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Araştırma Makalesi / Research Paper

To Create a CO_2 Emission Reduction Scenario of a Mass Housing Settlement in Isparta, Turkey until 2050

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ABSTRACT

Energy plans are at the center of countries' development plans. The share of buildings in energy consumption is about 40%. Energy consumption in buildings can be reduced by 25-45% with the measures taken. The European Union has published the Energy Performance Directive on Buildings (EPBD) to reduce the energy consumption of buildings. European Union member and candidate countries are obliged to fulfill the provisions of the regulation. Turkey is among the candidate countries for accession to the European Union (EU). Therefore, the energy consumption of the existing buildings and the reduction of CO_2 emissions were examined in this study. Since The Intergovernmental Panel on Climate Change (IPCC) predicts that global temperatures will increase by a range of 1.1°C to 6.4°C by the end of the twenty-first century, future climate data were also taken into consideration in this study. For the study, measures were determined to achieve the EU's total CO_2 emission reduction targets. A mass housing settlement built by the Housing Development Administration (TOKİ) in Isparta has been identified as the study area. Improving the heating systems of these buildings, increasing the energy performance of the building envelope and the production of electricity with photovoltaic (PV) panels were studied in this study. As a result of the study, it was determined that it has 66% CO_2 emissions in 2020, 79% in 2030, and 84% less in 2050 compared to 1990.

Keywords: Building energy simulation, climate change, CO_2 emissions, energy efficiency measures

Isparta'da Bir Toplu Konut Yerleşiminin 2050 Yılına Kadar CO_2 Salınımını Azaltma Senaryosunun Oluşturulması

ÖZ

Enerji planları, ülkelerin kalkınma planlarının merkezindedir. Binaların enerji tüketimindeki payı yaklaşık %40'tır. Alınan tedbirlerle binalarda enerji tüketimi %25-45 oranında azaltılabilmektedir. Avrupa Birliği, binaların enerji tüketimini azaltmak için Binalarda Enerji Performansı Direktifini (EPBD) yayınladı. Avrupa Birliği'ne üye ve aday ülkeler Avrupa Birliği'nin yayınladığı yönetmelik hükümlerini yerine getirmekle yükümlüdür. Türkiye, Avrupa Birliği'ne katılmaya aday ülkeler arasındadır. Bu nedenle bu çalışmada Avrupa Birliği'nin belirlediği hedefler doğrultusunda mevcut binaların enerji tüketimi ve CO_2 emisyonlarının azaltılması incelenmiştir. Ayrıca Hükümetler Arası İklim Değişikliği Paneli'nde (IPCC) yirmi birinci yüzyılın sonunda küresel sıcaklıkların 1,1°C ile 6,4°C aralığında artacağını tahmin ettiğinden, bu çalışmada iklim değişikliği de dikkate alınmıştır. Çalışmada Avrupa Birliği'nin toplam CO_2 emisyonu azaltma hedeflerine ulaşmak için önlemler belirlenmiştir. Isparta'daki Toplu Konut İdaresi Başkanlığı (TOKİ) tarafından yaptırılan toplu konut yerleşimi çalışma alanı olarak belirlenmiştir. Bu binaların ısıtma sistemlerinin iyileştirilmesi, bina kabuğu enerji performansının artırılması ve fotovoltaik paneller ile elektrik üretimi araştırılmıştır. Çalışma sonucunda iklim değişikliği ve önlemlerin etkisi ile CO_2 emisyonundaki değişimler incelenmiştir.

Anahtar Kelimeler: Bina enerji simülasyonu, iklim değişikliği, CO_2 emisyonu, enerji etkin önlemler

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INTRODUCTION

Countries take measures on energy efficiency due to the increase in energy consumption (Sümer Haydaraslan and Yaşar, 2019). Buildings have an essential share in energy consumption. It is easier for companies to build new buildings energy-efficient. However, when the lifetimes of the existing buildings are examined, it is foreseen that 75-90% of the existing buildings in the northern hemisphere will be used in 2050 (IEA (a), 2019). Accordingly, the EU states that existing buildings should be renewed within the scope of energy efficiency (EED, 2012). It is also aimed to reduce primary energy consumption by 14% in the National Energy Efficiency Action Plan of Turkey. It was emphasized that the existing buildings should be made more efficient to achieve this goal (NEEAP, 2018). Nowadays, because of the use of fossil fuels as an energy source, the release of greenhouse gases that cause climate change is increasing. The energy consumption growth rate in 2010 doubled in 2018 (Global Energy&CO_2 Status Report, 2018). CO_2 emissions from energy increased by 1.7 %, reaching 33.1 Gt CO_2 level with a historical record. While CO_2 emissions from all fossil fuels increased, CO_2 emissions from buildings reached the highest level in 2018 (TCEP, 2017). Increased CO_2 emission causes climate change. According to climate change reports published by the Intergovernmental Panel on Climate Change (IPCC), temperatures are expected to increase in the range of 1.1ºC to 6.4ºC by the end of the 21st century (IPCC, 2013). Rising temperatures due to climate change increase the need for cooling in buildings. The one-fifth increase in energy consumption in 2018 is due to the increase in cooling demand (TCEP, 2017; WEO, 2018)

Buildings are responsible for 40% of the energy consumed, and 36% of CO_2 emissions in the EU (EU, 2019). In addition to this situation, studies on building energy efficiency have increased with the increasing awareness of climate change (Depecker et al., 2001; Tsanas and Xifara, 2012; Nguyen et al., 2014; Zhang et al., 2017). In these studies, it is seen that it is possible to reduce the energy consumption of the buildings by 25-45% (Chowdhury et al., 2008). The most crucial parameter in reducing building energy consumption is heating - cooling system equipment and building envelope (Technology Roadmap, 2013). The lifetimes of the buildings are extended with the developing building technologies. The majority of the existing buildings will continue to be used in the coming years (Huang and Hwang, 2016). When the effects of climate change on the energy performance of the existing buildings are taken into consideration, it arises that the buildings should adapt to this change (IPCC, 2013). Studies on future climate scenarios and buildings were carried out (Wang and Chen, 2014; Nik et al., 2015). Some of these studies examined the effects of building envelope according to climate change (Huang and Hwang, 2016; Ferrara and Fabrizio, 2017; Domínguez - Amarillo, 2019). It includes the improvement of the mechanical systems of existing buildings within the scope of climate change (Jentsch et al., 2008; Kurnitski et al., 2014). In the studies carried out on a regional scale, the situation in energy consumption costs was examined according to the temperature increase (Asimakopoulos, et al., 2012; Wan et al., 2012).

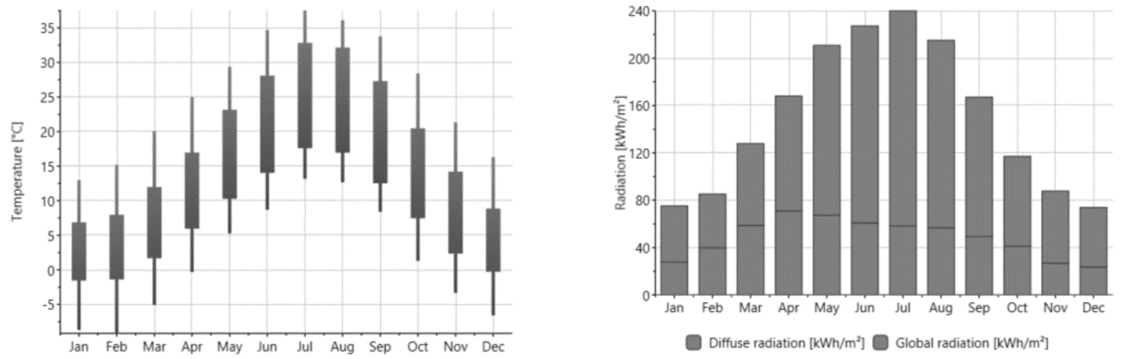
The envelope of the buildings is the parts of the building that interact directly with the environment. The building envelope has the most significant effect on heating or cooling the building. For this reason, the energy conservation needs to improve the building's envelope in terms of energy performance, new buildings, or an existing building. On the other hand, building envelope energy performance should be increased by 30% by 2025, due to the increase in square meters for comfort needs (ETP, 2017). Windows are the building elements within the building envelope (Yaşar and Maçka Kalfa, 2012). According to the US Department of Energy, 40% of the total energy consumed in America is consumed by buildings. 25% of this energy consumed is due to the heat transfer in the windows. To reduce heat transfer from glasses, it was recommended to add shading elements or to improve the glasses according to the climate. In this context, low-e film coatings were recommended for buildings in cold climates (Technology Roadmap, 2013). There are studies where films were coated on the glass to increase the energy performance of existing buildings (Martin-Palma et al., 1998; Amirkhani et al., 2019). In two of these studies, low-e film coating was applied to reduce the heat transfer of the glass. They reduced the heat transfer value of the glass by more than 50% with the glass film (Solovyev et al., 2015; Kou et al., 2019).

The two most important parameters in the reduction of energy consumption of buildings are the heating and cooling systems and the building envelope (Technology Roadmap, 2013). The. According to the Energy Efficiency Directive, it was stated that the heating systems should be improved in new and existing buildings to reach energy efficiency targets (EED, 2012). Accordingly, studies were carried out to improve the mechanical systems of buildings. In some of these studies, solar energy support was provided to the existing energy systems of the buildings or the existing system was replaced with a heat pump (Wang et al., 2010; Lerch et al., 2015). 80% of new homeowners in the USA, Japan, and China use heat pumps. The use of heat pumps is becoming widespread in European countries (IEA, 2019b). Besides, studies have been made to obtain energy from the sun for domestic hot water and electricity (Buonomano et al., 2016; Maçka Kalfa, et al., 2018). The use of the four clean energy technologies among thirty-eight clean energy technologies in the Paris Agreement is becoming widespread. PV is one of these four clean energy technologies. (Paris Climate Agreement, 2016. In one of these studies, BIPV/T (PV and DHW) saved 67-89% primary energy consumption in a dwelling to which the system was added and calculated 11-29 years as the recycling period.

The EU aims to reduce total CO_2 emissions by 20% by 2020, 40% by 2030, and 80-95% by 2050 compared to 1990 (EU, 2019a). EU candidates and EU member countries are obliged to comply with the goals set by the EU. Turkey is one of the EU candidate countries. In this direction, it is aimed to reduce the CO_2 emissions of the existing buildings in line with the goals set by the EU. In addition, the effects of climate change in the coming years are taken into consideration in the study. A mass housing settlement located in Isparta, which was built by the Mass Housing Administration (TOKİ), was chosen as the study area. It was studied for the building, which has an average value in terms of primary energy consumption and CO2 emissions of the buildings in this settlement. Firstly, the solid fuel boiler of this building was converted to natural gas. Secondly, solar energy support was added to this system. Thirdly, this system was replaced by a heat pump. Later, low-e film coating was applied to the glasses in order to increase the energy performance of the existing glasses. Finally, electricity production with PV panel was implemented as a measure. The effects of these measures on energy consumption and CO_2 emissions were examined separately.

MATERIAL AND METHODS

This study aimed to reduce CO_2 emissions in existing housing buildings. In this context, measures that could be taken on existing buildings were examined. Isparta was chosen as the case area from the Mediterranean Region. The meteorological data of Isparta province was given in Figure 1.



(a) (b)

Figure 1. Meteorological data of Isparta, (a) temperature (b) radiation (Meteonorm, 2020).

A mass housing settlement built by TOKI in Isparta was determined as a study area. The architectural and mechanical properties of the settlement were obtained from the Housing Development Administration (TOKI). The buildings in the settlement were modelled with the DesignBuilder building energy simulation program (DesignBuilder, 2020). Primary energy consumption and CO_2 emission amounts of the buildings in the settlement were calculated.

The reference year for the EU's targets to reduce CO_2 emissions is 1990. For this reason, climate data from 1990 were obtained from the Meteonorm software for the study. According to the 1990 data, the buildings were simulated. Primary energy consumption and CO_2 emissions were determined for this year. It was studied for the building, which has an average value in terms of primary energy consumption and CO_2 emissions of the buildings in this settlement. In order for the building to reach the goal set by the EU until 2050, a scenario was created in which steps were taken gradually in ten-year periods. Climate data in the coming years were used to determine the energy consumption of the building between 2020 and 2050. Future climate data are given in the Intergovernmental Panel on Climate Change (IPCC) in three different scenarios as IPCC AR4 B1, IPCC AR4 A1B, and IPCC AR4 A2 (IPCC, 2013). The future climate data organized according to these scenarios were obtained from Meteonorm software. Which of these scenarios could be used has been decided by the preliminary study. Accordingly, the energy required per square meter for the heating of a building between 2020 and 2080 was calculated for all three scenarios. The result of the calculation is given in Figure 2. As a result, the IPCC AR4 A2 scenario, which provides an average approach over the other two scenarios in the long term, was chosen.

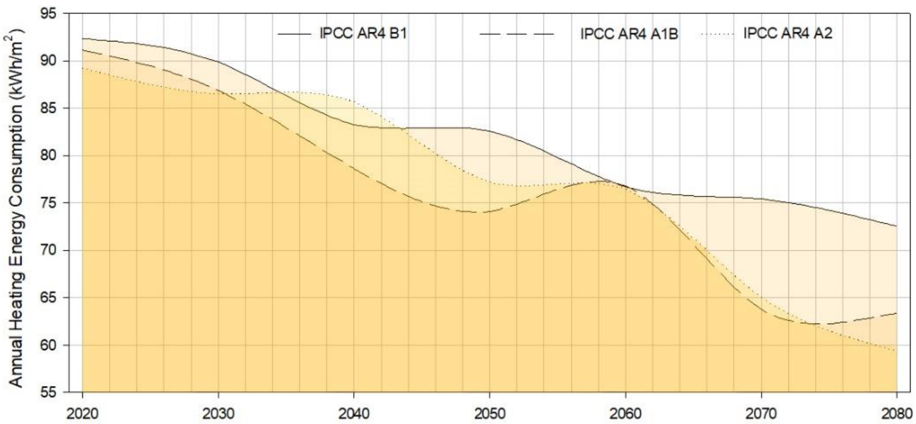


Figure 2. Change of future climate scenarios by years

While determining the measures in the scenario, both the lifetimes of the devices to be used and the initial investment costs were taken into consideration. Device lifetimes are accepted as 20 years for boiler and 25 years for thermal solar and PV panels (EN 15459, 2007). The first investment costs for the devices are taken from the Construction Unit Prices of the Ministry of Environment and Urbanization in 2020 (MEU, 2020). Within the scope of the scenario created, the measures were applied to the selected building to obtain heating, DHW, and electrical energy consumption. These consumptions were converted into both primary energy consumption and CO2 emissions. Primary energy consumption;

$$\mathit{Primary\ energy\ consumption} = \sum (\mathit{Energy\ consumption\ x\ P.E.Conversion\ Coefficient}) \quad (1)$$

It is calculated according to the Formula 1. While the P.E. conversion coefficient for gas and electricity is 1 and 2.36 in Turkey (CEDBIK, 2016).

CO_2 emissions;

$$CO_2 = \sum (\mathit{Energy\ consumption\ x\ } CO_2 \mathit{\ Conversion\ Coefficient}) \quad (2)$$

It is calculated according to the Formula 2. The CO_2 conversion coefficient is taken as 0.467 for solid fuel, 0.234 for natural gas, and 0.626 for electricity (CEDBIK, 2016).

Definition of Reference Building

The housing settlement, which is selected as a study area in Isparta, was built in 2016 by the Republic of Turkey, Ministry of Environment and Urbanization Housing Development Administration (TOKİ). The housing settlement is located on sloping terrain. The terrain is hillside type. There are eight buildings in the settlement (Figure 3). Six of these buildings are architecture type B, and two are architecture type C.

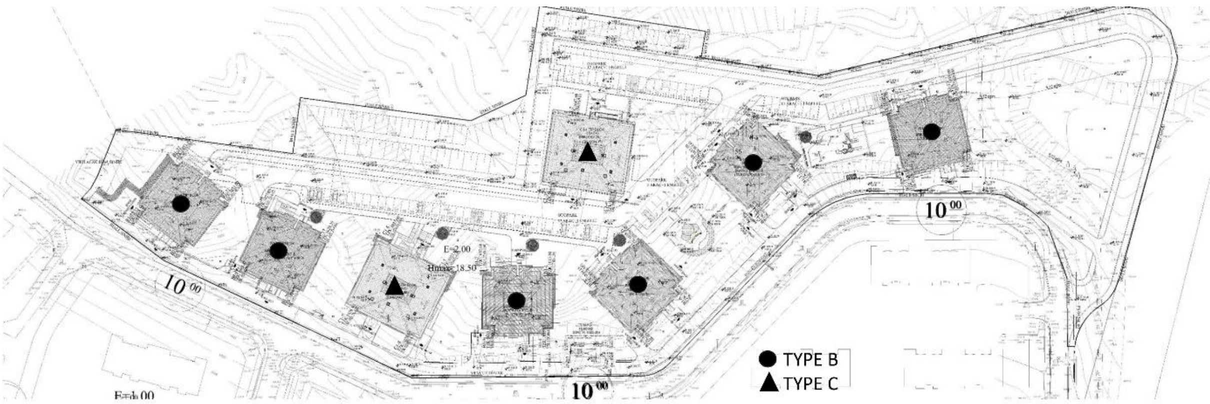


Figure 3. Housing Settlement Site Plan

The buildings consist of three basements, ground, and three normal floors. There are four flats on each floor. B type in which flats are 75 m^2, flats are designed as 2+1. C type in which flats are 110 m^2, flats are designed as 3+1. Type B and C architectural plans are given in Figure 4.

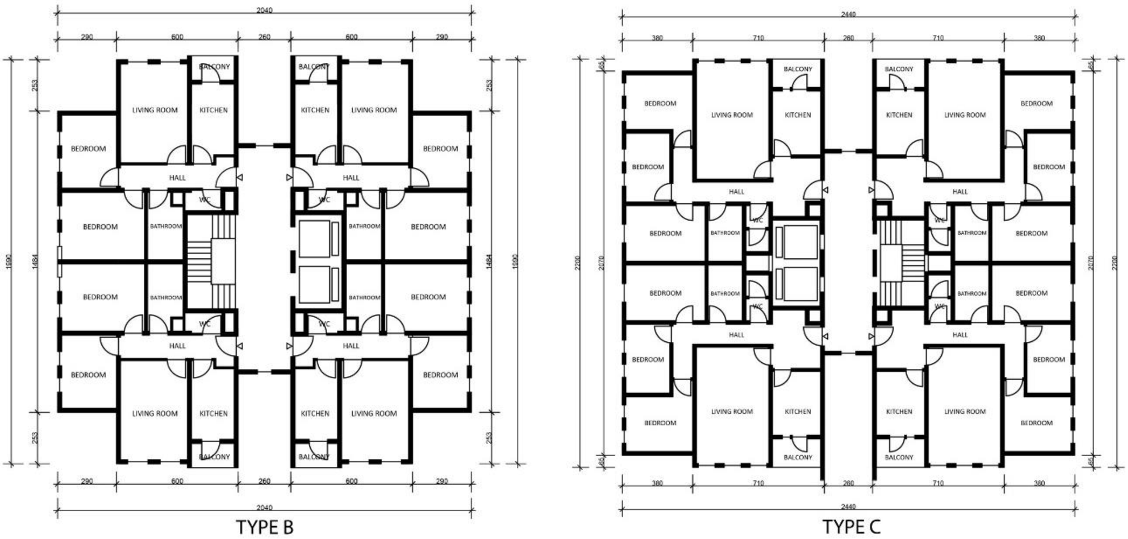


Figure 4. Type B and C architectural plans

The occupants' effects on the building energy performance because of their latent load which is relation with activity level (Sümer Haydaraslan and Yaşar, 2018). The number of occupants of buildings was determined using by Turkey Statistical Institute (TUIK) 2018 data. According to these data, the average number of occupants is 3.4. However, the number of occupants for Isparta is 2.9 (TUIK, 2020). Therefore, the number of occupants was taken as 3. The building occupancy hours of the occupants were determined according to the Family Structure Survey of TURKSTAT (Family Structure Survey, 2013). The activity levels of the occupants were defined according to the program "ASHRAE-55 - Thermal Environmental Conditions for Human Occupancy standard" (ASHRAE, 2010). Occupancy behaviors for Isparta are given in Table 1.

Table 1. Occupancy behaviors for Isparta

Hours	Number of occupants	Activity	Activity level (W/m^2)	Space
Weekdays				
00:00-07:00	3	Sleeping	40	Bedrooms
07:00-07:30	3	Breakfast	60	Kitchen
07:30-12:30	1	Home works	115	All space
12:30-15:30	1	Rest	45	Living room
15:30-16:30	1	Home works	115	All space
16:30-19:00	3	Home works	115	All space
19:00-20:00	3	Dinner	60	Kitchen
20:00-20:30	3	Rest	45	Living room
20:30-23:00	3	Sitting, Reading	60	Living r. / Bedrooms
23:00-24:00	3	Sleeping	40	Bedrooms
Weekend				
00:00-00:30	3	Sitting, Reading	60	Living r. / Bedrooms
00:30-08:30	3	Sleeping	40	Bedroom
08:30-12:30	3	Sitting, Reading	60	Living r. / Bedrooms
12:30-15:30	0	Outdoor activities	-	-
15:30-18:30	3	Sitting, Reading	60	Living r. / Bedrooms
18:30-22:30	3	Sitting, Reading	60	Living r. / Bedrooms
22:00-24:00	3	Rest	45	Bedroom

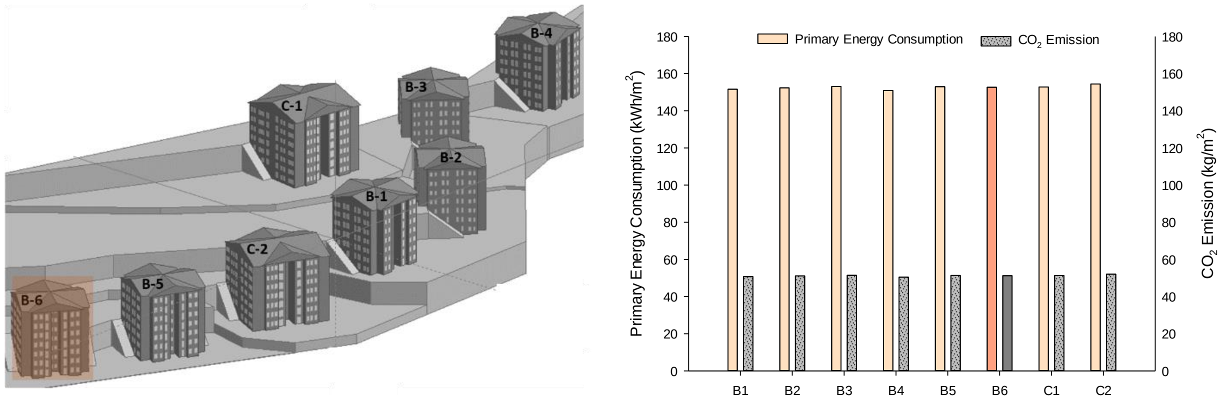
While designing the buildings, the properties of the building materials were determined according to TS 825 Building Thermal Insulation Rules (TS 825, 2013). Expanded Polystyrene (EPS) insulation material has been used on the external walls of 6 cm. Information on buildings and building components are given in Table 2. The infiltration value of the building is 0.8 (ac/h) (BEP TR, 2008), and the heating set temperature is 20ºC (TS2164, 1988). B type buildings are heated by a 90.000 kcal/h solid fuel heating boiler, while C type buildings are heated by a 95.000 kcal/h solid fuel heating boiler. There is no cooling and mechanical ventilation system in the buildings. The domestic hot water requirement is heated with an electric water heater. With this information, the buildings in the settlement have been modelled and simulated with the DesignBuilder energy simulation program.

Table 2. Building information and parameters used in the model

B Type building dimensions					
Gross Length (N-S direction)	20,4 m		Gross Floor Area		335,4 m^2
Gross Length (W-E direction)	19,9 m		Gross Area		2347,8 m^2
Gross Height	20,4 m (7 floors)		Gross Roof Area		403.96 m^2
B Type building geometry					
	Total	North	South	East	West
Gross Wall Area (m^2)	2062,55	433,08	433,08	598,19	598,19
Window Area (m^2)	182,00	28,84	57,54	47,81	47,81
Window-Wall Ratio (%)	8,82	6,66	13,29	7,99	7,99
C Type building dimensions					
Gross Length (N-S direction)	20,4 m		Gross Floor Area		469,9 m^2
Gross Length (W-E direction)	22,0 m		Gross Area		3289,3 m^2
Gross Height	20,4 m (7 floors)		Gross Roof Area		556,28 m^2
C Type building geometry					
	Total	North	South	East	West
Gross Wall Area (m^2)	2455,20	520,66	520,66	706,94	706,94
Window Area (m^2)	234,56	38,40	67,20	64,48	64,48
Window-Wall Ratio (%)	9,55	7,38	12,91	9,12	9,12
Weather data	Meteonorm Isparta data 2020 IPC AR4 A2 Scenario				
Construction					
U_{wall}	0,369 W/m^{2}K		$U_{floor\ (semi\text{-}exposed)}$		0,453 W/m^{2}K
$U_{ceiling\ (semi\text{-}exposed)}$	0,263 W/m^{2}K		U_{window}		1,9 W/m^{2}K
$U_{partition}$	1,099 W/m^{2}K		Infiltrasyon		0,8 (n/h)

Although the architectural plans and geometrical features of the 6 B type buildings in the housing settlement were the same, their energy consumption was not the same because the buildings shade each other and turn in different directions. The same situation exists in C type buildings. For this reason, primary energy consumption, CO_2 emissions per square meter of buildings in the housing settlement, and the average of these values were determined (Table 3). Since the building closest to average primary energy consumption and CO_2 emissions is B6, the impact of the scenario was investigated in this building.

Table 3. Determination of the building closest to the average primary energy consumption and CO_2 emission



Determining the Scenario

Energy consumption and CO2 emissions of buildings can be reduced by active and passive measures. Passive measures ensure that the building's heating and cooling load is low when designing buildings. Parameters such as optimum utilization of the sun, window-wall ratios, insulation thicknesses, and correct selection of glass-window systems are within this group. The right selection of systems such as heating, cooling, and DHW is included in the active measures group. It is also important to provide the resources of these systems with renewable energy technologies (Technology Roadmap, 2013).

Window systems in the passive measure group can be selected to keep primary energy consumption and CO_2 emissions to a minimum while the building is in the design phase. However, considering the cost and technical features in existing buildings, replacing the existing windows is not the optimum solution (Kaklauskas et al., 2006). Technology Roadmap has developed some recommendations for developed and developing countries, both in hot and cold climates and for new buildings and retrofits to be built. In developing countries, the use of Low-e window films is recommended for retrofit in cold climates, according to Technology Roadmap (Technology Roadmap, 2013). Due to the cold climate of Isparta in the study, Low-e film was used according to this suggestion. It is important that the film used will prevent the heat from passing from the internal environment to the outer environment when there is no sun, and that it will not prevent the gain of the sun when the sun is present. Accordingly, a preliminary study was made to determine the glass film. Glass film properties selected according to the preliminary study are given in Table 4.

Table 4. Properties of the selected glass film (Solar Gard, 2020)

Properties			Properties		
Gauge	(microns)	: 75	Visible Reflectance Exterior	(%)	: 13
Solar Energy Transmittance	(%)	: 43	Visible Reflectance Interior	(%)	: 4
Solar Energy Reflectance	(%)	: 28	Emissivity	(%)	: 0,09
Visible Transmittance	(%)	: 68	Winter U-Factor	(W/m^{2}C)	: 0,61

There are heating, cooling, and DHW systems in the active measure group. The type and energy source of these systems should be selected according to the region and building. In order to reduce the energy consumption of the buildings, studies that improve the heating system were examined. In these studies, central and district heating systems were used as the system type. Besides, natural gas, solar energy, soil/air source heat pumps were used as energy sources. In addition to all these, PV usage is seen for the electricity needs of buildings (Hailu et al., 2015; Xia et al., 2017). Solid fuel central system boilers were used for heating in the buildings in this study. There is no cooling and mechanical ventilation system in the buildings. The hot water of the buildings was heated by an individual electric water heater. Since the buildings selected for the study are existing buildings, retrofit is recommended. Therefore, the construction of the heating system on a district basis presents technical and economic difficulties. For this reason, the use of the central system continued, but the use of natural gas, solar energy, and heat pumps instead of solid fuel was used as a measure in the scenario. Solar energy was used to support both natural gas and heat pump systems. Thermal solar panels were identified in the number of the roof slope and to fit the western surface of the roof. Also, in order to meet some of the building's electricity consumption, PV panels were used at the angle of the roof slope and the area of the southern surface of the roof. Solar thermal and PV panel properties used in the study are given in Table 5.

Table 5. Selected solar thermal and PV panel properties (Baymak, 2020)

Solar Thermal Colector					
Gross area	(m^2)	: 1.98	Absorber surface area	(m^2)	: 1.87
Length	(mm)	: 1740	Permeability	(%)	: 95
Width	(mm)	: 1140	Efficiency	(%)	: 74.4
PV Colector					
Length	(mm)	: 734	Cell dimensions	(mm)	: 52 x 156
Width	(mm)	: 1001	Maximum power	(Wp)	: 100
Cells per module	(-)	: 72	Max. power point voltage	(V)	: 37.6
Cell type	(-)	: Poly crystalline	Max. power point current	(A)	: 2.75

The lifetimes and investment costs of the measures were taken into account in 10-year periods. The initial investment costs of the measures were taken from the 2020 Construction Unit Prices of the Ministry of Environment and Urbanization (MEU, 2020). The implementation of the measures was gradually calculated from low-cost systems to high-cost systems. In the study, it is planned to transform the existing solid fuel system and individual electric water heaters in the buildings into a central system originating from natural gas in 2020. Besides, low-e film was coated on glasses in 2020 in the study. Since the heating and DHW system would complete its life in 2030, solar energy support was provided to these systems. Also, it was planned to establish an electricity generation system with PV panels this year. As the boilers producing hot water for heating and DHW would expire in 2040, these devices were replaced with a heat pump. With solar thermal collectors installed in the previous decade, solar support continues for the heat pump system. Since the life of these systems was not completed in 2050, no measures were planned this year. The scenario created to reduce primary energy consumption and CO_2 emissions was given in Table 6.

Table 6. Scenario created to reduce primary energy consumption and CO_2 emissions

	2016 (Reference)	2020	2030	2040	2050
Heating system	Central system (Solid Fuel)	Central system (Natural gas)	Central System (Natural Gas + Solar Energy Support)	Central System (Heat Pump + Solar Energy Support)	-
DHW system	Individual system (Electricity)	Central hot water system (Natural gas)	Central Hot Water System (Natural Gas + Solar Energy Support)	Central Hot Water System (Heat Pump + Solar Power Support)	-
Electricity	Consumption from network	-	Electricity Production with PV Panels	-	-
Other	-	Low-e film	-	-	-
CO_2 Emission Reduction Target (Compared to 1990)	-	% 20	% 40	-	% 80 – 95

RESULTS

Effect of Measures

In line with the EU's targets to reduce CO_2 emissions, a scenario was created that includes different measures in ten-year periods from 2020 to 2050. The effects of the measures in this scenario on primary energy consumption and CO_2 emissions were examined on the existing buildings in Isparta. In these buildings, 6 cm thick EPS insulation was applied. The heating system of the building is a solid fuel heating boiler. There is no cooling and mechanical ventilation system. The DHW of the building was provided with an electric water heater. The model of the building in the settlement was established with the DesignBuilder energy simulation program with this information. Heating, DHW, and electrical energy consumption of this building were calculated annually and per square meter. Both primary energy consumption and CO_2 emission of the building were calculated with these data. The reference year for the EU's targets to reduce CO_2 emissions is 1990. Therefore, the climate data of 1990 was used as a reference year in the study. While modeling the reference building, it was simulated according to the 1990's technologies (with non-insulated and single glass window systems). If the scenario was not implemented in the existing building until 2050, the change in primary energy consumption and CO_2 emission due to the impact of climate change was given in Figure 5. Increasing outside temperature due to climate change provides an advantage as it decreases heating energy for cold climates, while it also provides disadvantages in terms of cooling load in hot climates.

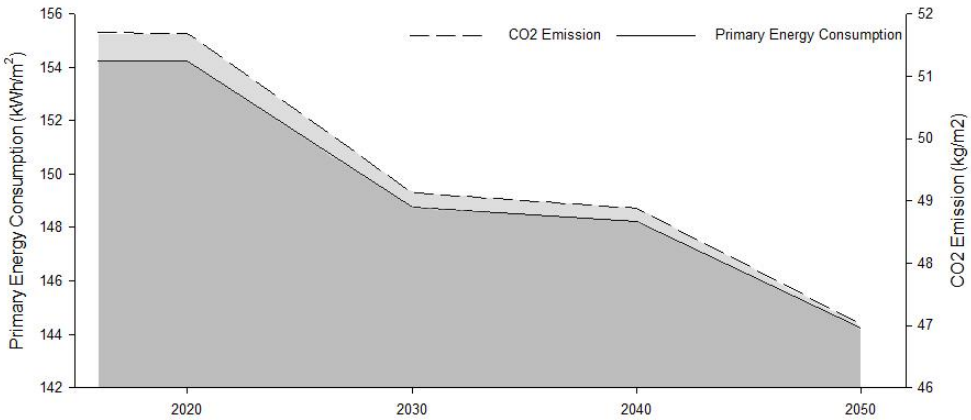


Figure 5. The primary energy consumption and CO_2 emissions change of the existing building until 2050

One of the measures of 2020 in the scenario is the low-e window film application recommended by IEA for existing buildings in cold climates (Technology roadmap, 2013). As a result of the preliminary study to examine the effect of window film application on energy consumption and CO_2 emission in existing buildings, the film given in Table 4 was selected. The window film was applied separately according to the whole building and directions. Since there is no cooling system in the building, the change in heating energy consumption is examined (Figure 6).

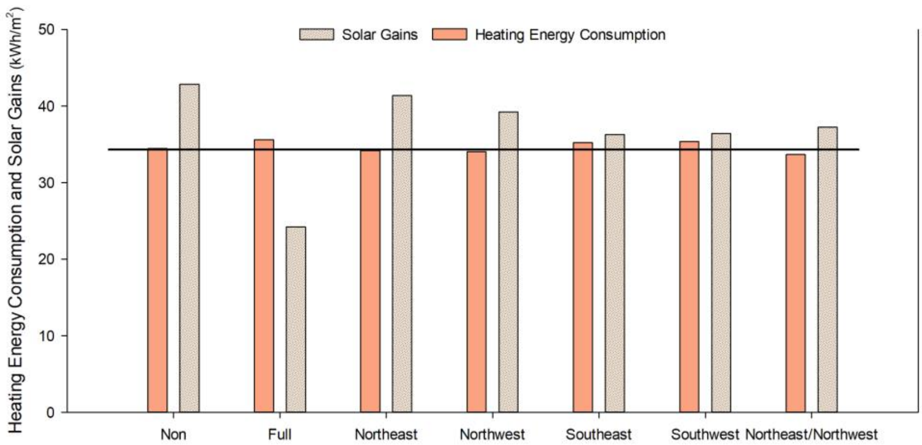


Figure 6. Effect of window film on heating energy consumption and solar gain according to directions

The film reduced heat transfer when applied to glasses in the south-east and south-west directions of the building. However, since it reduces the solar gain, it increases the energy consumption for heating. For this reason, the window film was applied to the interior part of the windows located in the north-east and north-west directions in the building. The heating load of the building was reduced with the film in these directions. Another measure in the scenario in 2020 was used the natural gas boiler instead of the solid fuel central system boiler. In addition, a natural gas sourced central system was used instead of individual electrical DHW systems. Since the heating and DHW system did not complete its life in 2030, the solar-assisted system was integrated into them. Solar thermal collectors placed on the roof were integrated into the heating system to support the system in sunny winter days (Figure 7). Also, the electricity production system was established with PV panels this year. Due to the limited roof area, 84 PVs were placed in the south-west direction of the roof and 26 solar thermal collectors in the south-east direction. Since the heating system was expired in 2040, the natural gas boiler was replaced by an earth source heat pump. The solar-assisted system continued to be used with this system. The change in monthly heating energy consumption of natural gas boiler and heat pump systems with and without solar thermal collector is given in Figure 8.

Since the systems did not complete their life in 2050, there are no precautions. Primary energy consumption and CO_2 emissions were obtained by applying the measures to the building by years (Figure 9).

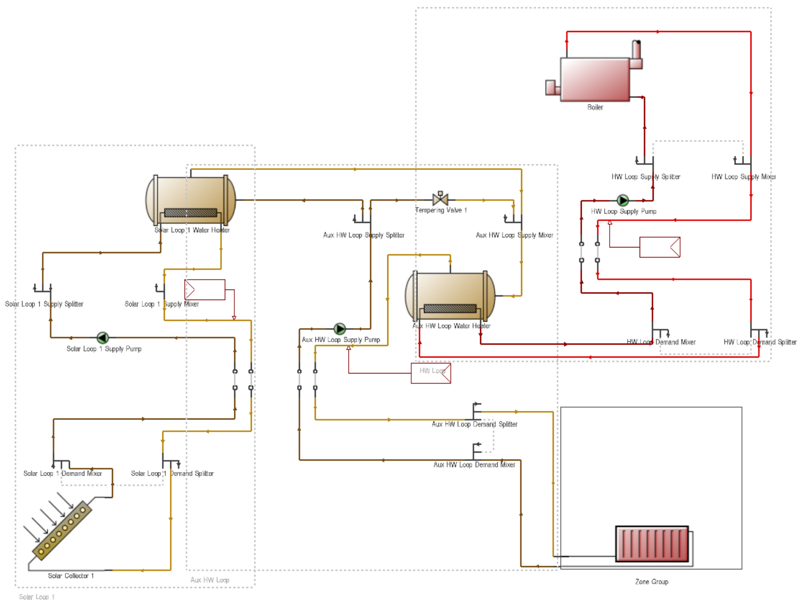


Figure 7. Solar assisted hot water system

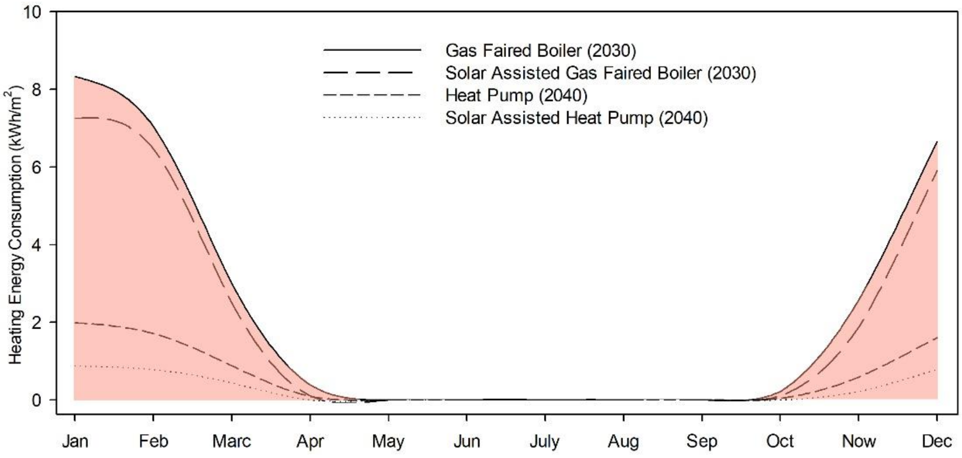


Figure 8. Effect of solar energy on the heating systems

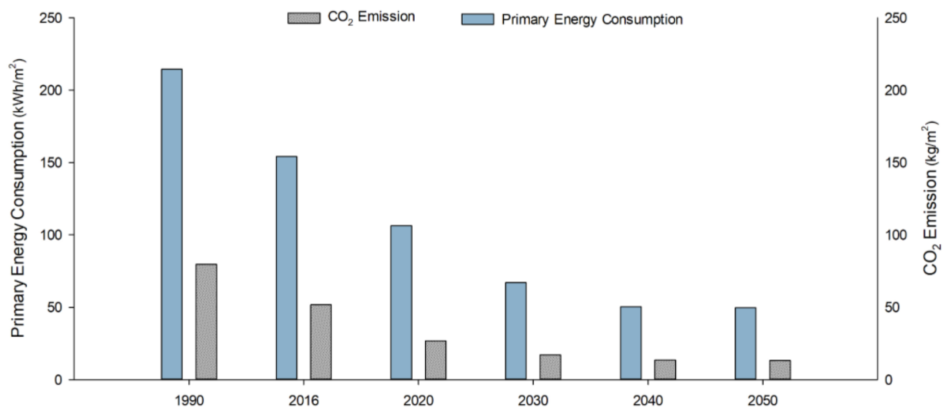


Figure 9. Primary energy consumption and CO_2 emissions of the measures

Approach to the Target

In the scope of the EU's targets to reduce CO_2 emissions, a scenario consisting of different measures was created. The effects of the measures on the primary energy consumption and CO2 emissions were examined. The approach of the scenario created with these measures to the target of the EU, which is the reduction of CO_2 emissions by 20% in 2020, 30% in 2030, and 80-95% in 2050 compared to 1990 was determined (Figure 10).

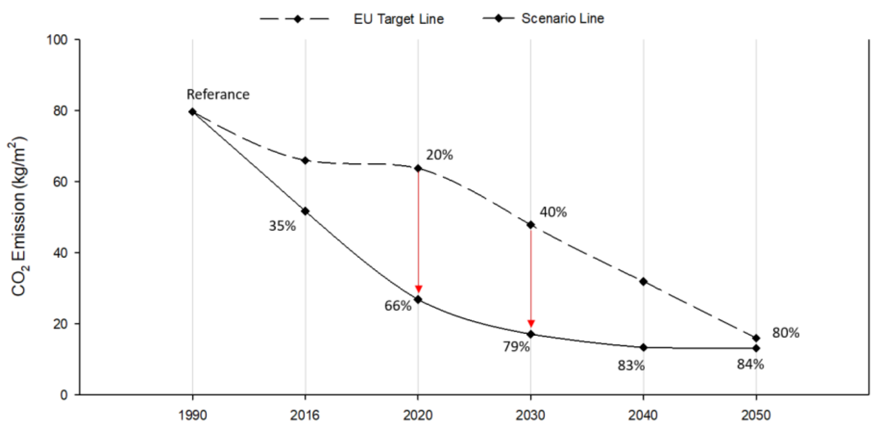


Figure 10. Comparison of the scenario and the EU target

The current building has 35% less CO_2 emissions than the reference year of 1990. The measures of 2020 provided less CO_2 emissions than the EU's 20% target (66% less than the 1990 reference year). This was the same for 2030 measures. While the EU's 2030 target is 40% less CO_2 emissions, the building's CO_2 emission this year decreased by 79%. In 2050, while the target was 80-95% less CO_2 emission, the building's emission was reduced by 84%. It is seen that this scenario, which can be applied to existing buildings, has reached the targets of the EU. In addition, if the reference year is taken as the year in which the building was built (2016), not the year 1990, the building had 48% less CO_2 emissions in 2020, 67% in 2030, and 75% in 2050. It is also seen that this situation is approaching the EU's target except in 2050.

CONCLUSION

According to IEA reports, CO_2 emissions are expected to increase by 130% by 2050 in the world. CO_2 emissions in Turkey in 2017 compared to 1990 increased by 182% (including all sectors). Accordingly, the study aimed to reduce CO2 emissions, which have the highest rate of emission and are among the gases that pose a risk when they increase. In this context, in the study, measures that can be taken on existing buildings are examined. A settlement built by TOKI in Isparta was chosen as a study area. The primary energy consumption and CO_2 emissions of the buildings in the settlement were calculated using the energy simulation program. The building closest to the average primary energy consumption and CO_2 emission at the settlement was selected. The effect of a scenario with different measures over the years was examined in this building. The climate data created within the scope of IPCC AR4 A2 scenario were used to determine the energy consumption of the building between 2020 and 2050. At the end of the study, the effects of the measures on primary energy consumption and CO_2 emissions were examined. Moreover, the approach of the scenario created with these measures to the target of the EU, which is the reduction of CO_2 emissions by 20% in 2020, 30% in 2030, and 80-95% in 2050 compared to 1990, was determined. The determined scenario has 66% CO_2 emissions in 2020, 79% in 2030, and 84% less in 2050, with reference to the data in 1990. It is important in terms of the applicability of the scenario that the measures in the scenario are gradually changed from low-cost systems to high-cost systems. The scenario created for this study complies with CO_2 reduction targets of the EU by 2050. In this respect, the study was achieved its purpose. The scenario can also be applied to existing buildings in Isparta and similar climates.

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