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INVESTIGATION OF ENERGY CONSUMPTION AT DIFFERENT FLOORS IN BUILDINGS AND IMPROVEMENT OF ENERGY EFFICIENCY: BALIKESIR CASE

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Abstract
As the population increases day by day and technology develops, the need for energy increases. Natural resources are mostly used to meet the energy needs of people and over time, especially non-renewable resources are depleted. Buildings in which many actions are performed in daily life play an important role in energy consumption. While performing actions in the interior spaces of the buildings, users need to meet certain building physical conditions and one of these conditions is thermal performance. In order to provide thermal comfort conditions in the interior of the building, it is necessary to make cooling in summer periods and heating in winter periods. The decisions to be taken at the design stage affect the energy consumption required for heating-cooling. The thermal insulation status of the building envelope and air leaks are parameters affecting energy consumption. Factors such as the material used in the outer wall mesh, thermal insulation application, window/wall ratio have an important role on the amount of energy required to provide the most suitable indoor thermal comfort for the building users since they affect the heat intake to the interior and the preservation of the existing heat. In addition, when it comes to indoor thermal comfort, the effect of the activity on the floor above or below is important. Besides, the intended use of the space determines the heating-cooling times of that space. For example, a place with commercial use is mostly used during daytime hours and is heated during the hours it is used in winter. There is heat exchange between the spaces separated from each other by walls or floor surfaces. For this reason, the volumes to which the space is related are important in terms of thermal comfort.
The study aims to analyse comperatively the energy consumption of 3 different identical floors with a commercial function space underneath, with apartments both above and below and with a roof above, by simulation method. It is concluded that House A, located on the first floor of identical houses, provides thermal comfort conditions with the least energy consumption. House C, located under the roof, consumes the most energy to ensure indoor thermal comfort. As a result of the study the apartment with the best thermal performance were further anlaysed to reduce energy consumption by making simulations according to different building envelope scenarios and examining different types of wall materials.

Keywords: *Building simulation, energy consumption, energy efficiency, building monitoring, residential.*

YAPILARDA FARKLI KOTLARDAKİ ENERJİ TÜKETİMLERİNİN İNCELENMESİ VE ENERJİ VERİMLİLİĞİNİN GELİŞTİRİLMESİ: BALIKESİR ÖRNEĞİ

Özet
Her geçen gün nüfus arttıkça ve teknoloji geliştikçe enerjiye olan ihtiyaç artmaktadır. İnsanların enerji ihtiyacını karşılamak amacıyla çoğunlukla doğal kaynaklar kullanılmakta olup zamanla özellikle yenilenemeyen kaynakların tükenmesine yol açmaktadır. Günlük hayatta birçok eylemin içerisinde gerçekleştirildiği yapılar enerji tüketiminde önemli rol oynamaktadır. Yapıların iç mekanlarında eylemler gerçekleştirilirken kullanıcıların belirli başlı yapı fizik koşullarını sağlaması gerekmekte olup bu koşullardan birisi de ısıl performanstır. Yapının iç mekanında ısıl konfor koşullarının sağlanabilmesi için iç mekanda yaz dönemlerinde soğutma, kış dönemlerinde ise ısıtma yapmak gerekmektedir. Tasarım aşamasında alınacak kararlar ısıtma-soğutma için gerekli enerji tüketimini etkilemektedir. Bina kabuğunun ısı yalıtım durumu, hava kaçakları da enerji tüketimini etkileyen parametrelerdir. Dış duvar örgüsünde kullanılan malzeme, ısı yalıtım uygulaması,

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pencere/duvar oranı gibi etmenler iç mekana ısının alınmasını ve mevcut ısının korunmasını etkilediğinden dolayı yapı kullanıcıları için en uygun iç mekan ısıl konforunun sağlanması için gerekli enerji miktarı üzerinde önemli bir rolü bulunmaktadır. Ayrıca söz konusu iç mekan ısıl konforu olduğunda ele alınan mekanın kaçıncı katta bulunduğu, altındaki veya üzerindeki kattaki aktivitenin etkisinin önemli olduğu bilinmektedir. Mekanın kullanım amacı o mekanın ısıtma-soğutma sürelerini belirlemektedir. Örnek vermek gerekirse ticari kullanımlı bir mekan çoğunlukla gündüz saatlerinde kullanılmakta olup kış aylarında kullanıldığı saatlerde ısıtılmaktadır. Birbirleriyle duvar veya döşeme yüzeyiyle ayrılan mekanlar arasında ısı alışverişi olmaktadır. Bu nedenle mekanın ilişkili olduğu hacimler ısıl konfor açısından önemlidir.

Bu çalışma kapsamında temelde altında ticari fonksiyonlu mekan bulunan, hem alt hem de üstünde daire bulunan ve üzerinde çatı bulunan birbirleriyle özdeş 3 farklı katın enerji tüketimlerini simülasyon metoduyla incelemek ve sonuçları karşılaştırmak hedeflenmektedir. Çalışmanın sonucunda elde edilecek en iyi ısıl performansa sahip daire için farklı bina kabuğu senaryolarına göre simülasyonlar yapılarak farklı duvar malzemeleri çeşitleri incelenerek enerji tüketimini azaltılmak hedeflenmektedir.

Anahtar Kelimeler: *Bina simülasyonu, enerji tüketimi, enerji verimliliği, bina izleme, konut.*

1. INTRODUCTION

The construction sector has a significant potential in terms of energy efficiency and environmental sustainability in our country as well as in the rest of the world. While most of the energy in buildings is consumed during the construction phase, an important part is consumed in order to provide indoor comfort during the usage phase, which is the longest period of the building life cycle.

As a result of the concept of energy efficiency, which expresses the evaluation of energy resources with the highest efficiency at all stages from production to consumption, terms such as green buildings, sustainable environment and resource use appear in both practice and legal regulations with the European Union's Our Common Future report. In line with the goals of the Paris Agreement, the European Commission continues to work to lead the transition to a climate-neutral economy by 2050. A comprehensive package was adopted in 2009 to meet the EU's 2020 climate and energy targets. The 20-20-20 targets of this package are 20% increase in energy efficiency, 20% reduction in greenhouse gas emissions compared to 1990 levels and 20% increase in renewable energy use by 2020 (Malinauskaite, 2020). In 2016, 2030 climate and energy targets were set with the Clean Energy for All Europeans package, which emphasizes “Energy Efficiency First” as one of the basic principles of energy, since energy efficiency is a more cost-effective way to reduce emissions, increase energy reliability and energy consumption for all users (URL-1). Important decisions were taken in the 2012 Energy Efficiency Directive to ensure that the EU achieves its 2020 target of 20% energy efficiency (URL-2). EU member states are required to use energy more efficiently at all stages of the energy chain, including energy generation, transmission and end-use consumption, and the energy efficiency target for 2030 has been set at least 32.5% by the EED (Union Oj of the E. Directive (EU) 2018/2002). The European Commission has published a strategy for a climate-neutral economy with net zero emissions by 2050 under the Paris Agreement (URL-3). In addition, the EU operates EU Emissions Trading Systems that price greenhouse gas emissions to reduce emissions and create fiscal incentives for industry and businesses (Malinauskaite, 2019).

It has taken an important step in energy efficiency by publishing the European Union (EU) Building Energy Performance Directive (2002/31/EC) in 2002. The Building Energy Performance Directive aims to provide more efficient use of energy in buildings by establishing a regular inspection and evaluation mechanism, as well as bringing certain standards and a common method for energy performance assessment in both existing and new buildings in Europe. Building energy class certification is the most important method in determining the energy consumption rate. It is aimed to make this practice mandatory in all member states. According to the "Energy Performance in Buildings Directive (2010/31/EU)" revised in 2010, it is necessary to prepare the regulations based on the optimum cost and define the development methods, taking into account the different life processes of the buildings according to the purpose of use, primarily according to the targets brought to the member countries on the minimum energy requirement. According to the European Union energy targets, it has been determined that all public buildings will be approximately zero energy buildings by 2018-2019 and all other buildings until 2020-2021. In addition, it is the responsibility of the member states to establish a separate control system for the heating and air conditioning systems of the buildings (Islamoglu, 2017). The purpose of the Building Energy Performance Directive is to regulate all energy use values and CO2 emissions of a building, taking into account external climatic conditions, user needs and cost effectiveness (URL-4).

Based on the Energy Performance in Buildings Directive (2010/31/EU), the Energy Performance Regulation in Buildings in Turkey aimed at limiting greenhouse gas emissions in terms of primary energy and carbon dioxide (CO2) emissions of buildings, and obtaining an Energy Identity Certificate was made mandatory on January 1, 2011 (URL-5).

In Figure 1, the share of residences in the distribution of energy by sectors in Turkey is seen as 37%, while in Figure 2 it is seen that this rate was 27% in the EU in 2011 (Ecoyfs; OeEB, 2013). The fact that buildings have a large share in energy consumption throughout the world has brought the concept of low-energy buildings to the agenda, taking measures for energy-efficient buildings. The concept of energy efficient building has led to the emergence of energy efficient buildings with passive design parameters, technological developments and the use of new materials (Su, 2021).

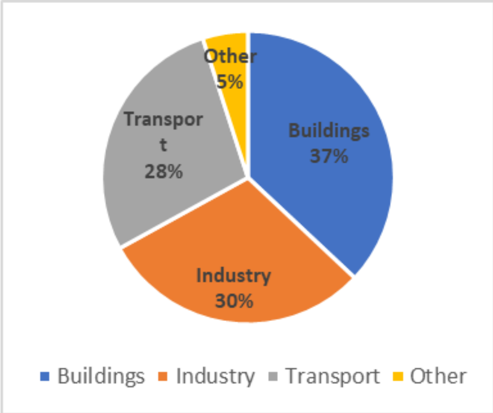


Figure 1. Turkey's total energy consumption distribution, 2015 (Ecoyfs).

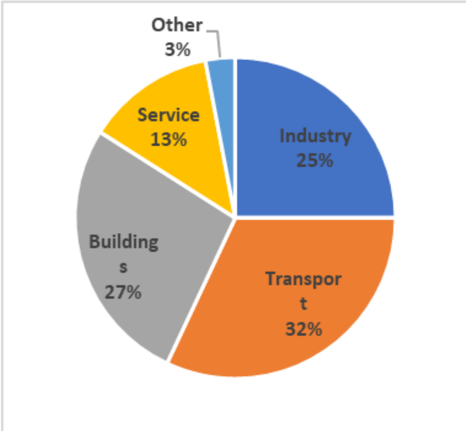


Figure 2. Distribution of the EU's total final energy consumption, 2011 (OeEB, 2013).

K. Fabbri, in his study, made measurements with a datalogger in a 4 and 5 age group nursery and investigated user satisfaction by making a survey (Fabbari, 2013). Y. Diler was examined from 2015 to 2018 in order to examine the thermal comfort of the Great Mosque in Manisa, which is a cultural heritage. Hourly temperature data of the mosque were examined and different scenarios were created for thermal reinforcement with the DesignBuilder program. In study by F. Han et al., the largest certified PH office building in China was considered and examined as a field study. It has been confirmed as a result of the monitoring that this structure is approximately 69% more energy efficient than the current public building standards in China (Han, 2022). M. Motalebi et al.'s study presents a BIM-based mathematical optimization model to increase the energy efficiency of existing buildings. In this study, effective strengthening measures and alternative material selection are applied. With the scenario created, a 24% - 58.2% reduction in energy consumption is achieved (Motalebi, 2022).

Z. Su et al. A metaheuristic method called the Balanced Water Strider Optimization Algorithm is presented to predict the thermal variables of a building. In this study, DesignBuilder simulation program was used to create the thermal model. The operation of the proposed model is demonstrated by applying simulated building and energy usage data in two different geographical conditions in New Zealand. The model of the building is also simulated according to the geographical environment of another city. According to the results obtained, it is understood that the proposed method can efficiently predict the changes according to the geographical conditions (Su, 2021). Y. Liu et al. estimating building energy consumption based on the design of the building envelope, which includes the comprehensive heat transfer coefficient and solar radiation absorption coefficient of the exterior walls, the comprehensive heat transfer coefficient and solar radiation absorption coefficient of the roof, the comprehensive heat transfer coefficient of the exterior windows, and the window-to-wall ratio. proposes an approach to In this study, a Building Information Model of an education building in China is created in Revit and energy consumption analysis is made in DesignBuilder. The results show that the most important parameters with the highest correlation with building energy consumption are the overall heat transfer coefficients of exterior walls and exterior windows and the window-to-wall ratio (Liu, 2021).

In the study of A. Darvish et al., the tree configuration and types that affect the indoor and outdoor thermal comfort and energy demand of courtyard buildings were analyzed by modeling in the DesignBuilder program and field measurements. In this study, two courtyards with and without trees on the campus of the International Imam Khomeini University in Qazvin, Iran, were modeled and simulated. Also, in this study, it was observed that deciduous and coniferous trees located near the interior thermal zones increase the annual energy demand from April to October (Darvish, 2021). In another study by H. Huang et al., it was stated that existing residential buildings have a significant share in energy consumption and the existing housing stock should be strengthened. Within the scope of this study, a high-rise residential building in the north of China was chosen as a field study, and the electricity consumption and indoor temperature of the target building were collected and analyzed. In addition, with the help of the DesignBuilder program, necessary measures were determined to adapt the target building to the Passivhaus standard. With the measures to be taken as a result of the simulation, it was observed that the energy used was reduced by 96% for heating, 8.7% for cooling, and 78.9% in total (Huang, 2020). Aboelata's study indicated that buildings in Cairo are exposed to extremely high temperatures, which increases the demand for cooling energy. This study aims to investigate the effect of air temperature and buildings on reducing energy demand as an alternative strategy in urban areas of different densities. The DesignBuilder model was then used to calculate the cooling energy savings resulting from lowering the air temperature of the buildings. Combining trees with cool flooring reduced cooling energy by 3.2% while maintaining this balance in a low-density urban area (Aboleta, 2021). In the study conducted by M. A. M. Alhefnawi et al., the effect of the use of aluminum and terracotta coating on energy in an educational facility in Saudi Arabia was investigated. Simulations and analyzes were carried out in the DesignBuilder program regarding the properties of both coating materials. As a result of the study, it was stated that the thermal insulation efficiency of terracotta was better than aluminum plates. As a result of the study, it was stated that the thermal insulation efficiency of terracotta is better than aluminum sheets (Alhefnawi, 2021).

The main hypothesis in this study is that the energy consumption of houses on different floors will be different, even if they are identical. For this reason, a building in Balıkesir Province will be discussed, and the residences on different floors of this building will be modeled in the DesignBuilder program and the energy model will be simulated. In this way, energy consumption on different floors of an apartment building with identical residences will be compared. Additionally, energy consumption improvement will be presented with different model scenarios to be applied on the model of the mezzanine flat in this building.

2. MATERIAL AND METHOD

2.1. Local Climatic Data

One of the most widely used climate classification methods in the world to classify climates is the Koppen–Geiger climate classification (URL-6). (Turkey climate According to Köppen Climate Classification, 2020). According to Geiger, it has been revealed that there are 13 different climate zones in Turkey (Figure 3). Balıkesir Province, where the building examined in the field study is located in a very dry and hot summer climate (Csa) Region according to Köppen-Geiger climate types, and in the 2nd degree-day region of Turkey according to TS 825 Thermal Insulation Rules in Buildings Standard (Figure 4).

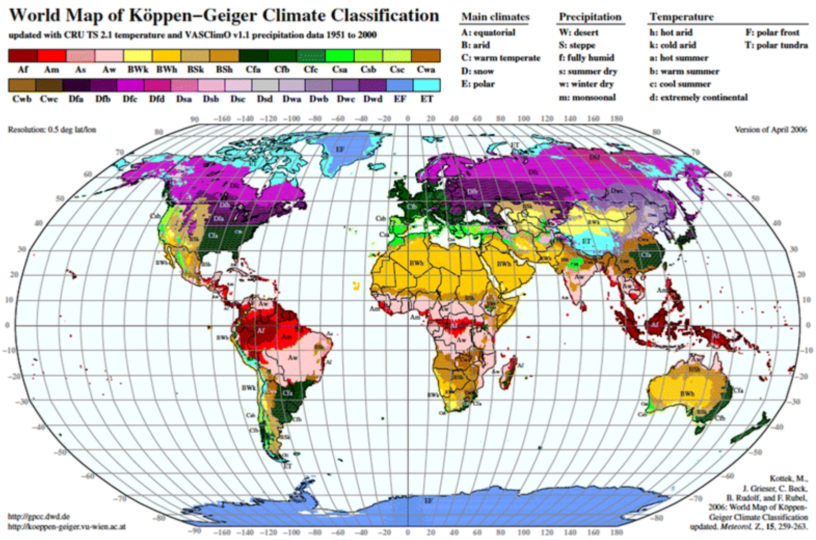


Figure 3. Koppen Geiger world climate classification map (URL-6).

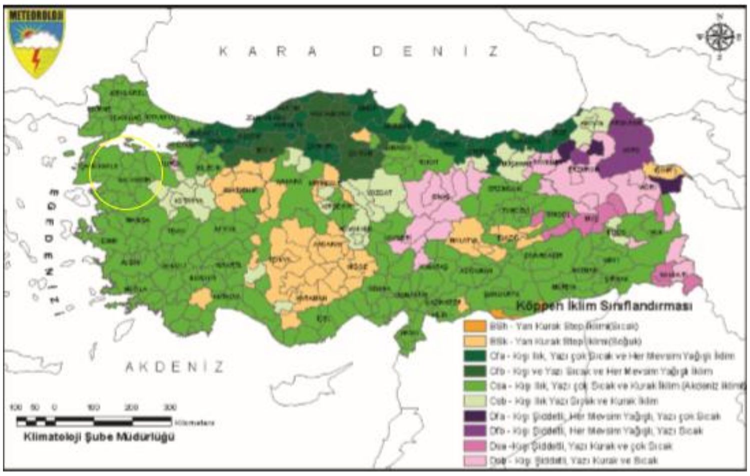


Figure 4. Climate types of Turkey according to Koppen climate classification (URL-6).

2.2. Method

In the research, first of all, a detailed literature review was conducted on energy consumption and efficiency in residences. Within the scope of the study, floors were modeled separately in the DesignBuilder program in order to estimate the energy consumption of residences on different floors. In order to calibrate the model created in DesignBuilder, measurements were taken with hobo simultaneously while the model was being created. The method of the study is shown in detail in Figure 5.

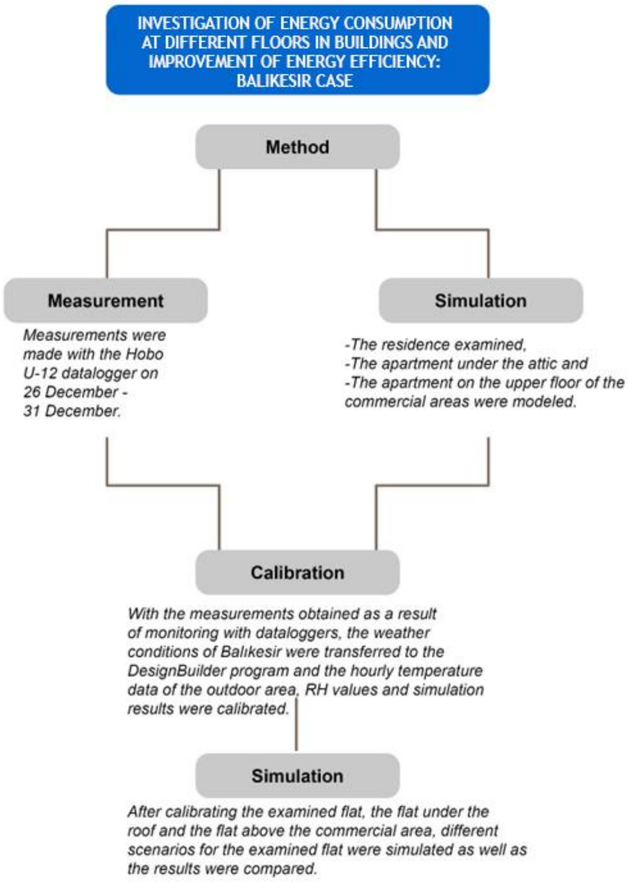


Figure 5. The method of study.

2.3. Case Building

The building considered as a field study is located in Balıkesir Province (Figure 6). The building was built in 2007 as a reinforced concrete frame system. Figure 6 also shows the relationship of the building with its surroundings through the layout plan.

Figure 6. The location of Case Building in Balikesir and Location of the building on the aerial photograph.

As seen in Figure 7, the east facade of the building is adjacent and there are windows only on the east and west facades. As can be seen in the figure, the ground floors of the examined building and adjacent structures are for commercial purposes and the upper floors are for residential purposes. The examined building consists of 1 basement + ground floor + 5 identical floors. In the section of the building given in Figure 7, the relationships of the examined floors with the lower and upper floors are also indicated.

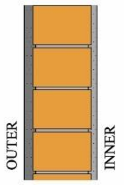
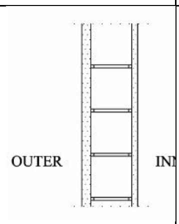
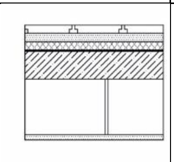
Figure 7. Photograph and section of the east facade of the examined building.

Floor plans of identical houses considered as field studies are given in Figure 8. The gross area of the examined flat is 95.20 m2 and the net area is 86 m2. The balconies in the residences are closed and used as winter gardens. The gross volume of the flat is 285.6 m3 and the net volume is 223.6 m3. As seen in the floor plan given in Figure 8, this apartment consists of a living room, a room, a children's room, a bedroom, two bathrooms, a corridor and two winter gardens. House A is located on the first floor of the building, above the commercial space on the ground floor. House B has identical apartments above and below and is on the third floor of the building. House C is located on the fifth floor, which is the last floor of the building, and while there is an identical apartment on the lower floor, there is an attic above House C.

Figure 8. Schematic plan of the selected apartment flat.

The building considered as a field study was designed in 2006 and its construction was completed in 2007. The building was designed as a reinforced concrete frame system. The flooring used in the building is hollow block flooring and its thickness is 32 cm. The exterior walls of the building are made of aerated concrete wall material and its thickness is 19 cm. On exterior walls, 2 cm to the inner surface of the aerated concrete wall material and 3 cm to the outer surface. No insulation material is used on external walls. The interior walls separating the flats are made of 19 cm brick material, 2 cm in size. It consists of plaster. 20 cm in rooms. on the ground, 3 cm. on reinforced concrete floor. A mattress was applied over the leveling concrete application, and laminate flooring was applied on the mattress. Low flooring was made in wet areas, 30 cm of slag was filled on a 20 cm reinforced concrete slab, leveling concrete was applied on it and ceramics were applied with ceramic adhesive. The roof has tile covering from outside to inside, bitumen waterproofing, roof board and rafters. PVC double glass was used in the building. The interior doors of the flat are wooden and the main door is steel. U values of the materials are given in Table 1.

Table 1. Base Case materials thicknesses and thermal values.

BASE CASE MATERIALS							
COMPONENT	**LAYERS**	**U-VALUE W/M^2-K**	**MATERIAL**	**CONDUCTIVITY W/M -K**	**SPESIFIC HEAT J/kg-K**	**DENSITY Kg/m^3**	**THICKNESS (m)**
External Wall		0,878	Cement/Plaster/ Mortar	0,35	840,00	950,00	0,040
			Aerated Concrete Block	0,240	1000,00	750,00	0,190
			Gypsum Plastering	0,40	1000,00	1000,00	0,025
Internal Wall		2,194	Cement/Plaster/ Mortar	0,72	840,00	1760,00	0,02
			Brick	0,72	840,00	1920,00	0,85
			Gypsum Plastering	0,400	1000,00	1000,00	0,02
Flat Roof		0,731	Marble (White)	2,770	802,00	2600,00	0,03
			Floor/Roof Screed	0,4100	840,00	1200,00	0,03
			EPS Expanded Polystyrene (Lightweight)	0,046	1400,00	10,00	0,03
			Bitumen, felt sheet (not to scale) Floor/Roof Screed	0,230 0,410	1000,00 840,00	1100,00 1200,00	0,005 0,05
			Concrete, Reinforced (with %2 steel)	2,500	1000,00	2400,00	0,10

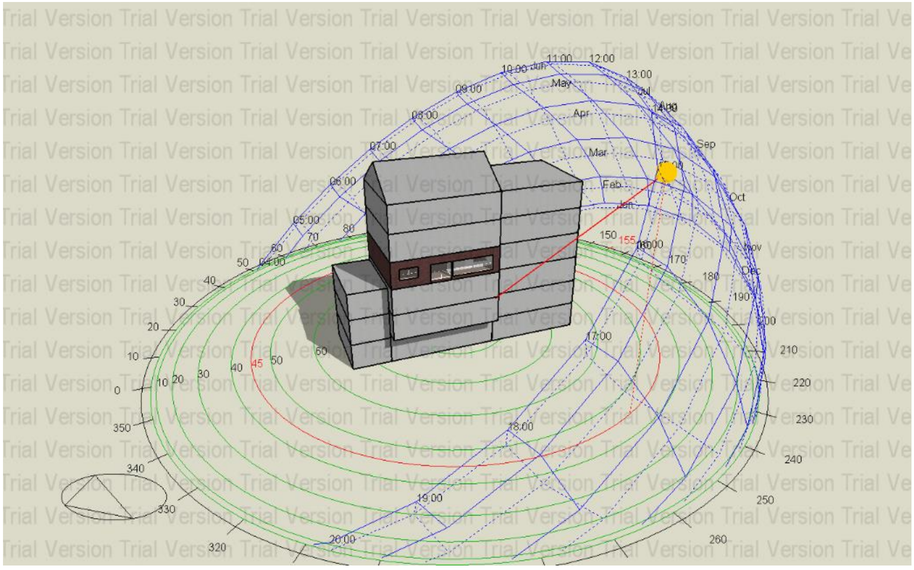


Figure 9. DesignBuilder model of examined House.

In addition, 5 different scenarios will be created in the study and these scenarios will be processed through House B and compared with the current situation.

Scenarios;

A model of the apartment above the commercial areas on the ground floor of the apartment building and the residence under the roof will be made and the energy consumption of these three identical residences will be compared. In addition, modeling was done for different scenarios for House B, and the energy consumption of House B was compared with its current situation. In the first scenario, 10 cm to the existing external walls. foam polyurethane, 5 cm to existing walls and interior floors in the second scenario. EPS insulation material, and in the third scenario, the outer wall system was changed, EPS thermal insulation was applied between two 8.5 cm. bricks and the amount of energy required for monthly heating was compared with the simulation results of the current situation with these scenarios. In the fourth scenario, sunshades are added and it is calculated how much the energy required for cooling in summer will decrease. The properties and thermal values of the materials used in these scenarios are shown in the Table 2.

Table 2. Scenarios different materials and thermal values.

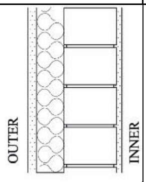
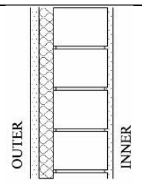
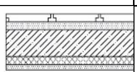
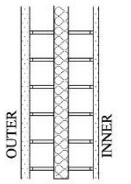
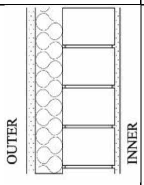
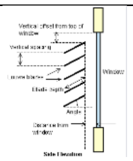
	COMPONENT	LAYERS	U-VALUE W/M^2-K	MATERIAL	CONDUCTIVITY W/M -K	SPESIFIC HEAT J/kg-K	DENSITY Kg/m^3	THICKNESS (m)
SC 1	External Wall		0,213	Cement/Plaster/Mortar	0,35	840,00	950,00	0,040
				Foam-Polyurethane	0,3500	840,00	950,00	0,10
				Aerated Concrete Block	0,240	1000,00	750,00	0,190
				Gypsum Plastering	0,40	1000,00	1000,00	0,025
SC 2	External Wall		0,453	Cement/Plaster/Mortar	0,35	840,00	950,00	0,040
				EPS	0,046	1400,00	10,00	0,05
				Aerated Concrete Block	0,240	1000,00	750,00	0,190
				Gypsum Plastering	0,40	1000,00	1000,00	0,025
	Internal Floor		0,558	Flooring Blocks	0,14	1200	650	0,0076
				0,3 in Shingles				0,0076
				Concrete, Reinforced (with %2 steel)	2,50	1000	2400	0,20

Table 2. (Cont.)

				EPS	0,046	1400,00	10,00	0,05
				Gypsum Plastering	0,40	1000	1000	0,020
SC 3	External Wall		0,606	Cement/Plaster/Mortar	0,35	840,00	950,00	0,040
				Brick	0,7200	840,00	1920,00	0,085
				EPS	0,046	1400,00	10,00	0,05
				Brick	0,7200	840,00	1920,00	0,085
				Gypsum Plastering	0,40	1000,00	1000,00	0,025
SC 4	External Wall		0,606	Cement/Plaster/Mortar	0,35	840,00	950,00	0,040
				Foam-Polyurethane	0,3500	840,00	950,00	0,10
				Brick	0,7200	840,00	1920,00	0,19
				Gypsum Plastering	0,40	1000,00	1000,00	0,025
SC 5	Louvres			Blade mat.				
				Steel				0,002

3. FINDINGS

3.1. Measurements

The examined house was examined with a data logger between 26-31 December to monitor the outdoor and indoor climate conditions. In order to monitor the outdoor temperature and relative humidity, a HOBO U-12 datalogger device was installed on the balcony of the flat on the 3rd floor to prevent the dataloggers from getting wet from rain and from direct sunlight. A data logger was installed in the living room of House B to record the indoor air temperature. These data loggers recorded indoor and outdoor temperature and relative humidity every ten minutes. During the measurement, there was no electricity consumption or ventilation in the room where the data logger was placed. During the measurement, the windows were never opened, and the doors and lights were generally not turned on. The plan given in Figure 10 shows the locations of the data loggers placed indoors and outdoors. Figure 11 shows photographs of these dataloggers in place.

Outdoor Measurements: The hourly temperature and relative humidity curves as a result of the measurements made outdoors are shown in Figure 12. The temperature values measured as a result of the measurements carried out between 26 December 00.02 and 31 December 23:59 vary between 22,39717 oC and 17,44283 oC. The highest temperature during the measurement was measured on 27 December. During the lowest measurement on 31 December, RH values vary between 32.925% and 57.55333%, when the highest temperature value is reached, the RH value is 40.44%, and when the lowest temperature is measured, the RH value is 44.34%. When the highest relative humidity was measured, the temperature value was 21,393 oC, while the lowest relative humidity was 22,142% (Table 3).

Table 3. Maximum and minimum recorded values of drybulb temperature (T) and relative humidity (RH) of outdoor weather.

	Day	**Time**	**T(^{0}C)**	**RH (%)**
T(^{0}C) max	27.12.2021	14.02	22,39717	40,44
T(^{0}C) min	31.12.2021	07.02	17,44283	44,34
RH (%) max	27.12.2021	12.02	21,393	57,5533
RH (%) min	30.12.2021	14.02	22,142	32,925

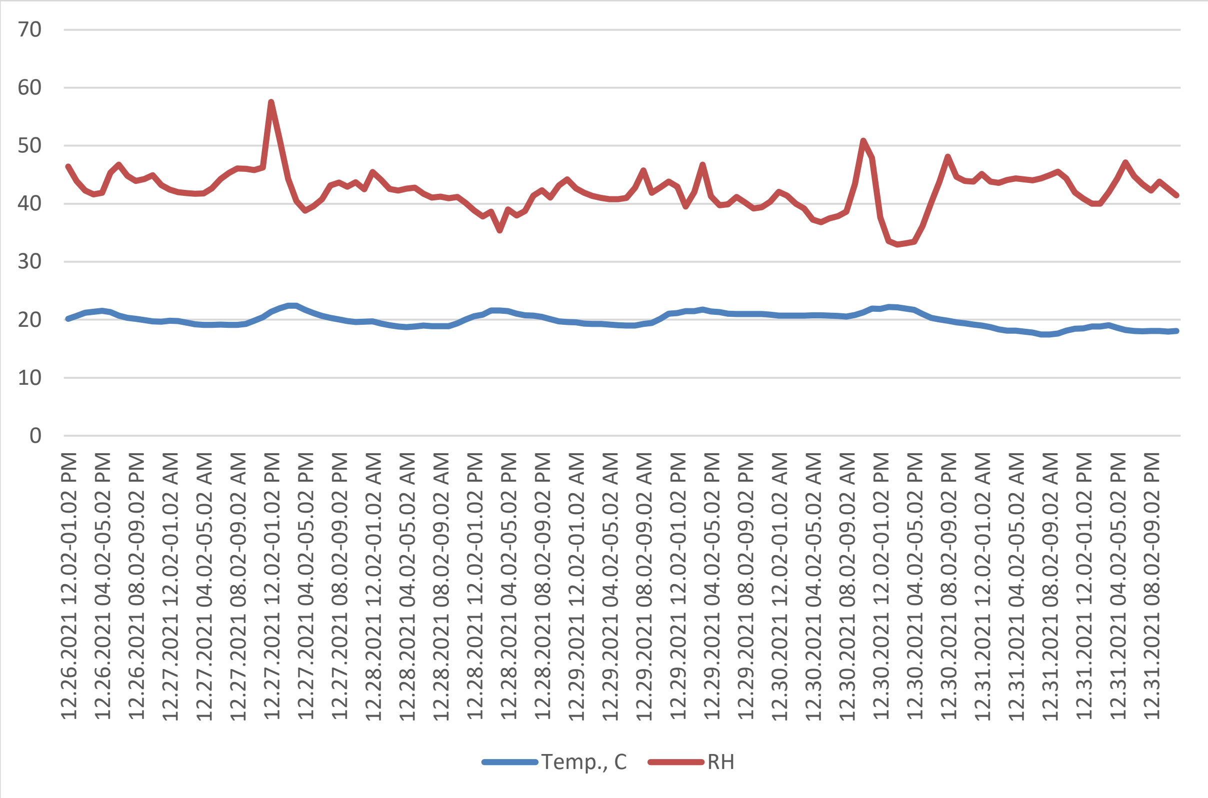


Figure 12. Outdoor temperature and relative humidity during monitoring period.

Indoor Measurements: In this part, the data recorded by the datalogger in the interior is evaluated and the temperature and relative humidity values obtained during the measurements are shown in Figure 13. The temperature values measured as a result of the observations made between 00.00 on 26 December and 23.59 on 31 December vary between 25.61 oC and 27,764 oC. During the measurement, the highest temperature was measured at 17.12 on 26 December, and the lowest temperature was measured at 03.02 on 29 December. The RH value was 38.47% at 03.02 on 29 December when the lowest temperature was measured, and 34.62% at 17.12 on 26 December when the highest temperature was measured. During the measurement, RH values vary between 29.79% and 43.55%. The lowest relative humidity was measured at 9.42 on 26 December, and the indoor temperature was measured as 26.39 oC when this relative humidity value was measured. The highest relative humidity was measured at 08:42 in the morning of 29 December, and the indoor temperature at this hour was 26 oC (Table 4). When the data obtained during the monitoring period were examined, the average indoor temperature was calculated as 26,3328 oC, and the average relative humidity was calculated as 37.1973%.

Table 4. Maximum and minimum recorded values of drybulb temperature (T) and relative humidity (RH) of indoor weather.

	Day	Time	T(⁰C)	RH (%)
T(⁰C) max	26.12.2021	17.12	27,764	34,62
T(⁰C) min	29.12.2021	03.02	25,61	38,47
RH (%) max	29.12.2021	08.42	26,00	43,55
RH (%) min	26.12.2021	09.42	26,39	27,79

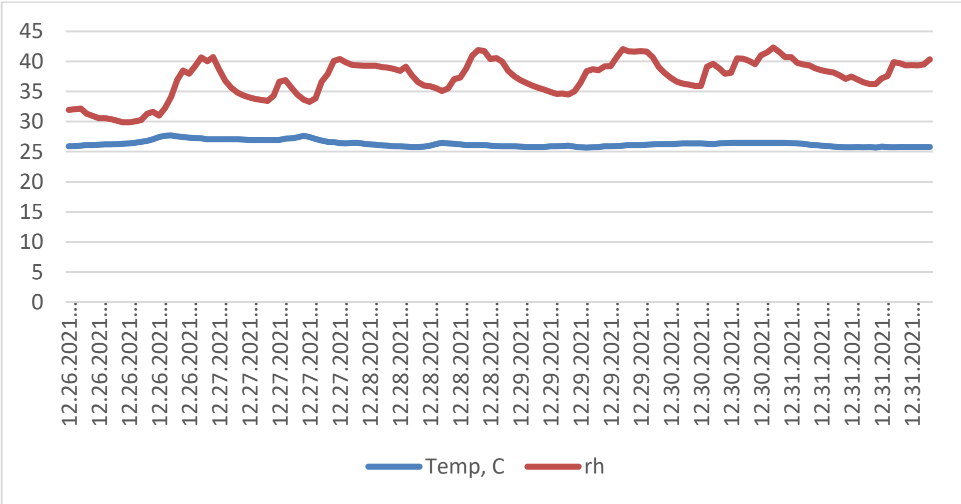


Figure 13. Indoor temperature and relative humidity during monitoring period.

3.2. Simulations

The heating values obtained as a result of the simulations of House A, House B and House C in DesignBuilder are given comparatively in Figure 14. According to the results obtained, the house that needs the most energy for heating is House C, located under the roof. The flat with the least energy required for heating is House A, which has a commercial place on the ground floor.

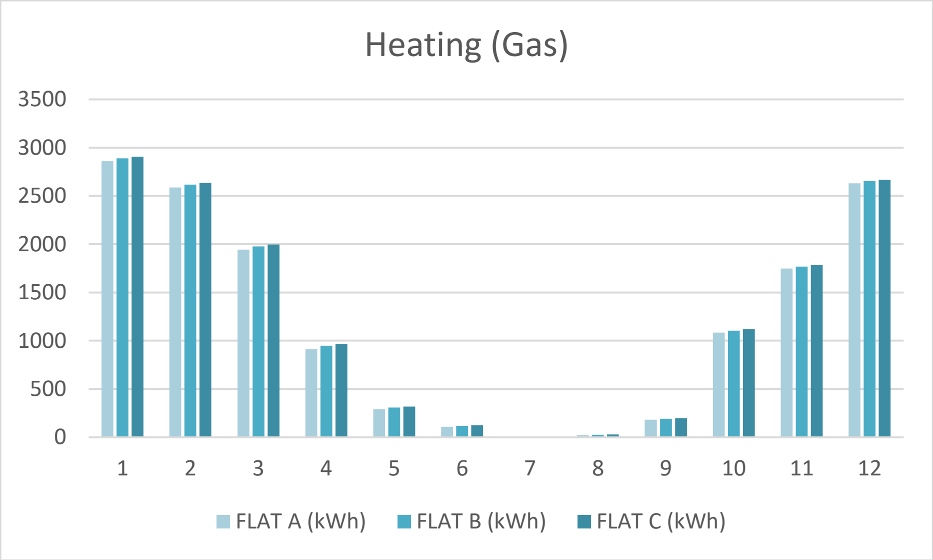


Figure 14. According to the simulation results, the amount of energy required for heating of 3 houses.

The cooling values obtained as a result of the simulations of House A, House B and House C in DesignBuilder are given comparatively in Figure 15. According to the results obtained, the house that needs the most energy for cooling is House A, located on the commercial floor. The apartment with the least energy required for cooling is House C, which is located under the roof.

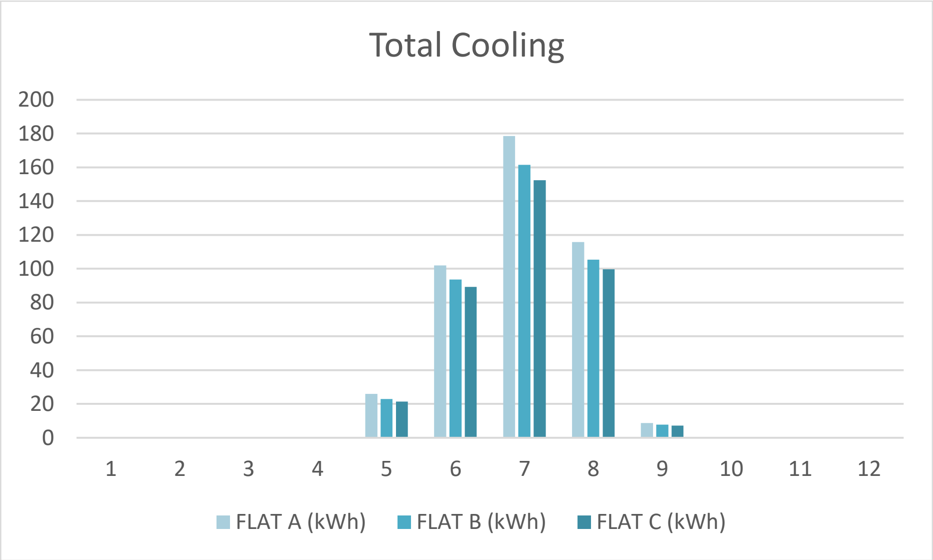


Figure 15. According to the simulation results, the amount of energy required for cooling of 3 houses.

3.3. Calibrations

Simulation is generally accepted as a best practice approach to performance analysis in the construction industry, and there may be significant differences between the simulation results and the measured consumption values of existing buildings (Clarke, 2007). Therefore, it is necessary to calibrate the models with the measured data. Reddy et al. (2006) explored the various tools, techniques, approaches, and procedures commonly used to calibrate building energy models and explored manual iterative calibration, graphing, and procedures based on user experience, which consists of adjusting inputs and parameters on a trial-and-error basis until the program output matches known data. It is classified as calibration based on statistical methods and automatically calibrated methods based on analytical procedures and tests involving specific challenges and measurements. However, these methods are not precise. In addition, different methods such as the use of graphical and statistical analysis methods can be used together to support manual calibration (Mustafaraj, 2014). An effective method for measuring the accuracy of a model for the calibration of the building model is the approach in ASHRAE Manual 14 (Pisello, 2016). As seen in the table, if the MBE (Mean Bias Error) for monthly values is in the range of ±5% and CV RMSE is below +15% for monthly values, the results obtained from the model are considered to be in the safe range.

$$MBE(\%) = \sum_{İ=1}^{Np}(mi - si) / \sum_{İ=1}^{Np}(mi)$$

mi: actual measured value

si: simulated value

Np: It is the number of data in the “p” interval (Nmonthly=12).

For the calibration, firstly the hourly internal temperature values and the temperature values measured as a result of the simulation were taken as a basis. According to MBE, the value obtained as a result of the transaction is 6.38%. In the hourly evaluations according to the ASHRAE standard, the calibration result should be below 15%. This model is reliable based on calibration over internal temperature (Figure 16).

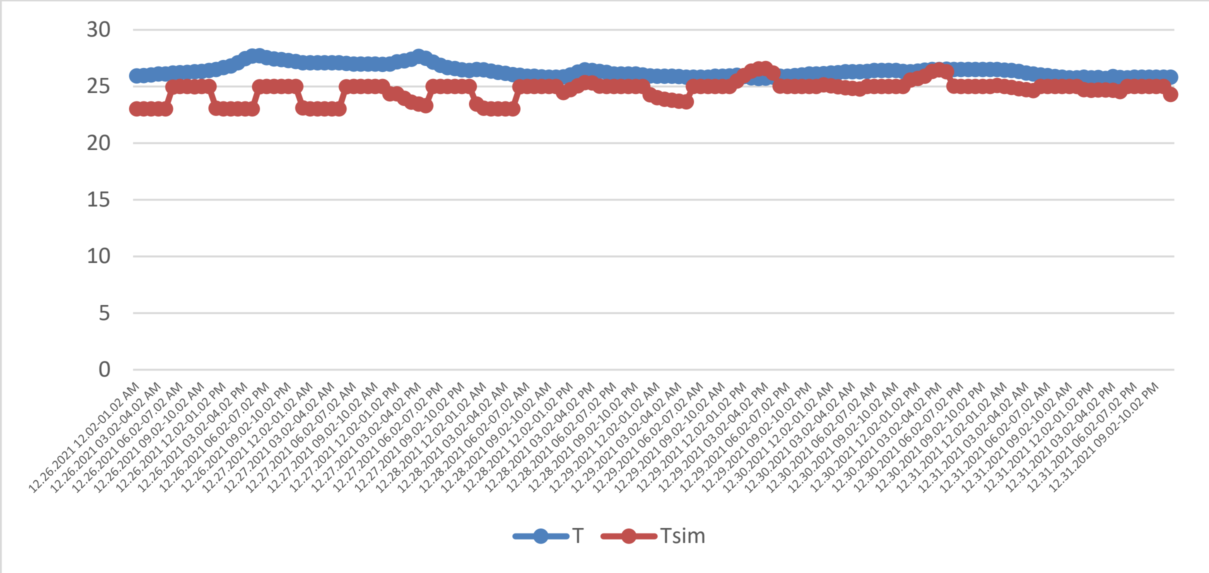


Figure 16. Measured and Simulated Indoor Temperatures.

The second calibration was made from indoor hourly average relative humidity. Values measured indoors and obtained as a result of simulation were processed in the MBE formula and the result was obtained as 16.14%. According to the ASHRAE standard, the hourly calibration value should be below 15%. It can be said that the model is safe because the output value is at the limit (Figure 17).

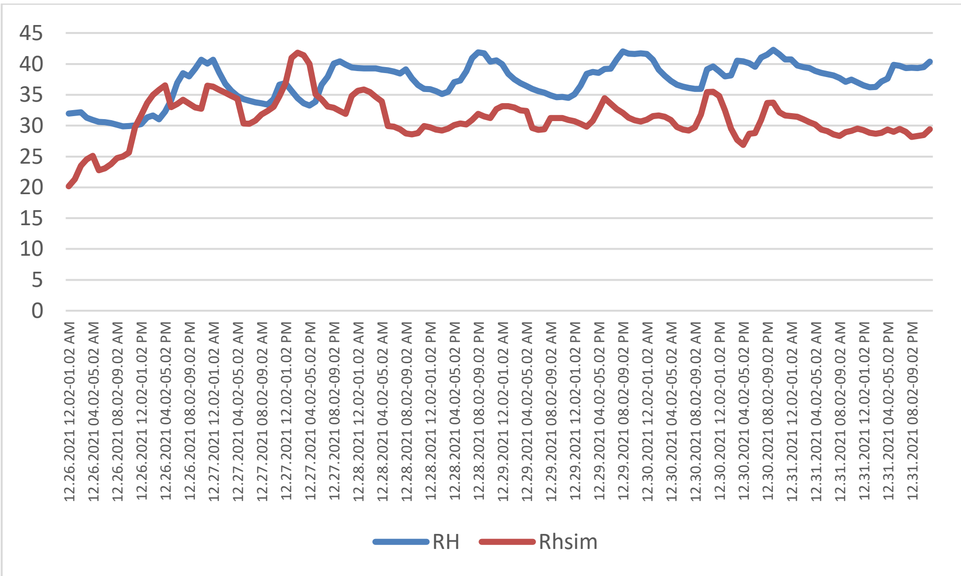


Figure 17. Measured and Simulated Indoor Rh values.

When the measured indoor temperatures and simulated indoor temperatures are calibrated according to CVRMSE, the result is 20.6%. According to the ASHRAE standard, this value should be less than 30% in monthly results. The model is reliable.

3.4. Scenarios

In the first scenario, a 10 cm foampolyurethane was applied to the exterior walls. As a result of the simulation made in the Designbuilder program, it was determined that the amount of energy consumed for heating decreased to 52 percent compared to the current situation (Figure 18).

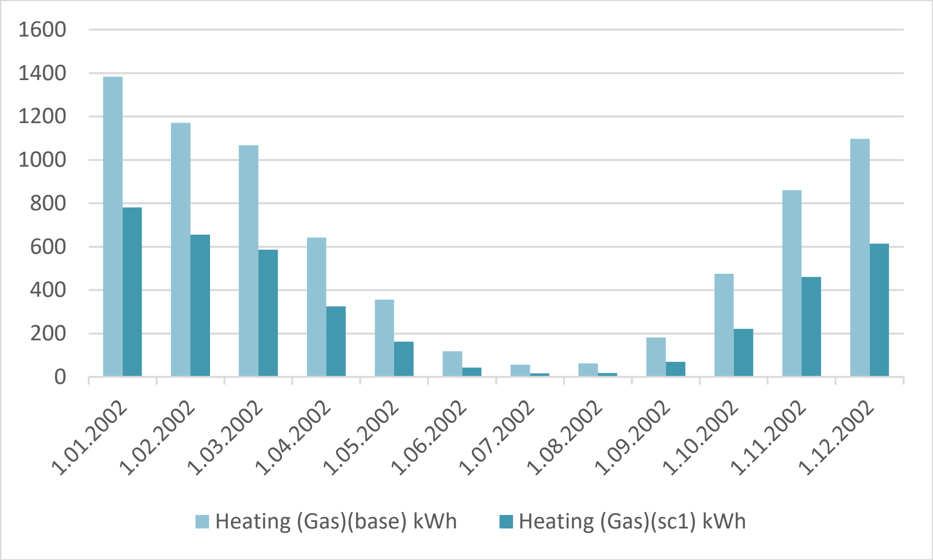


Figure 18. Base Case and Scenario 1 Simulation Heating Results.

In the second scenario, 5 cm EPS was applied to the exterior walls and under the reinforced concrete floor. As a result of the simulation made in the Designbuilder program, it was determined that the amount of energy consumed for heating decreased to 63 percent compared to the current situation (Figure 19).

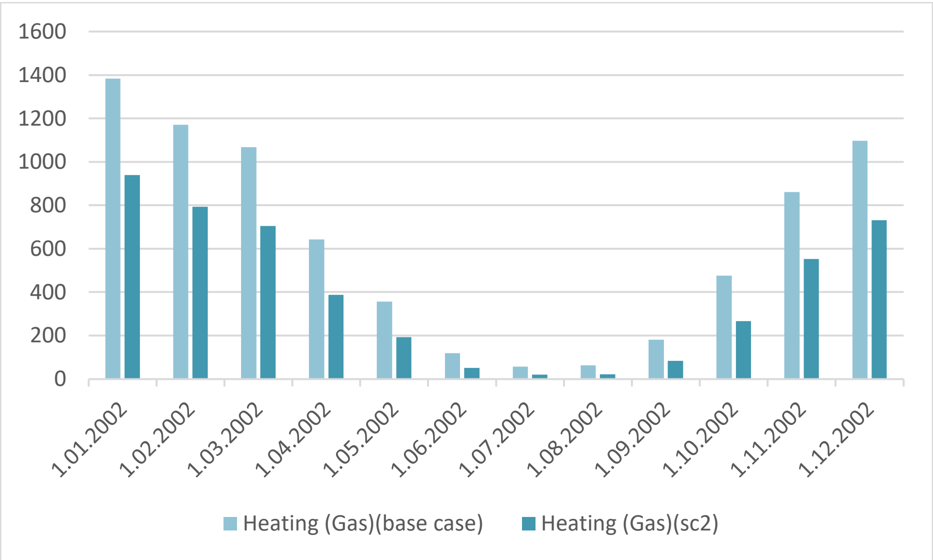


Figure 19. Base Case and Scenario 2 Simulation Heating Results.

In the third scenario, the exterior walls were processed between double bricks as a 5 cm EPS thermal insulation application. As a result of the simulation made in the Designbuilder program, it was determined that the amount of energy consumed for heating decreased to 69 percent compared to the current situation (Figure 20).

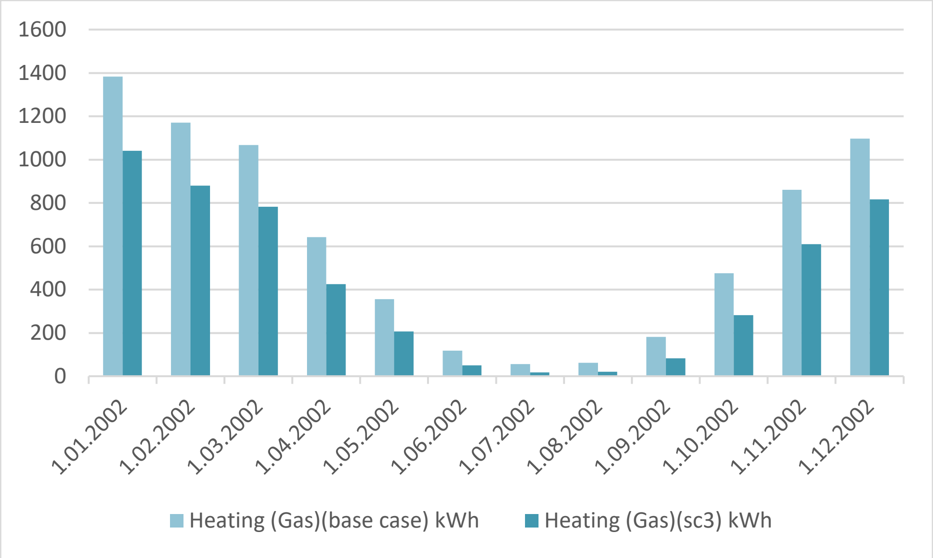


Figure 20. Base Case and Scenario 3 Simulation Heating Results.

In scenario 4, the exterior wall material was processed as bricks and a 10 cm foampolyurethane was applied. As a result of the simulation made in the Designbuilder program, it was determined that the amount of energy consumed for heating decreased to 53 percent compared to the current situation (Figure 21).

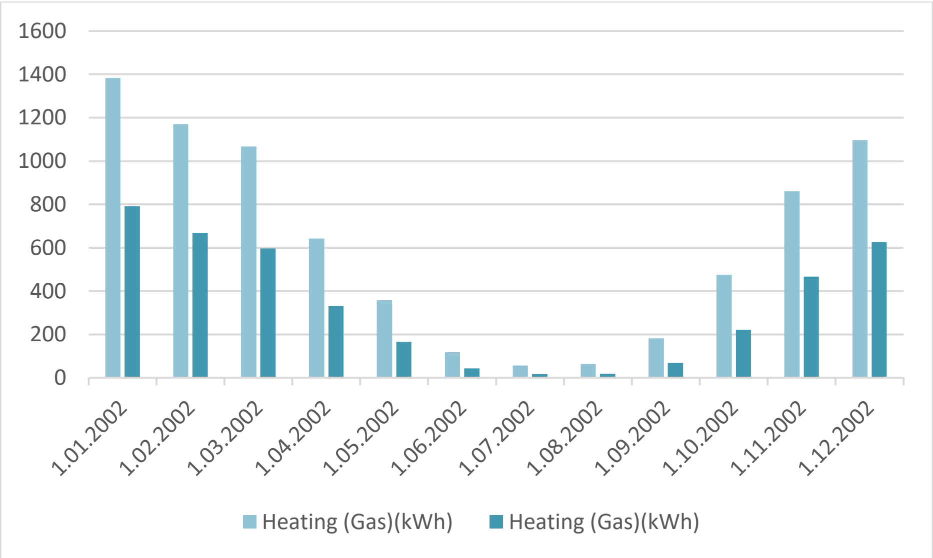


Figure 21. Base Case and Scenario 4 Simulation Heating Results.

In scenario 5, steel sunshades were added to the windows of the flat. As a result of the simulation made with these sunshades, the amount of electricity consumed for total cooling decreased by 5% compared to the current situation (Figure 22).

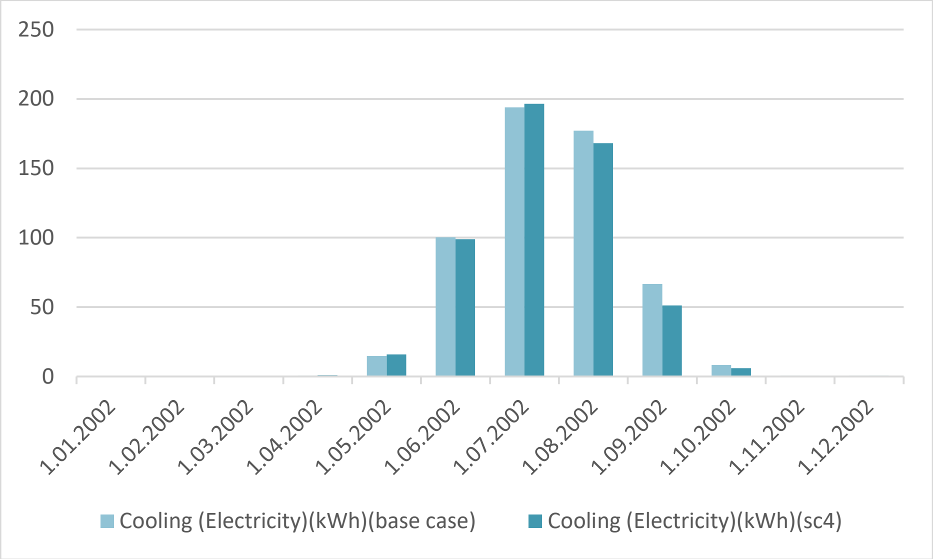


Figure 22. Base Case and Scenario 5 Simulation Cooling Results.

4. CONCLUSION

In the study, the building, which was primarily considered as the field study, was monitored and recorded with Hobo dataloggers between 26-31 December. Then, the current state of the flat was modeled in the DesignBuilder V7 simulation program and the model was calibrated with the data obtained as a result of monitoring with data loggers. However, this study was followed for a limited period of time. It would be healthier to increase the reliability of calibration if the monitoring period for calibration is longer and includes different seasonal periods.

When the simulation results in the study are examined, it is seen that House A, which is the residence on the ground floor, requires less energy during the heating period than the other two residences. According to the simulation results, House C, located under the roof, needs the most heating energy. However, there is no big difference between the heating energy required by houses. The reason for this situation is thought to be that the air temperature decreases as you move up from the ground plane. The simulations were repeated for the cooling period, and when the simulation results of the cooling period were examined, it was concluded that the house that required the least energy for cooling was House C. When the simulation results are examined, the issue that requires the most energy for cooling is House A.

In the study, different scenarios were created and different wall systems and thermal insulation systems were processed in these scenarios. The presence of thermal insulation in the processed scenarios decreased the U values of these wall materials. In addition, the amount of energy required for heating decreased significantly in these scenarios. In the 5th scenario, a sunshade design was made on the windows of the building and other parameters were kept constant. Thus, it has been determined that the amount of electricity to be consumed for cooling, especially in summer, will decrease by 5%.

This study emphasizes the effect of the building envelope and the importance of thermal insulation in energy efficient building design. It provides information for future studies on how different materials to be used in the building envelope and the floor on which the house is located will affect energy consumption.

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