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Toward a Greener Building Envelope: Analyzing Sustainable Cladding Materials through BIM for Energy Efficiency

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ABSTRACT

The proper building materials used in the building envelope provide better thermal and energy efficiency of the building by allowing for better thermal regulation between the inside and exterior. The scope of this research involves the optimization of the building envelope's features to enhance the thermal ambiance and lower the energy requirements of residential structures in a specific environment. Critical design choices include the facade cladding system and building insulation materials. In order to select the most effective facade cladding system among widely used materials in the Black Sea climate conditions, this study attempts to develop sustainable design options by building information modeling of a sample site security cabin modeled with the BIM-based Autodesk Revit software, followed by a building energy model. Finally, building energy simulation was carried out with Green Building Studio, which can be integrated with the Autodesk Revit program. The heating, cooling, and total energy consumption of the sample site security cabin project were determined by the analysis. Seventy-two alternative designs resulting from eight different coating materials, three commercial insulation materials, and three different structural materials were evaluated. In terms of energy efficiency, EPS and siding were obtained as the most effective insulation materials and coating materials for Trabzon province. This way, it has been aimed to provide the designers with the information through the sample project for the buildings to be designed in the determined climatic conditions.

Keywords: Building Information Modeling; Energy Efficiency; Insulation Materials; Building Envelope; Cladding Materials

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1. Introduction

Every facet of daily life is affected by the goal of lowering energy use and greenhouse gas emissions. A significant effort has been made in this regard, particularly in the building industry, albeit there is still room for improvement given the discrepancy between actual performance and the required trajectory. Practitioners and researchers have collaboratively focused on improving the design, construction and building information modeling in the construction sector. Recent years have brought an increase in environmental and sustainable development concerns. Due to such issues, many nations are compelled to implement a number of measures that improve energy efficiency and set benchmarks in line with international norms. One of the main contributors to worldwide climate change and warming is reliance on petroleum-based fuels to meet the rising demand and this enormous and steadily increasing amount of energy usage. The main public concerns over the past ten years have included the increasing amount of gases in the atmosphere resulting in the greenhouse effect, a worsening energy constraint, and steadily increasing energy demand [1]. Buildings are one of the biggest energy consumers, contributing up to 45% of global energy usage and a comparable amount of gases in the atmosphere affecting the greenhouse effect [2]. Over 33% of CO_2 emissions come from buildings. HVAC (heating, ventilation, and air conditioning) accounts for a sizeable amount of the energy utilized in buildings [3–5]. The construction industry urgently needs to design energy-efficient structures due to the mounting challenges posed by global warming. Building codes all across the world are being called for to develop stricter energy assessment standards and design requirements with a long-term objective of net-zero-energy buildings. Building energy consumption can be greatly reduced and sustainability in the built environment achieved by developing and deploying innovative energy sectors and improving the energy performance of building mechanisms [6, 7]. Thoughtful selection of materials for the external applications of buildings is one of the passive-planning tactics to be used to reduce cooling and heating demand [8]. External walls are among the largest components and have a vital role in the heat transfer between the internal and external environment of buildings, accounting for 20% to 30% of the entire energy demand and having a high thermal transmittance [9].

The latest developments in building regulations are focused more on reducing the energy needs of buildings, which depend on improving the building's external wall coating materials' heat insulation. Thus, it should be considered when making a decision [10]. For instance, one of the design and marketing criteria is contemporary external surfaces of building planning that create a distinctive view for the construction [11]. Therefore, choosing a façade coating material is crucial because it impacts the sustainability of the structure, construction time, project cost, and final shape. The primary development in the market for insulation is the regulatory support provided by countries in various regions to promote the installation of insulation mechanisms in buildings for the purpose of energy preservation. By reducing heating and cooling needs in the winter and summer, respectively, and avoiding heat gain and loss, an insulated structure can achieve energy efficiency while saving up to 20% on energy expenses. The federal government of the USA, for instance, provides tax incentives on the purchase of insulation items [12].

Building heat insulation is a crucial topic in terms of energy conservation, cozy living spaces, and legal requirements. Several materials can be used as building coatings and employed as thermal insulators. There is a constant need for durable building materials' effective utilization with a lower negative ecological effect on sustainable ecology [13]. The thermophysical characteristics of the building components that make up the building envelope dictate how the envelope reacts to the environment [14].

Allowing solar light into the structure, protecting it from sun heat, storing heat in the walls, and utilizing insulation to stop thermal transfers are all possible goals. Preventing moisture or air from penetrating the building envelope is also an effective way of enabling natural cooling of the building interior. The occupancy pattern, equipment load, orientation, and specific climate affect each of these features to a great extent [15, 16]. According to Aksamija, the orientation, aspect ratio, placement of the building masses, and fenestration are the two factors that define the energy-efficiency building envelope's design. Spending on energy-efficiency constructions increased in 2019 for the first time in 3 years, with investment in construction energy performance across worldwide markets reaching 152×10^9 USD at the end of 2018. All the same, this displays a minor percentage of the 5.80×10^{12} USD invested in the structure and building industry. Consequently, investing in energy performance lags behind the investment in the industry, necessitating extra work to decarbonize constructions. Indeed, in the building industry, for every dollar invested in energy performance, 37 USD is used up in traditional construction methods [17]. Green buildings offer one of the most significant worldwide investment opportunities of the near future, with the "International Economic Company" estimating a 24.70×10^{12} USD opportunity through the end of 2029 [18]. Nations have a critical role in realizing this possibility, particularly today. While the pandemic poses numerous difficulties, it also provides an opportunity for change; through methodically incorporating building decarbonization measures into recycling packages, they can obviously raise real estate value, create jobs, and channel investment into zero-carbon buildings [19]. The market for "green" construction materials is predicted to expand at a yearly rate of 8.60 percent through 2027, down from 11.70 percent in 2019 [20, 21].

1.1. Green Building

As a leader in sustainable development in the twenty-first century, green building now balances the long-term needs of the economy, the environment, and society. The green structures have been promoted as cost-effective alternatives to conventional structures [22].

Green buildings use less of natural resources compared to conventional buildings incorporating features such as energy efficiency and eco-friendliness. Green buildings also release less waste and help build healthier living conditions. The buildings integrate effective landscape usage, renewable energy sources, recycled materials, and better indoor air quality for comfort and health [22]. Sustainable building is the practice of creating buildings through methods that are resource- and ecologically conscious during all phases of the life cycle of a building, including design, operation, construction, maintenance, demolition, and restoration. Insulation materials are often regarded as "green" materials since they are used to reduce energy loss from buildings. The sustainable construction method takes a building's overall financial and ecological efficiency into account, from product manufacturing and resource extraction to building design, maintenance and operation, product transportation and construction, and building disposal and reuse [23].

1.2. Green Building Studio Simulation

To achieve a greener building, the procedure for choosing a façade system characteristically depends on various variables, including the function of the structure, the location, the budget, and the local climate. Choosing a façade material is now a difficult issue for designers and master developers because there are so many elements to consider. The development of new building processes, the need for extremely controlled interior environments, the emphasis on energy economy, and the introduction of new materials have all made building façade design much more difficult. Construction material selection using only a single factor is not sufficient; a simulation tool is required [24]. Therefore, it is essential to use a combined appoarch that contributes to closing the gap between the factors used in the process. The integrated application of several building model software applications is known as BIM. The structure can be represented in BIM by generating data for parameterized models, which are then shown in 3D and evaluated by computers using useful software [25]. According to researchers like Succar, BIM is a parameterized management system that allows collaboration and interaction with one another while technology, processes, and regulations are integrated for data management across the complete building life cycle [26]. Fischer and Kunz go on to broaden the definition of BIM and focus on organizational and process models in addition to the physical model of the product [27].

The application process of BIM has obvious practical qualities that are expressed in two aspects and are influenced by the fundamental characteristics of the engineering project production process: the application, software, and hardware of BIM are all varied. Studies conducted have shown that BIM may be utilized at various stages and take into account the content, sectors, and application points of various participants [28]. Numerous pieces of BIM hardware and software are required to implement these functions. BIM software essentially encompasses a collaborative project management platform in addition to fundamental model generation, analysis, and simulation software. The infrastructure for BIM applications is made up of these kinds of BIM software and related hardware. Secondly, the use of BIM is task-dependent across organizational boundaries. The use of BIM in engineering projects necessitates task interdependence because it is a complicated information interaction process that calls for collaboration and cooperation between various stakeholders. This structure exemplifies a specific kind of inter-organizational cooperation. Strong task dependency is created by the cross-organization coordination of information exchange and interaction based on BIM in the project layer. Individuals can carry out individual BIM tasks, such as model creation and collision detection. However, multiple participants are necessary for cross-organizational collaboration [29]. Due to its ability to integrate and manage this information across the course of a construction's entire life cycle, building information modeling presents a practical option for the engineering, architectural, and building industries. Additionally, it presents a chance to design buildings that are environmentally friendly through the use of an integrated approach.

The focus of the work here is to assess the performance of the most popular and favored façade materials in terms of construction thermal performance and energy usage, especially the cooling and heating load in Trabzon, a city in the Black Sea region. For contemporary and healthy life, one of the main goals of the research is to identify the best cladding material option for assessing the façade coating system's energy efficiency in the Black Sea climate. Green Building Studio software is utilized to assess the planned analyses of the facade systems' energy efficiency of a sample site security cabin. In order to fill the conceptual gap between the structure materials' performance utilized in the building's external wall and the climatic context over time, several studies have aimed to optimize the thermal behaviour of the building envelope. These studies have focused on the construction material features of the envelope, to evaluate and improve its role in the energy performance of the building. The goal of this research is to produce design suggestions for façade coating materials and systems that the developer prefers to satisfy the market demand while achieving energy conservation goals in a particular climatic region. In an attempt to contribute to the literature of energy efficiency of buildings, this paper addresses the following research question:

> Research Question 1: What is the best cladding material for energy efficiency in the Black Sea climate zone?

The rest of this paper is organized as follows: Section 2 presents a review of the related literature. The methodological approach is presented in Section 3, followed by the Results and Discussions in Section 4. Finally, Section 5 provides the conclusions of the study along with the directions for future studies.

2. Literature Review

Numerous researches about enhancing the energy efficiency of existing buildings and utilizing BIM-based programs have been published in the literature. To be able to apply prospective design changes prior to the construction process with the main lines, Flores sought to estimate the building's energy usage. He attempted to create a structure efficiency study utilizing Autodesk Revit in an educational facility for this purpose [30]. Using the Autodesk REVIT program, Savaşkan created many types by changing the roofing material, the number of rooms, the thermal insulation material, and the transparency. He has undertaken research that demonstrates how these situations could be used to construct high-energy efficiency buildings [31]. Le has designed a program for analyzing buildings called Autodesk Green Building Studio. This software provides the energy usage results, including water consumption and expenses, possibilities for natural-sourced ventilation, C-emissions depending on actual modeling, available regional energy supplies, and meteorological information. Green Building Studio simulation is such a powerful and practical mechanism that operates under genuine norms and gives very reliable outputs [32].

The validity of building information modeling-sourced energy analysis during the notional project phase of a building has been investigated by Kuo et al. Through comparison of the outputs of the electric usage computed in the software with the observed actual outputs of the electric generation, this study has demonstrated the reliability and applicability of the energy assessment by building information modeling-sourced software [33]. The standards by which the software utilized in the computations of energy load to be evaluated have been established by Akcatir and Nacar. To do this, they carried out an application with EnergyPlus software and looked at how EnergyPlus, Hourly Analysis Programme, and Design Builder simulation items were used. They concluded by saying that it has shown to be as reliable as the key software components [34]. Ergen and Ktem sought to create a manual for businesses to follow as they made the transition to building information modeling. For this, two frameworks have been created, and their usefulness and validity have been evaluated. An operational building information modeling framework that the enterprises might use as a reference has been created as a result [35]. Sancaktar has looked at how well the heating performed in the structures built before 2000. By reconfiguring the five-story two-block building with the improvements that could be carried out in accordance with TS 825 norm and upon computation program, he conducted performance and cost analysis. Improvements made to the walls and windows have reduced energy consumption by 56.8% [36].

Douglass has investigated how building information modeling is used in conjunction with energy analyses and simulations. In order to do this, he performed evaluation research on a building that the author had previously modeled using DesignBuilder, Ecotect, and Revit. As a result, the author has noted that various issues arise while transferring building information modeling data to the analytical tools. Additionally, the Ecotect and DesignBuilder simulation results revealed a 15% difference in annual cooling and heating energy between the passive solar planning techniques in the worst and best conditions [37]. Martin used comparative analysis and the Autodesk Green Building Studio to look at how one school's life-cycle energy costs, energy use, and C-emissions are affected by building information modeling. While doing this, analyses that will demonstrate the advantages of the sustainability and utilization life costs of the structures have been carried out using building information modeling. He has stressed the significance of the early incorporation of energy modeling evaluations in the notional planning of the building design as a consequence of his studies. Additionally, he has stated that early design energy analysis will present a chance for energy savings by using cost decision-making, building information modeling, and green building studio from the beginning of the building's life cycle [38]. Using the BEopt and Stephens EnergyPlus programs, Stephens and Leinartas estimated the costs and energy performances of sample buildings in Chicago that were built before 1980, were free, and had brick as their outer wall material. As a result, they have demonstrated that building upgrades might result in energy savings of at least 50%. Additionally, it has been reported that the Chicago region will have investment opportunities if these energy renovations are implemented in all of the residential structures constructed before 1987 [39]. Byers and Abanda used a model building to calculate this building's energy usage in the Revit application. It has been determined that energy can be saved when building orientations are changed, particularly in terms of fuel and electricity use [40]. Review on the applications of building simulation for operation is given in **Tables 1−3**.

In light of the information provided in the literature review above, it can be said that the increasing use of BIM-based simulations in early design stages and in planning with different components are important tools for designing more energy-efficient buildings.

3. Methodology

Given that it consumes a sizable portion of global energy, material, and electrical sources and is the primary pollution factor, there is currently a growing concern about the construction industry's economic and environmental sustainability [41]. As a result, the necessity of lowering building costs as well as increasing the effectiveness of the construction process is emphasized [42]. In fact, there is an increasing interest in predicting the energy performance of structural materials and elements under normal circumstances since architects must design structures in accordance with durability criteria [43].

The strategy of this research is based on the energy consumption calculations that have been completed; as a result, energy and environmental parameters are then calculated for each component of the building's envelope that is linked to the self-styled building information modeling, allowing for a straightforward view of the overall environmental effects of the structure and showcasing a significant scientific contribution of our research.

In this study, a site security cabin was projected in Trabzon province in the Black Sea region. This building was designed in the climatic conditions of the province. The outer walls of the building are planned as insulated from the outside. Eight different coating materials [Aluminium, Stone chipping, Granite (red), Granite (gray), Marble (white), Pine boards, Siding, Cement plaster], three commercial insulation materials [rockwool, EPS, woodwool] and three different structural materials (pumice block, brick and gas concrete) were used. A tile roof was used in the study. 72 alternatives are divided into scenarios [A, B, C, D, E, F, G, H, and I].

Table 1. For operation, the building simulation's implementations.

Tools	Optimization Strategy	Type of Buildings	Component	Equipment	System	Ref.
EnergyPlus	In mixed-mode buildings, air fans were controlled by windows and ventilation supplies.	office building	x			[41]
TRNSYS	The optimal performance and cooling capacity were determined by selecting the operation mode (mechanical cooling, partial cooling, free cooling, and free cooling).	data center	x			[42]
Matlab	It was anticipated that clogging would cause pressure drops in the AHU's filters.	–	x			[43]
EnergyPlus, CONTAM, and Matlab	Fan pressure and damper angle optimal trajectories were established.	–	x			[44]
IES-VE	The VAV's airflow and the AHU's supply temperature are tuned separately.	commercial building		x		[45]
TRNSYS	By modifying the chilled water outlet temperature set points, the chiller loading was maximized.	metro station		x		[46]
R	The cooling tower fan speed, the supplied chilled water temperature, and the chilled water and condensing water flow rates are identified.	educational building		x		[47]
EnergyPlus	The temperature response and occupancy forecast are used to adjust the HVAC setpoint schedule, subject to the thermal comfort threshold.	mosque			x	[48]
DeST	The solar CCHP's output strategies under climate change were addressed.				x	[49]
Design	The air conditioner's heating and cooling settings were chosen as the deciding factors.				x	[50]
Modelica	K P and T I, the PID-controller settings for compressor speed, were optimized.				x	[51]

The BIM-based Autodesk Revit program was utilized. The sample site security cabin project is modeled in this program. Consequently, the building energy model was generated. In the next stage, building energy simulation was carried out with Green Building Studio, which can be integrated with the Autodesk Revit program. The heating, cooling, and total energy consumption of the sample site security cabin project were determined by the analysis.

Project and exterior view and 3D view of a sample site security cabin are illustrated by Lumion software in **Figures 1** and **2**.

Figure 3 illustrates the series of steps followed in the methodology.

With the help of Autodesk Green Building Studio, a versatile online cloud-based tool, building performance simulations can be performed at the start of the design for energy efficiency maximization and reaching carbon neutrality. Designing high-performance buildings in a fraction of the time and expense of traditional approaches is made possible by Green Building Studio [6]. Both conceptual and detailed information-building models can be used to examine energy usage [8]. All building components can be modeled in Revit to automatically generate an Energy Analytical Model. After that, Green Building Studio receives this data for energy simulation. The architecture, location and certain detailed models and energy can be changed using the energy settings. Lastly, the Energy Simulation is activated within the system [9]. There is no need to enter climatic data because it is already in the cloud in the Autodesk GBS program. However, some information needs to be entered and verified first, specifically: the address, the value in the energy settings, and the material's U-value for the study.

Some advantages of Green Building Studio: It is easy to use and has a straightforward appearance. The Revit model can be quickly converted to gbXML format. If the model is connected with Revit, some preparation is required. Processing is done automatically, requiring little data input, and everything is cloud-connected. Some drawbacks of Green

Table 2. Review of performance-driven design applications.

Simulation Tool	Building Kinds	Air Quality	Daylighting	Thermal	Energy Related	Ref	Optimization Objectives
Rhinoceros; DIVA	Office		x			[52]	useful daylight illuminance
EnergyPlus	Education and Office			x	x	[53]	Energy use, Non-comfortable hours, Exergy destructions
EnergyPlus Radiance			x	x		[54]	cooling and heating loads Daylighting scores
EnergyPlus eQUEST DesignBuilder;	Education	x		x		[55]	Indoor air temperature CO_2 concentration
Radiance, Sketchup	Education		x			[56]	useful daylight illuminance daylight autonomy
IBE-e, TRNSYS	Office		x		x	[57]	Energy consumption
Hospital	Hospital		x			[58]	Mean air age
EnergyPlus DesignBuilder	Residential				x	[59]	CO_2 emissions Energy consumption
Honeybee Grasshopper Rhinoceros	Office		x			[60]	useful daylight illuminance, spatial daylight autonomy, annual solar exposure
Green Building Studio	Residential				x	[61]	CO_2 emissions Energy consumption

Table 3. An overview of three distinct approaches to simulating building energy performance [62].

Tool/Typical Method	Order	Method	Limitation	Advantage
Support vector machine (SVM) Artificial neural network (ANN) Multiple linear regression	Inverse	Regression and Statistical	Low physical interpretation Solely for present buildings	Fast calculation Accurate prediction
TRNSYS EnergyPlus DOE2	Forward	Detailed physical	Complex inputs	High physical result Visualization tools
Bim method Degree-day method	Forward	Simplified assessment	Limited applicability	Fast calculation Simple inputs

Building Studio include the internet connectivity requirement since all data is connected to the cloud.

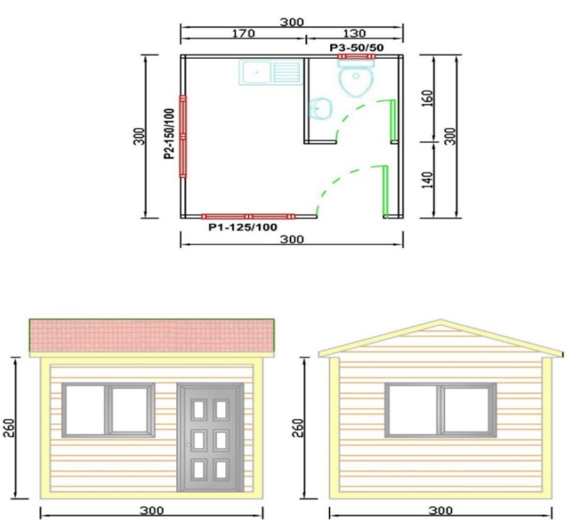


Figure 1. Project and exterior view of a sample site security cabin.

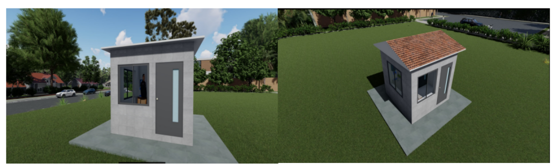


Figure 2. 3D view of a sample site security cabin by Lumion software.

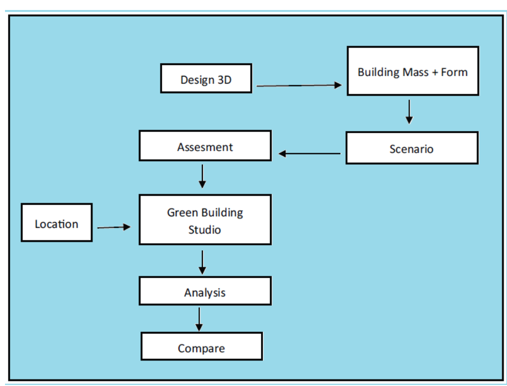


Figure 3. Research framework.

Building information of the site security cabin is given in **Table 4**. Building envelope design alternatives of the security cabin are shown in **Figure 4**.

Table 4. Building information of site security cabin.

Site Security Cabin Building Information	
Carrier system	Masonry construction
Number of floors	Ground floor
Story height	2.6 m
Dimensions	3 m × 3 m
Gross area	9 m²
Net area	8 m²
Wall thickness	33 cm

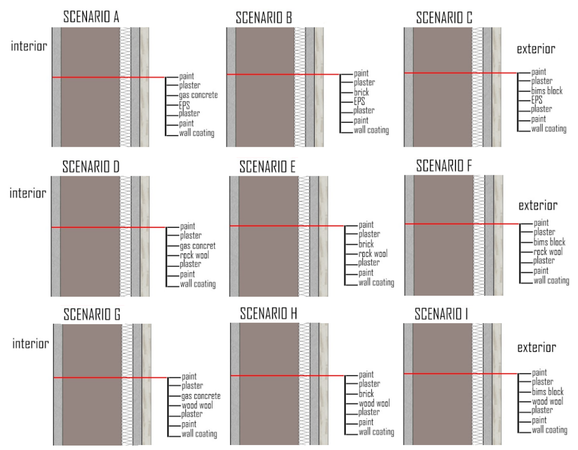


Figure 4. Building envelope design alternatives of a sample site security cabin.

Designed alternative type properties for the site security cabin and technical properties of the used materials at the designed site security cabin are given in **Tables 5** and **6**.

4. Results and Discussion

The results provide a comprehensive validation study on sustainable cladding materials for building envelopes using Building Information Modeling (BIM). The study utilizes Autodesk Revit and Green Building Studio for simulating energy performance, focusing on the energy efficiency of different façade materials under specific climatic conditions. It validates the effectiveness of various insulation and cladding materials in reducing energy consumption in buildings by comparing 72 combinations of materials and designs across multiple scenarios. Key findings show a significant variation in energy savings based on material choice, highlighting the study's validation framework for optimized building envelope design in the Black Sea region. Based on the eight scenarios that were created in the previous step, energy consumption values according to alternative types of designed site security cabins are illustrated in **Figure 5**.

Table 7 provides the maximum and minimum results obtained from the scenarios with simulation analysis.

When the 72 alternatives created are compared in terms of cooling energy consumption, the maximum annual cooling energy value is found as 904 kWh by the three different types (Type 18, Type 22, and Type 23). All of the types are defined in Scenario C. In Scenario C, bims block (20 cm) and EPS (6 cm) are used as building material and insulation material at the external insulated wall structure. Stone chipping, pine boards, and siding are used as coating materials in Type 18, Type 22, and Type 23, respectively.

The minimum annual cooling energy value is obtained as 842 kWh by Type 61 in Scenario H. Brick (20 cm), wood wool (6 cm), and white marble (3 cm) are used as building material, insulation material, and coating material at the external insulated wall structure. When the annual cooling energy values obtained with the analysis were compared, an energy saving of 6.85% was calculated between the maximum (Type 18) and minimum (Type 61) values.

Figure 5. *Cont.*

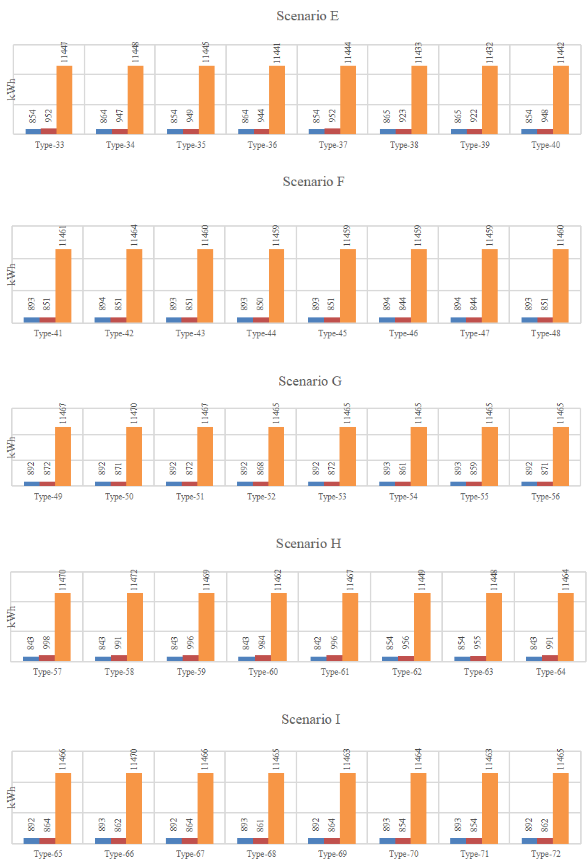


Figure 5. Energy consumption values according to alternative types of designed site security cabin.

According to the annual heating energy values, the maximum value is found as 998 kWh by Type 57 [brick, wood wool, and aluminum are used as building material, insulation material, and coating material, respectively] in Scenario H. The minimum value is obtained as 834 kWh with the above-mentioned materials for Type 22 and Type 23 in Scenario C. When the annual heating energy values obtained with the analysis were compared, an energy saving of 16.43% was calculated between the maximum (Type 57) and minimum (Type 22) values.

In the framework of annual total energy, the maximum value is determined as 11,472 kWh [annual cooling energy value 843 kWh and annual heating energy value 991 kWh] through Type 58 [brick, wood wool, and stone chipping are used as building material, insulation material, and coating material, respectively] in Scenario H.

The minimum value is found as 11,419 kWh (annual cooling energy value 876 kWh and annual heating energy value 893 kWh) by Type 15. In Scenario B, Type 15 included brick (building material), EPS (insulation material), and siding (coating material). When the annual total energy values obtained with the analysis were compared, an energy saving of 0.46% was calculated between the maximum (Type 58) and minimum (Type 15) values.

Table 5. Designed alternative type properties for site security cabin.

Type	Wall (cm), (in-out)					
1					Aluminum (3)	
2					Stone chipping (3)	
3					Granite (red) (3)	
4					Granite (gray) (3)	
5		Gas concrete (20)			Marble (white) (3)	
6					Pine boards (3)	
7					Siding (3)	
8					Cement plaster (3)	
9					Aluminium (3)	
10					Stone chipping (3)	
11					Granite (red) (3)	
12	Plaster (2)	Brick (20)	EPS (6)	Plaster (2)	Granite (gray) (3)	Tile roof
13					Marble (white) (3)	
14					Pine boards (3)	
15					Siding (3)	
16					Cement plaster (3)	
17					Aluminium (3)	
18					Stone chipping (3)	
19					Granite (red) (3)	
20					Granite (gray) (3)	
21		Bims block (20)			Marble (white) (3)	
22					Pine boards (3)	
23					Siding (3)	
24					Cement plaster (3)	

Table 5. *Cont.*

Type	Wall (cm), (in-out)					
25	Plaster (2)	Gas concrete (20)	Rock wool (6)	Plaster (2)	Aluminium (3)	Tile roof
26					Stone chipping (3)	
27					Granite (red) (3)	
28					Granite (gray) (3)	
29					Marble (white) (3)	
30					Pine boards (3)	
31					Siding (3)	
32					Cement plaster (3)	
33		Brick (20)			Aluminum (3)	
34					Stone chipping (3)	
35					Granite (red) (3)	
36					Granite (gray) (3)	
37					Marble (white) (3)	
38					Pine boards (3)	
39					Siding (3)	
40					Cement plaster (3)	
41		Bims block (20)			Aluminum (3)	
42					Stone chipping (3)	
43					Granite (red) (3)	
44					Granite (gray) (3)	
45					Marble (white) (3)	
46					Pine boards (3)	
47					Siding (3)	
48					Cement plaster (3)	
49		Gas concrete (20)	Wood wool (6)			
50					Stone chipping (3)	
51					Granite (red) (3)	
52					Granite (gray) (3)	
53					Marble (white) (3)	
54					Pine boards (3)	
55					Siding (3)	
56					Cement plaster (3)	
57		Brick (20)			Aluminium (3)	
58					Stone chipping (3)	
59					Granite (red) (3)	
60					Granite (gray) (3)	
61					Marble (white) (3)	
62					Pine boards (3)	
63					Siding (3)	
64					Cement plaster (3)	
65		Bims block (20)			Aluminium (3)	
66					Stone chipping (3)	
67					Granite (red) (3)	
68					Granite (gray) (3)	
69					Marble (white) (3)	
70					Pine boards (3)	
71					Siding (3)	
72					Cement plaster (3)	

Table 6. Technical properties of used materials at designed site security cabin.

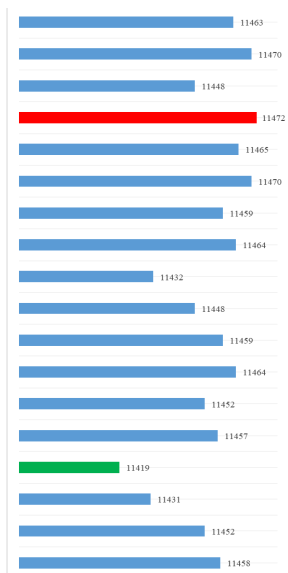
Wall Material	Thermal Conductivity W $(m\cdot K)^{-1}$	Density kg m^{-3}	Insulation Materials	Thermal Conductivity W $(m\cdot K)^{-1}$	Density kg m^{-3}
Gas concrete	0.11	350	EPS	0.035	15
Bims block	0.23	770	Rock wool	0.045	150
Brick	0.5	1200	Wood wool	0.060	350
Plaster	1.0	1800			

Table 6. *Cont.*

Wall Coating Material	Thermal Conductivity W $(m \cdot K)^{-1}$	Density kg m^{-3}	Slab Materials	Thermal Conductivity W $(m \cdot K)^{-1}$	Density kg m^{-3}
Aluminium	160	2800	Slab on grade—Reinforced concrete slab	2.5	2400
Stone chipping	0.96	1800	Bedding mortar—Reinforced screed	1.4	2000
Granite (red)	2.9	2650	Protective concrete	1.65	2200
Granite (gray)	0.36	1840	XPS	0.04	35.00
Marble (white)	2.77	2600	Granite covering	2.8	2500
Pine boards	0.10	506			
Siding	0.094	640			
Cement plaster	0.72	1865			
	U Value W $(m^2 \cdot K)^{-1}$			**U Value W $(m^2 \cdot K)^{-1}$**	
Floor slab	0.7729		Tile Roof	0.33	
Suspended slab	8.6420				
Floor Slab (cm)					
Slab on grade (50.00)	Waterproofing (0.10)	Bedding mortar (5.00)	XPS (4.00)	Protective concrete (3)	Reinforced screed (5.00)
Suspended Slab (cm)					
Wall paint (0.10)	Plaster (2)	Reinforced concrete slab (15.00)	Reinforced screed (5.00)		

Table 7. Maximum and minimum results obtained from scenarios with simulation analysis.

Scenario	Type	Value
A	2	Min.
	6	Max.
B	9–10	Min.
	15	Max.
C	18	Min.
	22–23	Max.
D	26	Min.
	30–31	Max.
E	34	Min.
	39	Max.
F	42	Min.
	44–47	Max.
G	50	Min.
	52–56	Max.
H	58	Min.
	63	Max.
I	66	Min.
	69–71	Max.



5. Conclusions

In order to fill the conceptual gap between the structure materials' performance utilized in the building's external wall and the climatic context over time, several researches have aimed to optimize the thermal behaviour of the building envelope. These studies have focused on the construction material features of the envelope, to evaluate and improve its role in the energy performance of the building.

In order to be energy efficient, green buildings frequently take steps to reduce both the embodied energy needed to remove, transport, process, and establish construction materials in addition to the operating energy needed to provide services such as equipment power and heating. Porches, awnings, and trees have been positioned to shadow roofs and windows in the course of summer while optimizing sun-based gain in the course of winter. Windows and walls have also been angled. Additionally, properly positioned windows allow more natural light, decreasing the requisition for electricity lighting in the course of the day. Electricity expenses are further reduced through sun-based water heating. To improve the efficiency of the building's external walls and lower operating energy consumption, high-performance windows and insulation to the ceilings, walls, and floors are added.

When building sustainably, an investor's decision to choose a particular type of alternative is influenced by their choice of environment-friendly and energy-efficient alternatives. Material choices made while constructing a new structure, however, have an important impact on the structure's environmental and energy performance. This is why our study uses a BIM technique to perform an organized examination of the environmental and energy impact of construction external wall components.

The goal of this research is to produce design suggestions for façade coating materials and systems that the developer prefers to satisfy the market demand while achieving energy-conservation goals in a particular climatic region. When the analyses were examined in terms of masonry material for total energy consumption, the material that gave the most positive and the most negative results was determined to be brick. In terms of energy efficiency, EPS and siding were obtained as the most effective insulation materials and coating materials for Trabzon province. This way, it has been aimed to provide the designers with the information through the sample project for the buildings to be designed in the determined climatic conditions. Future direction for research involves the application of the developed approach to other climatic regions to validate the results in different settings.

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Conceptualization, data curation, and literature review, F.B.; first draft, editing, and proofreading, L.S.; software, and analysis, H.B.

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Data Availability Statement

Data will be made available by the authors upon request.

Conflicts of Interest

There are no conflicts of interest reported.

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