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# Determinants of Energy Consumption in Turkey: Innovation and Foreign Direct Investment

**(Research Article)**

*Türkiye'de Enerji Tüketiminin Belirleyicileri: İnovasyon ve Doğrudan Yabancı Sermaye Yatırımları*

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**ABSTRACT**

*In this study, it is purposed to investigate the determining factors of energy consumption in Turkey between the years 1995-2019. Accordingly, the role of foreign direct invesment (FDI) and innovation in energy consumption has been examined using the least squares estimation method. The multiple regression model was used in the study, and total energy consumption was used as the dependent variable, while the ratio of FDI to gross domestic product and the total number of patent applications were used as independent variables in the model. Annual data from OECD statistics and the World Bank were utilised in the study. Consequentially, it is determined that FDI and patent applications have a statistically significant and positive effect on energy consumption in analysis. The results of the study indicate that FDI and innovative activities are the determinants of energy consumption.*

***Anahtar Kelimeler:***
*Enerji, Doğrudan Yabancı Sermaye Yatırımları, İnovasyon, En Küçük Kareler Yöntemi*

**ÖZET**

*Bu çalışmada 1995-2019 yılları arasındaki dönemde Türkiye'de enerji tüketiminin belirleyici faktörlerinin araştırılması amaçlanmıştır. Bu doğrultuda, doğrudan yabancı sermaye yatırımları ve inovasyonun enerji tüketimindeki rolü en küçük kareler tahmin yöntemiyle incelenmiştir. Çalışmada çoklu regresyon modeli kullanılmış olup, modelde toplam enerji tüketimi bağımlı değişken, doğrudan yabancı sermaye yatırımlarının gayrisafi yurtiçi hasılaya oranı ve toplam patent başvuruları sayısı ise bağımsız değişken olarak kullanılmıştır. Çalışmada OECD stat ve Dünya Bankası'ndan elde edilen yıllık veriler kullanılmıştır. Analiz sonucunda, doğrudan yabancı sermaye yatırımlarının ve patent başvurularının enerji tüketimi üzerinde istatistiksel olarak anlamlı ve pozitif bir etkiye sahip olduğu*

*tespit edilmiştir. Çalışma sonuçları, doğrudan yabancı sermaye yatırımlarının ve inovasyonel faaliyetlerin enerji tüketiminin belirleyicisi olduğuna işaret etmektedir.*

## 1. INTRODUCTION

Energy is generally defined as the ability to do business. In addition, energy; it can be found in different shapes and fields such as chemical, electrical, thermal, mechanical, nuclear and sound. Energy has the ability to store, transform or be strengthened depending on the application. On the other hand, energy resources can be classified into three main areas: fossil (oil, coal, natural gas, etc.), renewable (geothermal wind, solar, sea, hydrogen, etc.) and divisible (uranium, thorium, etc.) (Bilgen, 2014: 891).

There are various factors together with the energy policies, which are thought to be significant in determining the projections of nation states for economic growth and social development. Population growth, technological developments, consumer needs, economic performance, and the amount of exports and imports can be given as examples of these factors. Along with these factors, the energy policies of the states and the developments in the world energy markets may play a key role in the future energy production and consumption models (Sözen et al., 2005: 211).

The question of whether energy consumption policies have an impact on economic and financial activities has attracted great interest in many platforms where global warming and greenhouse gas emissions are discussed in recent years. Excess of energy consumption is one of the most important issue of today's world. This situation has become important not only economically but also ecologically (Butala and Novak, 1999: 241). Historically, various energy crises such as oil, climate change and greenhouse gas emissions experienced in the 1970s in the world caused a strong destruction on the economies of the countries and caused an increase in energy prices. Such developments have brought energy savings to the agenda in national economies. In particular, with the oil crisis in 1973, OPEC cut off the supply of crude oil and put an embargo on the transfer of crude oil to Western countries, and energy saving gained more significance (Soytaş and Sari, 2006: 740).

The energy demand in the world increased by approximately 44% from 1971 to 2014. In this increase, fossil fuels such as oil, gas and coal constitute 80% of production. Due to the carbon dioxide released by the large amount of energy consumption into the atmosphere, there has been a serious increase in carbon emissions, especially global warming. This situation has accelerated the transition of countries to renewable energy in energy consumption. Defined by the World Bank as a driving force of technological diffusion in developing countries, FDIs are stated to have a positive effect on the use of renewable energy, as well as acting as an important intermediary in bringing modern technology to middle-income countries. Otherwise, FDIs play an noteworthy role in both reducing non-renewable energy consumption and raising environmental standards by providing a basis for making technological and management practices with more environmentally friendly methods (Yasmeen et al., 2022: 1).

FDI refers to the transfer of technology, knowledge, management styles from developed countries to underdeveloped economies (Doytch and Narayan, 2016: 291). In other words, FDI is explained as a reliable way of improving the domestic production capability of a country's economy, expediting its investments through recent financing and accessing innovative technologies. In this context, FDIs can bring superior technologies as innovations from

developed countries to underdeveloped countries. Similarly, it is emphasized that one of the factors that can attract FDIs to countries is energy use (Rafique et al., 2020: 23900).

In Figure 1, the average energy supply in some selected country groups and Turkey between the years 2000-2020 is seen in million tons. Accordingly, while the average energy supply of OECD member countries was 82.8 million tons in 2000, it increased to 88.1 million tons in 2010 and reached 83.1 million tons in 2020. In the G20 countries, beside, while the energy supply exhibited an increasing trend in general between 2000-2019, except for 2009, a decrease was observed in the energy supply in 2020. While the average energy supply for Turkey was 76.3 million tons in 2010, this figure increased to 105.7 million tons in 2000 and 147.7 million tons in 2020.

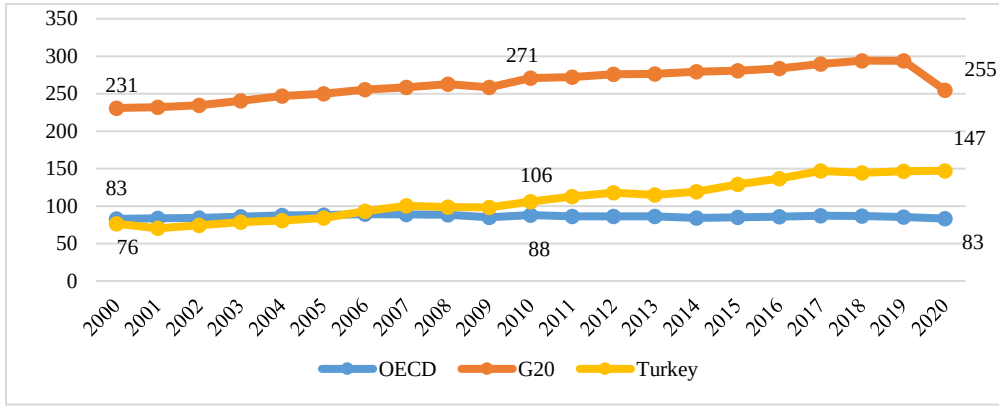


**Figure 1. Total Energy Supply in Selected Country Groups and Turkey (Million Tons)**
**Source:** *Created by the author using data from the OECD Stat database.*

Information on the types of energy supply in the 11-year period between 2000-2020 in Turkey is presented in tons in Figure 2. Accordingly, among the relevant periods, it was observed that the highest energy supply in Turkey in general was oil, coal and natural gas. In Figure 2, it was noteworthy that oil energy supply was higher than other types of energy especially between the years 2015-2020.

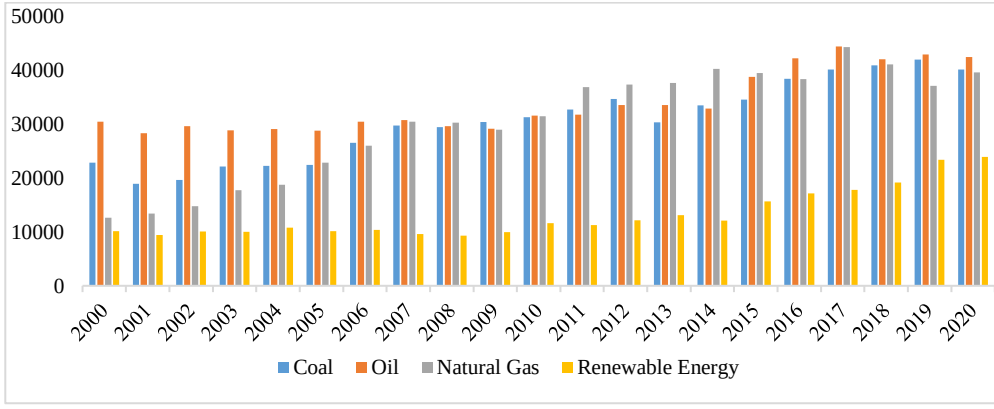


**Figure 2. Types of Energy Supply in Turkey (Million Tons)**
**Source:** *Created by the author using data from the OECD Stat database.*

Table 1 indicates the energy consumption in Turkey for the term 2005-2019, the share of FDI in gross domestic product and the number of patents. A generally increasing trend was observed in energy consumption between the related years. The situation was similar for the number of patents. The number of patents increased by more than 8 times, especially in the period between 2005 and 2019. On the other hand, the average share of FDI in gross domestic product in the same period was 1.88%.

**Table 1. Energy Consumption, FDI and Number of Patents in Turkey**

| Year | Energy Consumption, (Tons) | FDI (% GDP) | Number of patents(pcs) |
|---|---|---|---|
| 2005 | 65,378 | 1.98 | 928 |
| 2006 | 72,679 | 3.62 | 1,072 |
| 2007 | 76,642 | 3.24 | 1,810 |
| 2008 | 73,891 | 2.58 | 2,221 |
| 2009 | 74,470 | 1.32 | 2,555 |
| 2010 | 78,458 | 1.17 | 3,180 |
| 2011 | 82,348 | 1.93 | 3,885 |
| 2012 | 86,164 | 1.56 | 4,434 |
| 2013 | 85,568 | 1.42 | 4,392 |
| 2014 | 86,006 | 1.42 | 4,766 |
| 2015 | 93,601 | 2.23 | 5,352 |
| 2016 | 97,863 | 1.59 | 6,230 |
| 2017 | 105,035 | 1.29 | 8,175 |
| 2018 | 103,043 | 1.65 | 7,156 |
| 2019 | 104,394 | 1.22 | 7,871 |

**Source:** *Created by the author using data from OECD Stat and World Bank databases.*

Within the framework of the above information, in this study, it is purposed to investigate the determining factors of energy consumption in Turkey in the context of FDI and innovation. In line with this purpose, the study has been completed after the introduction, under four main headings: literature review, methodology and conclusion, respectively.

## 2. LITERATURE REVIEW

In the literature, studies on the determining factors of energy consumption focuses on the relationship between foreign direct capital investments and innovation and energy consumption within the scope of energy efficiency. From a theoretical point of view, the increase in energy efficiency attributes to two factors in the literature. The first of these is the transition from low-efficiency industries to high-efficiency industries and the second is the improvement in energy use efficiency through technological development based on innovative activities (Jin et al., 2019: 62). In this context, as a result of innovative activities, the marginal productivity level of production factors will increase, and in this case, it will be able to reduce energy consumption by increasing energy efficiency (Peng et al., 2019; Zhu et al., 2019). Another view is that there is an inverse relationship between energy efficiency and innovation. Through theoretical point of view, it has been expressed as the rebound effect of technological progress. In other words,

innovative activities does not occur at an adequate level in energy consumption areas and concentrate for different areas (Liu et al., 2018: 887).

Foreign direct investment playing a significant role on energy consumption refered to the transfer of technology, management skills and knowledge from advanced economies to less developed economies (Doytch and Narayan, 2016: 291). From a theoretical perspective, it was emphasized that foreign direct investments could be attracted to countries through financial development and energy use (Rafique et al., 2020: 23901). It was also observed that the studies were conducted by taking into account different country samples and different time intervals (Omri and Kahouli, 2014; Adom, 2015; Azam et al., 2015; Leitão, 2015; Amri, 2016; Lin and Benjamin, 2018). The results of some empirical studies investigating the relationship between energy consumption and foreign direct investment (Sadorsky, 2010; Leitão, 2015; Amri, 2016; Behera and Dash, 2017) indicated that there was a positive relationship between energy consumption and foreign direct investment. In other words, in studies, results were obtained that the increase in foreign direct capital investments would increase energy consumption. In the study conducted by Anyanwu (2012), the use of natural resources was pointed out among the factors determining foreign direct capital investments. On the other hand, in the literature, there were studies revealing a statistically negative relationship between energy consumption and foreign direct investment (Mielnik and Goldemberg, 2002; Dube, 2009; Foon-Tang, 2009; Adom 2015). In line with the general conclusion drawn from these studies, energy intensity will decrease as foreign direct capital investments increase. This situation can be explained as a result of the introduction of modern technologies into the country's economy along with foreign capital inflows.

An inverse relationship was discovered between energy consumption and energy demand and technological innovation in the studies investigating the relationship between energy consumption and innovation (Sohag et al., 2015; Murad et al., 2019; Zeraibi et al., 2020; Zhou et al., 2020; Wang and Wang, 2020; Li and Solaymani, 2021; Liu et al., 2021; Naimoğlu, 2022; Özbek and Oğul, 2022). In other words, it was revealed in the literature that energy efficiency would increase with technological development and there would be a decreasing trend in energy consumption. It is also emphasized in the literature that the policy makers should focus on innovative activities on issues related to energy consumption due to the more intense energy consumption in sectors such as industry and agriculture. Rafique et al. (2020), on the other hand, examined the impact of foreign direct capital investments, technological innovation and financial development on carbon emissions in his study. As a result of the study, they found a bidirectional causality relationship between the variables.

It can be stated that studies investigating the relationship between energy consumption and foreign direct capital investments in Turkey are intensive. It was determined that there was a statistically significant relationship between energy consumption and foreign direct investment in line with these studies (Altıntaş, 2013; Seker et al., 2015; Gökmenoğlu and Taşpınar, 2016; Öztürk and Öz, 2016; Kızılkaya, 2017; Koçak and Şarkgüneşi, 2018; Yalman, 2019; Çetin and Kantarcı, 2020; Uğur and Oğul, 2022). Köprücü (2017), Tekin and Şanlısoy (2016) and Mike and Oransoy (2017) revealed in their studies that foreign direct capital investments contributed to innovative development. On the other hand, no relationship was found between foreign direct investment and energy consumption in studies conducted by Polat (2018) and Arı (2021).

There were also studies in domestic and foreign literature linking energy consumption with economic growth and financial development (Mahalik and Mallick, 2014; Bhattacharya et al., 2016; Tang et al., 2016; Şahin, 2018). The study results revealed that economic growth

supported energy consumption. In terms of the financial development factor, attention was drawn to the importance of financial development in establishing and mobilizing this fund on scarce resources for more efficient industrial investments. On the other hand, Cebi Karaaslan and Algül (2023) presented the factors affecting energy use in her study and made policy recommendations in order to minimize the risks arising from energy imports and expenditures.

## 3. METHODOLOGY

In this part of the study, the methodology of the study is included. First of all, the data set, model and method of the research were included and then the section was completed by referring to research findings.

### 3.1. Dataset of Research

In the research, annual data collected from the OECD statistics and World Bank databases and for the period 1995-2019 were utilised. The variables utilised in the study and the explanations of the variables are illustrated in Table 2.

**Table 2. Variables of Research**

| Variable name | Variable description | Abbreviation for variable | Variable type | Data source |
|---|---|---|---|---|
| Energy Consumption | Total Energy Consumption (tons) | ENERGY | Dependent variable | OECD Stat |
| Foreign Direct Investments | Ratio of FDI to GDP (Net inflows) | FDI | Independent variable | The World Bank |
| Patent Applications | Total of Residents' Patent Applications | PATENT | Independent variable | The World Bank |

According to Table 2, total energy consumption was utilised as a dependent variable with the symbol ENERGY in the study. The ratio of FDIs to GDP is used with the symbol FDI, and total patent applications are used with the symbol PATENT and are considered as an independent variable

### 3.2. Research Model

In the research, the effect of FDI and innovation on energy consumption was analysed with a multiple regression model. This model is as follows:

$$ENERGY_t = \beta_0 + \beta_1 FDI_t + \beta_2 PATENT_t + \alpha_t \quad (1)$$

In the model, the constant term is $\beta_0$, $\beta_1$ and $\beta_2$ represents the trend parameters, and t represents time (years). ENERGY is the dependent variable, FDI and PATENT are the independent variables.

### 3.3. Research Method

In the research, the least squares estimation method was used to examine the effect of FDI and innovation activities on energy consumption.

### 3.4. Research Findings

The descriptive statistics of the variables included in the study are indicated in Table 3.

**Table 3. Descriptive Statistics**

| Variable | Mean | Standard deviation | Minimum | Maksimum | Number of observations |
|---|---|---|---|---|---|
| **ENERGY** | 73,444.77 | 18,319.01 | 48,101.84 | 105,035.5 | 25 |
| **FDI** | 1.3555 | 0.9023 | 0.3053 | 3.6235 | 25 |
| **PATENT** | 2,690.84 | 2,671.93 | 170 | 8,175 | 25 |

In Table 3, mean, minimum and maximum, standard deviation, the number of observations values of the data belonging to the variables used in the research are presented. Accordingly, it is seen that the number of observations of the data on all variables is 25. In the data series of the ENERGY variable, it is seen that the average is 73,444, minimum value is 48,101 and maximum value is 105,035. The average of the data series belonging to the FDI variable is about 1.36, the minimum value is about 0.31, and the maximum value is 3.62. The average of the data series belonging to the PATENT variable is 2,690, the minimum value is 170, and the maximum value is 8,175.

Before the least squares analysis, the stationarity test of the variables performed with KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test. The results of this test are indicated in Table 4. When the results obtained from the KPSS test, which is one of the unit root tests, are compared with the criterion values, the result should be less than the criterion value (Sarıkovanlık et al., 2019: 31). KPSS test statistical results of the series of variables included in the study are smaller than the criterion values obtained at the level of 1% significance. In this context, it has been determined that the series of variables with intercept and trend-intercept at the level of 1% significance are stationary.

**Table 4. KPSS Test Results**

| Variable | Intercept | | Trend-Intercept | |
|---|---|---|---|---|
| | **KPSS test statistics** | **Asymptotic critical value at the level of %1** | **KPSS test statistics** | **Asymptotic critical value at the level of %1** |
| **ENERGY** | 0.147068 | 0.216000 | 0.147068 | 0.216000 |
| **FDI** | 0.319210 | 0.739000 | 0.134886 | 0.216000 |
| **PATENT** | 0.680335 | 0.739000 | 0.189485 | 0.216000 |

The model of the study was estimated by the robust standard errors method of least squares. The tests of the assumptions regarding the prediction and the findings related to the prediction of the model are stated in Table 5.

Table 5 illustrates prediction results of the resistive standard errors least squares regression model. Moreover, results of the tests in which the assumptions about the least squares estimation method are tested are also included Accordingly, the Breusch-Pagan/Cook Weisberg and White tests were first tested for the presence of heteroskedasticity in the model. As a result of both tests, existence of heteroskedasticity in the model was determined. Secondly, whether there is autocorrelation in the model was tested by the Breusch Godfrey Lagrange Multiplier (LM) and the Durbin Watson test. The presence of autocorrelation in the model was tested with the Breusch Godfrey Lagrange Multiplier (LM) up to the fourth order, and it was concluded that there was no autocorrelation in the model. In addition, the Durbin Watson value of the model is close to 2, indicating that there is no autocorrelation.

**Table 5. Estimated Results of Robust Standard Errors by Least Squares Method**

| Variables | Coefficient | Robust Std. | t statistics | Probability |
|---|---|---|---|---|
| **FDI** | 3,811.13 | 517.45 | 7.37 | 0.00 |
| **PATENT** | 6.30 | 0.2139534 | 29.43 | 0.00 |
| **Constant term** | 51,336.59 | 1320.79 | 38.87 | 0.00 |
| **$R^2$** | 0.9758 | | **F(2,22)** | 485.43* |
| **Breusch-Pagan/ Cook Weisberg Test** | 0.0179 | | **White Test** | 0.0423 |
| **Breusch Godfrey Lagrange Multiplier(LM)** | 0.8781 (1)<br>0.9458 (2) | 0.9774 (3)<br>0.9553 (4) | **Durbin Watson** | 1.8470 |
| **Jarque-Bera Normality Test** | 0.1073 | | **VIF Criteria** | FDI(1.09<br>PATENT(1.09) |

**Note**: ** indicates significance at the 1% level.*

Third, the Jarque-Bera test was performed to determine whether the error terms of the model were normally distributed, and it was determined that the error terms were normally distributed. Finally, it was seen that the variance increase factor (VIF) values obtained to detect the multicollinearity problem between the independent variables in the model were less than 5 and it was concluded that there was no multicollinearity problem between the independent variables. After testing the assumptions, it was found that there were no autocorrelation, multicollinearity connection problems in the model, and the error terms showed a normal distribution. However, both tests performed to determine the presence of heteroskedasticity showed that there would be a heteroskedasticity problem in the model. Accordingly, the least squares estimation method with robust standard errors to heteroskedasticity was used to estimate the model. The probability value of the F statistic obtained as a result of the prediction shows that the model is significant in general terms.

Accordingly, the model is generally significant. The $R^2$ value, which expresses the explanatory power of the model, has been calculated as approximately 98%. Accordingly, the FDI and PATENT variables explain the ENERGY variable by 98%. Independent variables' level of explanation of the dependent variables is quite high. When the coefficients and probability values related to the variables have been examined, it is determined that they are significant and positive. Accordingly, while the effects of other variables were constant, an increase of 1% in the FDI variable causes increase the ENERGY variable by 38.11%. Namely, an increase of 1% in the ratio of FDI to GDP cause increase the total energy consumption by 38.11%. Additionally, an increase of 1 unit in the PATENT variable causes increase the ENERGY variable by 6.30 units. In other words, an increase of 1 unit in total patent applications causes increase the total energy consumption by 6.30 units. In line with all the findings obtained, it is determined that the increase in FDI and PATENT variables has caused an increase in the ENERGY variable. Therefore, FDI and PATENT variables have been discovered to have a statistically positive and significant effect on the ENERGY variable, according to the results of least squares estimation with robust standard errors.

## 4. CONCLUSION

In the study, the effect of innovation and FDI on energy consumption in Turkey in the period of 1995-2019 was investigated utilising the least squares method through multiple regression model. In the model, the ratio of FDI to GDP and the total number of patent applications were considered as independent variables, while total energy consumption was considered as

dependent variables. The data on the variables in the research were obtained from the World Bank and OECD statistics database.

The least squares method was used to estimate the model in the study. Depending on the assumptions of the method, the existence of normality, heteroscedacity, autocorrelation and multicollinearity in the model were investigated. The following tests were applied in the model: Jarque-Bera test for normality of error terms; Breusch-Pagan/Cook Weisberg and Durbin Watson test for testing autocorrelation; Breusch Godfrey Lagrange Multiplier (LM) and White test for testing heteroscedasticity. In addition, the VIF values of the model were examined to detect the multicollinearity problem. As a result of the tests, it was determined that there was a heteroscedasticity problem in the model, but there was no autocorrelation, multicollinearity problem and the error terms were normally distributed. Accordingly, the model was estimated using the least squares method robust to heteroscedasticity.

Regarding estimation of the model, the statistically positive effect of foreign direct capital investments on total energy consumption was determined. This situation could be explained as an increase in foreign capital investments, more energy demand and accordingly, more energy use. Additionally, it could be stated that energy use was required in increasing foreign direct capital investments. On the other hand, a positive relationship was observed between innovation and energy consumption. This situation could be explained as the rebound effect of technological development in the literature (Liu et al., 2018: 887). In other words, it can be stated that there is no technological development at a level that will reduce energy demand and energy consumption in Turkey, or that technological development is concentrated in different areas. In the literature, energy price, urbanization and energy use have also been identified as determinants of energy intensity (Özbek, 2023: 124).

Consequently, one of the main purpose of the energy policies of nation states is to use energy more effectively and efficiently. Thus, it is observed that environmental factors are starting to come to the forefront by countries with alternative energy use options such as wind, bioenergy and solar energy. It can be said that in recent years, countries have turned to more renewable energy sources in order to achieve their economic growth and development goals with climate change. In this context, within the framework of the results obtained from the empirical study, it is seen that innovative activities such as more foreign capital and patents are required in order to meet the energy consumption adequately. Therefore, incentive policies are supposed to be developed to increase FDI and patent applications as the determining factors of energy consumption. In addition, FDI might be invested in more innovative and environmentally friendly technologies. In future studies, a comparison of the determining factors of energy consumption between countries or between certain country groups could be performed. Economic and socio-cultural variables at macro and micro level could be also examined at the point of investigating the determining factors of energy consumption.

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