. Nevşehir Hacı Bektaş Veli Üniversitesi, Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi. Nevşehir, s. 114, (2021).

[31] Bulhaz, Ç., Uğurlu, M. A., "Kapadokya Sinasos Bölgesi, Konut Yapısının Henri Lefebvre Kuramları Çerçevesinde Mekansal Üretiminin İncelenmesi". ***Social Science Development Journal***, 6 (27), 43-59, (2021).