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Article

A comparative analysis of energy performance for external wall types in practice

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ABSTRACT

Urban regeneration has accelerated after the establishment of the Law on Transformation of Areas Under Disaster Risk and has been carried out intensively. Building renewal, especially at a parcel scale, cannot deal with environmental problems on an urban scale and accordingly, the sustainability principles cannot be addressed holistically. Since building renewal at a parcel scale affects a large area throughout the city, it is required to include design criteria for environmental impacts. In this context, it is important to reduce heating and cooling energy consumption, which constitutes a large part of the total energy consumed in the use of buildings, and to take environmental measures. This study aims to analyse the energy performance of external walls in new buildings constructed after 2012 in the Suadiye Neighbourhood and to determine the most appropriate wall section. For this purpose, external walls were determined with a field study, and scenarios related to building orientation, the distance between buildings and external wall sections were created on a sample building. The scenarios were analysed with DesignBuilder simulation and TS825 calculation. The results for the scenarios were evaluated comparatively. The study differs from existing studies with its scope by dealing with both building renewal and energy efficiency and analysing the external wall types in different scenarios with DesignBuilder and TS825 for the temperate humid climate zone. As a result of the study, the most suitable wall sections for the scenarios were determined and suggestions were developed. The results of the study contribute to the country's economy by ensuring the efficient use of resources.

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INTRODUCTION

Urban redevelopment practices that became prominent due to economic, social reasons and natural disasters as a result of the need for renewal, redevelopment and improvement of the existing building stock gained momentum with the enactment of the Law on the Transformation of Areas under Disaster Risk, which entered into force in 2012. After the publication of the Law, priority redevelopment areas in the earthquake belts of Turkey were determined for urban redevelopment projects to be carried out. Urban redevelopment activities in Istanbul, which is one of the pilot provinces, started in Esenler and Fikirtepe districts regionally. Whereas, in districts such as Kadıköy

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and Bakırköy, the plot scale renewal method became the leading practice. In the province of Istanbul, when urban redevelopment projects on the plot scale carried out with the building renovation method were evaluated, it is seen that the build-and-sell housing production style that emerged in the 1950s in Turkey has been the dominant practice. Especially on the Anatolian side, along the railway and the coastal line from Kadıköy to Bostancı, the building stock, which was produced in the form of apartment blocks replacing the houses with gardens, was demolished and rebuilt on a plot scale, again with the build-and-sell method within the scope of urban redevelopment of the 2000s. Renovation works carried out at the plot scale is defined as 'building renewal'. Building renewal practices affect a wide area when viewed at the urban scale. However, the projects produced are not designed as a part of the whole city but are handled individually. This situation prevents the environmental problems that arise due to intense urbanization to be handled at a higher scale. While environmental sustainability is ignored during the construction phase of these practices, it is also seen that the design criteria for reducing the negative impact of the buildings on the environment are not included in the usage phase as well.

Buildings in Turkey have a 35% share of the energy consumed. For this reason, it is necessary to take measures to reduce energy consumption in buildings. 65% of the energy used in buildings is used for heating, cooling and ventilation. In this direction, it is important to apply design criteria that are effective in heating and cooling energy conservation during the design phase of buildings. Reducing heating and cooling energy consumption creates the potential for energy saving (Çevre ve Şehircilik Bakanlığı). Based on this potential, the subject of the study has been determined as the evaluation of the exterior wall types in terms of energy efficiency, which are utilized in the building renewal practices at the plot scale within the scope of urban redevelopment. In this direction, it is seen that the subject of external walls has been studied under different titles in the literature.

LITERATURE REVIEW

There are many variables that need to be addressed in exterior wall design. Koç and Altun created a relative evaluative checklist for exterior wall design (Koç & Altun, 2012). Chasan examined the effect of thermal insulation on both temperature and humidity performance (Chasan, 2013), whereas Koçu examined the condensation problems encountered in thermal insulation application details (Koçu, 2010). Şenkal Sezer, on the other hand, examined the external wall thermal insulation systems applied in residences in Turkey by classifying them (Şenkal Sezer, 2005).

When the studies that deal with the issue of external walls in terms of energy are reviewed, it is seen that there are many studies on improving the energy performance of the existing building stock (Valancius, Vilutiene, & & Rogoža, 2018; Matthew & Leardini, 2017; Lassandro & Di Turi, 2017; Biseniece, ve diğerleri, 2017; Rodriguesa, White, Gillott, Braham, & Ishaque, 2018; Liu, Liu, Ye, & Liu, 2018; Xu & Liu, 2018; Poortinga, Jiang, Grey, & Tweed, 2018). Usta compared the insulated and non-insulated walls in terms of energy efficiency according to TS825, since the thermal insulation plays a very important role in the energy efficiency of the building in the usage phase of the wall cross-section (Usta, 2009), Erbil and Akıncıtürk, on the other hand, evaluated the thermal comfort conditions in a mass housing built with a tunnel formwork system, using a survey, thermal camera and TS825 calculation method, and concluded that thermal insulation had to be compulsory (Erbil & Akıncıtürk, 2006). Erdemir Kocagil and Koçlar Oral analysed the impact levels of design decisions on building energy consumption in scenario alternatives created in a temperate-humid climate zone, with a performance-oriented simulation method for energy-efficient settlement pattern and building design (Erdemir Kocagil & Koçlar Oral, 2021).

Due to the fact that the cost issue is at the forefront, especially in buildings produced by the private sector, Salandin and Soler developed a method to determine the factors in the design of an exterior wall by minimizing the cost and choosing the option that complies with the energy regulations and requires the lowest cost (Salandin & Soler, 2018). Şenel Solmaz evaluates the optimization of cost criteria and saving solutions for different climatic regions by considering the components on the facade of an office building with a simulation-based approach (Şenel Solmaz, 2016). Baykal, in his master's thesis, discussed the change of section thickness of thermal insulation according to directions from an economic point of view, (Baykal, 2014), Aksöz, on the other hand, made a thermal and economic analysis of thermal insulation (Aksöz, 2009).

There are many studies conducted separately on building renewal and energy efficiency issues, however, there is no study that deals with both topics together and evaluates their reflection on each other. This herewith study differs from the existing studies in that it evaluates the exterior wall types in practice in different scenarios with DesignBuilder and TS825 for the temperate humid climate zone. While existing studies evaluate only the building in energy consumption simulation models, this study presents an evaluation in which the surrounding buildings are also modelled within the city texture as well as considering environmental effects in this context.

The purpose of the study is to evaluate the energy performance of the exterior wall types applied in the selected area in a temperate humid climate region and to determine the most appropriate exterior wall type options in terms of energy efficiency. In addition, it is also aimed to evaluate the wall cross-sections used under different conditions as a result of the comparisons between the TS825 calculation method and DesignBuilder dynamic energy simulation and to offer suggestions for the development of applications being used in the market currently.

TS825 Thermal Insulation Requirements for Buildings is the regulative code for new buildings in Turkey. "The aim of the standard is to limit the energy amounts used in the heating of the buildings in Turkey" (TSE, 2008). The code offers a calculation method that uses the degree day approach with monthly average temperature data. However, current studies mainly use simulation tools incorporating hourly weather data of that specific region or city. Therefore, this study uses TS 825 calculation method as a mandatory tool of Turkey and additionally DesignBuilder simulation tool for compare the results as it contains a user-friendly graphic interface.

According to the 2013 data from the Ministry of Environment and Urbanization, there are approximately 19 million residential buildings in Turkey and it is estimated that 6-7 million of these buildings need to be renewed or reinforced (Çevre ve Şehircilik Bakanlığı). Considering these conditions, it becomes important to integrate sustainability principles into the built environment and to use resources efficiently, while there is restructuring with the rapid urban redevelopment practices being carried out. In this context, the transformation realized is seen as an opportunity to achieve energy efficiency. "Considered within urban policies, although sustainability and urban transformation represent parallel series, there is limited coordination between the two approaches" (Yorgancı, 2011). Ensuring energy efficiency, which is among the objectives of the study, will be beneficial in establishing the necessary coordination between urban transformation and sustainability. It is thought that the suggestions developed and the conclusion reached in the study will create awareness and consciousness in terms of the importance of the organization of the external wall cross-section in such applications, and the return of this awareness to action will contribute to the national economy as well as the environmental benefits that will be created in terms of efficient use of the country's resources.

MATERIAL AND METHOD

In the study, the areas where urban redevelopment projects were carried out intensively by means of building renewal at the plot scale with the enactment of the Law on the Transformation of Areas under Disaster Risk were evaluated. Although there are other regions that require more urgent intervention, these projects, which were initiated to ensure earthquake safety, are concentrated as plot-scale building renewal in the Suadiye Neighbourhood that was chosen as the pilot region following Fikirtepe in Kadıköy due to the economic crisis, the revival of the construction sector, etc. For this reason, Suadiye Neighbourhood was determined as the study area. The study covers the exterior wall types included in the building renewal projects made at the plot scale within the boundaries of the study area, within the framework of urban transformation, after 2012.

First of all, the exterior wall elements and components of the buildings renovated by building renewal in the selected area were determined. In the next step, a sample new building was fictionalized in the study area. Apart from the existing conditions of this building, different combinations were created with the chosen exterior wall cross-sections and scenarios for different parameters. Changing parameters were determined as the distance between the buildings, the orientation of the building and the external wall cross-section. For all scenarios, the properties of the most frequently used transparent component were accepted as a result of the inventory analysis. The results were evaluated by making changes in the opaque wall cross-section in the scenarios. For the opaque wall cross-section, an energy simulation was carried out with the DesignBuilder software on the sample building by using the most used cross-sections in the area, which were determined by the inventory analysis. Afterward, the same scenarios were evaluated with TS825 Thermal Insulation Rules in Buildings Calculation Method and the results were compared with the results of the DesignBuilder software. As a final outcome of the study, the section types for the scenarios were evaluated and suggestions were developed for the improvement of the applications (Figure 1).

FIELD STUDY

As a result of the research conducted in terms of historical, physical and demographical characteristics of Suadiye Neighbourhood, Suadiye Neighbourhood and Bagdat Street are addressed on the basis of their immediate surroundings and Kadıköy district to which they are contingent due to the effects of the developments on each other. Bagdat Street, which shapes the development process of the region chosen for the fieldwork, starts in Kızıltoprak and stretches all the way to Maltepe. As soon as it extends to the Maltepe neighbourhood, the social structure of the street changes. For this reason, the area considered as Bağdat Caddesi in the study is its section between Bostancı and Kızıltoprak.

In the Ottoman Period, in the area towards Bostancı, there were residences of senior public officials, gardens and towards the inner parts; there were villages (Akbulut, 1994). All taking place after the second half of the 19th century, the establishment of the city line ferry management (1857),

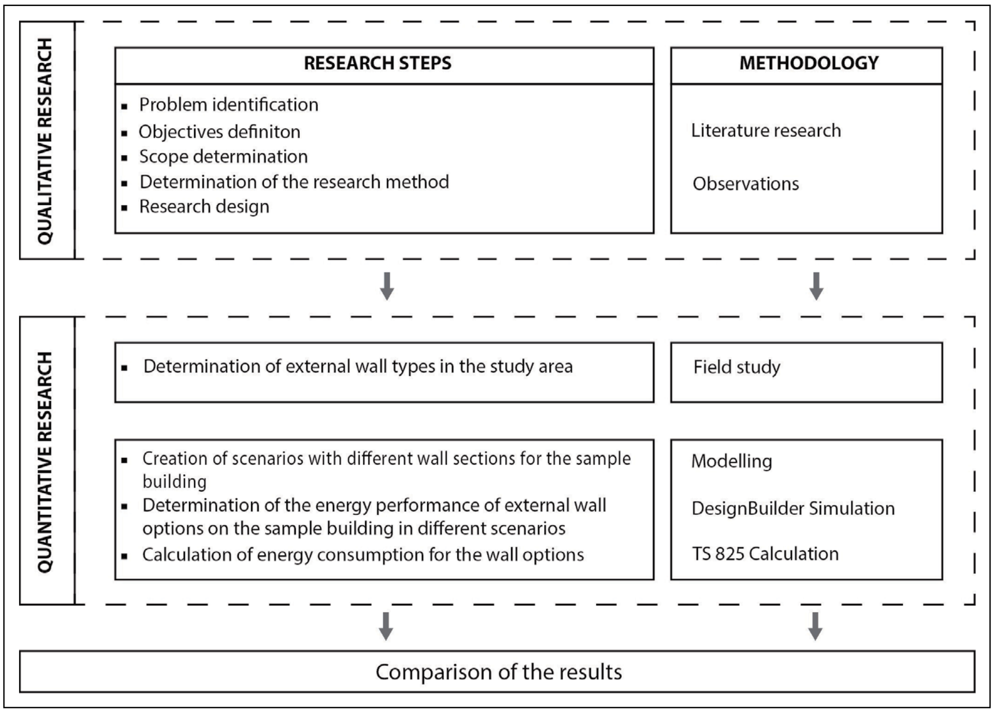

Figure 1. Research methodology.

enactment of the Ebniye Law (1882) and the laying of the Haydarpaşa-Pendik Railway (1883) are the main factors affecting the development of the region. With the Ebniye Law, which aimed to regulate the zoning and construction work areas, in addition to the neighbourhoods that started to develop around the railway, mansions and summerhouses were started to be built in the coastal part of Bağdat Street. Between the railway and Bağdat Street, it is seen that a grid system settlement is formed consisting of main roads perpendicular and parallel to the sea (Halu, 2010).

With the opening of Suadiye and Caddebostan beaches in the 1930s, as well as the asphalt pavement of Bağdat Street, social life shifted to Bağdat Street (Giz, 1994). After 1935, tramlines were created on both sides of the street; additionally, the land on the street was divided into small plots, and generally, two-story residential buildings were started to be built. With the Property Ownership Law published in 1965, the low-density settlement pattern was abandoned and the way for high-density concentration was paved as a result of the construction of apartments which were built mostly with the build-and-sell method (Halu, 2010).

With the 1/5000 scale, Bostancı-Erenköy regional Zoning Plan being made in 1972, building densities for the area were increased to a 1.8 and the Bosporus Bridge was completed in 1973, the region transitioned from a summer resort into a permanent residential area. Fatih Sultan Mehmet Bridge being put into service during 1986/1988 and was connected to the region via Kozyatağı, led the region to be selected for non-residential functions as well, and the function of the area within the city as a whole to be transformed (Akbulut, 1994).

As a result of the concerns of a possible earthquake expected in Istanbul and the need to organize the north of the region, a master development plan in 2005 and a new implementation development plan in 2006 was announced. Accordingly, Kadıköy District has been handled by the Istanbul Metropolitan Municipality as two different planning areas as Kadıköy Centre and Kadıköy Centre- E-5 Highway Buffer Zone. Bagdat Street and its surroundings, which are discussed in the study, are within the scope of the Kadıköy Center-E5 Highway Buffer Zone development plan.

While the building coverage ratio was specified as 2.07 in the zoning plan dated 11.05.2006, the floor area ratio was increased from 0.25 to 0.35. Considering the zoning status in 2021, it is seen that the first plots facing the coastal road has a floor area ratio of 0.25 and the maximum height permit is 11 m – 3 floors. Height allowance is 14.50 m – 4 floors at the secondary plots located adjacent to the coast. In the second block, the height limit increases to 15 floors. The height limit of the plots on Bağdat Street is determined as 18.00 m – 5 floors and the drawing distance from the street is 10 m. Other plots in the region have a limit of 15 floors and a floor area ratio of 2.07. With the 1/1000 scaled implementation zoning plan, plan note and legend amendment dated 21.02.2017, the limit to build a maximum of 15 floors in the region has been brought (Table 1).

Table 1. Zoning status of plots

	Building coverage ratio – TAKS	Floor area ratio – KAKS	Hmax (m)	Front garden distance
Coastline	0,25	-	11.00 m (3 storey)	5 m
Coastline	0,25	-	14.50 m (4 storey)	5 m
Bağdat Street	0,25	-	18.00 m (5 storey)	10 m
Other plots	0,35	2,07	15 storey	5 m

General Information on Suadiye Neighbourhood

Suadiye Neighbourhood has the Marmara Sea to the south, Caddebostan, which has a coastline, to the west, Erenköy, to the north, 19 Mayıs and Kozyatağı to the north, and Bostancı neighbourhoods to the east. Bagdat Street divides Suadiye Neighbourhood into two on the east-west axis. The location and orientation of Suadiye Neighbourhood can be seen in Figure 2. The area between Bağdat Street and the coastal road offers easy access to the green areas and the sea-front where the land value is high. Legal regulations within the neighbourhood differ in this region. In the area located between Bağdat Street and the minibus road, the neighbourhood's public transportation means vary, and hence, the area attracts multi-purpose commercial functions in addition to cafes and restaurants. Ayşe Çavuş Street in the neighbourhood gains importance as it provides access to Bağdat Street and the train station (Figure 2).

When the climate characteristics are examined, it is seen that the Suadiye Neighbourhood is located in the temperate humid climate zone, which also encompasses Istanbul. In this climate region, the summer months are hot and less rainy, and the winter months are mild and rainy. The coldest months in Istanbul are December, January, and February, while the hottest months are July and August. The region is among the second region degree-day provinces in the TS825 Thermal Insulation Requirements for Buildings.

Figure 2. Location and orientation of Suadiye Neighbourhood.

Field Study and Results

A field study was conducted in Suadiye Neighbourhood to determine the exterior wall types used in the applications carried out under building renewal. Within the scope of the study, the current base map of neighbourhood was obtained primarily. There are 75 streets in Suadiye Neighbourhood.

An inventory form was created to organize the information of the residential buildings-building name, construction company, block/plot, year of construction, number of floors, number of basements, front, side, and rear façade, and photographic information.

When the site plan of the area is examined, it is seen that the buildings are generally placed with a grid plan and at an angle of 30 degrees to the north. The settlement is in a garden setting and therefore all buildings have at least 4 façades.

In the area, 183 residential buildings built after 2012 were determined. The construction year of these residential buildings, the number of floors, whether the building has a basement or not, as well as the features properties fo the components that make up the façade and the external wall are emphasized. Brick, aerated concrete blocks and precast panels are seen often as the wall body on the external wall.

The most preferred type of cladding on the façades of buildings facing the street is ceramic and aluminium composite panels. Plaster and paint are used on the rear façades. All façades are applied in the same way in buildings using precast panels.

PVC or aluminium happens to be preferred for the joinery for the transparent components on the external walls. In addition to the use of double-glazing with air gaps as a glass type, there are also examples supported by Low-E cladding and argon type glass used as well. The transparency rate is higher on-street façades with windows used up to the floor than on other façades. Motorized shutter systems controlled by the user are used as shading elements.

ENERGY PERFORMANCE ANALYSIS OF EXTERNAL WALL TYPES

Energy consumption in buildings is being able to be reduced by developing passive solutions to meet user needs. Variables that can be passively controlled include the building's location, orientation, building spacing, the form of the building, volume organization, and building envelope's optical and thermo-physical properties. Efficient use of energy is being able to be achieved by the appropriate use of these variables.

Within the scope of the study, the values given in the TS825 Thermal Insulation Requirements for Buildings Standard updated in 2013 were used for the U values of the building elements and the thermal properties of the products in between the layers.

Properties of the Sample Building

The data obtained as a result of the fieldwork were tested on a sample building. The example building is created with the following properties

- garden layout with 4 façades
- 2 flats on the floor, flats having 3+1 rooms
- flat floor area 125 m^2
- ground floor +10 normal floors
- common areas and janitor's apartment on the ground floor
- floor height 3.00 m
- 1 basement floor parking area
- hipped roof without roof space

The ground and normal floor plans of the sample building is shown in Figure 3.

In the sample building, the layers of all the building elements except the external wall were determined, and the properties of the building products that make up the building elements were considered constant. The properties of the said building elements are given in Table 2.

In the transparent component, the joinery is accepted as 4 cm PVC and the glass as Low-E 6+16 mm Argon+ 6 double layer. Window U-value is taken as 1.724 W/m^2K.

Creation of Scenarios for the Analysis

In the case study carried out within the scope of the research, the location of the building, the volume organization and the building form variables were kept constant, while the orientation of the building, the building spacing and the characteristics of the building envelope were diversified with scenarios.

Scenarios for the Building Orientation and Distance between Buildings

The orientation of the sample building and related scenarios have been shaped depending on the orientation of the grid system, which is particularly prominent in Suadiye Neighbourhood, making an angle of 30 degrees to the north. Building orientation and building spacing variables are considered together within the scope of scenarios. The

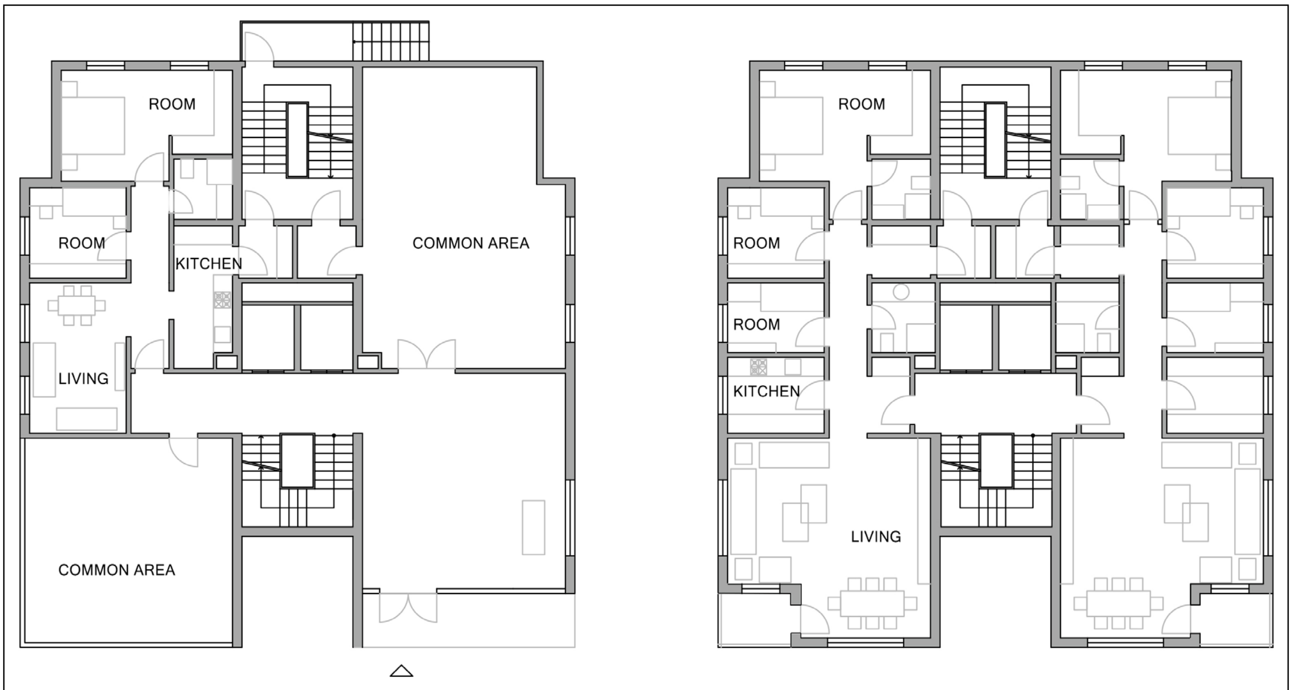

Figure 3. Ground floor and normal floor plan of the sample building.

Table 2. Properties of building elements

	Materials	Thickness d (m)	Thermal conductivity λ (W/mK)	Heat transfer coefficient U (W/m²K)
Roof	Roofing tile	0.025	1.00	2.084
	Air gap	0.02	d/λ = 0.15 (m²K/W)	
	Waterproofing	0.01	0.19	
	OSB board	0.018	0.13	
Floor (Apartment-roof)	Screed	0.05	1.40	0.40
	Thermal insulation	0.08	0.035	
	Reinforced concrete floor	0.12	2.20	
	Plaster	0.01	1.0	
Floor (Apartment-Apartment)	Laminated wood	0.018	0.20	2.246
	Screed	0.05	1.40	
	Reinforced concrete floor	0.12	2.20	
	Plaster	0.01	1.0	
Floor (Apartment-Parking)	Laminated wood	0.018	0.20	0.559
	Screed	0.05	1.40	
	Reinforced concrete floor	0.12	2.20	
	Thermal insulation	0.05	0.035	
	Plaster	0.01	1.0	
Foundation	Screed with fibre additives	0.08	1.40	1.035
	Raft foundation	0.60	2.20	
	Protection concrete	0.04	1.65	
	Waterproofing	0.01	0.19	
	Lean concrete	0.10	1.65	
	Blockage	0.15	0.52	
Interior Wall	Plaster	0.02	1.00	1.483
	Brick	0.135	0.36	
	Plaster	0.02	1.0	
Foundation Wall	Thermal insulation	0.05	0.035	0.553
	Waterproofing	0.01	0.19	
	Reinforced concrete wall	0.30	2.20	
	Plaster	0.02	1.0	

situations of the created scenarios in the site plan are seen in Figure 4.

The distance with the neighbouring building has been accepted as at least the drawing distance in the zoning plan, and it has been taken as 4+4=8 m. On the façades facing the street, when the street drawing distance of 5 m in the zoning plan is taken for both buildings and the street width is added, the distance has been designed as 18.50 m in total.

Scenarios for the Building Envelope

In the scenarios related to the building envelope, precast glass fibre reinforced concrete panels are considered, as well as wall-filling materials such as brick and aerated concrete, which are used extensively in the area. When the exterior claddings applied in the field are evaluated; it is seen that ceramic and aluminium composite claddings are frequently preferred. These claddings are applied by hanging with a structure. In this context, different exterior wall scenarios were created with the combinations of the specified exterior wall bodies and claddings. The stratification information regarding the created exterior wall scenarios is given in Table 3.

Twenty scenarios were produced with different combinations of 4 different site plans and 5 different exterior wall cross-sections. The rendering matrix of these twenty scenarios is shown in Table 4.

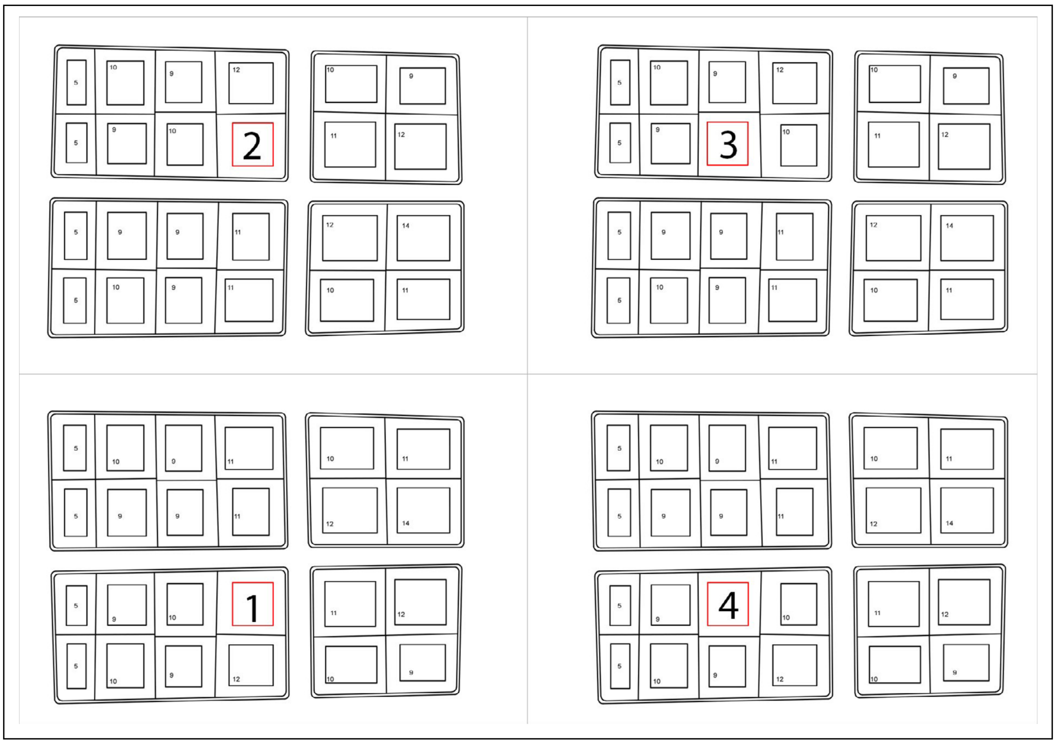

Figure 4. Site plan scenarios for orientation and distance.

Analysis of Scenarios on DesignBuilder

Twenty scenarios created in the study and mentioned in the previous section were analysed using the DesignBuilder software. DesignBuilder software is a software that calculates heating, cooling, ventilation and lighting energy consumptions by using climatic data of the place and thus can show the effect of energy consumption variables in the design. The software also facilitates the thermal simulation of EnergyPlus with its interface that allows the buildings to be modelled easily. For this purpose, the sample building created primarily was modelled in the program, and heating and cooling energy consumptions were calculated for different scenarios.

While creating the cross-sections of the determined building elements, the features of the products in the DesignBuilder library were compared with the product features specified in the TS825 Standard for Thermal Insulation Rules in Buildings, and new products were created in the library when the appropriate products were not found in the library.

Modelling of Sample Building on DesignBuilder

In the modelling of the sample building, the IWEC climate data file accessed from the EnergyPlus database and included in the DesignBuilder software was used for the climatic data of the province of Istanbul. As the building location, the coordinates were determined with the help of Google Earth, and the coordinates of 40.57 North 29.04 East were defined, and the height of the area above sea level was accepted as 28 m. The sample building modelled in the DesignBuilder software is seen in Figure 5.

In the building, 4 zones have been created on the floor, with circulation areas as one zone and apartments as another zone. The flat is considered as a single zone, however by using the dividers for the rooms, the heat storage capacities of the inner walls are included in the calculations.

The assumptions made in the simulation modelling and the values used are given below.

- The density of people in the dwelling was determined as 0.04 person/m^2 and metabolic 1.00 Met.
- The clothing value is set at 1.00 Clo for winter and 0.50 Clo for summer.

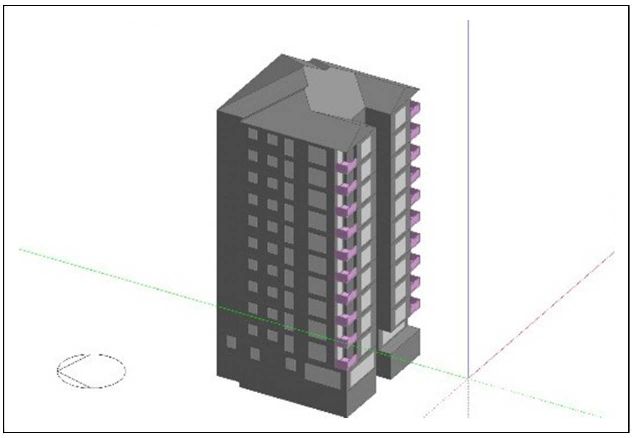

Figure 5. 3D model of the sample building on DesignBuilder.

Table 3. Scenarios for the external wall and properties of layers

		Thickness d (m)	Thermal conductivity λ (W/mK)	Mass per volume kg/m³	Specific heat Jkg/K	Heat transfer coefficient U (W/m²K)
A	Ceramic	0.01	0.85	1900	840	0.428
	Gap	0.05	d/λ = 0.15 (m²K/W)			
	Heating insulation	0.05	0.035	120	840	
	Brick	0.19	0.36	700	840	
	Plaster	0.02	0.51	1200	840	
B	Ceramic	0.01	0.85	1900	840	0.299
	Gap	0.05	d/λ = 0.15 (m²K/W)			
	Heating insulation	0.05	0.035	120	840	
	Aerated concrete	0.20	0.13	400	840	
	Plaster	0.02	0.51	1200	840	
C	Aluminium	0.005	45	7680	420	0.430
	Gap	0.05	d/λ = 0.15 (m²K/W)			
	Heating insulation	0.05	0.035	120	840	
	Brick	0.19	0.36	700	840	
	Plaster	0.02	0.51	1200	840	
D	Aluminium	0.005	45	7680	420	0.300
	Gap	0.05	d/λ = 0.15 (m²K/W)			
	Heating insulation	0.05	0.035	120	840	
	Aerated concrete	0.20	0.13	400	840	
	Plaster	0.02	0.51	1200	840	
E	Precast GRC	0.012	1.00	2100	840	0.47
	Heating insulation	0.05	0.035	120	840	
	Gypsum board	0.0125	0.25	1200	840	

Table 4. Matrix for the scenarios

	Layout 1	Layout 2	Layout 3	Layout 4
External wall A	Scenario 1A	Scenario 2A	Scenario 3A	Scenario 4A
External wall B	Scenario 1B	Scenario 2B	Scenario 3B	Scenario 4B
External wall C	Scenario 1C	Scenario 2C	Scenario 3C	Scenario 4C
External wall D	Scenario 1D	Scenario 2D	Scenario 3D	Scenario 4D
External wall E	Scenario 1E	Scenario 2E	Scenario 3E	Scenario 4E

- In energy consumption, the consumption arising from hot water and lighting is not considered, only heating and cooling energy consumption is taken into account.
- Radiator heating, local cooling system and natural ventilation are defined in the apartments. Heating and cooling systems are not simulated in the circulation area and on the parking floor. The heating system is assumed to be working with natural gas and the cooling system to work with electrical energy.
- The indoor comfort temperature is defined as a minimum of 12°C and a maximum of 20°C in the period when heating is desired. In the period when heating is not desired, the indoor comfort temperature was accepted as the lowest at 26°C and the highest at 28°C.
- Heating system efficiency was taken as 0.85, and the COP value of the cooling system was taken as 3.
- The infiltration value was accepted as 0.70 ac/h.

Results of DesignBuilder Simulation

Heating, cooling and total energy consumptions for the scenarios constructed during the creation of the simulation results are shown in Figure 6.

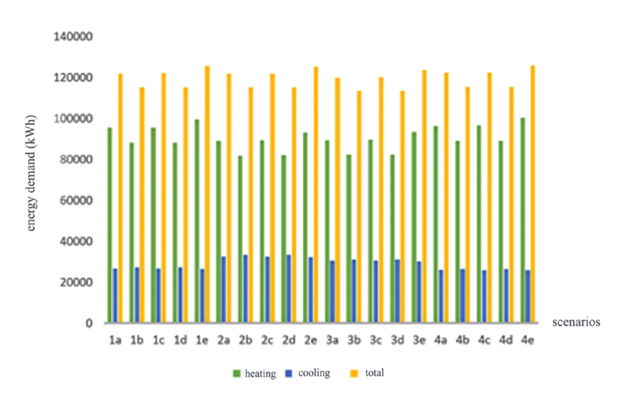

Figure 6. Heating, cooling and total energy consumption of scenarios.

In scenario 1, the sample building is located on the corner plot. The inclusion of street width in addition to the building spacing in the street direction reduces the shadow effect of the surrounding buildings thereby increasing the level of exposure of the sample building to the environmental conditions. Consequently, it is seen that the heating consumption of the sample building increases and the cooling consumption decreases, due to the fact that the entrance façade of the building faces northeast and neighbouring buildings are located in the south direction, where solar heat gains are high.

In scenario 2, the sample building is oriented on the corner plot, and therefore streets are located in the southwest and southeast directions of the plot. Due to the location of the entrance façade of the building in the southwest direction, the thermal gains due to solar heat increase. While this situation reduces the heating energy consumption in the heating period, it increases the electrical energy consumption in the cooling period.

Within the scope of scenario 3, the sample building is situated in an intermediary plot. The heating energy consumption of the building is low due to the fact that the entrance façade is positioned in the southwest direction. In addition, the presence of neighbouring buildings on the three sides of the building and the increase in shadow effects also reduce cooling energy consumption.

The sample building in scenario 4 is placed on the intermediary plot. The entrance façade is located in the northeast direction. It is seen that the heating energy consumption increases depending on the north orientation of the building. This ensures a reduction in energy consumed for cooling.

When the scenarios are evaluated in terms of external wall cross-sections, it is seen that the heating consumption of cross-sections with aerated concrete wall bodies is lower than that of pre-built cross-sections with brick wall bodies. This can be explained by the lower U value of scenarios using aerated concrete. However, the U value difference does not make a big difference in the cooling consumption. When comparing the claddings, it is seen that the aluminium cladding increases the heating consumption slightly.

Analysis of Scenarios According to TS825

In the study, the properties of the materials, the limit U values and the calculation method were studied in accordance with the 2013 TS825 Thermal Insulation Requirements for Buildings Standard. While making the calculations in this study, since Istanbul is located in the second-degree day region, the outside temperature values specified for this region in the standard were used in the heat loss calculations. The average monthly solar heat intensity value is given in common for all regions and depending on the directions.

TS825 Calculations for the Sample Building

In order to determine the TS825 heating energy requirement of the sample building created in the study, calculations were made with the wall, ceiling, floor, window, and door information of the building. Accordingly, this information used in the calculation is given in Table 5.

After the information of the sample building was arranged, the calculation method suggested in TS825 was applied. In the study, the value of 0.5, which is defined as "in the orientation of buildings with attached layout and/or with buildings higher than 10 floors are located", was used as appropriate for the scenarios. After making the necessary calculations for all months, the total heat loss of the building was found in kilo Joules. The total value is converted to kWh. When the calculations made for scenario 1A as a sample are summarized with the table recommended in the standard, the values in Table 6 are observed.

Table 5. Data used in calculations for the sample building

Window area AP	**464.4 m²**	**External wall area A_D**	**1395 m²**
$A_{P, North}$	72 m²	Floor area A_t	296.28 m²
$A_{P, South}$	158.40 m²	Roof area A_T	296.28 m²
$A_{P, East}$	117 m²	Total area A_{top}	2857.56 m²
$A_{P, West}$	117 m²	Gross volume $V_{brüt}$	8888.4 m³
Reinforced concrete area A_{bet}	369.6 m²	Net usage area A_n	2502.3 m²

Table 6. Calculation results for scenario 1A

Months	Isı kaybı			Isı kazançları			KKO	Heat gain	Heating
	Specific heat loss	Temperature difference	Heat losses	Internal heat gain	Solar energy gain	Total		Utilization factor	Energy demand
	H=HT+HV (W/K)	θi-θe (K,°C)	H(θi-θe) (W)	φi (W)	φs (W)	φT =φi +φ s (W)	γ (-)	ηay (-)	Qay (kJ)
January	3204.75	16.1	51596.475	12511.5	3872.88	16384.38	0.32	0.96	93091199.25
February		14.6	46789.35		5049.36	17560.86	0.38	0.93	78930118.24
March		11.7	37495.575		6503.76	19015.26	0.51	0.86	54761638.89
April		6.2	19869.45		7598.88	20110.38	1.01	0.63	18782750.72
May		1.0	3204.75		9162.72	21674.22	6.76	0.14	-
June		-	0		9707.04	22218.54	-	-	0
July		-	0		9427.68	21939.18	-	-	0
August		-	0		8612.64	21124.14	-	-	0
September		-	0		6878.16	19389.66	-	-	0
October		4.9	15703.275		5209.2	17720.7	1.13	0.59	13705774.51
November		10.5	33649.875		3738.96	16250.46	0.48	0.87	50410644.48
December		15.2	48712.2		3350.16	15861.66	0.33	0.95	87055099.4
								Total	396737225.5

Results of TS825 Calculation

As a result of the calculations made with TS825, the annual heating energy need for the simulated scenarios is seen in Figure 7. In scenarios related to building orientation and spacing, the method offered by the standard for distance between buildings could not be evaluated. This is because the standard defines the shadow effect of surrounding buildings in calculations through the number of floors. In view of that, since the neighbouring structures of the sample building are 10 floors or more, the standard defines a single shading factor, and it does not make any difference in terms of calculations whether the building is situated in a corner plot or intermediary plot. Accordingly, scenario 1 with the same orientation is tackled with scenario 4, and scenario 2 with scenario 3.

When the results presented graphically in Figure 7 are evaluated, it is observed that

- for scenarios 1 and 4, where the entrance façade, which has a higher transparency rate than the other façades, is oriented to the northeast, the heating energy requirement is higher for all wall cross-sections compared to scenarios 2 and 3,
- scenarios 2 and 3, whose entrance façade is oriented to the southeast, have lower heating energy needs,
- in terms of exterior wall cross-sections, the scenarios where the wall body is designed as aerated concrete have the lowest heating energy need, followed by brick and pre-built GRC panel body walls,
- in terms of cladding, it is seen that the aluminium composite cladding increases the heating energy needed slightly compared to the ceramic cladding.

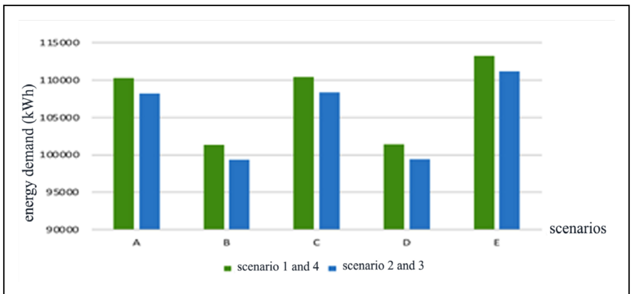

Figure 7. Heating energy demand for scenarios.

When the calculations for the scenarios are evaluated, it is seen that the data related to the transparency ratio is effective in the scenarios related to the building spacing and orientation, and the U value is effective in the scenarios related to the exterior wall cross-section.

Comparison of the results of DesignBuilder and TS825

Heating and cooling energy needs can be calculated with the DesignBuilder software. On the other hand, since TS825 only gives the energy needed for heating, the comparison is made on this data alone (Table 7).

When the results for scenarios 1 and 4 with the entrance façade oriented to the northeast, and scenarios 2 and 3 for the entrance façade oriented to the southeast, are analysed according to the building orientation and building spacing,

Table 7. Comparison between energy demand of scenarios according to DesignBuilder and TS825

Scenarios	DesignBuilder			TS825
	Energy demand (kWh)			Energy demand (kWh)
	Heating	Cooling	Total	Heating
1A	95250.26	26600.92	121851.2	110292.95
1B	87982.56	27144.92	115127.5	101344.88
1C	95418.42	26601.06	122019.5	110432.70
1D	88051.42	27126.85	115178.3	101413.48
1E	99300.42	26292.24	125592.7	113233.94
2A	88982.91	32597.49	121580.4	108238.91
2B	81785.73	33279.39	115065.1	99381.30
2C	89148.6	32586.81	121735.4	108377.31
2D	81881.54	33254.68	115136.2	99449.18
2E	92986.37	32215.41	125201.8	111151.78
3A	89399.66	30332.67	119732.3	108238.91
3B	82187.13	31040.14	113227.3	99381.30
3C	89546.36	30345.69	119892.1	108377.31
3D	82246.03	30963.68	113209.7	99449.18
3E	93385.54	30000.83	123386.4	111151.78
4A	96179.23	25979.18	122158.4	110292.95
4B	88905.16	26442.43	115347.6	101344.88
4C	96365.24	25929.5	122294.7	110432.70
4D	88949.1	26449.22	115398.3	101413.48
4E	100262.1	25655.68	125917.8	113233.94

the following is observed;

- when the results of scenario 1 and scenario 2, which are corner buildings, are compared, the difference between all results is 2% according to TS825, and according to DesignBuilder, this difference varies between 6.3% and 7%,
- when the results of scenario 3 and scenario 4, which are intermediary buildings, are compared, the difference between the results is 2% according to TS825, and it varies between 7% and 7.5% according to DesignBuilder,
- when scenario 1 with the corner building oriented to the northeast and scenario 4 with the intermediary building is compared, this difference could not be evaluated according to TS825, but a 1% difference is found according to DesignBuilder,
- when scenario 2 with a corner building oriented to the southeast is compared with scenario 3 with an intermediary building, this difference could not be evaluated according to TS825, and a 0.5% difference is found according to DesignBuilder.

When scenarios are considered in terms of external wall cross-sections, it is determined that;

- All A scenarios with a brick wall body compared to all B scenarios with an aerated concrete wall body, there is an 8% decrease in both DesignBuilder and TS825 results,
- In scenarios created with precast panels, the heating energy need is higher than other wall cross-sections.

When the results are evaluated, it is seen that the heating energy need values calculated with the DesignBuilder software are generally lower than the values calculated with the TS825. While DesignBuilder evaluates climate data over daily and hourly values, calculations are made with monthly average outdoor temperature values in TS825. In addition, TS825 defines the effect of the surrounding buildings through the number of floors and three types of shading factors. In the DesignBuilder software, the shadow effect of the surrounding buildings is considered hourly. In this sense, DesignBuilder gives results with more precise evaluations. Solar energy gains are most prominent on the southeast façade. Therefore, the lowest heating energy requirement emerged in the scenarios where the façade, which has a higher transparency rate than the other façades, is oriented to the southeast according to both calculation methods.

When the results are compared according to the building orientation and building spacing, the results obtained according to the TS825 make the same difference, while the results encountered with DesignBuilder coming in various ratios show that the DesignBuilder software produces more accurate results. Considering the corner building and intermediary building scenarios for both orientation scenarios, there is a difference of less than 1% according to DesignBuilder. However, according to the TS825 calculation method, separate calculations cannot be made for the two scenarios because the variables of these scenarios do not differ.

When the scenarios are evaluated in terms of exterior wall cross-section results, it is seen that the energy consumption of the scenarios with an aerated concrete wall body is lower than the scenarios with a brick wall body in both DesignBuilder and TS825 calculations. In the scenarios created with pre-built panels, it was determined that the heating energy requirement is high. This situation changes in parallel with the U-value of the cross-sections. Although the thermal conductivity calculation values of the external wall coverings are very different, they are not effective enough to change the calculations on the heat transmission coefficient due to the very thin cross-sections.

When the cooling energy consumption results calculated with the DesignBuilder software are evaluated, it is observed that the cooling energy consumption is higher in the scenarios with the entrance façade facing the south. This is due to the increase in thermal gains caused by exposure to the sun. In the intermediary plots, it was determined that the cooling energy consumption was lower. When the cooling energy consumption is analysed in terms of the scenarios related to the wall cross-sections, it is seen that the U-value, which is very effective in the heating energy consumption, is not very effective on the cooling energy consumption.

CONCLUSION

It is important to minimize energy consumption due to the decrease in non-renewable energy sources in increasing building renewal applications carried out in urban redevelopment projects. The external wall section has an important role in reducing energy losses and therefore energy consumption. Since the choice of exterior wall in applications is based on criteria such as cost, current fashion, as well as brand value and since energy performance is not among one of the main criteria, exterior wall types in the market should be evaluated in terms of energy consumption. In this study, the energy consumption of the exterior wall types used in the selected research area was evaluated and the most suitable options were determined. In Suadiye Neighbourhood, energy consumption evaluations were made with sample building scenarios created for the exterior wall sections used in building renovation applications after 2012. During the evaluations, DesignBuilder energy simulation software and TS825 calculation method were used. Since TS825 calculation method is for heating energy needs, comparisons are made only in terms of heating energy requirements. However, cooling energy consumption was also evaluated over the DesignBuilder results.

The examined site plan scenarios constitute samples for the settlements that are generally seen in the study area. The wall cross-sections discussed in the scenarios were also determined with the most common cross-sections in the area. In this direction, the following are recommended in the site plans,

- incorporating solar control in buildings with façade orientation in the corner plot position, since the cooling energy consumption is high,
- in buildings with a north façade orientation in the corner plot position, reducing the U-value of the wall section in order to reduce the heating energy consumption,
- in buildings that are in the intermediary position, according to the orientation, precautions should be taken, especially in terms of heating energy consumption.

While calculating energy consumption during the analysis of the scenarios, the detailed transfer of the variables to the program in the DesignBuilder simulation software ensures that the results are more precise. In addition, the ability to easily create different scenarios for the variables allows for a more detailed evaluation of design options by comparing the results. On the other hand, the lack of practical and widespread software that will enable TS825 calculations to be made easily limits its use for determining variables during the design phase. It is important to establish a practical method for calculations. In addition, according to TS825, corner buildings and intermediary buildings cannot be compared. For this reason, it is important to develop the TS825 calculation method in order to calculate the effects of the surrounding buildings more precisely.

Observing the principles of sustainability should be seen as an opportunity in building renewal practices carried out within the scope of urban redevelopment. Considering the damage to the environment and the cost of use in the construction of new buildings, the creation of wall cross-sections for minimum energy consumption and the selection of appropriate building products are valuable in terms of the better use of resources and the country's economy. With this study, it is thought that consciousness and awareness about energy consumption will be achieved. It is also believed that the study that deals with the heating and cooling energy consumption in the usage process of the exterior sections will pave the way for future studies in which variables such as maintenance and repair need and cost will be examined in terms of life cycle durations.

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REFERENCES

Akbulut, M. R. (1994). Kadıköy. In İstanbul Ansiklopedisi, Cilt 4 (pp. s. 329–339). İstanbul: Türkiye Ekonomik ve Toplumsal Tarih Vakfı, T.C. Kültür Bakanlığı.

Aksöz, H. (2009). Betonarme Binalarda Uygulanan Isı Yalıtım Amaçlı Duvar Elemanlarının Isıl ve Ekonomik Yönden Analizi. Tekirdağ: Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü.

Baykal, C. (2014). Binalarda Yönlere Göre Yalıtım Kalınlığının Ekonomikliğinin Araştırılması. İstanbul: Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü.

Biseniece, E., Zogla, G., Kamenders, A., Purvins, R., Kass, K., Vanaga, R., and Blumberga, A. (2017). Thermal performance of internally insulated historic brick building in cold climate: A long term case study. Energy and Buildings 152:577–586.

Chasan, S. (2013). Dış Cephe Bitirme Sistemlerinde Isı Yalıtımının Sıcaklık Ve Nem Performansına Etkisinin İncelenmesi. Edirne: Trakya Üniversitesi Fen Bilimleri Enstitüsü.

Çevre ve Şehircilik Bakanlığı. (2013). BEPtr Sunumu. Retrieved 10 21, 2013, from www.csb.gov.tr

Erbil, Y. and Akıncıtürk, Y. (2006). Tünel Kalıp Sistemiyle Üretilen bir Toplu Konut Örneğinin Isısal Konfor Koşulları Açısından İncelenmesi. Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi 11(2).

Erdemir, K. İ. and Koçlar, O. G. (2021). A parametric model proposal for energy efficient settlement texture and building design: Temperate-humid climate zone. Megaron 16(4):735–750.

Fedorczak-Cisak, M., Furtak, M., Hayduk, G., and Kwasnowski, P. (2019). Energy analysis and cost efficiency of external partitions in low energy buildings. IOP Conference Series: Material Science and Engineering 471.

Giz, A. (1994). Bir Zamanlar Kadıköy. İstanbul: İletişim Yayınları.

Gorshkov, A., Vatin, N., Nemova, D., Shabaldin, A., Melnikova, L., and Kirill, P. (2015). Using life-cycle analysis to assess energy savings delivered by building insulation. International Scientific Conference Urban Civil Engineering and Municipal Facilities. Procedia Engineering v.117.

Halu, Z. Y. (2010). Kentsel Mekân Olarak Caddelerin Mekânsal Karakterinin Yürünebilirlik Bağlamında İrdelenmesi, Bağdat Caddesi Örneği. İstanbul: İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü.

Koç, R. and Altun, M. (2012). Dış Duvar Tasarımında Kullanılabilecek bir Kontrol Listesi. 6. Ulusal Çatı & Cephe Sempozyumu 12–13 Nisan 2012. Bursa: Uludağ Üniversitesi Mühendislik ve Mimarlık Fakültesi.

Koçu, N. D. (2010). Dış Duvarlarda Isı Yalıtımı ile Enerji Tasarrufu Sağlanması ve Detaylarda Karşılaşılan Sorunlar (Konya Kentinden Örnekler). 5. Ulusal Çatı & Cephe Sempozyumu 15–16 Nisan 2010. İzmir: Dokuz Eylül Üniversitesi Mimarlık Fakültesi.

Lassandro, P. and Di Turi, S. (2017). Façade retrofitting: from energy efficiency to climate change mitigation. AiCARR 50th International Congress; Beyond NZEB Buildings, 10-11 May 2017 (s. 182–193). Matera, Italy: Energy Procedia v. 140.

Liu, Y., Liu, T., Ye, S., and Liu, Y. (2018). Cost-benefit analysis for energy efficiency retrofit of existing buildings: A case study in China. Journal of Cleaner Production 177:493–506.

Matthew, P. and Leardini, P. (2017). Towards net zero energy for older apartment buildings in Brisbane. International Conference on Improving Residential Energy Efficiency, IREE 2017. (s. 3–10). Energy Procedia.

Poortinga, W., Jiang, S., Grey, C., and Tweed, C. (2018). Impacts of energy-efficiency investments on internal conditions in low-income households. Building Research & Information 46(6):653–667.

Rodriguesa, L., White, J., Gillott, M., Braham, E., and Ishaque, A. (2018). Theoretical and experimental thermal performance assessment of an innovative external wall insulation system for social housing retrofit. Energy and Buildings 162:77–90.

Salandin, A. and Soler, D. (2018). Computing the minimum construction cost of a building's external wall taking into account its energy efficiency. Journal of Computational and Applied Mathematics 338:199–211.

Şenel, S. A. (2016). An approach to identify the optimal solutions in the context of energy and cost criteria for buildings in different climates. Megaron 11(4):592–606.

Şenkal, S. F. (2005). Türkiye'de Isı Yalıtımının Gelişimi ve Konutlarda Uygulanan Dış Duvar Isı Yalıtım Sistemleri. Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi 10(2).

Türk Standartları Enstitüsü. (2008). TS825 Binalarda Isı Yalıtım Kuralları. Ankara.

Usta, S. (2009). TS 825 "Binalarda Isı Yalıtım Kuralları" Standardına Göre İkinci Bölgede Bulunan Bir Binanın Yalıtımsız ve Yalıtımlı Durumlarının Enerji Verimliliği Bakımından Karşılaştırılması. Yapı Teknolojileri Elektronik Dergisi 5(1):1–2.

Valancius, K., Vilutiene, T., and Rogoža, A. (2018). Analysis of the payback of primary energy and CO2 emissions in relation to the increase of thermal resistance of a building. Energy & Buildings 179:39–48.

Xu, M. and Liu, Y. (2018). Comparative study on energy saving effect of energy efficiency retrofit of existing residential buildings in cold area. 15th International Conference on Service Systems and Service Management (ICSSSM) 21–22 July 2018. Hangzhou, China.

Yorgancı, M. (2011). Sürdürülebilir Gelişme Çerçevesinde Yeşil Yerleşim Ölçütlerinin Kentsel Dönüşüm Uygulamaları Açısından Anlamı. İstanbul: Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü.