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Considering the potential of energy efficiency of the mountain house by alternative roof design

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Abstract

As our everyday lives become increasingly reliant on automated household devices, higher energy demand has placed a significant strain on electricity use in major housing models. In the main provinces, a large number of apartment buildings and old houses are not energy-efficient, resulting in significant overloading of current structures. Furthermore, effects such as an increase in the electric unit ratio have an economic impact on the landowners of the buildings. The need of assessing the energy effects of building components early in the design process is generally acknowledged. Altering the external and internal designs of a structure can have an influence on the annual upkeep income of buildings and other structures. The primary goal of this study is to show how a BIM-based evaluation of the energy effects of building roof components allows planners to focus on conceptual planning while still keeping track of the possible consequences of design and material choices. Revit is Building Information Modelling-based energy simulation program. It enables building performance simulations to be conducted early in the design phase in order to maximize energy efficiency and move toward carbon neutrality. It aids to plan efficiency buildings at a fraction of the conventional methods' cost and time. In this study, it is suggested that more recent policies be improved by taking into account roof materials from important variants that support energy efficiency and planning more energy-efficient structures using the Revit database. Together with the XPS-brick duo, one of the most broadly used building-insulation materials, the changes in the energy performance of a mountain house with roofs designed in various combinations (standing seam roof, tile roof, green roof) was investigated. The results show that standing seam roof (31308 kWh) can be used as the most energy efficient material among alternatives when used same insulation and building material.

Keywords: Roof material, Roof design, Energy efficiency, Revit, Building Information Modelling

1. Introduction

The maintainable constructions have fewer environmental impacts, are more energy efficient, and provide people with higher-class living standards. Rule makers all over the world promise to build a sustainable building by modifying models, building codes, introducing innovative products, and even providing financial incentives to accomplish the goal. [1, 2]. The current energy classification schemes can assess the maintainability concept through selecting source usage properties, affecting emissions and energy consumption in the process. [3]. The decrease of energy consumption at various stages of the building life cycle, from subtraction through transportation, production, construction, maintenance, operation, demolition, or deconstruction, is the main indicator for ensuring an environmentally friendly structure currently [4]. The energy efficient plan can sufficiently discuss the energy efficiency plan characteristics for a particular climate region and helps in the selection of appropriate heating, ventilating, and air conditioning tools for the energy-efficient building. [5]. Builders and architects are working on incorporating energy efficiency policies to meet national targets and strict structure codes to reduce greenhouse gas emissions. [6].

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Energy efficiency planning is the integration of various substantial architecture planning strategies with the contextual needs that study with the given climatic conditions [7]. The policies include orientation, thermal conductivity of the building facade, solar incidences, geometrical parameters, and other evaluations such as ventilation, evaporation, and thermal mass. [8]. Energy efficiency and energetic policy, such as low-energy usable electrical devices and on-site maintainable energy industries, contribute to zero-net energy constructions [9]. The four primary ways for constructing energy-efficient structures are as follows:

- The incorporation of renewable energy systems for building electrification,
- Energy conservation through the use of energy-efficient technologies,
- The use of low-embodied energy-construction materials,
- The construction's passive design,

These examine the advantages and disadvantages of each aspect, as well as the fact that solar-based renewable and passive industries are the most useful in reducing CO_2 emissions from the construction industry, and proposes the use of locally available construction materials to reduce embodied energy [8]. The feasibility of a grid-connected solar system in a house building record [9]. Nowadays, the thermal efficiency of diverse construction productions containing glass window materials is evaluated [10]. Planning of self-energy adequate structures utilizing construction interconnected photovoltaic is researched, with the government's solar energy strategy assisting in shortening the payback period [11]. The impact of geometrical factors such as window placement and window-to-wall ratio on cooling, heating, and lighting energy usage is investigated [12]. An examination into this issue found that the required capability of photovoltaic placement can preserve 54 percent of energy in the construction during a life-span of twenty-five years, based on an energy effective life-cycle analysis made in Indian constructions [13].

Appropriate choice of energy efficiency plan characteristics during the planning stage will bring convenience to the building's residents while lowering energy emissions and costs during the operating stage. Computer software helped in decision making, energy simulation is a useful database for selecting construction plan alternatives, energy optimization, and standard compliance. [10]. Building information model improves a construction modelling with its functional and physical parameters [14]. It is more than just a three-dimensional model of a building; it also contains data like topography details, materials, orientation, energy utilization details, weather data, and location, among other things. In the construction energy software industry, building information model databases are widely used. The Revit database also helps with strengthening analysis for energy performance. The most popular construction plan simulation databases are Open Studio, Archicad Sketchup, and Revit. Furthermore, many energy software programs, such as First-Rate5, BLAST, BSim, DeST, DOE-2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, EnergyPlus, and eQUEST, have been improved over a 45-year period [11-13].

Building information model is a gaining concept in the structure sector that discusses the integrated exchange of data throughout a construction's life-cycle, from the initial design step to the final eradication [14]. It is a believable resource for acquiring material characteristics and features, but it cannot be compared to various alternative plans and assessed for maintainability. The widely available energy evaluation databases can include maintainability factors such as insulation, shading, orientation, sealing, natural ventilation, and others throughout the construction's running stage. The combination of a building information model and energy tools can predict the total ecological influences attributed to operational and embodied energies as a result of structure material selection. As a result, the structure and design of the construction utilizing chosen products can contribute to proper decision-making. According to studies, the Revit database is the most widely used database for construction planning. Green building studio tool, which is a cloud-based energy evaluation database, Revit database's web-version is one of the most widely used construction energy evaluation databases, following e-Quest and Energy Plus. [15]. In a reinforcement examination, the Revit database was utilized to define the event irradiation on the construction's external cladding in order to estimate the construction's solar potency. [16]. The Revit database was used to model a construction to calculate electricity production from construction-embodied solar cells. The energy evaluation was carried out in the REVIT database, and the results provided reliable conclusions on the efficiency of building-integrated photovoltaics. [17]. To convert an existing school into a low-energy structure, a total energy efficiency evaluation is performed using the Revit tools. The cooling-heating load, daylighting analysis, and sun path analysis were all estimated using the Revit database. The Revit database was extremely useful for estimating energy efficiency in both retrofitted and existing situations. [18].

A few studies used building information modeling and similar ecological gaseous for the materials' change under the modeling. Building information model (Autodesk Revit) was utilized in a work for quantization the embodied energy utilizing three diverse constructional elements, like steel, wood, and concrete [19, 20]. Revit simulation was used to predict the quantity of material and then emission elements from an institution were found for the planned 3 construction materials to calculate their total embodied energies. Nonetheless, the quantified materials input by hand makes the guess process time-consuming and therefore sensitive to errors. Even the operational impact due to material selection was not part of the research. In another research, an automatic computer network was improved to align the mensuration with UK's current norms, predict carbon-dioxide emissions, and embodied energy of the constructions. [21]The building information modeling database quantifies the quantities of materials and decides with research analysis constructions of the measurement's UK novel. In the above-mentioned studies, Building an information modeling database has not been identified as the primary stage for information combination. The operation of implementing building information modeling to contribute green construction evaluation operation was examined, and advantages such as green building evaluation result prediction and administration of implementation papers were defined. The green building information modeling has faced challenges like a lack of technology standards, low technological adoption of green building information modeling implementations, and a lack of appropriate plan distribution methodologies. The improved software through Yang and his colleagues was the initial stage in the improvement of building information modelling green construction assessment system [22]. It was a mutual effect database designed to accelerate the planning process for a suitable green structure. Mahmoud and his colleagues improved a global maintainability evaluation technique for current buildings in order to continue this investigation [23]. The suggested maintainability evaluation database was separated into poly elements with quantitative and qualitative features utilizing fuzzy-logic theory.

The purpose of this research is to use the REVIT database in the mountain house energy efficiency simulation in Antalya, Turkey, and to optimize the building roof modeling. The energy performance of designed building is evaluated by utilizing various roof materials.

2. Revit Methodology

In this study, the Revit database is used to analyze the roof design of a building using diverse roof materials. The building information modelling incorporates overall energy-sourced data and may be utilized for energy simulation and management. It can be utilized to produce a building energy modeling in the Revit database by entering extra energy adjustments. Energy simulation in the Revit database can be applied based on notional masses, construction components, or both. [24]. Because the research is based on a current construction and the building information modeling includes itemized architectural data about the construction components, specified and material thermal features, the evaluation was based on construction components. The produced building energy modeling in the Revit database can be validated, viewed, and used for energy analysis before being exported to third-party energy software implementations or Green Building Studio in a variety of common formats.

3. The Climatic Data in Antalya City

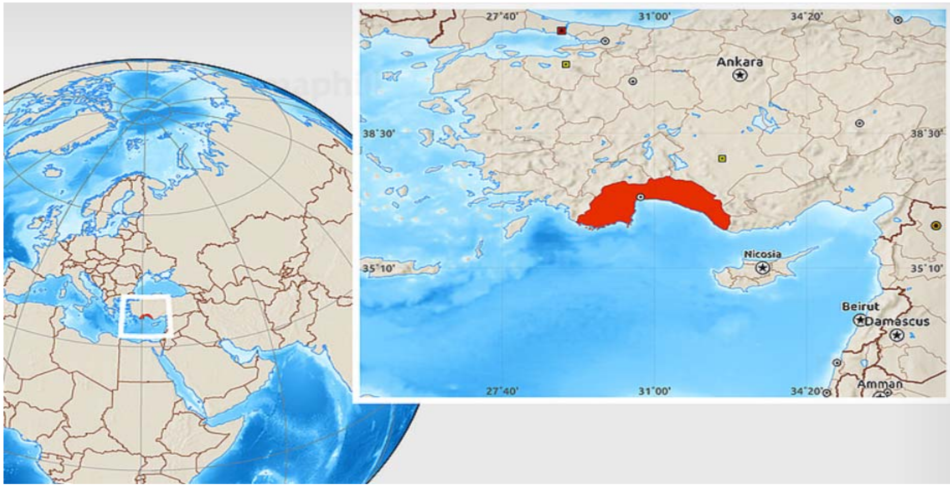


Figure 1. The location of Antalya city.

The winters in Antalya are partly cloudy, long, and cold, while the summers are humid, clear, extremely hot, and arid. Throughout the year, the temperature normally varies from 35°C to 5°C, never exceeding 31°C or falling below 19°C. In Antalya, the sky is cloudy for four to five months out of the year (between May and October). The annual rainy season lasts from June to September. The predominant mean hourly wind direction is from the north throughout the year. The wind speed is heavily influenced by the topography of the region. The intense wind in Antalya lasts from November to April, with mean wind speeds ranging between 3.6 and 2.4 meters per second. It debates the total daily event short-wave sun power arriving at the ground's superficies over a broad field, considering of the Sun's elevation above the horizon, the seasonal changes in the day's length, and adsorption through clouds and different atmospheric constituents. UV radiation and visible light are examples of short wave irradiation. The annual brighter period lasts 3.5 months when the mean incident short-wave energy per m2 exceeds 8.4 kWh on a daily basis. Antalya's weather obviously varies throughout the year. The year's moist season lasts from June to October [25].

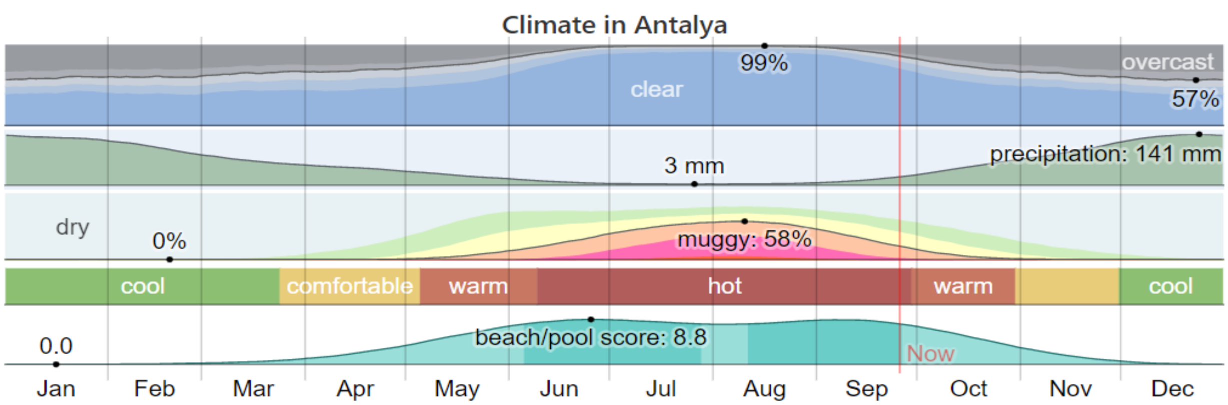


Figure 2. The climatic data in Antalya city.

4. The Project and Component Properties of Analyzed Building

A mountain house Project with a gross area of 2+1-100 m^2 was designed in Antalya. The Project includes 2 bedrooms, 1 living room, 1 kitchen and 1 bathroom-wc. The walls of the mountain house project were designed as externally insulated walls using Revit software. 4 cm XPS wall insulation from outside to inside and 20 cm Brick were used as externally insulated wall layers, respectively. Clamp roofs, tile roofs, and green roofs are the roof types that have been created. Then, in the Revit context of the model, the energy model was created, and the annual total energy amount was calculated in the Green Building Studio environment.

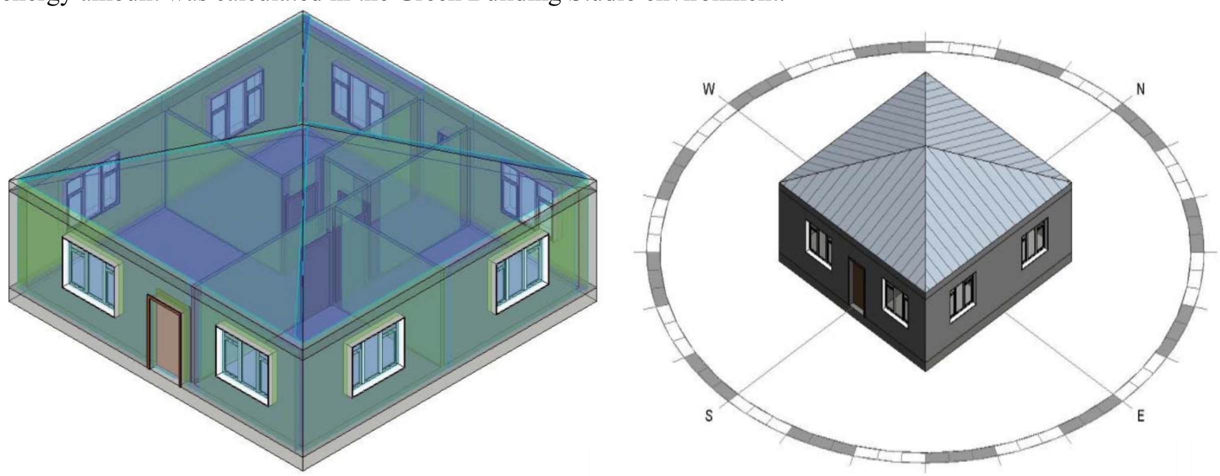


Figure 3. The view of the analyzed building.

Table 1. Layers according to roof type

Roof Type	Layers
Standing Seam Roof	Standing Seam Roof Coating
	Timber Boarding
	Ventilated Air Space / Counter Batten
	Brather Membrane
	Insulation / Rafter
	Plywood and OSB Optional
	Vapour Control Layer
Tile Roof	Tile Coating
	Wood – Tile Batten
	Fabric – Wierer
	Vapor Retarder – Wierer
	Wood – Countern Batten
	Fabric – Wierer
	Wood – Tile Batten
	Vapor Retarder – Wierer – Divoroll Universal 25
	Isolation – Wierer – Rock Wool
	Vapour Barrier
Green Roof	Extensive Green Roof Layers (sedum/drainage)
	Protan SE Titanium
	Mineral Wool
	Vapour Control Layer

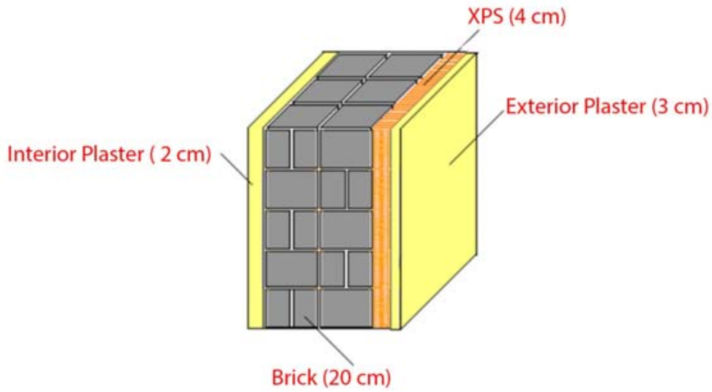


Figure 4. The external wall structure of the analyzed building.

Table 2. The external wall material properties of the analyzed building [26-28].

Materials	Thermal Conductuvity
Brick	0.3300 W/(m·K)
XPS	0.0360 W/(m·K)
Exterior Plaster	0.4 W/(m·K)
Interior Plaster	0.4 W/(m·K)

Table 3. The roof material properties of the analyzed building [29].

Materials	Heat Transfer Coefficient (U)	Thermal Resistance (R)
Standing Seam Roof	0.1457 W/(m²·K)	6.8656 (m²·K)/W
Tile Roof	0.33 W/(m²·K)	3.0301 (m²·K)/W
Green Roof	0.1194 W/(m²·K)	8.3785 (m²·K)/W

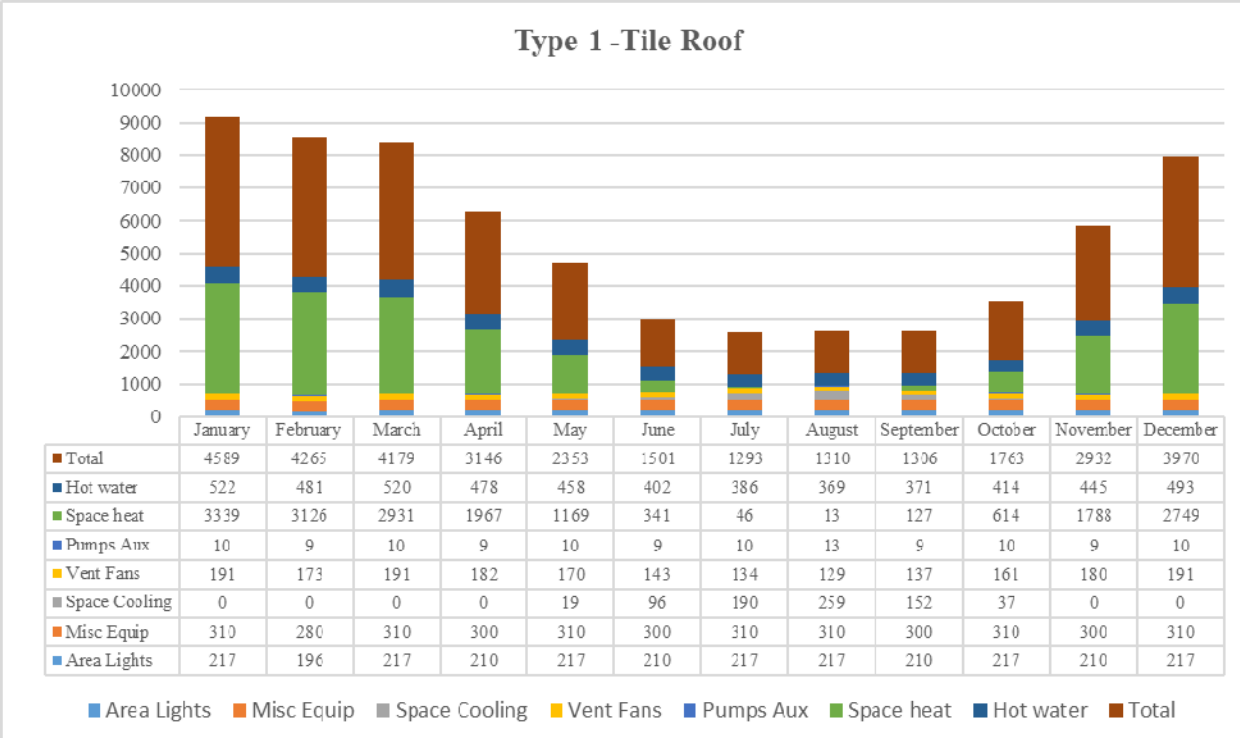
5. Results and Discussion

The Green Buildings Studio based Revit energy analysis report includes other relevant information about the building's energy performance, such as monthly heating and cooling loads and climate data about wind, diurnal weather averages, and humidity, all of which were obtained from the weather station.

Examining the monthly heating loads reveals that the greatest heat loss values occur in January, February, and December, implying that these months require more heating to compensate for this loss and maintain thermal comfort. Thermal losses are mostly caused by conduction through windows and walls. Throughout the year, the monthly cooling loads chart reveals that the windows are the biggest contributors to heat gains in the building. July and September have the highest heat gains and, as a result, the highest cooling demands if thermal comfort is desired.

Figures 8, 9, and 10 show that moderate velocity winds blow primarily to the north in July and August (the months with the greatest cooling needs, according to the heating loads study). Because the facade has windows facing this direction, full advantage of natural ventilation is provided, and building occupants in rooms adjacent to this facade's walls may not be compelled to use auxiliary cooling solutions such as fans to maintain thermal comfort, thereby, contributing to the building's energy consumption. The months of December, January, and February, as expected, have higher heating demands.

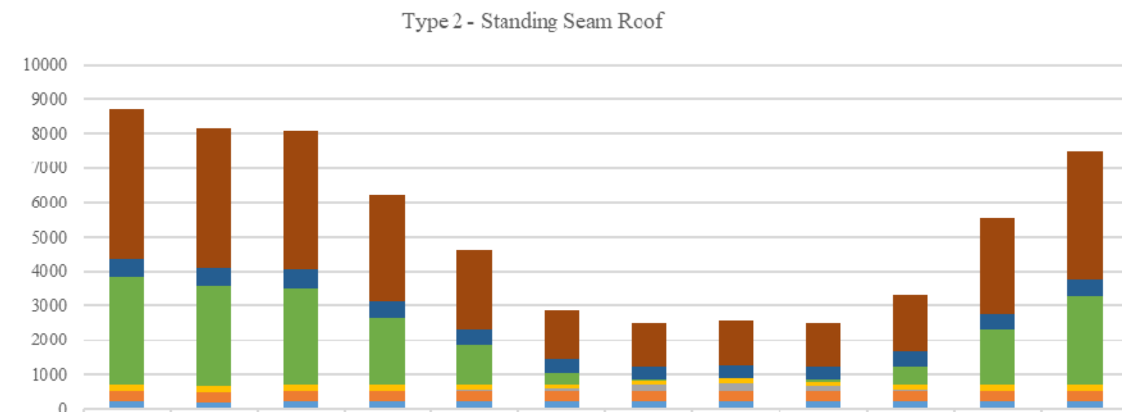
At roof design, the total energy use values obtained were 32607 kWh [Type 1 (Tile Roof)], 31355 kWh [Type 3 (Green Roof)], and 31308 kWh [Type 2 (Standing seam Roof)]. The lowest and highest energy consumption values in these roof types were obtained from pumps aux. and space heat, respectively.



	January	February	March	April	May	June	July	August	September	October	November	December
Total	4589	4265	4179	3146	2353	1501	1293	1310	1306	1763	2932	3970
Hot water	522	481	520	478	458	402	386	369	371	414	445	493
Space heat	3339	3126	2931	1967	1169	341	46	13	127	614	1788	2749
Pumps Aux	10	9	10	9	10	9	10	13	9	10	9	10
Vent Fans	191	173	191	182	170	143	134	129	137	161	180	191
Space Cooling	0	0	0	0	19	96	190	259	152	37	0	0
Misc Equip	310	280	310	300	310	300	310	310	300	310	300	310
Area Lights	217	196	217	210	217	210	217	217	210	217	210	217

Figure 5. The energy consumption values (kWh) of the mountain house designed as tile roof.

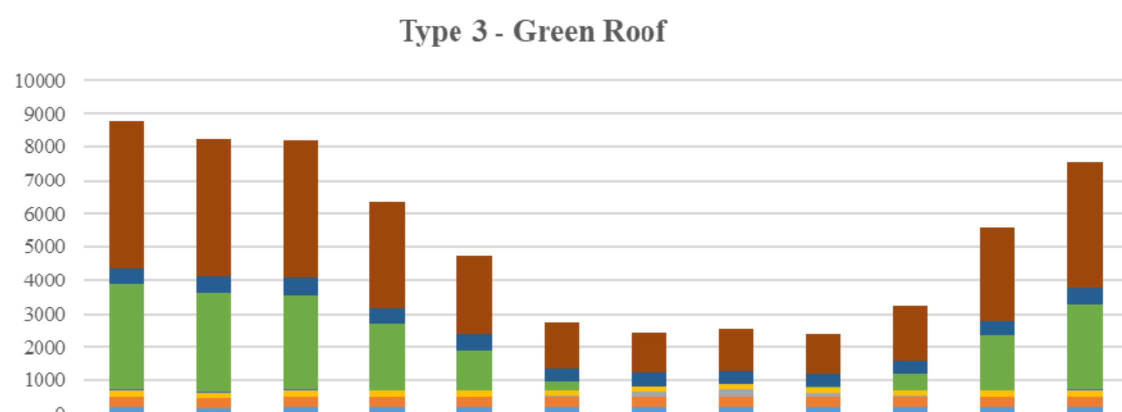
The maximum energy consumption value determined in January was 4580 kWh at Type 1 (Tile Roof). In the month of January, the maximum energy consumption for space heat at Type 1 was 18210 kWh (Tile Roof). In July, the minimum energy consumption value determined as 1293 kWh at Type 1. In the month of July, the minimum energy consumption value obtained as 10 kWh for pumps aux among energy-consuming elements of analyzed building.
The minimum energy consumption value obtained in September was 1246 kWh at Type 2 (Standing seam Roof). In the month of September, the minimum energy consumption for pumps aux at Type 2 was 9 kWh. In January, the maximum energy consumption value obtained as 4360 kWh at Type 2. In the month of January, the maximum energy consumption value determined as 3110 kWh for space heat among energy-consuming elements of analyzed building.
At Type 3 (Green Roof), the maximum and minimum energy consumption values determined in January and September were 4387 kWh and 1189 kWh, respectively.



	January	February	March	April	May	June	July	August	September	October	November	December
Total	4360	4078	4040	3107	2324	1439	1250	1279	1246	1662	2771	3752
Hot water	522	481	520	478	458	402	386	369	371	414	445	493
Space heat	3110	2939	2792	1926	1146	300	23	4	77	518	1627	2531
Pumps Aux	10	9	10	9	10	9	10	10	9	10	0	10
Vent Fans	191	173	191	184	174	145	135	128	137	161	180	191
Space Cooling	0	0	0	0	9	73	169	241	142	32	9	0
Misc Equip	310	280	310	300	310	300	310	310	300	310	300	310
Area Lights	217	196	217	210	217	210	217	217	210	217	210	217

Area Lights, Misc Equip, Space Cooling, Vent Fans, Pumps Aux, Space heat, Hot water, Total

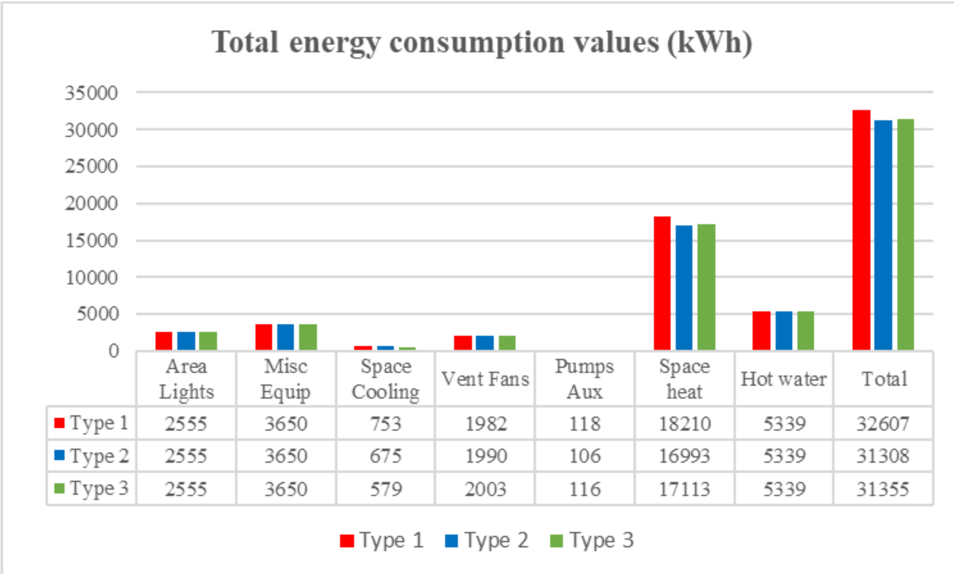
Figure 6. The energy consumption values (kWh) of the mountain house designed as standing seam roof.



	January	February	March	April	May	June	July	August	September	October	November	December
Total	4387	4113	4085	3167	2370	1376	1219	1262	1189	1616	2799	3772
Hot water	522	481	520	478	458	402	386	369	371	414	445	493
Space heat	3137	2974	2837	1985	1195	258	7	0	33	484	1652	2551
Pumps Aux	10	9	10	9	10	9	11	10	9	10	9	10
Vent Fans	191	173	191	185	178	148	136	127	138	162	183	191
Space Cooling	0	0	0	0	2	49	152	229	128	19	0	0
Misc Equip	310	280	310	300	310	300	310	310	300	310	300	310
Area Lights	217	196	217	210	217	210	217	217	210	217	210	217

Area Lights, Misc Equip, Space Cooling, Vent Fans, Pumps Aux, Space heat, Hot water, Total

Figure 7. The energy consumption values (kWh) of the mountain house designed as green roof.



6. Conclusions

Green building studio enables the reduction of human error in energy modeling as well as the cost and time optimization of the time-consuming energy simulation operation. Designers may use the findings of a green building studio's energy analysis to make informed choices about a variety of building properties, such as what type of construction components to use, window placement, building orientation, heating ventilating and air conditioning systems, and so on, to develop end user comfort, decrease the building's ecological impact, and post occupancy energy performance.
Nonetheless, Green building studio is helpful during the operation process because it allows you to compare architectural planning options and investigate retrofit alternatives for existing structures.
This study conducts a quantitative and qualitative investigation into the climatic responsiveness of mountain house roof design models. The determined outputs are below:
-The thermal quality performance's quantitative research based on Autodesk Revit Architecture Simulation Program displays that building with Type 2 (Standing seam Roof) is more effective than other roof types in energy efficiency. The use of Type 1 (Tile Roof) mountain house construction results in higher energy consumption.
- According to the qualitative research, a mountain house with Type 3 (Green Roof) consumes less energy than a mountain house with Type 1 (Tile Roof).
- It was found that Type 1 (Tile Roof) consumed more 0.14 % and Type 3 (Green Roof) consumed 3.98% more energy compared to the Type 2 (Standing seam Roof) with the best energy performance.
The results show that Type 2 (Standing seam Roof) can be used as the best efficiency alternative to other materials when used as roof material.
The energy analysis reported through this paper displayed the efficacy of building energy performance on sample a mountain house of the Revit database. In overall energy-based planning cases, the construction efficiency can be developed through implementing a minor structural modify that doesn't influence the primary design objectives and requirements. Diverse energy simulation should be applied to all designs, even the smallest ones. More consciousness and expansion among stakeholders and architects are required to highlight the importance of energy evaluation in the conceptual planning stages. In planning studios, architecture designs should focus on the energy evaluation with the scale and same value as other planning needs like urban design, structure, site and so on.

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