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ENERGY CONSUMPTION FORECAST FOR THE BUILDING SECTOR IN TURKEY UNTIL 2030

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Abstract

Original scientific paper

As in the rest of the world, energy consumption is increasing in Turkey as a result of population growth and technological developments. Energy efficiency studies are becoming more and more important for Turkey, which meets more than half of its energy needs from imported sources. When the sectors where energy is consumed intensively are analyzed, it is seen that the share of building sector energy consumption in total energy consumption is approximately 20%. This high rate shows that energy efficiency studies in the building sector will reduce the amount of energy imports and the current account deficit, as well as help to ensure the security of supply.
In this study, Turkey's population, Gross Domestic Product (GDP), number of buildings and the total amount of energy consumed in buildings in the past 20 years are used to estimate how much energy will be consumed in the building sector for the future. Within the scope of the study, how much energy will be consumed in the building sector in Turkey until 2030 is estimated by using the Artificial Neural Networks (ANN) method in Matlab program. It is calculated that Turkey will consume 37.868 thousand Tons of Oil Equivalent (TOE) of energy in the building sector in 2030. In addition, the importance of energy efficiency studies in the building sector is emphasized.

Keywords: *Energy, energy efficiency, energy consumption in buildings, artificial neural networks.*

TÜRKİYE'DE 2030 YILINA KADAR BİNA SEKTÖRÜNDEKİ ENERJİ TÜKETİM TAHMİNİ

Özet

Orijinal bilimsel makale

Dünya genelinde olduğu gibi Türkiye'de de nüfus artışı ve teknolojik gelişmelerin sonucu olarak enerji tüketimi artmaktadır. Enerji ihtiyacının yarısından fazlasını ithal kaynaklardan karşılayan Türkiye için enerji verimliliği çalışmaları her geçen gün daha önemli hale gelmektedir. Enerjinin yoğun olarak tüketildiği sektörler incelendiğinde bina sektörü enerji tüketiminin, toplam enerji tüketimi içerisinde payının yaklaşık olarak 20% gibi bir orana sahip olduğu görülmektedir. Bu yüksek oran bina sektörde enerji verimliliği çalışmaları sayesinde enerji ithalat miktarını ve cari açığı azaltacağını aynı zamanda arz güvenliğini sağlamaya yardımcı olacağını göstermektedir.
Bu çalışmada Türkiye'nin geçmiş 20 yıldaki nüfus, Gayri Safi Yurtiçi Hâsıla (GSYH), bina sayısı ve binalarda tüketilen toplam enerji miktarı verilerinden yararlanılarak geleceğe yönelik bina sektöründe ne kadar enerji tüketileceği tahmin edilmeye çalışılmıştır. Çalışma kapsamında, Türkiye'nin 2030 yılına kadar bina sektöründe ne kadar enerji tüketeceği Matlab programında Yapay Sinir Ağları (YSA) metoduyla tahmin edilmiştir. Yapılan tahminde Türkiye'nin 2030 yılında bina sektöründe 37.868 Bin Ton Eşdeğeri Petrol (TEP) enerji tüketeceği hesaplanmıştır. Ayrıca, bina sektöründe enerji verimliliği çalışmalarının önemi vurgulanmıştır.

Anahtar Kelimeler: *Enerji, enerji verimliliği, binalarda enerji tüketimi, yapay sinir ağları.*

1 Introduction

Energy consumption is increasing along with population growth worldwide. When energy consumption is analyzed from past to present, it is seen that fossil fuels are consumed predominantly. As an alternative to fossil fuels, there has been a significant increase in the consumption of renewable energy sources in recent years. The increase in the share of renewable energy sources in total energy consumption is very important both for the economies of countries and for slowing down global warming. To slow down global warming, the importance of energy efficiency as well as the spread of renewable energy sources has been realized and energy efficiency studies have started to gain importance worldwide.

When the energy-consuming sectors are analyzed, the building sector has approximately one-fourth of the total energy consumption. This situation increases the importance of energy saving and energy efficiency studies in the building sector. Turkey meets a significant portion

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of its energy needs from imported sources and the economic cost of this situation is quite high. For this reason, energy efficiency is of critical importance in reducing energy demand and foreign dependency. Looking at energy efficiency on a sectoral basis, there is a great potential for energy savings in buildings.

Energy efficiency can be defined as reducing energy consumption without damaging the quality and quantity of production in industry and without reducing the standard of living and service quality in buildings. [1].

The increase in population, improvement in living standards, development of technology and the increase in energy demand lead to an increase in energy consumption and thus environmental pollution [2]. Buildings account for 30-40% of the world's primary energy consumption and 40% of greenhouse gas emissions [3]. Energy efficiency studies in the building sector, which causes such high rates of energy consumption and greenhouse gas emissions, have started to be prioritized by decision-makers. With the enactment of the National Energy Efficiency Action Plan (NEEAP) by the Ministry of Energy and Natural Resources of the Republic of Turkey within the scope of efficiency studies, it is aimed to reduce Turkey's primary energy consumption by 14% in 2023 with 55 actions defined in 6 categories: energy, buildings and services, industry and technology, transportation, agriculture and horizontal agriculture. With this plan, investments were made for energy efficiency in 2017-2021 and as a result, 4.473 kTEP energy savings were achieved [4].

Heating/cooling, hot water and ventilation systems account for 75% of energy consumption in residential buildings, while lighting systems account for 50% of total consumption in public and service buildings [5]. It is seen that a 5% reduction in electricity consumption can be achieved by switching to compact fluorescent instead of incandescent lamps used in residential buildings in Turkey, and at the same time, the savings realized will contribute to the target of 20% reduction in energy intensity in 2023 by looking at the 2011 rate [6]

With the artificial neural network based modeling method, the energy required for heating/cooling in buildings can be determined by simulation. In the artificial neural network (ANN) model, it is envisaged that heating and cooling loads can be calculated while the building is in the design process by selecting buildings in different design models as input and heating load as output [7].

Multi-output and single output regression methods can be used with machine learning to estimate the energy consumed for heating/cooling in buildings. With the multi-output regression method, these can be compared and it is seen that the energy load in buildings can be greatly reduced [8]. Building energy consumption can be predicted by teaching many data such as area-volume, heating type, and building typological characteristics as input to the ANN model [9].

Successful results are obtained in energy consumption forecasting studies conducted with ANN. In the study where Turkey's net energy consumption was estimated with the help of ANN and Adaptive Network Based Fuzzy Inference System (ANFIS) models using import, export, GDP and population data, both models were found to be successful in energy consumption forecasting [10].

Another study showed that ANFIS and ANN forecasting models can be used as energy supply forecasting tools and it was concluded that ANN can be used in studies with less data since it allows working with less data. [11]. In another study conducted for electric energy demand forecasting, ANN was found to give successful results among forecasting models [12].

Turkey's population, GDP and primary energy supply data were used to determine the future energy needs of Turkey by using ANN and it was observed that ANN gave successful prediction results [13]. In a study on the statistical estimation of residential energy consumption in Turkey in 2030, it was determined that residential energy consumption in that year will be 48 million TOE and the 95% confidence interval is 37-59 million TOE. In other words, a minimum of 37 and a maximum of 59 million TOE is expected. It is also stated in the study that the effect of the GDP index on energy consumption was found to be high [14].

In this study, the building energy consumption forecast for 2030 was found to be approximately 38 million TOE. In the data set applied to the model, it was observed that the decline and slowdown in GDP and the resulting decline in energy consumption in some years caused a slow increase in the forecast data in the model result. In case of a steady increase in GDP, energy consumption is expected to be higher.

This study aims to calculate how much energy will be needed in 2030 in the building sector, which has a significant share in sectoral energy consumption in Turkey. By estimating the amount of energy to be consumed, it is aimed to draw attention to the importance of energy efficiency studies in this sector.

This study is considered to be a reference source as it is one of the few studies that estimate how much energy will be consumed in buildings in Turkey in 2030. It is aimed to guide institutions and researchers on the factors affecting energy consumption in buildings, the negative effects of building energy consumption on the environment and the importance of energy efficiency in buildings.

2 Building Sector Energy Consumption and CO_2 Emissions

According to the most recent reports published by the Ministry of Energy and Natural Resources (the latest data published for 2021), 34% of sector-based energy consumption in Turkey is in industry, 25% in transportation, 21% in buildings, 10% in commercial enterprises and 10% in other areas. [15]. Efficiency studies are of great importance in these sectors where energy consumption is high. When the data are analyzed, it is seen that the share of building sector energy consumption in total energy consumption is high.

When the data for 2021 in Turkey are analyzed, the number of buildings increased by 131,8% and the number of apartments by 105,6% compared to the previous year. For the same year, 58,6% of the total surface area in Turkey was determined as residential area [16]. As a result of this, energy consumption in the building sector also increases at the same rate.

Figure 1 shows the energy consumption in the buildings and services sector in Turkey between 2000 and

2021. Energy consumption in this sector was 19.556 thousand TOE in 2000 and 38.121 thousand TOE in 2021.

Energy consumption in buildings refers to the amount of energy used in residential, commercial and institutional buildings. Buildings consume energy for various purposes, including heating, cooling, lighting, appliances and other electrical devices.

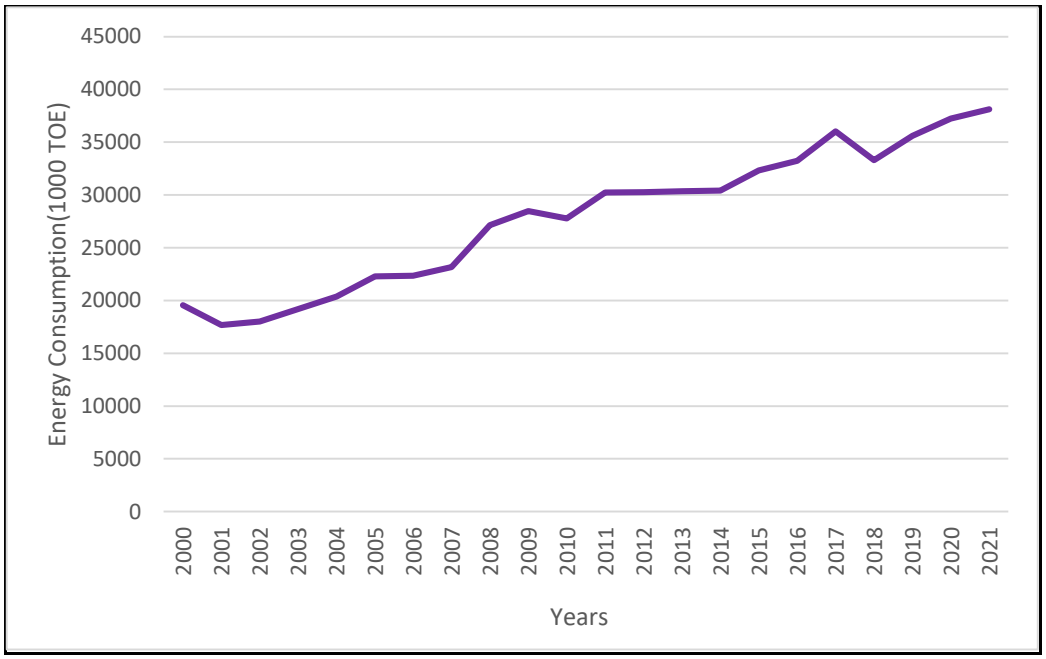

Figure 1. Energy consumption in buildings and services sector in Turkey (2000-2021) [15].

The distribution of energy consumption by sources in the building sector in Turkey in 2021 was realized as Natural Gas 13.760, Electricity 5.289, Renewable resources 2.940, Hard coal 1.963 and Other resources 2.196 thousand TOE. [15]. It is seen that the share of Natural Gas, which is an imported source, in total consumption is significantly higher and this situation increases both the current account deficit due to the fact that natural gas is an imported source and CO_2 emissions due to the fact that it is a fossil fuel.

It is observed that energy consumption in the building and services sector has almost doubled in the last 20 years. The increase in energy consumption causes a significant increase in CO_2 emissions in this sector. Turkey's sectoral CO_2 emission rates were realized as 37% Transportation sector, 34% Industry sector and 29% Building and services sectors as of 2021 [17].

Buildings cause 48% of CO_2 emissions in the world and 29% of CO_2 emissions in Turkey [17,18]. CO_2 emissions caused by the building sector threaten sustainable future plans. Energy efficiency studies in buildings gain great value at this point.

3 Materıals and Methods

Within the scope of this study, an ANN model was created using MATLAB program. The ANN model was trained and tested on the dataset including population, GDP, number of buildings and final energy consumption values between 2000-2021 in Turkey. As a result of the tests, the final energy consumption in the residential and services sectors in Turkey between 2022-2030 was estimated by using the model with high regression value.

3.1 Analysis Data

In this study, data on population, GDP and number of buildings in Turkey between 2002 and 2021 were entered as input to the ANN model created in this study. Final energy consumption data in the building and services sectors were determined as output data. Table 1 shows the dataset on which the ANN model will be evaluated.

In this study, multilayer perceptrons, which are the most appropriate ANN models, are used to predict energy consumption data in the building and services sector from population, GDP and number of buildings data. Multilayer perceptron consists of input, output and hidden layers. These layers are feed-forward and supervised networks with connections between them. Population, GDP and number of buildings, which are determined as independent variables, are given as inputs to the ANN model, while the amount of energy consumption in the housing and services sector, which is determined as the dependent variable, is obtained as the output of the ANN. The simple ANN for energy consumption forecasting has one hidden layer.

3.2 Artificial Neural Network

ANN is a computational method that models the biological structure of the human brain and consists of layers. ANNs are also mathematical models consisting of interconnected nodes that can be defined as artificial nerve cells, or neurons. The input signals to the nodes are multiplied by certain weights and summed, and the bias value is added to this total value. The resulting signal is then passed through the activation function to generate the output signal. Figure 2 shows the structure of an artificial neural cell.

Table 1. ANN analysis dataset (2000-2021) [15,16,19].

Years	Population (thousand)	GDP (Million USD)	Number of Buildings (Number)	Final Energy Consumption (thousand TOE)
2002	66.402	240.191	7.926.331	18.000
2003	67.187	314.752	8.014.767	19.178
2004	68.010	409.127	8.096.901	20.391
2005	68.861	506.186	8.201.819	22.284
2006	69.730	555.126	8.339.328	22.355
2007	70.586	680.489	8.480.767	23.172
2008	71.517	770.820	8.624.892	27.145
2009	72.561	648.797	8.795.733	28.470
2010	73.723	776.558	8.972.636	27.762
2011	74.724	838.508	9.153.106	30.230
2012	75.627	880.141	9.347.208	30.259
2013	76.668	957.504	9.563.904	30.348
2014	77.696	938.512	9.809.347	34.186
2015	78.741	864.071	10.044.061	32.329
2016	79.815	869.280	10.265.648	33.221
2017	80.811	858.932	10.495.833	36.015
2018	82.004	779.694	10.741.752	33.298
2019	83.155	760.516	10.962.749	35.609
2020	83.614	719.919	11.134.476	37.234
2021	84.680	806.804	11.304.492	38.121

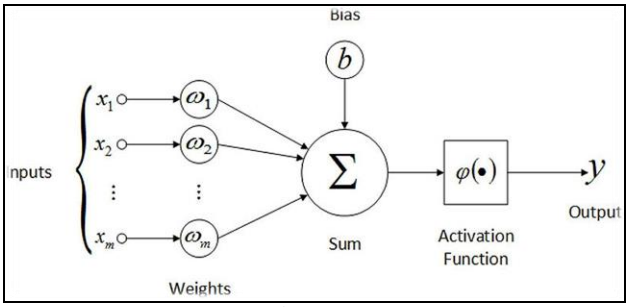

Figure 2. Artificial Neural Cell [20].

There are basically 3 layers in an ANN: Input layer, intermediate (hidden) layer and output layer. There can be more than one hidden layer between the input and output layers. Hidden layers enable the model to learn by using the information in the input. In the input layer, numerical data or images are received and an output value is generated using the weights of the network. In the output layer, possible predictions and classifications are made using the output values obtained.

In the training of the ANN, the input data is initially multiplied by randomly determined weights, then the bias value is added and an output is obtained. This output value is then passed through an activation function to make it nonlinear. The final output value is compared with the actual output value and the mean square error (MSE) is calculated. Using the calculated error value, the weights in the ANN are updated. Updating the weights is done by a technique called back propagation. This back propagation performs gradient calculations according to the weights of the network errors and updates them to minimize the error. With these calculations, the network learns and improves its performance over time.

4 Finding and Discussion

While training the ANN, weights are generated according to a specific algorithm. Although the number of neurons in the hidden layers is determined without being dependent on any rule, it is generally seen in the literature that ANN analysis is performed with 10, 11 and 12 neurons in the input layer [21]. While determining the number of neurons in the hidden layer, networks with different numbers of neurons have been tested and in this study, the most appropriate number of neurons was determined to be 10. Figure 3 shows the ANN model used in this study.

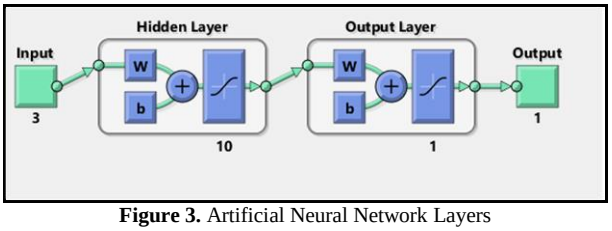

Figure 3. Artificial Neural Network Layers

While creating the model in ANN, 15% of the data was used for validation, 15% for test and 70% for training. The training process of the network was completed in 9 iterations. The lowest MSE value was reached at the 6th iteration. Figure 4 shows the performance graph of the model depending on iteration and the MSE value was found to be 6.2566e-10. A small MSE value means that the accuracy of the prediction is high.

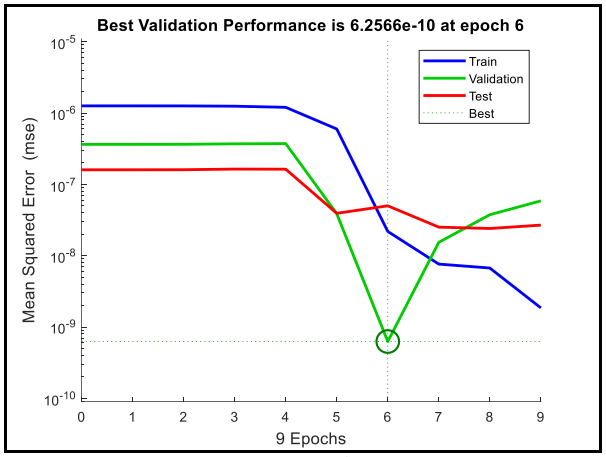

Figure 4. Error performances

Figure 5 shows the correlation coefficient (R) plots showing the performance of the model. Looking at the correlation coefficient values in Figure 5, R = 0.9823 for training data, R = 0.99045 for validation data, R = 0.9886 for test data and R = 0.97671 for all data. The fact that the values are close to 1 for all data indicates that there is agreement between the data obtained with the ANN model and the real data.

Population data, which is one of the data determined as input neurons to this network between 2022 and 2030, is taken directly from the future population scenarios of the Turkish Statistical Institute (TSI), while the scenarios for the other independent variables, GDP and number of buildings, are calculated by simple regression method. In regression calculation, the relationship between two independent and dependent variables is analyzed.

In this study, the population values between 2022 and 2030, which are used as independent variables in regression analysis, are the data taken from TSI population scenarios. GDP and number of buildings, which are dependent on population, are calculated with the regression equation given below.

In the Equation (1), y is the dependent variable, x is the independent variable, β_0 is the intercept term, β_1 is the slope coefficient and ε is the error term [22].

$$Y=\beta_0+\beta_1.x+\varepsilon \quad (1)$$

The x value given in this equation expresses the independent variable population, while the y value expresses independent variables such as GDP and number of buildings.

In Table 2, the population values between 2022-2030 are taken from the population scenarios of the TSI [23]. Using this population data, GDP and number of buildings data were found by regression calculation and then final energy consumption was estimated by ANN modeling using population, GDP and number of buildings values. Final energy consumption estimation values are given in Table 2.

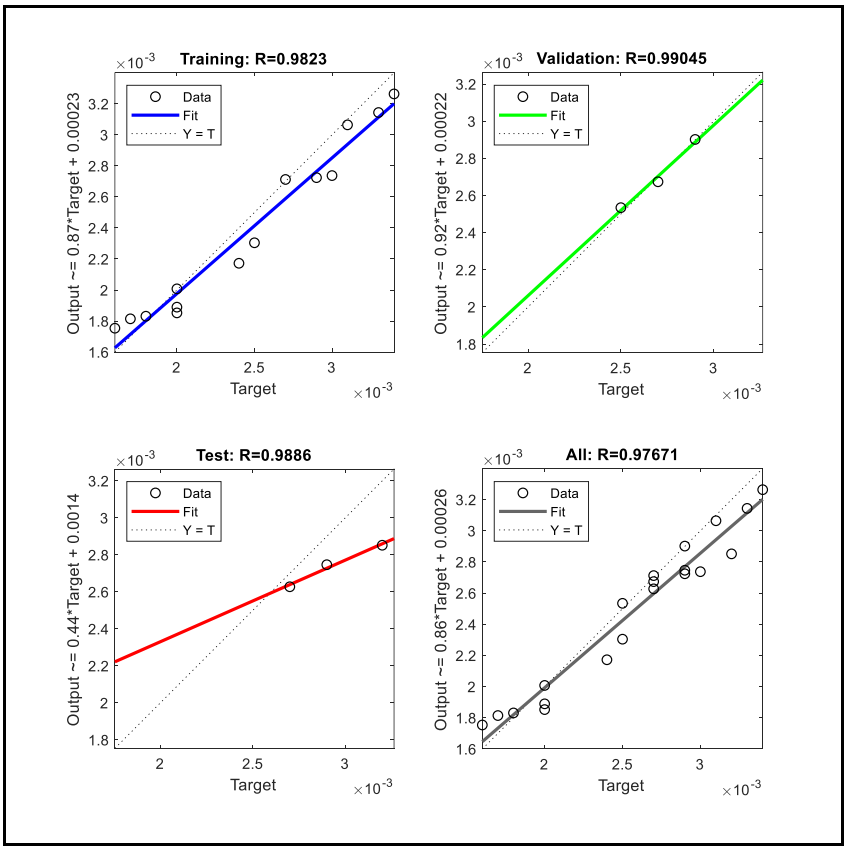

Figure 5. Regression values.

Table 2. ANN analysis for prediction data (2022-2030).

Years	Population (thousand)	GDP (Million USD)	Number of Buildings (Number)	Final Energy Consumption (thousand TOE)
2022	85.286	961.849	11.315.039	37.322,91
2023	86.154	983.856	11.480.379	37.655,26
2024	87.003	1.005.377	11.642.073	37.786,39
2025	87.832	1.026.397	11.800.002	37.824,83
2026	88.641	1.046.896	11.954.018	37.916,40
2027	89.428	1.066.854	12.103.966	37.862,14
2028	90.193	1.086.250	12.249.697	37.862,14
2029	90.935	1.105.067	12.391.075	37.918,66
2030	91.654	1.123.291	12.527.994	37.868,92

As a result of ANN analysis, the amount of energy consumption in the building sector in 2030 was found to be 37.869 thousand TOE. As a result of the ANN analysis, it is seen that the amount of energy consumption in the building sector is gradually increasing.

5 Conclusion

Energy efficiency is a very important concept in terms of reducing environmental impacts, ensuring energy supply security, protecting existing resources and ensuring economic development, especially in energy-dependent countries such as Turkey.

In this study, the amount of energy consumption in the residential and services sectors between 2022 and 2030 was estimated with the ANN model built on MATLAB. Population, GDP and number of buildings between the years 2002-2021 and the final energy consumption in the residential and services sectors between these years were found by reviewing the necessary literatures and taught to the network.

In this modeled and tested network, population, GDP and number of buildings values generated by literature and calculations between 2022 and 2030 were processed and the final energy consumption amount in the housing and services sector between 2022 and 2030 was estimated. As a result of the estimations, the energy consumption estimate for the building sector in 2030 was found to be 37.869 thousand TOE. When these data are evaluated, it is determined that there is a regular and linear increase in the amount of consumption.

In this study, where ANN is used to forecast residential energy consumption for the year 2030, it is seen that declines and slowdowns in GDP in the dataset applied to the model directly affect net energy consumption. In 2008, the global and Turkish economic recession caused a decline in the GDP value in 2009, and by 2010, this value was only as high as the 2008 value. This decline in GDP also caused a decline in final energy consumption in 2010 compared to the year before.

Since 2015, the significant decline in GDP has also manifested itself as a decline in energy consumption amounts. It was observed that the declines in 2020 and beyond due to the Covid-19 pandemic disrupted the regular upward trend in GDP. When the data is analyzed, it is seen that there is a regular increase in population and the number of buildings, but the increase in GDP and energy consumption is not regular, and GDP directly affects energy consumption. In case of a regular increase in GDP, energy consumption in the building sector is projected to be more than 37,868 thousand TOE in 2030.

As can be seen in the analysis, increasing population, economic indicators and the number of buildings increasing with the acceleration of transition to urban life directly affect the demand for energy. This unstoppable energy demand can be reduced to a great extent with the efficient use of energy.

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Declaration

The authors declare that the ethics committee approval is not required for this study. There is no conflict of interest between the authors.

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