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Energy Consumption at Accommodation Buildings: A Case Study of a Boutique Hotel-Abdera

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Abstract

Global environmental problems such as decreasing biodiversity, natural disasters, climate change, and energy consumption are among the main concerns of the countries. Approximately 50% of the energy consumed worldwide is spent on architectural construction, use, and operation. The increase in energy consumption in buildings especially has taken the reduction of carbon footprint and the importance of energy efficiency to the fore. Physical environment, climate, orientation, envelope, and material properties are among the different factors in determining energy consumption in buildings. The share of tourism activities in total emissions is estimated to be 5%. However, it is also stated that tourism buildings have a share of 21 % of $C0_2$ emissions. This work aimed to research the energy consumption of a boutique hotel in Abdera, Greece. ArchiCAD, Graphisoft, and EcoDesigner software were used in the analysis of findings, and suggestions were put forward. Energy consumption and environmental effects were investigated when active solar systems (Solar Thermal Panel /STP (30 m^2), Photovoltaic Panel/PV (30 m^2)) were added to the roof surface (total 60 m^2 Panel) of the building. The analysis showed that the addition of active solar systems by 30% could reduce emissions. In Greece, which is located in a very favorable region in terms of geographical features, it is very important to use solar potential with integrated systems in buildings to provide energy needs.

1. Introduction

The growth of environmental problems on a global scale is indicated in the Brundtland Report published by the World Commission on Environment and Development (WCED) in 1987 [1]. The publication of the report entitled *"Our common future"* has ensured that worldwide environmental problems such as biodiversity, natural disasters, climate change, and energy consumption are at the top of the agenda of the world countries. In this regard, having respect for the right to life of the planet and future generations comes to the fore in the studies entitled "environment" in terms of adopting approaches to the effective use of living resources.

Energy supply is increasing on the scale of regions over the world day by day. As the primary energy supply approaches 15000 Mtoe, it is observed that non-renewable/fossil resources are used as the main resources [2], (Figure 1).

Currently, studies are being focused on the use of renewable energy resources such as solar, wind, etc., and integrating these resources into buildings to meet energy needs in buildings. Renewable resources are used as much as possible by passive and active methods, especially in regions with high solar energy potential [3-5].

It aims to create a low and zero-emission building stock by 2050 and to reduce greenhouse gas emissions by 80%-95% compared to 1990. Measurable milestones will be determined for 2030 and 2040 and national road maps will be created to ensure that buildings are decarbonized. Building energy efficiency becomes prominent in reducing energy losses and negative environmental impacts against an increasing building stock. At the COP 27 conference, which took place recently, solutions for achieving decarbonization were discussed.

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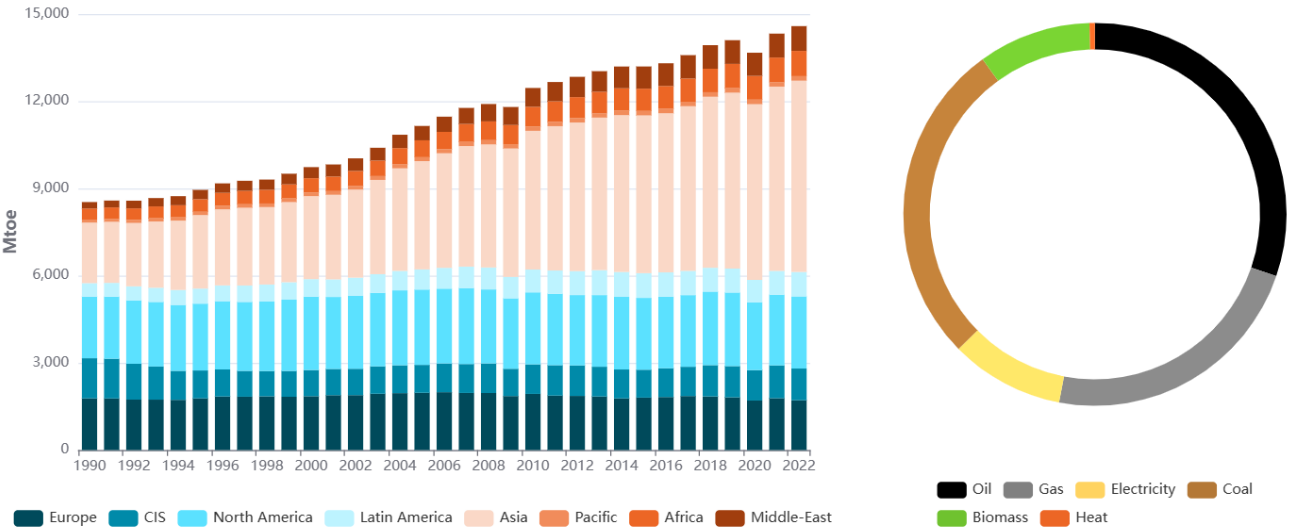

Figure 1. Primary energy supply and energy resource worldwide [2].

Although the science of ecology, which we can call environmental science, has emerged as a branch of biology, it has now transformed into an interdisciplinary field [6- 7]. At this point, the discipline of architecture, which is obliged to regulate the environment, spends about 50% of the energy consumed worldwide in the processes of building construction, use, and operation [8]. In this sense, it will be useful to research the life cycles and environmental effects of buildings designed by architects. Different building typologies serve different functions within the discipline of architecture. In particular, the tourism sector, which grew all over the world before the global pandemic, also led to a rapid increase in accommodation buildings [9-10]. Due to this fact, big accommodation buildings whose numbers increase rapidly consume energy and natural resources (use of materials), and produce waste, can have harmful effects on the natural environment. The share of tourism activities in total emissions is estimated to be 5% [11]. However, it is also stated that tourism buildings have a share of 21 % of $C0_2$ emissions. [5], [12]. High energy consumption is observed in hotels due to their operational characteristics, unlike other buildings [13]. This is mainly due to the need for air conditioning, cooking and a high rate of water use, etc [14]. With the energy consumption of these buildings, their environmental impact also increases [7].

This work aimed to examine the energy consumption of a boutique hotel in Greece. The energy efficiency and environmental effects to be achieved by integrating active solar systems into the building have also been calculated. The effect of active systems used in combination with passive methods in providing energy efficiency in settlements with high solar potential has been studied. Figure 2 also shows the stages followed in the study.

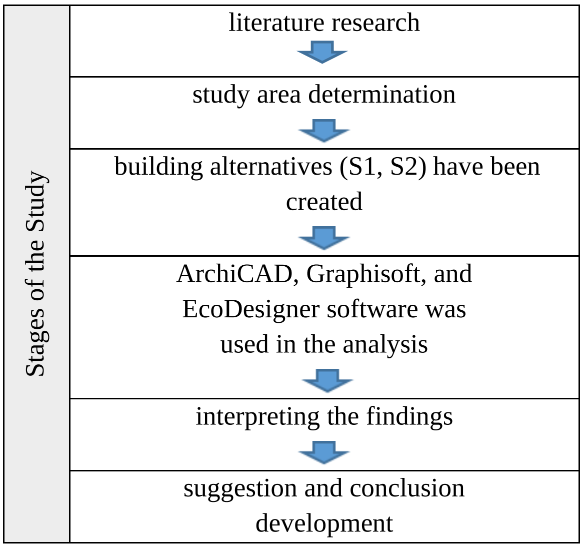

Figure 2. Stage of study

2. Literature Review: Accommodation Buildings

The activity of accommodation is a temporary stay at a place during a journey continuum. This static action is fulfilled by the discipline of architecture with *"accommodation buildings"*. Accommodation buildings have developed throughout history depending on changing environmental conditions. With the spread of railways in the 19th century, inns and caravanserais, which were accommodation buildings of previous centuries, were replaced by city hotels; while in the 21st century, they became boutique hotels, motels, star hotels, and resorts [15].

In the 21st century, with the consistent increase in environmental problems that began in the 1970s, it seems that the concept of energy consumption and comfort conditions of boutique hotels have started to be among the research topics [16]. In this century, where sensitivity to environmental resources is at the forefront, the concept of *"boutique hotel"* should be evaluated with an understanding respectful to humanity, aiming to use existing materials and energies effectively with the idea of efficient energy consumption and providing comfort conditions, evaluating environmental data with a minimum waste understanding, and aiming to transfer natural resources to future generations without deterioration.

There is no clear definition of a boutique hotel. In general, the common interpretation of all definitions is that boutique hotel units are small and have a unique design. They also vary in scale depending on country and location [17]. When we look at the definitions of Boutique Hotels in recent years, it is seen that the definitions coincide with the tourism demands of the period. With the reflection on the concepts of sustainability and energy efficiency in the tourism literature, it is seen that studies on environmental sensitivity have increased after 1990 [18]. The environmentally sensitive tourism approach has brought with it an understanding of environmentally friendly buildings. In this sense, the concept of a boutique hotel, one of the accommodation typologies, has also changed in parallel with the expectations of the period. It is seen that the scale of the boutique hotel has been reduced and definitions have been made considering visitor habits. According to Nobles and Thompson (2001), "Boutique hotels are hotels with a maximum of 100 rooms, a friendly atmosphere, personalized service, friendly attitude of staff and management, and excellent service that knows what the customer wants at what time". Looking at the common features of the definitions in later years in the same context, it is defined as a type of accommodation with max. 100 rooms, where individuality is at the forefront, comfort is provided, and a sensitive approach to people and the environment is adopted [19-30].

From the general concept analysis, it is concluded that the future hotel typology will be a boutique hotel. It is expected that boutique hotels, which are among the hotel concepts that will be preferred in the future, will respond to worldwide problems in terms of energy consumption and comfort condition approaches. It is expected for the approach of minimizing energy consumption to be adopted, since the increase in energy consumption has taken the reduction of carbon footprint and energy efficiency to the fore, especially in buildings. In this sense, when looking at the factors that determine the energy consumption of a boutique hotel, it can be seen that there are many factors like material properties, climate, physical environmental data, building envelope, orientation, etc.

The Building Energy Performance Directive was published by the European Union (EU) in 2002 and its revision in 2018, with the aim of increasing the energy performance in buildings [31]. This Directive aims to improve the energy performance in new and existing buildings, evaluate the applicability of renewable energy sources, limit greenhouse gas emissions and calculate energy performance, use energy efficiently and effectively, and protect the environment [32]. In addition, buildings are certified on a global scale in terms of sustainability, energy efficiency, environmental effects, user health, and comfort (LEED, BREAM, Green Star, etc.). In this concept, to ensure this in our country in 2008, the accommodation establishments were planned and realized in an environmentally friendly manner along with the adaptation of the facility to the environment, ecological architecture, awareness of the environment, providing training, and cooperation. The relevant institutions and organizations were given "Environmentally Friendly Accommodation Facilities with Tourism Management Certificate". The Communiqué on Granting the Certificate was issued and the "Green Star" project was implemented [33], [34]. In the Green Star scoring system, energy and ecological architecture constitute half of the total score, and the most effective title was determined as energy [35]. Similarly, in a European Country – Greece -, the Building Energy Performance Directive was adapted and published in 2020 [36]. In Greece, energy-efficient building performances are adapted for existing or new building revisions. In this sense, passive and active methods are applied, which are among the necessary methods to increase the energy performance in accommodation buildings [37].

Passive solar systems (South orientation, greenhouse, Trombe wall, etc.) are the oldest method used to provide energy efficiency in buildings. Active solar systems, which are used to meet energy needs and make more use of solar energy, are also being gradually developed and widely used today [38]. Active solar systems such as Solar Thermal Panel (STP) and Photovoltaic Panel (Photovoltaic Panel-PV) are the systems used to provide the "hot water and electricity" needs of buildings [39].

3. Materials and Methods

Greece, a tourism country, visited intensively seasonally, was chosen as the study area. Greece is in a very favorable region in terms of geographical features, the study area. Therefore, it has a very rich potential for solar radiation (Figure 3), [40]. It is very important to use the solar potential with integrated systems in buildings and provide energy needs. Greece, as a tourism country, is also affected by environmental problems on a global scale. In the supply-demand relationship, the number of accommodation buildings that can meet the increasing tourist density is also increasing [41], [11].

Figure 3. Solar Radiation Map of Greece [40].

The increase in accommodation buildings deteriorate the city's environmental resources [42]. Considering the capacity and characteristics of accommodation buildings, it is possible to exemplify hotels, pensions, boutique hotels, hostels, and chalets [43-45]. In Greece, where mass tourism is effective, with the understanding of improving energy consumption the tourist's interest in environmental tourism has increased, and in parallel, the tendency to small-scale accommodation buildings has increased. In this context, it is important to evaluate all data correctly within the physical environment data and to evaluate the necessary parameters in terms of user comfort by reviewing them in the design phase in boutique hotel buildings to ensure effective energy consumption and comfort. It is vital to take all these conditions into account and implement them at the design stage. It may not be possible for these problems to be solved later, both economically and with applicability.

It is very important to provide energy consumption at the design stage of the buildings within the framework of the efficient use of natural resources. With the decisions to ensure energy consumption and comfort conditions taken during the design phase, energy use will be minimized throughout this whole process, including the stages of design, construction, use/operation, and demolition. This study aimed to examine the energy consumption of a boutique hotel in Greece-Xanthi. According to the findings, it is aimed to identify the problems and develop suggestions for improvement. The data of the sample accommodation building was analyzed using the ArchiCAD Graphisoft EcoDesigner program and suggestions were developed for the findings. Graphisoft Archicad is one of the widely used BIM programs. Climate analysis, building energy model calibration, project-specific low-energy structure solution sets, architectural designs with low energy needs, and complete building energy optimization can be performed through the Eco Designer Star module in the Graphisoft ArchiCAD program. The environmental setting, climate data, and internal gain values of the buildings were introduced to the program. The properties of the building materials modelled in ArchiCAD can be selected from the building catalog. Also, in the program, renewable energy sources (wind, solar, etc.) can be defined for the buildings to evaluate their energy consumption [46]. The energy efficiency and environmental effects to be achieved by integrating active solar systems into the building have also been calculated.

4. Case Study: Abdera and sample building

The Abdera is a coastal city, located in Xanthi, Thrace in Eastern Macedonia, Greece. It is known as the old settlement area. The coastal City-Abdera lay 17 km east-northeast of the mouth of the Nestos River, almost directly opposite the island of Thasos. It was established due to its strategic location and was at the forefront throughout history. The coastal settlement of Abdera controls three passageways: one through the Nestos River, the other through the mountains north of Xanthi, as well as the sea route from its ports from Troas to Thrace and then to the coast of Macedonia [47]. In other words, it was located at the intersection of land, river, and sea passage. The Mediterranean region has a mild climate; summers are hot and dry, while winters are rainy and warm. The average temperature of the hottest months is 34-45 °C, and the average of the coldest months is 8-10 °C. The average annual temperature is 18 °C. Snowfall and frost are very rare. The boutique hotel, located in the coastal city of Abdera, is a two-story building with a basement. There are 3 identical blocks in separate rows in the layout plan. The load-bearing system of the boutique hotel is reinforced concrete, the construction area is 660 m^2 and the floor area is 220 m^2. As vertical mobility, the stairs are designed from the outside and consist of 7 rooms. The rooms are designed in the north and south directions, and each room and bathroom is approximately 20 m^2. On the ground floor, there is a reception desk and 4 rooms, while on the first floor, there are 3 rooms and two terraces opening towards both sides in east and west directions. Figure 4 includes the hotel building's location, plans, and cross-section.

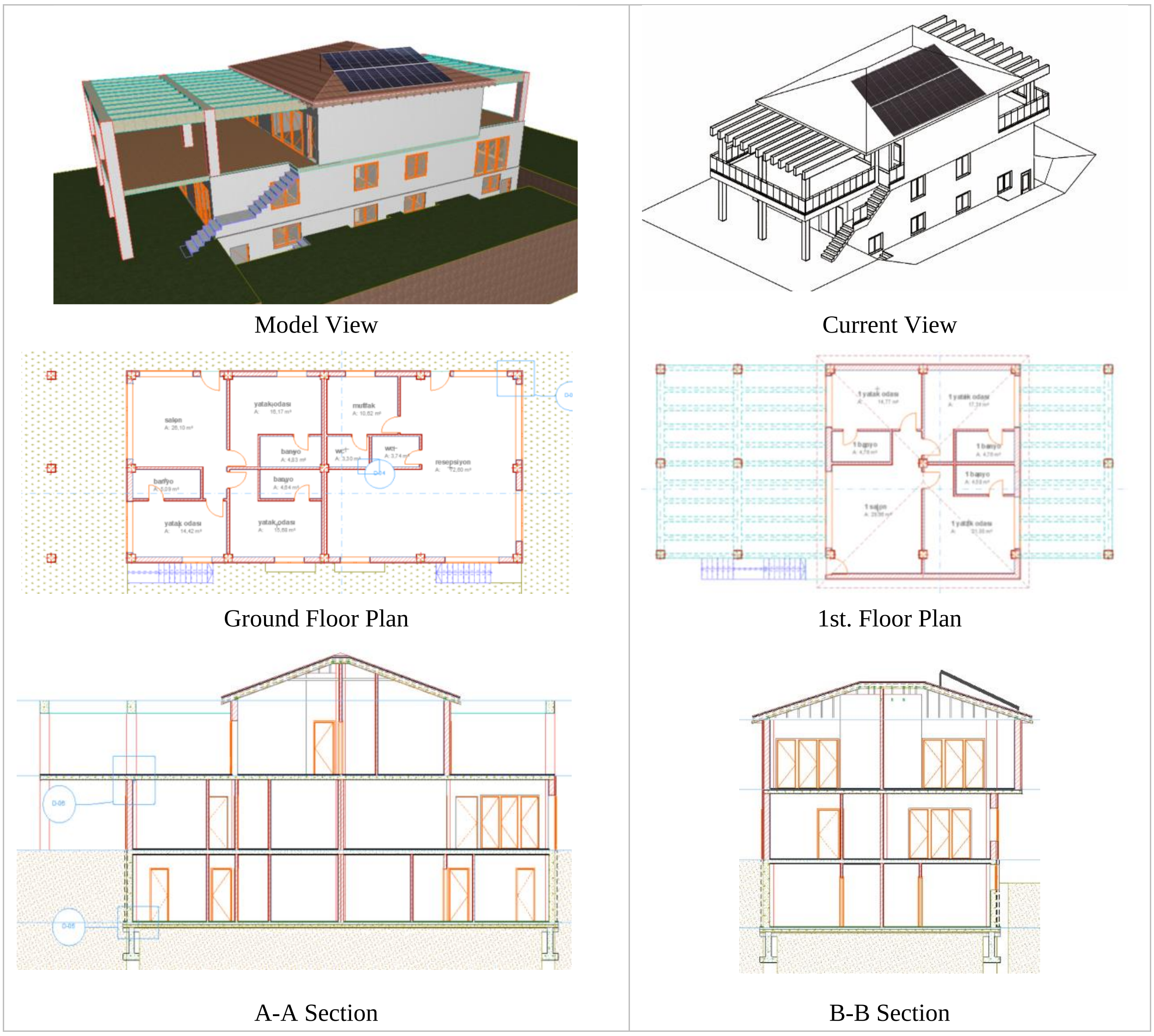

Figure 4. Boutique Hotel Building in Abdera

In the study, models of the building were created using the Graphisoft Archicad program. Afterward, with the Graphisoft Archicad Eco Designer Star module, the thermal transmittance of the building elements forming the building envelope has been calculated as thermally insulated. It is seen that the thermal transmittance / U values of the structural elements of the building are 0.57 W/m^{2}K on the walls, 0.28W/m^{2}K on the floors, 0.84 W/m^{2}K on the ceilings, 0.26 W/m^{2}K on the roof, and 1.7 W/m^{2}K on the windows (Table 1). Within the scope of the study, the annual energy requirement in the well-insulated building envelope (Insulation thicknesses of 5 cm on the wall, 10 cm on the flooring, 3 cm on the mezzanine flooring, and 10 cm on the ceiling) was calculated first in the sample boutique hotel building (S1). Then, as a result of adding a solar collector (Solar Thermal Panel-STP- 30 m^2) and photovoltaic panels (Photovoltaic Panel- PV- 30 m^2) used as active solar energy systems to the roof surface of this building, the energy need was calculated (S2) (Figure 5). Then, the change in energy consumption was evaluated by integrating Solar Thermal Panels and Photovoltaic panels from active solar systems on the roof of this building. It is observed that the active solar systems, used to fulfill the energy and hot water needs of the building, have decreased the energy need of the building.

The fossil-derived fuel oil, a type of fuel that is widely used in the region, was selected as the type of fuel in the building. The renewable solar energy systems to be used in the building after the specified insulation thicknesses are applied are determined as solar collectors (Solar Thermal Panel-STP) and photovoltaic solar panels (Photovoltaic Panel-PV). The solar collector is defined as a discharged tube with an angle of 32º to produce heating and hot water [48]. The photovoltaic solar panel has been preferred with a nominal peak power of 168W/m^2 and an efficiency of 17% in the multi-crystal type [49].

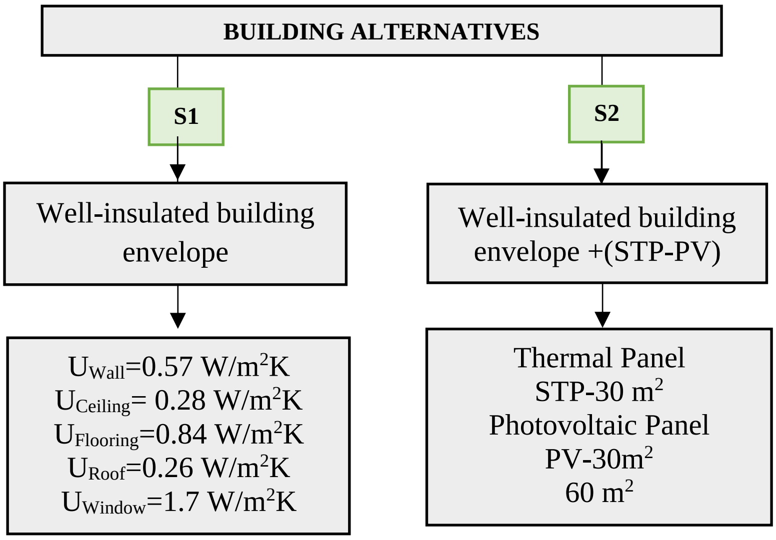

Figure 5. Building alternatives (S1,S2)

Table 1. Thermophysical properties of the building elements that make up the building of the boutique hotel

Building Elements	Material	Thermal Conductivity (W/mK)	Density (kg/m³)	Thermal transmittance U Value (W/m^{2}K)
Wall	Gypsum Plaster	0.57	1300	0.57
	Brick	0.58	800	
	EPS	0.042	15	
	Insulation Plaster	0.3	800	
Ceiling	Tile	1.5	2000	0.28
	Screed Concrete	1.4	2000	
	EPS	0.036	25	
	Concrete	1.15	1800	
	Blockade	0.121	648	
Flooring	Tile	1.5	2000	0.84
	Screed Concrete	1.4	2000	
	EPS	0.036	25	
	Reinforced Concrete – Str.	2.5	2400	
	Gypsum Plaster	0.57	1300	
Roof	Roof Tile	1	2000	0.26
	Membrane	0.23	1100	
	EPS	0.036	25	
	Wood Roof Str.	0.18	700	
	Gypsum Plaster	0.57	1300	
Window	Heat Treated Glass	1	2500	1.7
	PVC Windows	0.17	1390	

Assessing the energy consumption, when 30 m^2 of STP and 30 m^2 PV panels (60 m^2) are added to the roof surface, it is seen that the primary energy consumption of the building was 19979 kWh, and the CO_2 emission corresponding to the energy consumption was reduced to 5448 kg/m^2. This is reflected in the costs in a similar way (Table 2).

Table 2. Energy needs and gains of the boutique hotel insulated (S1) and insulated- STP- PV (S2)

		Building Alternatives	
		Well Insulated S1	Well Insulated+STP+PV S2
Primary Energy (kWh)	A fossil (Fuel Oil)	29027	19979
	Secondary (Electric)	18643	10458
	Secondary (Central Cooling)	130	130
	Renewable (Solar)	0	10953
Annual CO_2 Emission (kg/m²)	Fossil (Fuel Oil)	7916	5448
	Secondary (Electric)	1291	724
Energy Cost (€)	Fossil (Fuel Oil)	1176.80	810.01
	Secondary (Electric)	162.26	91.01

5. Discussion and Conclusion

The increase in energy consumption on a global scale has highlighted the importance of energy efficiency and carbon emissions reduction, especially in buildings. Energy consumption varies depending on the purpose and scale of use of buildings. Climate, orientation, characteristics of the building envelope, etc. are among other factors affecting energy consumption. It is important to ensure energy efficiency in buildings without compromising user comfort. For this purpose, it is necessary to evaluate the physical environment data correctly and to provide the necessary parameters for user comfort, by considering them at the design stage in accommodation buildings.

Energy consumption analysis was performed in this study on a sample boutique hotel building in Greece showing mild climate characteristics, and the results were obtained by using the existing well-insulated system (S1) first and then adding active solar energy systems (S2) by the ArchiCAD Graphisoft EcoDesigner software are as follows:

- The thermal transmittance U value varies between 0.57 W/m^{2}K on the wall, 0.84 W/m^{2}K on the floor, 0.26 W/m^{2}K on the roof, and 1.7 W/m^{2}K on the window depending on the structural elements insulated in the building. The CO_2 emission of the building, corresponding to the primary energy consumption of 29027 kWh, is 7916 kg/m^2.

When 30 m^2 STP ve 30 m^2 PV Panels (60 m^2 in total) are added to the roof surface of the building:

- The CO_2 emission corresponding to the primary energy consumption of the building of 19979 kWh decreases to 5448 kg/m^2.

In this study of boutique hotel building, the rate of decrease in energy consumption by the refurbishment of the building envelope and addition of the building envelope (well-insulated) and the addition of STP and PV from active solar systems.

Although tourism has positive effects on the economy, it is accepted that it has negative effects on environmental pollution and energy consumption [14].

In conclusion, the annual energy consumption in the examined accommodation building decreased by approximately 30% with the addition of active solar systems (STP and PV). It is also seen that comfort temperatures are ensured for different seasons in terms of indoor temperature in the building envelope.

Similarly, the study examining the energy system optimization, cost, and carbon emissions of a medium-sized hotel in Greece also states that by introducing a Photovoltaic (PV) net measurement system, carbon emissions associated with the energy system can be reduced by 31% [11].

Reducing energy consumption by ensuring energy protection of accommodation buildings that are heavily present in tourism regions is very important from an urban, social, and global point of view. As with all kinds of buildings, ensuring user comfort conditions in these buildings is among the basic requirements. The building envelope selected depending on the climate characteristics directly affects energy conservation. In addition, energy consumption decreases with the integrated use of renewable energy sources such as solar energy in buildings for providing building energy needs. It is also important to develop actions and buildings aimed at reducing the carbon footprint. It is very important to use the solar potential in places such as Greece, which is located in a very favorable region in terms of geographical features, with integrated systems in buildings and thereby provide energy needs. Energy needs are mainly covered through electricity in Greece, while petroleum and natural gas only supplement. The usage of renewable energy sources in the hotel sector is still low [13]. Solar energy, which will be used to meet the needs, will make an important contribution in many ways on a regional and global scale in terms of the environment, etc.

Declaration of Ethical Standards

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

Conflict of Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study was presented orally at the International World Energy Conference (IWEC) and only an abstract was published.

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