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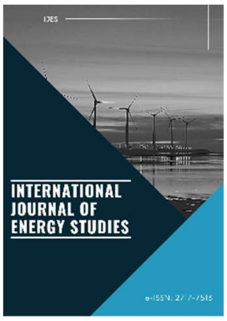

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Evaluation of energy efficient building envelope alternatives for sustainable cities

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Highlights

- Externally insulated building envelope with different structures and insulation materials was designed
- Energy consumption and energy use intensity values were analyzed with Green Building Studio.
- The energy costs of all building envelope designs were compared.
- The performance of renewable materials relative and non-renewable materials was evaluated.

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ABSTRACT

This study is aimed to create an exemplary project to present the contribution of the new buildings to energy savings when the residential buildings are transformed into green buildings. To create a sustainable built environment in residences, this study emphasizes that low-energy building strategies be combined with efficient and high-performance natural-sourced materials. Our findings show that using a natural-sourced material as the building envelope material has an impact on the use of primary energy and energy costs of the alternatives studied. In this study; In the case of replacing the building external wall components of an existing construction designed with internal insulation in the climatic conditions of Ankara, the change in energy performance has been investigated. The analysis was done with the help of BIM-based Revit Program and "Green buildings studio" where energy simulations were created. In the study, 54 different wall combinations were created by modeling combinations of different construction (porous, gas concrete, and pumice bricks), insulation (glass wool, rock wool, sheep wool, PUR, XPS, and EPS) and, roof (tile, asphalt shingle, and green roof) materials. When the outputs obtained from the analyzes were evaluated, the lowest energy consumption values were observed in the combination of pumice brick wall, green roof, and polyurethane insulation materials. In this scenario, the annual fuel consumption per square meter is determined as 30000.6 MJ/m2. On the other hand, the highest energy consumption values were observed in the combination of porous brick wall, tile roof and sheep wool insulation materials. In this scenario, the annual energy consumption per square meter is determined as 30026.6 MJ/m2. Although there are not high numerical differences between the findings, it has been observed that the results give consistent results with the thermal conductivity coefficients of the materials used in the combinations.

Keywords: Revit, BIM, Green buildings studio, Green building, Energy performance

1. INTRODUCTION

In recent years, parallel to technological developments, the world's need for energy has increased. Besides, interest in scientific studies on the introduction of alternative energy sources to rapidly decreasing fossil energy resources and the more effective utilization of existing energy sources has increased [1]. Currently, approximately 50% of the lives in provinces of the global population, and through 2030, it is anticipated that 60% of global population growth will live in cities. Approximately 75% of the energy consumed in the world and therefore the greenhouse gas emissions produced originate from cities and urban areas. Recent research emphasizes that one of the greatest potentials in terms of energy usage and the potential to reduce greenhouse gaseous emissions to the environment is possible with the arrangements that can be made on buildings. During the last few years, there have been much research on smart buildings, zero-energy buildings, and buildings that meet their energy needs with support from renewable energies or produce their own energy for this purpose. One of the main starting points of these studies is the regulation of living spaces, especially taking into account the protection of the ecological system and human health. To this end, transforming existing and new buildings into green buildings is one of the most efficient levers to overcome the difficulties of CO2 gases reduction in provinces.
Green building means both the nature and source-efficient operations and implementation of ecologically responsible during the life cycle of the building, from the planning stage to the construction, design, maintenance, operation, demolition, and renovation stage. Increasing green building research in recent years has become remarkable studies for the environment and comfort. To save energy in buildings or to decrease the effect on the ecology, reducing the utilization of non-renewable resources and energy, using building components or building products among alternatives that are suitable for human health as much as possible, or reusing some natural-waste components are some of the goals of green building projects [2, 3]. Thermal insulation materials and building materials are the primary elements of construction and are obtained using a great number of sources [4]. In the construction of a building, external wall components are the most significant part and are directly exposed to people. The quality and resources of the building material will affect the interior environment as well as the building's cost [5]. The usage of green building materials is one of the most innovative solutions to save energy and resources during construction progress [6]. Insulation is also an important element of green building planning. A well-insulated building space should keep it cool in the summer-months and warm in the winter-months, and when this is done using lower amounts of energy sources, it reduces carbon emissions from worldwide climate change. From the viewpoint of energy performance, investment in high-

level insulating materials for construction is more cost-efficient than investment in costly heating technologies. In terms of this research draws attention to the significance of construction insulation materials in the sustainable energy efficiency of green buildings. The green building concept can be identified as measures that increase the effectiveness of material, energy, and water use whilst reducing the negative effects of the building on the ecology. When looking at construction from the outside, the building insulation isn't one of the striking elements. All the same, building insulation is the most significant element that has the impact of making the building higher performance and more comfortably. Building's insufficient insulation causes energy loss throughout the cooling and heating operations, emerging in an inefficient mechanism. The insulation of green buildings saves energy usage and also aids to regulate human health. As a result of improper insulation, troubles that threaten human health as mold problems arise. For this reason, building insulation is a significant topic, many of which need to be addressed [7]. Green building insulation is the healthiest type of insulation for humans and the most suitable for the environment. Though it isn't precisely a kind of insulation, it is a framework that makes the construction more comfortable, more financial, and long lasting from the construction of the building to its daily use. Therefore, in order to maintain local, natural, and sustainable materials containing low waste are utilized and pollution is minimized during and after construction [8-10]. Briefly, insulation is the key to energy conservation, which is the cornerstone of green buildings. Insufficiently uninsulated or insulated buildings consume a lot of energy. On the other hand, well-insulated buildings save energy and reduce operating expenses, as well as make spaces healthy and more comfortable for humans. The insulation materials work through resisting the thermal flow, which is measured through an R-value (the higher the R-value, the larger the insulation). The R-value depends on the type, thickness, and density of the insulation. Comparing R-values is a way to favor one kind of insulation over another, but this value alone can be misleading if construction techniques and site conditions aren't taken into account. Insulation is an essential building element. Although homes can be retrofitted to add more insulation, often difficult and the operation is costly. Recommended R-values from resources like those in the U.S. Department of Energy should be viewed as nominative minimum values, not maximum. Well-sealed and well-insulated, homes require efficient ventilation. Non-insulated constructions, especially in cold regions, offer the maximal potential for energy savings because the maximum level of energy savings can be achieved from the initial insulation installation. It can also save a significant amount of energy from novel buildings without insulation in improving countries [10].

Numerous countries have applied green building promotion and practices that play a significant role in architectural improvement. On the other hand, the Kyoto-Protocol was suggested in 1997 and launched on February 16, 2005. This is an important step towards regulating greenhouse gas emissions for the first time in human history. The protocol proposed methods for controlling anthropogenic greenhouse gas emissions from worldwide countries industrialized in terms of crude material improvement, production, and energy usage. Greenhouse gas emissions were expected to reduce by 5.2% from 1990 to 2008 to 2012. The COP 15 contribution, which was held in Copenhagen, Denmark in Dec 2009, to reduce greenhouse gas emissions on a global scale, encouraged improved countries to supply economical support to improving countries and create policies. The Copenhagen agreement entered into force on 1 Jan 2010. To make the green building concept practical and operational, improved countries have established green building sorting mechanisms from 1990 to 2005 worldwide that can adapt various features [11].

In light of these data, during the design of a green building, it is significant to assess the energy efficiency of that building through considering the energy-efficient materials to be used in the structuring of the building, while meeting all the necessary conditions. These materials should be of a quality that will meet the different requirements required during the standard use of the building. At the same time, it should meet the necessary needs such as heating for hot water, space cooling, heating, lighting, and ventilation, as well as the anticipated needs for building and human comfort. The amount of energy required for these should be calculated by taking into account all the factors affecting the energy need such as installation and technical features, insulation, location and design taking account climatic features, the effect of surrounding buildings and sun exposure of the facades of the building, renewable energy production, and climatic comfort in terms of interior space. It is imperative to obtain healthy results by making use of all numerical data [12].

Since the conclusion of the study by considering all these parameters is a problem that requires both time and attention, simulation-supported solutions have attracted attention in recent years. There are many computer software designed for these purposes that work with the building information system in today's conditions. Software such as Bentley Microstation, Graphisoft Archicad, DDS-CAD, Nemetschek Allplan, IDEA Architectural, VectorWorks, Tekla Structures, Autodesk Revit support designers, civil engineers, architects, owners, and project managers in producing the right decisions and solutions. Especially ArchiCAD, Bentley Microstation, VectorWorks Architect, and Autodesk Revit stand out in the industry [13].

Autodesk Revit is building information modelling simulation used for 3D modeling. Building components such as windows, walls, and roofs are used to create 3D models with Autodesk Revit.

It provides quick and easy geometry creation from free forms with support for building modeling and conceptual design. It includes built-in tools for creating and converting complex models to building information models. It has high control possibilities with functions such as limitation and parameter assignment. It has many tools both during the design phase and for analyzing the final product. In the Autodesk Revit program, 2D and 3D views and bills of quantities consist of the same building database. While the users are working on any view, the Revit program collects the data needed for the building and stores it in the building information mechanism, and reflects it to the entire project. Any change made in a phase or part of the project is directly reflected in all lists and layouts. [13-15]. Autodesk Revit from an overview;

1. It provides high precision and control thanks to its features such as easy geometry creation, parameter assignment, constraint relations, and conceptual design.
2. Objects that provide the formation of the structure are style-based and parametric. It offers the opportunity to be customized by users.
3. With the tools it provides, manufacturers design their own products and offer them to engineers, architects, and designers.
4. It offers advanced modeling tools and techniques thanks to its software development interface. Forms created using curves that can be created using complex formulas can be controlled by changes made to the formulas used, and geometries can be created with it.
5. Artificial light and daylight work can be done.
6. Thanks to solid modeling tools, complex objects, and mass studies can be done.
7. Facilitates teamwork with various tools. It offers users the opportunity to work on the project without disturbing the work of other users. The data of the central file of the project is coordinated with Revit.

Bine Energy Model (BEM) is created with the energy information of any building. This model is a simulation model that calculates energy expenditures with parameters such as HVAC (Heating Ventilating and Air Conditioning) systems, lighting, heating, cooling, and insulation systems. During the creation of the energy model, the design parameters of the building, environmental factors such as climate and surrounding structures, energy loads, (cooling, heating, lighting, and air conditioning) and electrical loads, and renewable energy sources should be considered. The building energy model offers the opportunity to calculate these data together with criteria such as energy costs and user comfort. Advantages of BIM application in energy simulation; cost reduction, energy model generation time, specification of materials and equipment, and reduction of human error compared to traditional methods [14].

While building information modeling is construction-oriented, the building energy model focuses on the properties of building elements and their relationships with each other. Although BIM and BEM have different focuses, they have the same type of data storage. Therefore, there is an opportunity to work together.

They explored the interoperability between BEM and BIM. In the study, the issue of BIM software working together with analysis programs such as Revit's IES and Ecotect has been discussed Three common file formats DXF, IFC, AND gbXML were tried in the research. In the research, it was determined that gbXML is the most preferred format type in terms of information transfer between BIM and BEM. The collaboration between BIM and BEM is still in development. Green Building Studio (GBS) is a web-sourced implementation that utilizes the DOE-2 engine to simulate energy. GBS supplies information on the building's water use, energy use, materials expenses, carbon footprint, and more. It provides the opportunity to make a quick design decision by comparing design alternatives side by side. It has a simpler interface than other building energy simulation software. Building characteristics can be easily changed in this web-sourced interface [5]. The gbXML format is used as the bridge that allows the information to pass between Revit and the GBS implementation. If the model to be analyzed has no parameter definitions, GBS utilizes a default value to produce an energy modelling with the minimal information needed to simulate. These smart values are proper for building location, type, and size. These defaults mainly depend on CBECS, ASHRAE-62.1 ASHRAE-90.1, and ASHRAE-90.2 data. These alter with a building site, building type, and number of floors. Green Building Studio provides a potential energy savings chart by automatically testing different building features. In this way, it provides guidance on which alternatives will have the best effect on energy consumption. Integration between Green Building Studio and Revit has simplified the analysis used to design buildings for many architects, designers, and engineers. Green Building Studio uses regional building standards and codes to make assumptions based on the kind of building, location, and size of the building. Thus, appropriate material, system, construction, and equipment assumptions can be determined. Designers can simply quickly change settings to create alternatives. For example, changing the orientation of a material or building with a different thermal value, or changes in the HVAC system [13-16].

Many researchers have done different studies on this subject. Shivsharan et al. aimed to integrate the use of BIM into the existing structure in calculating the energy consumption of a building. For this purpose, Green Building Studio software and Autodesk Revit were utilized to apply the energy analysis of a residential building. As a result of the findings, it was emphasized that any maintenance or repair to be made in the future may be beneficial in terms of energy saving and energy waste if these results are used as a reference [17]. Henry et al. investigated the effects on energy and greenhouse gas emissions by considering the materials used in the construction of two different types of housing (cement block and adobe). Alternative planning suggestions were presented [18]. Koppinen et al. [19] and Korkmaz et al. [20], have presented their work that defines the planning processes for building information modeling-building energy modeling, which includes determining key performance criteria, considering data requests, and data sources for each planning stage. Luziani and Paramita calculated the energy analysis of a shopping mall building using Green Building Studio software and Autodesk Revit stated that commercial buildings consume a lot of energy. By creating three alternative scenarios for the analysis, they determined which scenario was the most efficient in terms of energy performance and energy savings [21]. Aljundi et al compared the flexibility and reliability of energy analysis utilizing the BIM-sourced simulation tools Green Building Studio and Autodesk Revit to explain the challenges of both systems. For this reason, the analysis results were compared with the EnergyPlus program. According to research, these systems save time and money, while also helping to develop more energy-efficient buildings [22]. Flores did a study on a building located in the state of Ecuador. The researchs aims to calculate the energy efficiency of the building to discover design changes that can be made before construction begins. For this purpose, the training structure was modeled with Autodesk Revit 2017 program and a building performance analysis was developed. It also highlighted the versatility of Autodesk-based programs such as Insight 360 and Revit, as well as the approach used to evaluate design development possibilities for the build in question [23]. Otuh researched the feasibility of energy analysis of Autodesk BIM software during the design phase of educational buildings. The researchs aims to increase design sustainability and energy potential by using BIM software in the project design process. For this, he used Autodesk Revit and Green Building Studio, both of which are BIM software. As a result, these programs have shown that energy analyzes can be made throughout the planning phase of a building and a more energy-efficient design can be started [24]. Abanda and Byers modeled an existing building in the BIM-based Autodesk Revit program. Then, the model was transferred to Green Building Studio, an energy simulation program, and the effect of energy use on the total energy usage of the building was computed in Green Building Studio depending on the different orientations of the building. As a result, it has been obtained that a well-oriented structure can save a significant amount of energy [25]. Kurekçi and Kaplan calculated and compared the cooling and heating loads of a single-story building with a net usage field of 196 m2 in the province of Istanbul using HAP and

Autodesk Revit programs. Both programs reported comparable results [26]. Leinartas and Stephens examined 10 types of single-family homes built before 1978 in Chicago to determine the most cost-effective way to improve energy consumption. They calculated the cost and energy performances by performing the necessary simulation studies using BEopt and EnergyPlus programs. It has been shown in the conclusion that the changes made can save up to 50% of energy [27]. Using the Green Building Studio simulation, Le modeled and analyzed the current design of a residence in Autodesk Revit. As a result, he offered the architects the most energy-efficient and sustainable design for their future projects. He emphasized that Green Building Studio produces consistent results [28]. Kuo et al used the Industrial Technology Research Institute's (ITRI, Taiwan) BIPV Experimental Demonstration House to investigate the reliability of BIM-sourced energy analysis during the conceptual planning phase, and the actual measured data were compared with the simulated electricity production values. It has proven the reliability and feasibility of BIM-based energy analysis [29]. In this study, different scenarios have been created if a building is designed with different construction (porous brick, gas concrete, and pumice brick), insulation (glass wool, rock wool, sheep wool, PUR, XPS, and EPS), and roof (tile, asphalt shingle, and green roof) materials in Ankara province. Energy performances were analyzed with the aid of the BIM-based Revit Program and Green Buildings Studio simulation, where energy simulations were created. The most performance combination that can support energy efficiency has been tried to be determined.

2. MATERIALS AND METHODS

In this study, an existing building in the province of Ankara was designed through the BIM-based Revit Program and Green Buildings Studio simulation, which are programs that can evaluate the city in terms of climatic conditions. Then, the physical properties of the materials were transferred to the simulation based on the existing wall thicknesses of the building designed as internally insulated. For the insulation materials, the studies for the climatic conditions of the province of Ankara were investigated and the most suitable insulation thickness was taken as 6 cm and transferred to the system. The wall structure designed for the existing building is shown in Figure 1 [30]. The physical features of the materials used in the building envelope and processed as input to the simulation are given in Table 1.

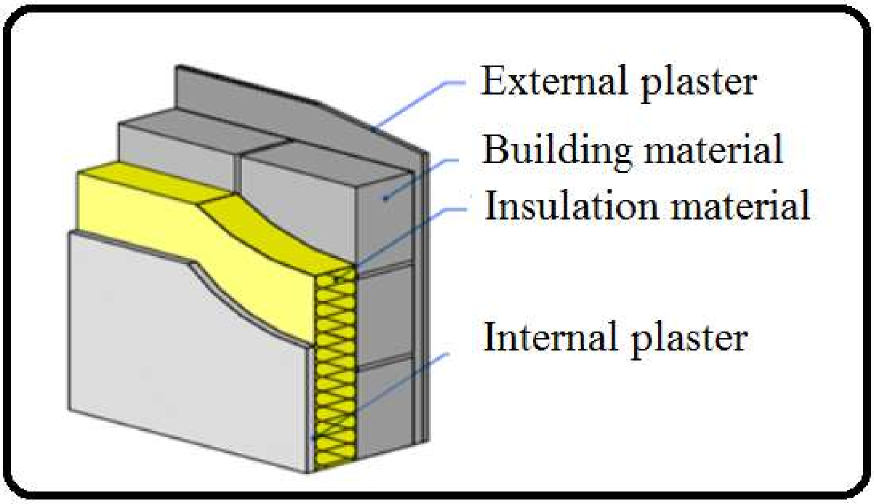


Figure 1. Internally insulated external wall [30].

Table 1. Physical properties of materials used in the analysis [31, 32].

	Material	Intensity [kg/m³]	Thermal Conductivity [W/(mK)]
Roof Materials	Tile Roof	1400	0,81
	Asphalt Shingle Roof	14	0,19
	Green Roof	--	--
Insulation Materials	Rock Wool	105	0.0390
	Glass Wool	56.5	0.0375
	Sheep Wool	30	0.0420
	Expanded Polystyrene Foam (EPS)	34	0.0350
	Extruded Polystyrene Foamboard (XPS)	50	0.0300
	Polyurethane Foam (PUR)	55	0.0230
Building Materials	Porous Brick	700	0.2600
	Aerated Concrete Brick	700	0.2200
	Pumice Brick	700	0.1800

In the analysis, 54 different scenarios were created for the internally insulated wall structure. In general, in all scenarios of the wall structure; layers of paint (0.1 cm), interior plaster (0.20 cm), insulation material (6 cm), building material (25 cm), exterior plaster (0.25 cm), and paint (0.1 cm) from the inside to the outside were used. The scenario numbers created according to the building, insulation, and roofing materials used in the analysis are given in Table 2.

Table 2. Scenario numbers created according to building, insulation, and roofing materials

Tile Roof	Asphalt Shingle Roof	Green Roof	Building Material	Insulation Material
1	19	37	Porous Brick	Rock Wool
2	20	38		Glass Wool
3	21	39		EPS
4	22	40		XPS
5	23	41		Polyurethane Foam
6	24	42		Sheep Wool
7	25	43	Aerated Concrete Brick	Rock Wool
8	26	44		Glass Wool
9	27	45		EPS
10	28	46		XPS
11	29	47		Polyurethane Foam
12	30	48		Sheep Wool
13	31	49	Pumice Brick	Rock Wool
14	32	50		Glass Wool
15	33	51		EPS
16	34	52		XPS
17	35	53		Polyurethane Foam
18	36	54		Sheep Wool

3. RESULTS

In energy-efficient building designs, it is important to construct the building by using the most suitable materials, taking into account the region and climatic conditions of the building, in order to use less energy and reduce the greenhouse gases released to the environment. The energy needed to provide thermal comfort (for cooling and heating buildings) in these living spaces is closely related to the thermal and physical features of the materials used while constructing the building. Therefore, it is important to bring together the most suitable combinations for thermal insulation, taking into account both the heating and cooling loads of the main materials used in the building design. In this way, it is also possible to reduce heat transfer in buildings by means of materials with low thermal conductivity.

Energy use intensity is a particularly useful parameter for setting energy use targets and benchmarks. It often varies depending on the environment, the construction design, and the size of the building.

Energy use intensity is expressed as the energy used per m2 per year. It is computed by dividing the building's total energy usage in a year (measured in kBTU or MJ) by the building's total gross floor area. In short, it is the sum of annual combined fuel and energy per project area. In this study, the highest energy usage density of 3026.6 MJ/m2 was obtained for “scenario 6” (Tile roof + Porous brick + Sheep wool). The lowest energy usage density was determined as 30000.6 MJ/m2 for “scenario 53” (Green roof + Pumice brick + Polyurethane foam). The highest energy use density values were determined in terms of roofing materials, tile roof, porous brick in terms of building materials, and sheep wool in terms of insulation materials. In this study, the energy usage density values of all scenarios applied to the existing building are shown in Figure 2.

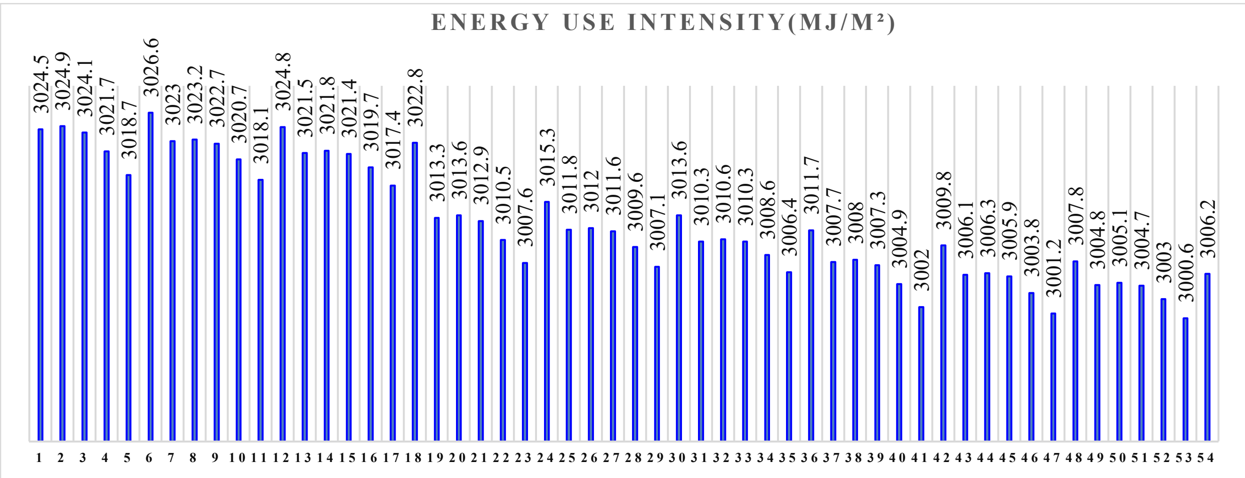
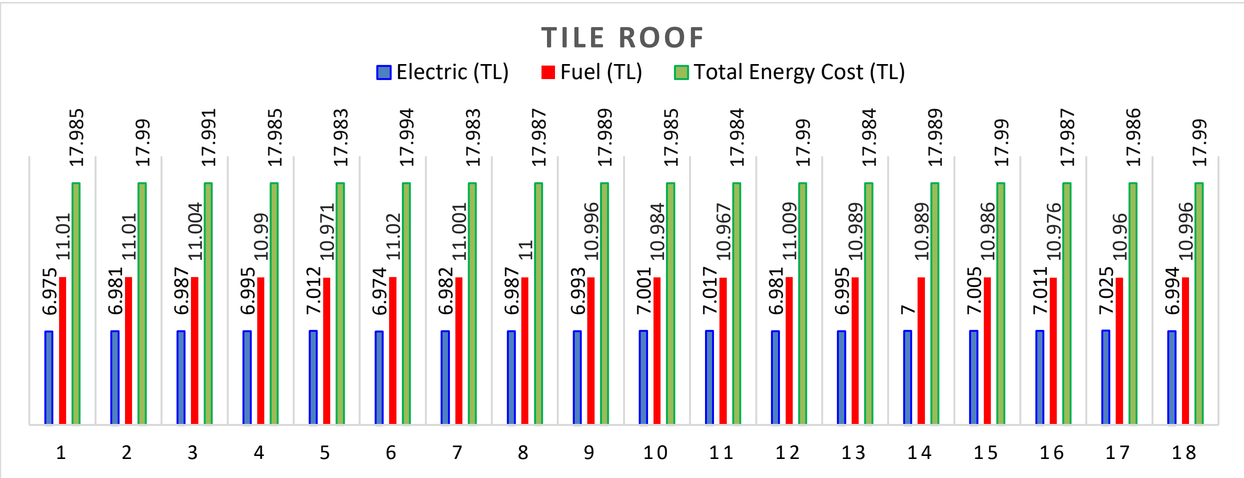


Figure 2. Energy use intensity (MJ/m2) for all scenarios

In order to reduce the energy costs that will arise when a building is started to be used, the right material selections made during the construction phase will also be reflected in the electricity bills in connection with the use of less fuel. In Figure 3, energy cost values for all scenarios in TL are shown in graphs according to three different roof materials: tile roof, asphalt shingle roof, and green roof. When all roof types were evaluated, the highest energy costs were obtained with tile roofs and the highest energy costs with green roofs. Maximum energy cost values were obtained with “scenario 6” on the tile roof, “scenario 24” on the asphalt shingle roof, and “scenario 42” on the green roof, and porous brick as construction material and sheep wool as insulation material was used in all 3 scenarios. Minimum energy cost values are 19,983 MJ/m2 in “scenario 5” (Porous brick + Polyurethane foam) and “scenario 7” (Aerated concrete brick + Rock wool) for tile roof, “scenario 25” (Aerated concrete brick + Rock wool) for asphalt shingle roof), 17,941 MJ/m2 and 17,902 MJ/m2 with “scenario 43” (Aerated concrete brick + Rock wool) on the green roof. Considering all scenarios, the minimum energy consumption was obtained with “scenario 43”.

In terms of energy usage of the building, the highest fuel consumption is 805.34 MJ in “scenario 6” (Tile roof + Porous brick + Sheep wool) and the highest electricity consumption is 50,639 kWh in “scenario 35” (Asphalt shingle roof + Pumice brick + Polyurethane foam) was obtained. The lowest fuel consumption was determined as 795,752 MJ in “scenario 53” (Green roof + Pumice brick + Polyurethane foam) and 50.111 kWh in “scenario 42” (Green roof + Porous brick + Sheep wool). The energy consumption sources for “scenario 53” and “scenario 42”, which have the lowest fuel and electricity consumption, respectively, are shown in Figure 5.



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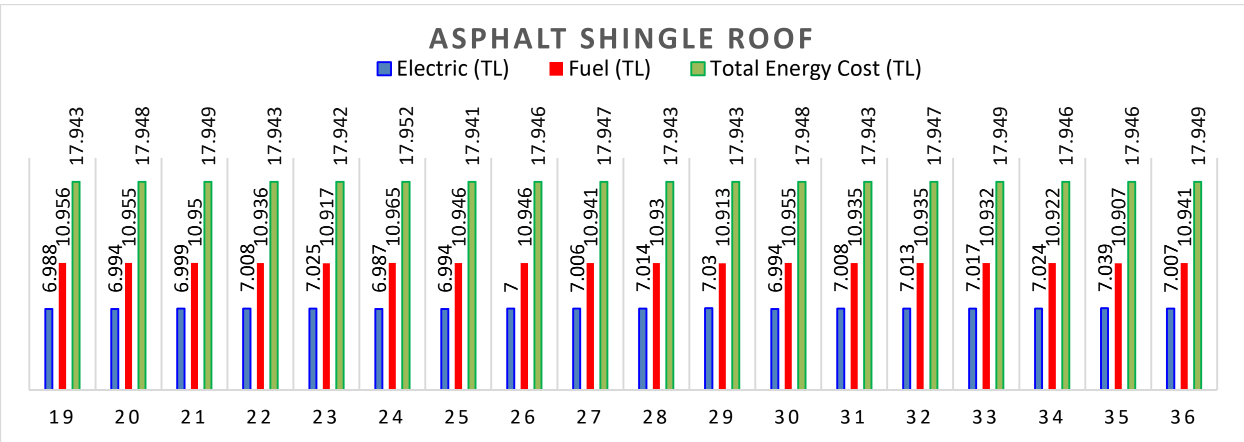

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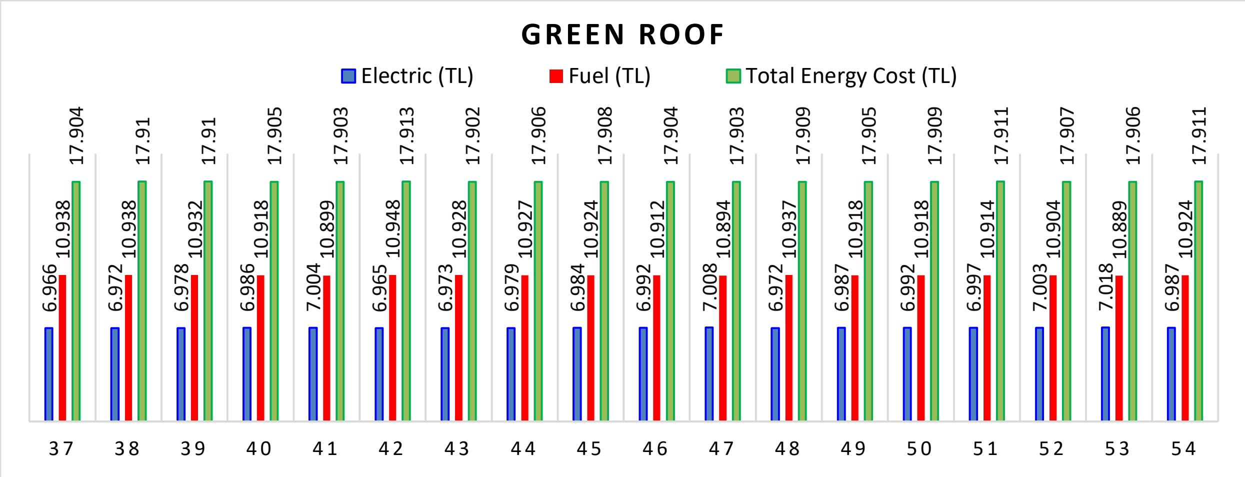
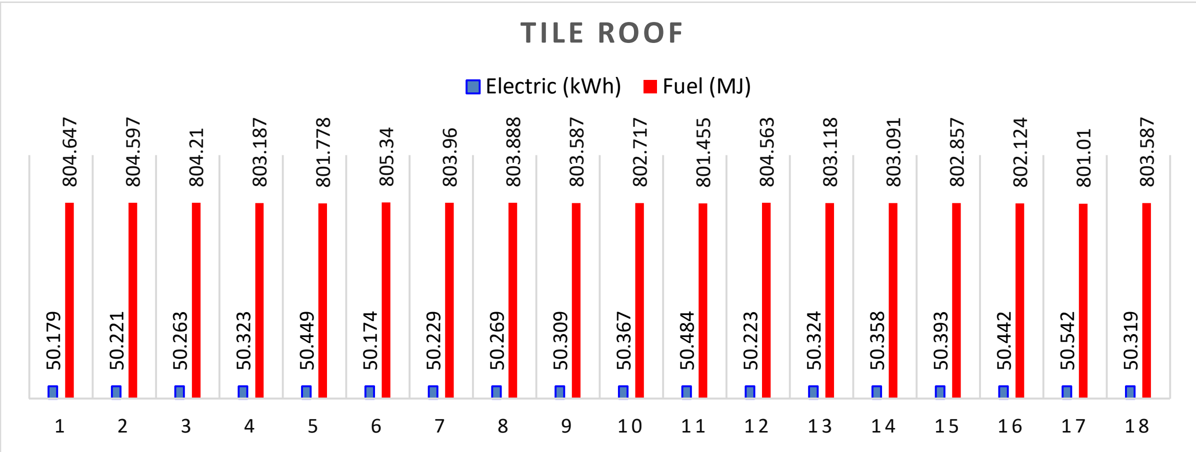


(c)

Figure 3. Energy cost (TL) for all scenarios



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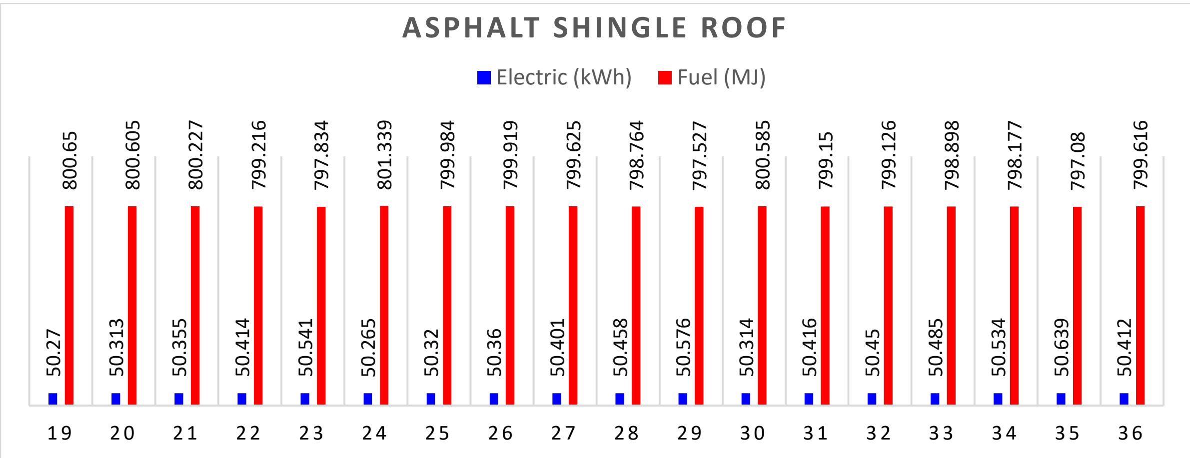

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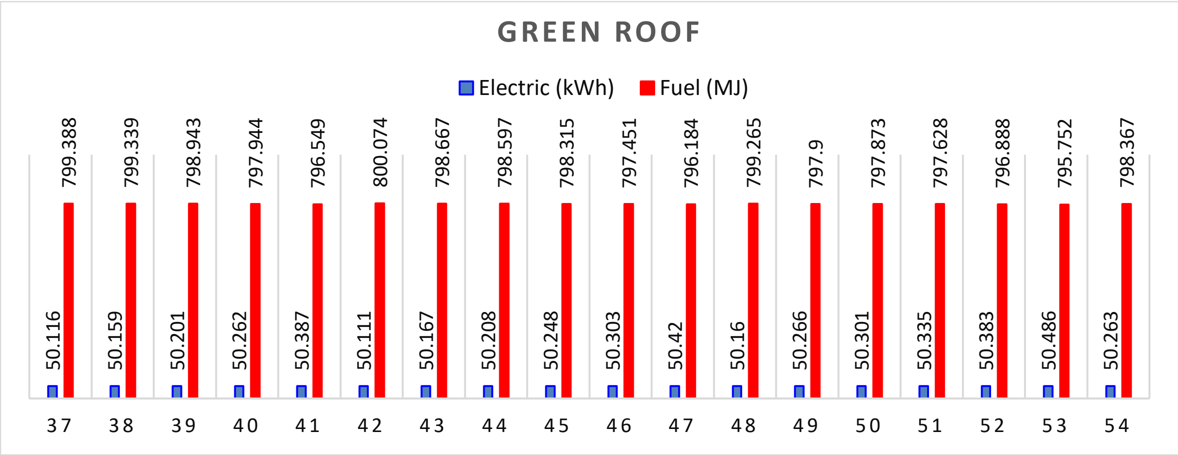

(c)

Figure 4. Energy consumption for all scenarios of analyzed villa

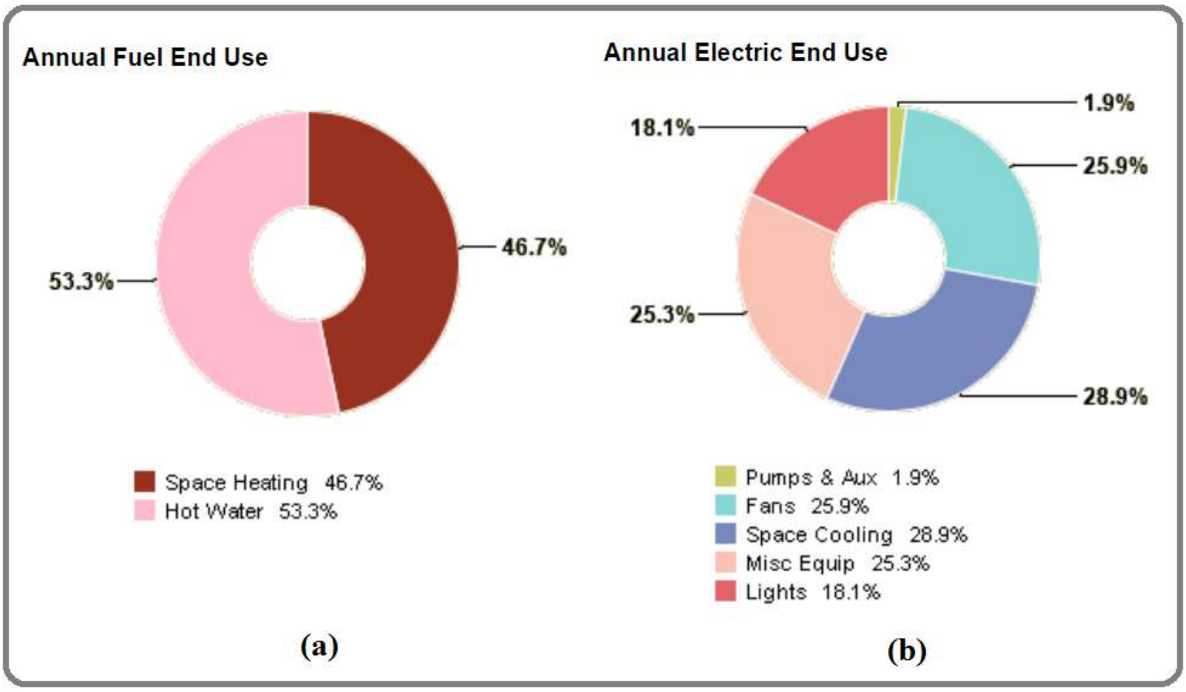

Figure 5. a. Energy consumption sources for "scenario 53" with the lowest fuel consumption

b. Energy consumption sources for "scenario 42" with the lowest electricity consumption

Among all alternative scenarios, the highest fuel consumption was found to be 805.34 MJ and the lowest fuel consumption was 795,752 MJ. The difference between the best-case scenario and the worst-case scenario was obtained as 1.19%. The outputs obtained from a few example studies in the literature are listed in Table 3.

Table 3. The outputs obtained from a few example studies in the literature are listed.

Country	**Conclusions**	**Procedure**	**Ref.**
India	50 percent of energy can be conserved in the building industry	Energy usage pattern	[33]
Canada	The exergy and energy performances of all mechanism are obtained to be 46.10 percent and 7.30 percent, respectively	A multi-generational mechanism adapting renewable energy re sources for a green house was designed and evaluated utilizing exergy and energy assessment.	[34]
China	Green constructions exhaust 26 percent low energy similar to conventional buildings.	From the perspective of an investor, rough set theory was used to examine the combat grade between various plan objectives.	[35]
Malaysia	Green price payments concluded through trial researchers range between 21 percent and 0.4 percent.	The review article information summary	[36]
USA	The ouputs defined 43 percent of the yearly diminish in energy consumption and costs for the average American home.	Describing of the affects of green building industry on building energy usage	[37]

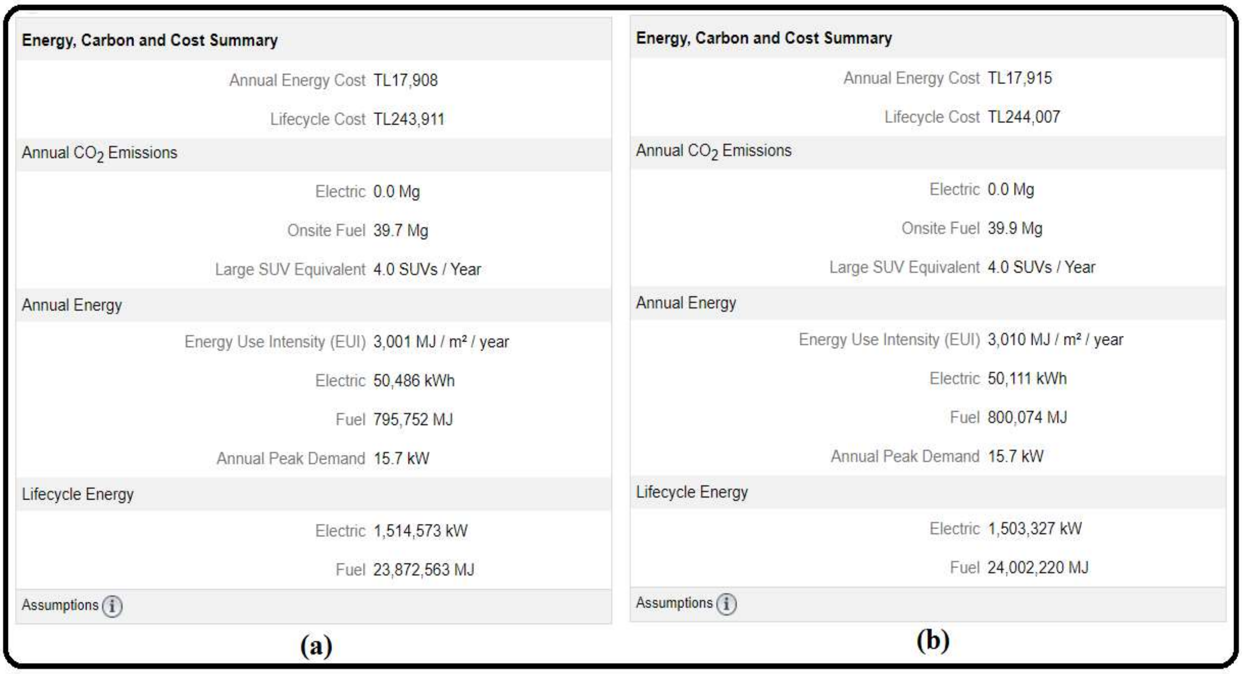

Figure 6. a. Energy cost summary for "scenario 53" with the lowest fuel consumption
b. Energy cost summary for "scenario 42" with the lowest electricity consumption

4. CONCLUSION

In this study, three different alternatives (building material, insulation material, and roofing material) were considered for the interior insulated building envelope scenarios. When all the parameters affecting the building's energy efficiency are evaluated, it has been determined that the most effective parameters are the thermal and physical features of the building and the materials that make up the building's exterior. The lower the thermal transmittance value of the material, the higher the total energy performance. Total energy consumption has grown or decreased in parallel with the heating energy usage due to the fact that Ankara, where energy surveys are conducted, is in the heating priority region, which is located in the 3rd climate zone of Turkey.

• It has been determined that it has a higher performance in terms of heating energy usage in scenarios where pumice brick is used as construction material. After pumice brick, the better-performing wall materials in terms of heating energy usage were determined as aerated concrete brick and porous brick, respectively.

• When investigated in terms of insulation material, polyurethane foam was determined as the insulation material with the best performance in terms of heating energy usage.

• During the studies, it has been determined that the green roof performs better than other roof types in terms of heating energy usage.

The BIM-based Revit Program, in which the model project is created, and the Green Buildings Studio simulation, in which energy simulations are created, can enable customers and designers dealing with energy problems to produce alternatives and obtain information. By analyzing the projects in the design or renovation process, it is possible to identify the most performance alternatives of energy-efficient design and architectural design processes. When we examine the numerical comparisons, we can see that the energy consumption in the projected building example varies depending on factors such as the use of different wall materials, insulation materials, and roofing materials. In consequence, the choice of proper building components during the design or renovation phase has a direct effect on the building's energy performance and also contributes to energy effective-sustainable plan. In this research, the energy performance of a large-scale building with intense energy usage was analyzed utilizing the Revit software program and suggestions for decreasing energy usage were presented. However, raising the number of alternative materials used may provide the opportunity to create more efficient combinations of building components with the results obtained. It is also known that buildings that receive support from renewable energy systems can help reduce the consumption of other energy sources. In the research on the energy efficiency of green buildings, it is significant to report the contribution that can be made by including renewable energy systems to the energy efficiency of the building designed with the most effective building envelope.

In future studies, it can be ensured that the model villa can be transformed into a greener building by using different natural origin and classical building-insulation materials and different wall structures (such as external insulation and sandwich). In this way, this research can guide contractors, designers, and engineers in order to design the buildings to be built in the region where the model villa is located and in regions with close climatic conditions in the future, to design the green building in a simpler way. The BIM-based Revit Program can be used in the design phase of buildings to be built in different climate zones, and the effects of different wall structures and different building envelope materials on the building's energy consumption can be investigated. In this way, less energy-consuming, more environmentally friendly, and healthier buildings can be developed during the design phase and contribute to a cleaner future with greener buildings.

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DECLARATION OF ETHICAL STANDARDS

The authors of the paper declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Alper Balo: Analysis, Acquisition of data, Interpretation of data, Writing - original draft

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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