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Evolution of Energy Strategies in Turkey: Forecasts by Time Series

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Authors' contributions

This work was carried out in collaboration between both authors. Author ST designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author HV managed the analyses, wrote the protocol and wrote the literature searches of the study. Both authors read and approved the final manuscript.

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ABSTRACT

As a developing country with over 70% external dependence on energy, there is an increasing demand for electricity in Turkey. In this study, energy resources strategies in Turkey have been investigated and the historical development of its energy usage was summarised. Turkey's energy demand has increased as a result of industrial development and the various energy sources have been selected in different periods to meet this need. In all periods, fossil fuels have taken the lead in energy production. Although investments in renewable and nuclear energy sources have increased, fossil energy sources will not be replaced in the near future. The future fossil fuel production, the electricity production and the greenhouse emissions have been calculated and interpreted by time series (ARIMA), statistically. The forecasts mainly show that natural gas based electricity generation will decrease to 9.3% and renewable energy based electricity generation will increase to 25.6% in the next decade. It is obvious that the fossil fuels based greenhouse emissions will be 375.61 million tons CO_2 equivalent in 2026 and the largest share of this emission will be derived from the natural gas by 66.3 billion m^3.

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1. INTRODUCTION

Turkey, which supplies about 70% of its energy from fossil fuels, has 1.5 billion tons of hard coal (HC), 8 billion tons of lignite, 80 million tons of asphaltite, 25 billion m^3 of natural gas (NG) and 7 billion barrels of crude oil reserves in total [1,2]. It has growing import values in all fossil energy sources except lignite and asphaltite. There is an increasing demand for electricity and energy dependency in the proportion of economic growth [3-5]. Turkey, which is experiencing a steady increase in greenhouse (GHG) emissions, also needs to take preventive measures. In 2015, 86.1% of CO_2, 11.8% of CH_4 and 11.2% of N_2O in the greenhouse gasses were due to the utilisation of fossil fuel resources in Turkey [6]. Investments in nuclear and renewable energy sources are increasing with investments in domestic lignite production in order to reduce external dependence on non-lignite fossil energy resources and to provide energy diversity [7-10].

United Nations Framework Convention on Climate Change (UNFCCC) act was adopted in 1992 and Turkey was listed in Annex I and II countries. However, the intricate relationship between the UNFCCC and Turkey postponed the regulations about necessary climate change preventing steps. This agreement aims to keep annual global warming increase below 2 degrees. Therefore, the agreement objects to provide adaptation to the adverse effects of climate change and to reduce GHG, simultaneously. Turkey should make every effort to achieve the objectives of the treaty as a stakeholder.

The need for electric energy, which is the most used energy form in life, is increasing day by day all over the world. Because electricity cannot be stored, the diversification of power generation facilities is essential to meet the growing need for electricity [11]. Renewable and clean energy sources such as solar, nuclear, wind and geothermal are the most important sources that can be used by developing and fossil fuel importing countries like Turkey [7,8]. Parallel to the direction in the world, Turkey is trying to give more importance to the efforts to meet this electricity need. In particular, the reform of the electricity market in 2001 is the clearest indication of this effort. The privatisation of electricity distribution and generation companies constituted the main lines of this reform. In addition, it was the most important criteria aiming to improve service quality and efficiency in electricity. The renewable energy law, adopted in 2005, also supports the 2001 law. In this legislation, it is aimed to contribute to the electricity production of the country by supplying surplus of the electricity obtained from renewable energy sources to the network. A new employment gate has been opened with this law [12]. Thus, the electricity production in the country is arranged so that it can be produced everywhere by being removed from the centripetal approach [13]. These two laws have been the most radical ones since the 1980s.

Population growth, urbanisation and rapid growth rates in the industry make it necessary for Turkey to estimate and plan the production of electricity. Turkey Energy and Natural Resources Ministry (MENR) have calculated the energy demands via Analysis of Energy Demand technique (MAED) since 30 years. However, the obtained data is often high because of excessive data observed [14]. It is necessary to consider actual data-based predictions instead of scenario-based estimates in order to reduce the error rate [15]. The estimates made using real electricity generation data, rather than the human characteristics of the population, such as economic, demographic and social structures, will be more accurate.

Most estimates about energy supply in Turkey were made using artificial intelligence algorithms because electricity generation estimates depend on many complex and nonlinear factors [16,17]. Since the significance of the variables to be used depends on the individual viewpoint of the person who set the algorithm, these techniques can be seen as closed boxes [18]. There are also estimates made using traditional regression analysis [19,20].

Forecasting is a method for estimating future aspects of a given time series. It is a method for translating experiences into estimates of the future. It is a useful tool that helps decision makers to cope with the uncertainty of the future. In statistical literature, forecasting methods such as Box and Jenkins models, neural network and fuzzy time series are quite well-known techniques [21]. These methods are also very useful in planning and evaluating the energy policies.

In this study, the historical evolution of fossil energy and electricity usage in Turkey has been widely examined. The place of the fossil fuels in the past, present and future energy sources of Turkey has been widely discussed. Afterwards, time series analyses have been applied to the historical fossil energy and electricity production data to obtain the predictions. Thus, the estimates for the years 2017-2026 have been obtained and the GHGs have been calculated by using the obtained future production data.

2. PETROLEUM BASED ENERGY STRATEGIES IN TURKEY

The most important reason for intensive use of petroleum is the widespread consumption network. Nowadays, there is a huge range of usage from power generation to transportation [22,23]. Although alternative energy sources and technologies partially fill up oil in heating, power and electricity generation, a global substitution of fuel in the transport sector will not seem to be

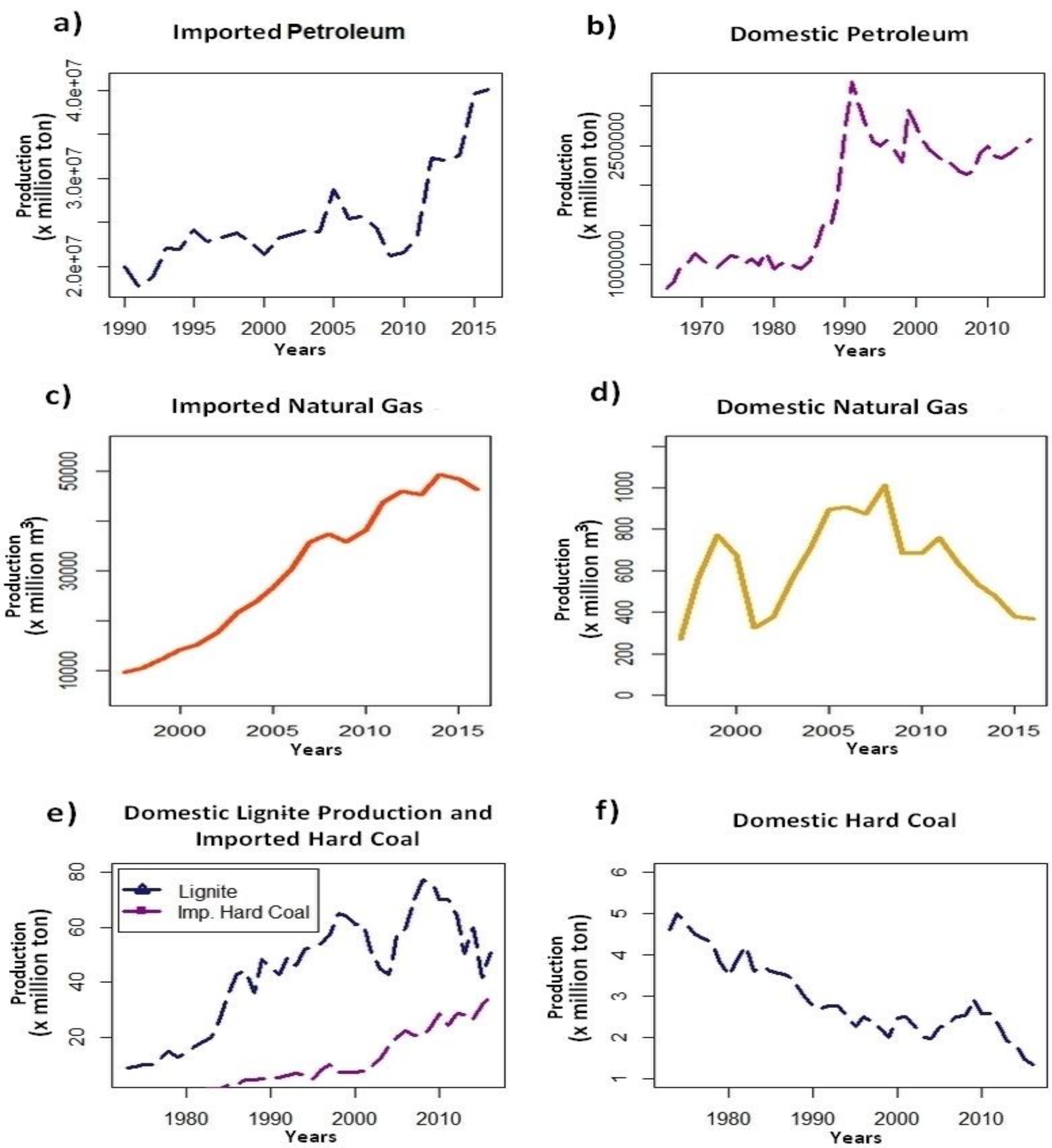

Fig. 1. Time series plots of the natural gas, coal and petroleum datasets [2,25]

very likely in the near hereafter [29]. However, it should be taken into account that fossil fuels are limited. The number of countries that prohibit diesel and gasoline vehicles is increasing. Countries such as China, India, France, England and Norway, among the world's largest economies, are preparing to ban gasoline and diesel vehicles at different dates to stop GHG. Turkey that shaped in the last geological time has very little reserves in terms of oil resources. Oil fields in the country's southeastern area are mostly small, old and costly to exploit [22,24]. Most of Turkey's oil needs are met through imports (Fig. 1a; Fig. 1b). It is stated that as the well operation period increase, the emissions also increase. The amount of emission is increasing in direct proportion to the well age. In addition, the productivity of the well is diminished [25,26]. In 2016, Turkey's recoverable oil reserves were recorded as 341.6 million barrels with a life time of 18.8 years [27].

Despite the decline in oil prices after 2014, Turkey is in the position of the most affected country by price fluctuations in petroleum. Turkey renews its petroleum policy in the energy sector and renewable sources gain power from day to day in the midst of uncertainty and political controversies in the Middle East.

Enhanced oil recovery is a CO_2 printing process for the well to increase the slowing oil production [28]. In the year 2014, 12750,16 MMSSF gas (92% CO_2) was printed and 10637,77 MMscf gas was produced back in the scope of the Project for the Upgrade of Western Raman Oil Production since 1986 [27,29]. At this point, Turkey should focus on alternative energy sources rather than making efforts to increase the petroleum resources in small quantities.

3. NG-BASED ENERGY STRATEGIES IN TURKEY

Nature-friendly NG has the advantage of a carbon reduction of approximately 40% throughout Turkey. In 2016 alone, 2.1 million consumers used NG instead of coal, resulting in 5.5 million tons less carbon emissions to the environment [27]. There are 80 trillion cubic meters (43%) of NG reserves in the Middle East, 54 trillion cubic meters (29%) in Russia and the Commonwealth of Independent States, 30 trillion cubic meters (16%) in Africa/Asia Pacific. NG reserves of Turkey are 18.8 billion m^3. When NG production fields are considered, the major production took place in Tekirdağ with 55.14% NG production. NG production was provided by Kırklareli and Istanbul with 16.95% and 15.36%, respectively. Turkey's installed power based on NG in electricity energy production was 26074 MW by the end of July 2017 and this value was 32.37% of its total installed power [1]. The NG production in Turkey is quite low (Fig. 1d). There are 6 NG contracts in Turkey for NG imports. Four of these lines have been completed. The first NG pipeline agreement was signed between BOTAS (Turkish Pipeline Company) and Gazexport in 1997. This agreement foresees NG transfer to Turkey for 25 years [30]. Another NG pipeline pact was signed between Iran and Turkey in 1996. 10 billion m^3 NG is transferred to Turkey via this route [31]. The gas flow started the production on July 2007 from The BTE (Baku-Tbilisi-Erzurum) NG Pipeline. Turkey-Greece NG Enterconnection Pipeline (ITG) started the gas supply on November 2007 [32]. Trans Anatolian NG Pipeline Project (TANAP) and Turkish Current Project (TÜRKAKIM) are the other big gas agreements for the future [33]. Investments in energy resources other than NG have gained momentum in Turkey in order to diversify energy sources and to reduce dependency on foreign gas, especially in NG [34]. In this context, 46.352 million m^3 of NG gas was imported to Turkey in 2016. NG imports decreased by 4.28% in 2016 compared to the 2015 (Fig. 1c).

In 2016, the majority of imports with a share of 52.94 % were done from Russia. In 2016, 7.627 million m^3 of LNG (both long-term contracts and spot) was imported, which is 16.46% of the total imports. While 27.84% of the total LNG imports was supplied form spot markets, the rest came from the long-term contracts of BOTAS with Algeria and Nigeria [1]. Given the investments made in nuclear power plants and renewable energy sources, it is anticipated that the share of NG in fossil fuels will decrease.

4. COAL-BASED ENERGY STRATEGIES IN TURKEY

Until the 1960s, coal remained the basic source of world energy, leaving it to the end of the 1960s for oil, but once the importance of coal for electricity production was revealed, it again gained an important position on the world energy agenda. A large amount of reserve brings the long term sufficiency of the coal. With current production levels, it is estimated that world visible coal reserves will be consumed in an average of 110 years [2,35].

The necessity for foreign fossil energy sources is vital to challenge for Turkey and the developing other countries in the last Century [36]. Reduction of foreign energy resources for developing countries is not possible without the use of local fossil energy resources. The utilisation of coal deposits, which can be found especially in every region of the world, is seen as a way of salvation for countries like Turkey that have not completed the industrial revolution. Undoubtedly, the production of local resources is the basis of economic development [37]. But, the limiting the environmental impact using clean coal technologies for the sustainable development must be the real challenge for every country.

4.1 Lignite-based Energy Production

The thermal values of Turkish lignites vary between 1000-5000 kcal/kg. Approximately 70% of total Turkish lignite reserves have low calorific value while 23.5% of them have the calorific value between 2000-3000 kcal/kg. 95% of the lignite reserves have sulphur content above 1% while 45% of the reserves have sulphur content above 2% [38]. In Turkey, coal cleaning operations are generally only implemented in some state-owned enterprises. The lignites distributing for social aids are not under health control mechanism. At the plants, harmful gases can be trapped by the flue gas treatment method, but emissions from household usage cannot be controlled. In Turkey, an average of 40-45 million tons of coal was produced each year until 2013 (Fig. 1e). However, due to the cheap imported HC, production has been around 20-30 million tons since 2013. Approximately 20 million tons of lignite was produced in 2016 [39]. Afsin-Elbistan, Konya/Karapinar, Thrace, Manisa-Soma, Afyonkarahisar-Dinar and Eskisehir-Alpu basins are the most significant lingite deposits of the country. Approximately 46% of Turkish lignites are located in the Afsin-Elbistan basin [14]. Turkey has been privatised the lignite fields that it has discovered with the condition of thermal power plant construction. The new lignite deposits were privatised with the following conditions:

- Located in Adana-Tufanbeyli; 323 million tons of coal-reserved area, with the condition of 600 MW minimum capacity thermal power plant installation, in June 2012,
- Located in Manisa-Soma; 153 million tons of coal-reserved area, with the condition of 450 MW capacity thermal power plant installation, in October 2012,
- Located in Bursa-Keles; 69 million tons of coal-reserved area, with the condition of 270 MW minimum capacity thermal power plant installation, in November 2012,
- Located in Kutahya-Domanic; 128 million tons of coal-reserved area, with the condition of 300 MW minimum capacity thermal power plant installation, in May 2013,
- Located in Bingol-Karliova; 80 million tons of coal-reserve site with the condition of 150 MW minimum capacity thermal power plant construction in August 2013.

The total installed power is 17316 MW that is equivalent to 22% of the total installed power. Installed capacity based on indigenous coal is 9842 MW (12.5%) and installed capacity based on imported coal is 7474 MW (9.5%). These projects, which are planned to be completed and commissioned within 5-6 years, are planned to obtain a total capacity of 3500 MW by evaluating coal reserves of close to 843 million tons [39].

Besides, Turkey has 80 million tonnes of asphaltite reserves in Sirnak province. There are thermal power plants for obtaining energy from asphaltites [40]. Soma Mining Disaster in Turkey was the biggest disaster in OECD countries and the history of the country [41]. This disaster that 301 miners died in 2014, Ermenek Mining Disaster that 18 miners died in 2014 and Sirnak Mining Accident that 7 miners died in 2017 are seen as the negative causes of state policy favouring privatisation in coal production. Therefore, the required effort should be made to prevent the accidents by the government while the privatisations are going on.

4.2 HC-Based Energy Production

Carbon ratio of HC ranges between 86% and 98%, while this ratio ranges between 35% and 86% in lignite. For this reason, CO_2 emissions are higher in HC. Most of the HC necessities of Turkey are met through imports (Fig. 1e). HC production in Turkey is carried out in Zonguldak Basin by TTK (Turkish HC Enteprise) and reorganised private companies. The complex geological structure of the Zonguldak Coal Basin prevents the full mechanisation, so coal production is carried out in a labor-intensive system based largely on human power [2,39]. The increasing production trend started to change and the production was less than 1 million tons in 2015. Starting from 1989, the operation of the privatisation of the reserves, which are not operated by TTK, has been initiated. This practice has continued to increase day by day [42]. In 2016, 1.33 million tons of HC was produced. 0.9 million tons of this amount was produced by TTK and the remaining amount was produced by private companies (Fig. 1f). As a result of the utilisation of many years, coal mining in Zonguldak Basin has become costly. Then, coal was imported from abroad especially after the 1980s [2]. Zonguldak Basin continues to be produced due to the employment in the region and its contribution to the country's economy despite the natural difficulties caused by the geology of the region. A rehabilitation project can be considered taking into account the occupational health and safety rules at these mines. Increased air pollution, such as the use of illegal coal, the failure to comply with the rules for burning of boilers, and the refurbishment of chimney filters, negatively affect life in the Zonguldak city. The NG pipeline is planned to spread over the entire city within the next 4 years.

5. OVERVIEW OF THE ELECTRICITY PRODUCTION IN TURKEY

The sources such as wind, sun, rivers have endless using capacity while fossil fuels and nuclear energy sources are finite sources. Renewables are predominant in the energy generation trend in recent years because of the environmental issues related to fossil fuels and the declining the prices of renewables. However, the use of domestic fossil energy sources is still very important for countries like Turkey, which cannot complete the technological evolution [34]. The share of free production, which was 55.83% in 2015, increased to 61.48% in 2016. There are two main reasons for this increase. Firstly, free production companies make large parts of new investments. Secondly, the intense government support for privatisation of existing public power plants is another reason. The demand for electricity has increased steadily since 2009. In 2016, the greatest increase in the last 4 years realised with 5.07% [1].

The electricity generation by sources in Turkey for the last 46 years is given in Fig. 2. The increase in NG-based production, especially since the 1980s, is remarkable. For the first time since 2000, the hegemony of NG in electricity generation ended in 2016. The electricity production from coal was 33.9% in 2016 while that in the NG was 32.2%. The government effort supporting domestic lignite production and investments in renewable energy sources have been effective for these circumstances. This phenomenon is an alert for changing of NG-focused energy production policy.

Installed capacity in 2016 was 77737 MW increasing by 6.27% compared to the previous year. As of the end of 2016, the share of NG power plants decreased to 32.77% from 34.1%.

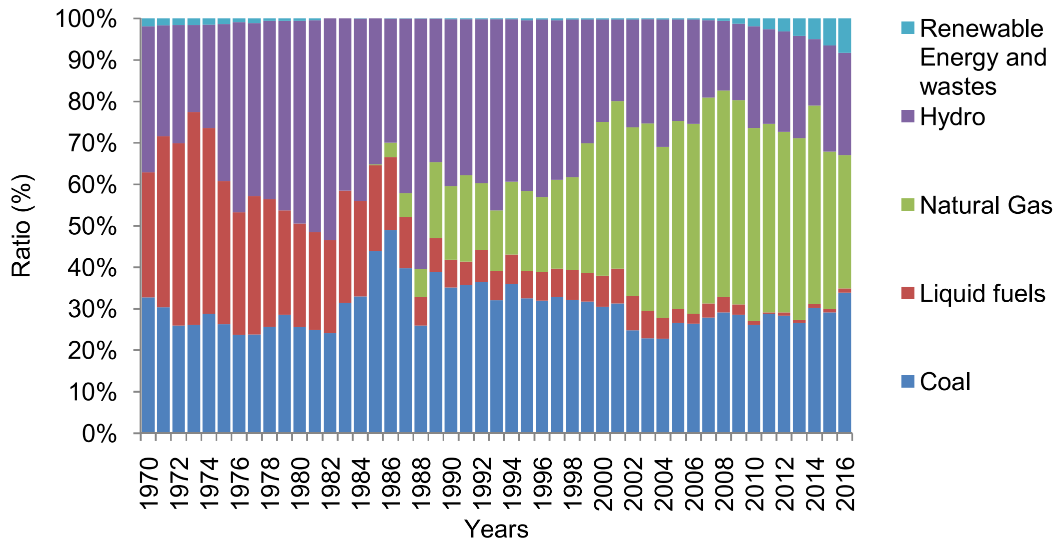

Fig. 2. Electricity generation by sources in Turkey [46]

The share of renewable sources in total installed capacity has increased to 43.41% from 42.71%. The highest installed power increase is seen in wind energy compared to the previous year. The share of private companies' installed capacities was 62.28% in 2016 when the same value was 59% in 2015 [2,43].

6. TIME SERIES ANALYSIS FOR THE FUTURE PREDICTIONS

The fossil fuel production/import and the electricity production percentages by resources type in Turkey have been used as materials for this study (Fig. 1, Fig. 2). Electricity production by hydraulic power has been researched apart from the renewable sources.

Firstly, time series have been investigated to ascertain whether the series is stationary or non-stationary. For the stationary time series $ARMA(p,q)$ and $ARIMA(p,d,q)$ models given by Box and Jenkings [21] are considered. In the other case, random walk process (with drift-without drift) is considered. The time series, partial autocorrelation function (PACF) and autocorrelation function (ACF) graphs help for determining whether the datasets are stationary or not. Besides, unit-root tests (Philips-Perron, Augmented Dickey-Fuller Test) are used to determine stationarity in the series. For the non-stationary time series, making stationary through differencing is an important part of the process of fitting an $ARIMA$ (autoregressive integrated moving average) model. Otherwise, the random walk process is one of the most used non-stationary time series models, especially in financial studies. Linear stochastic time series models for stationary datasets are the autoregressive (AR), the moving average (MA) and the autoregressive moving average models (ARMA). An autoregressive process of order p if:

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \cdots + \alpha_p X_{t-p} + e_t \quad (1)$$

It is similar to multiple regression model however X_t is not regressed by indepented variables. It regressed by its past values, hence the prefix 'auto'. An autoregressive method of order p is abbreviated as $AR(p)$ process [44]. A moving average route of order q, $MA(q)$ if:

$$X_t = \beta_0 e_t + \beta_1 e_{t-1} + \cdots + \beta_q e_{t-q} \quad (\beta_i \text{ 's are constants}) \quad (2)$$

Combining $AR(p)$ and $MA(q)$ techniques is named as $ARMA(p,q)$ process. It is formulated by:

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \cdots + \alpha_p X_{t-p} + e_t + \beta_1 e_{t-1} + \cdots + \beta_q e_{t-q} \quad (3)$$

In models, e_t is named as identically and independently distributed white noise series and it is purely random process with zero mean and variance σ_z^2 . Non-stationary time series are converted to stationary ones through differencing (d times). These models made stationary by differentiating named as $ARIMA(p,d,q)$ model. Writing $W_t = \Delta^t X_t$, the general autoregressive combined moving average process is of the form:

$$W_t = \alpha_1 W_{t-1} + \alpha_2 W_{t-2} + \cdots + \alpha_p W_{t-p} + e_t + \beta_1 e_{t-1} + \cdots + \beta_q e_{t-q} \quad (4)$$

In the other case, random walk process is the most used process for non-stationary time series data. When a time series shows irregular growth and if the stability cannot be provided with differentiating, random walk models can be used for forecasting. This model assumes that the series take a unsystematic step away from its previous values in each period and the periods are individually and similarly distributed. The random walk model is given as following:

$$X_t = \rho X_{t-1} + e_t \quad (5)$$

In this model, if $\rho = 1$ it means X_t has a unit-root and it is a random walk process with a unit-root (non-stationary time series example). If the distribution of the step sizes of the series has a non-zero mean, a random walk is said to have a "drift" and a non-zero stable term (α) should be included in the model. It is named as "random walk with drift" model. A random walk with a drift model is given as:

$$X_t = X_{t-1} + \alpha + e_t \quad (6)$$

It is not easy to determine that distribution of the step sizes has zero or non-zero mean. Therefore, experimental experience is important to detecting the drift. The random walk model can be regarded as a exclusive case of ARIMA. It is defined as $ARIMA(0,1,0)$.

An ARIMA process has four procedural steps. First step is determination of the model specification and parameters p, q, d. In this stage, time series schemes, unit-root tests, ACF and

PACF Figs are used. Then, the fitted models are adapted and the diagnostic tests are performed by the residuals and correlograms. Finally, forecasts are obtained for the future years based on fitted models.

6.1 Fossil Fuel and GHG Forecasts

Fig. 1 shows that only produced NG data seems stationary and all other datasets need to take difference to make them stationary.

According to the test results and plots given in Fig. 3, first difference taken domestic petroleum, second difference taken produced HC and the produced NG datasets were stationary time series (Fig. 3). However, import petroleum, lignite, imported coal data and imported NG datasets were unable to be stationary.

Therefore, forecasts for this time series were obtained by considering the random walk model. In this way, best fitting $ARIMA$ models for forecasting were obtained as *ARIMA(0,1,1)*, *ARIMA(0,0,1)* and *ARIMA(0,2,1)* with non-zero mean for domestic petroleum, domestic NG and HC respectively. On the other hand, random walk model $ARIMA(0,1,0)$ was considered for import petroleum, domestic lignite, imported coal and imported NG datasets. Considering equation (7) and equation (8), corresponding time series models were reported in Table 1.

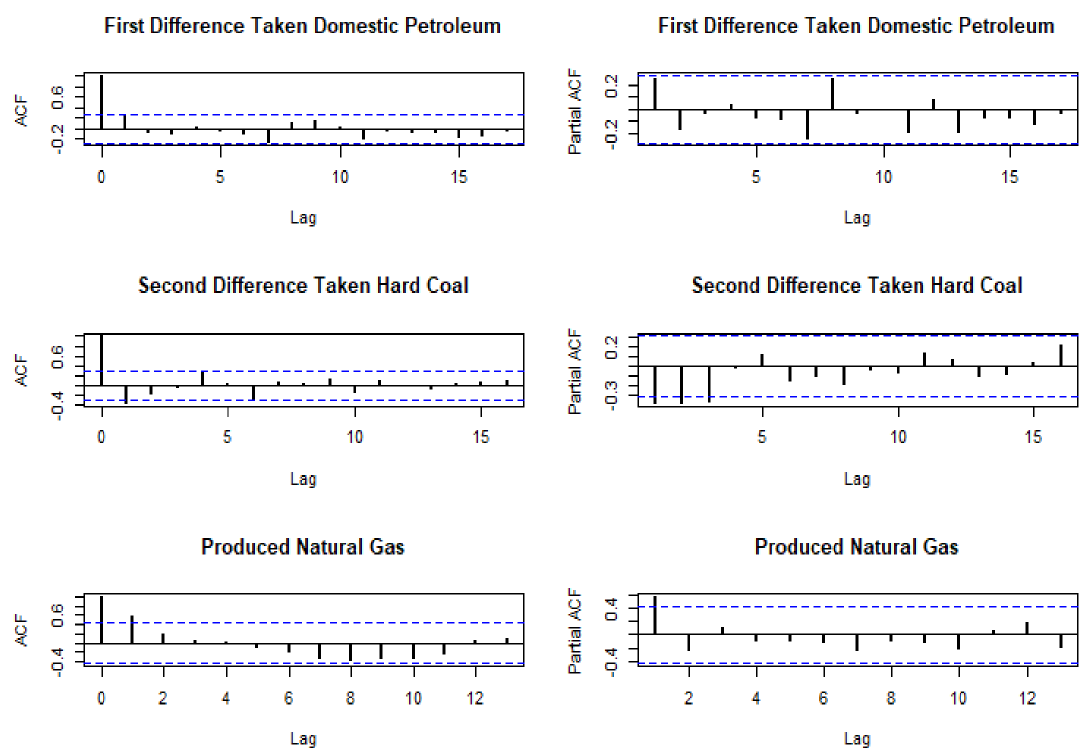

Fig. 3. ACF and PACF plots of the original and differentiated time series datasets

Table 1. The time series models for the operative forecasting of fossil fuels

Fossil fuel	Fixed model	Analysis module
Imported NG	$X_t = X_{t-1} + 1914.316 + e_t$	$ARIMA(0,1,0)$
Domestic HC	$X_t = 2X_{t-1} - X_{t-2} - e_{t-1}$	$ARIMA(0,2,1)$
Produced NG	$X_t = 608.1978 + X_{t-1} + 0.7472e_t$	$ARIMA(0,0,1)$
Domestic petroleum	$X_t = X_{t-1} - 0.3113e_{t-1}$	$ARIMA(0,1,1)$
Imported HC	$X_t = X_{t-1} + 0.8121 + e_t$	$ARIMA(0,1,0)$
Imported petroleum	$X_t = X_{t-1} + e_t$	$ARIMA(0,1,0)$
Lignite	$X_t = X_{t-1} + e_t$	$ARIMA(0,1,0)$

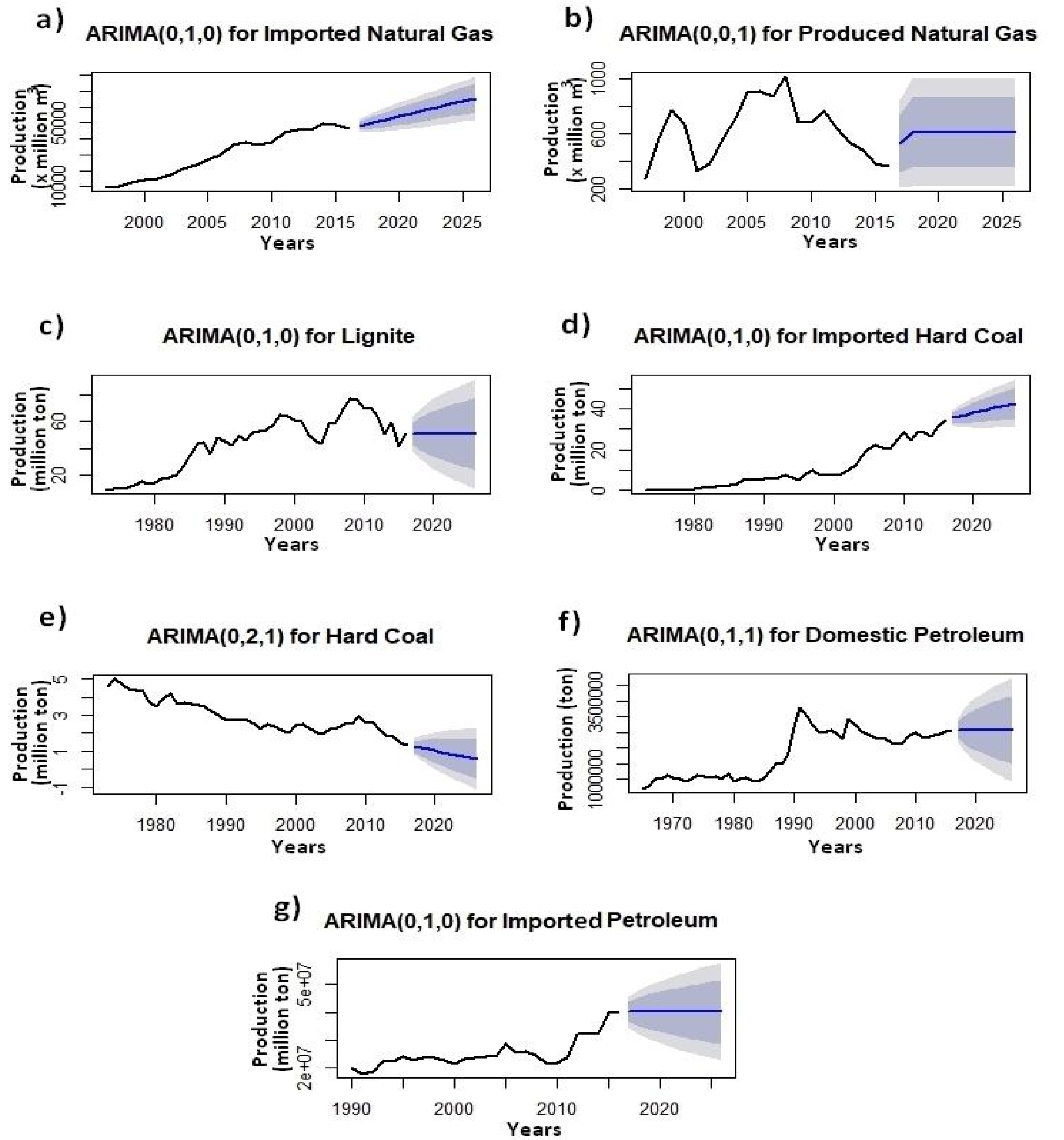

Fig. 4. Probability ranges for the fossil fuels

Afterward, based on determined models, tests for significance of the model parameters and residual analysis were performed and obtained results indicated that these models are the best fitting for the corresponding datasets. Further, for supporting the decisions about the determined models the automatic ARIMA (auto.arima) algorithm that combines unit root tests, minimal Akaike Information Criterion and Maximum Likelihood Predictions was used to obtain an ARIMA model. Test statistics are obtained for the coal data $= -2.919$ ($p = 0.05$), for first difference taken liquid data $t = -6.234$ ($p = 0.0$) , for second difference NG data $t = -10{,}702$ ($p = 0.00$) and for the renewable energy and wastes data series $t = -12.010$ ($p = 0.00$). We obtained same results with the automatic algorithm. Finally, forecasts for the future years were obtained (Table 2).

There will be a linear increase for imported NG and no change in domestic production Fig. 4a; Fig. 4b). Lignite production will be same level and imported HC will be increased (Fig. 4c; Fig.

4d). But HC production will be able to decrease (Fig. 4e). A significant fluctuation will not be expected for domestic and important oil (Fig. 4f; Fig. 4g). The increase in consumption of oil by population will be proportional. Besides, it was determined that the error rate may be up to 6.67% when considering the correlation between the fossil resources production and the greenhouse emission data in the past years (R^2=0,93) as seen in Fig. 5.

NG values were taken as billion tons and the other fossil fuels were taken as million tons while total fossil resource amounts for the last 20 years were calculated. The future greenhouse emissions were calculated by considering the future fossil resources utilisation and the correlation equation (Table 3).

6.2 Electricity Production Forecasts

The most important indicator of economic growth is electricity consumption. The Fig. 2 shows that the time series of coal data seems stationary while the liquid fuels, the NG and renewable energy and wastes data series seems not stationary. Also, the random walk is seen in the hydro data. To provide these considerations and determine the stability; ACF, PACF plots and unit-root tests have been used (Fig. 6).

Table 2. Forecasts of the fossil energy resources for the next 10 years in Turkey

Years	Imported natural gas	Produced natural gas	Lignite	Imported hard coal	Hard coal	Imported petroleum	Petroleum
	(x million m^3)		(million ton)				
2017	48286.32	525.80	50.88	35.73	1.25	40.05	2.58
2018	50220.63	525.80	51.00	36.54	1.17	40.06	2.59
2019	52154.95	600.10	49.98	37.35	1.10	40.05	2.57
2020	54089.26	608.19	50.42	38.16	1.02	40.06	2.56
2021	56023.58	605.15	51.50	38.98	0.94	40.07	2.56
2022	57957.89	609.10	50.48	39.79	0.87	40.07	2.54
2023	59892.21	603.50	52.14	40.60	0.79	40.06	2.55
2024	61826.53	608.19	53.14	41.41	0.72	40.08	2.55
2025	63760.84	608.19	52.14	42.22	0.64	40.11	2.55
2026	65695.16	608.25	50.88	43.04	0.56	40.12	2.53

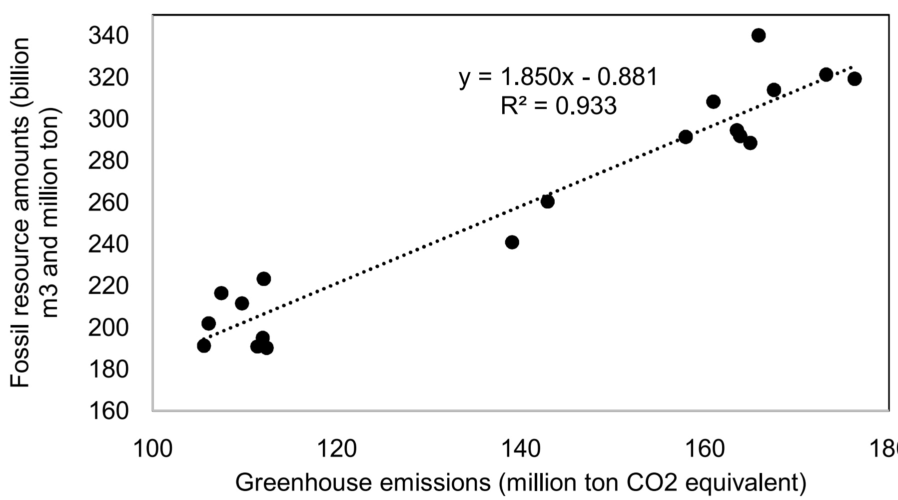

Fig. 5. The correlation between greenhouse emissions and fossil resource amount in Turkey

Table 3. Future GHG derived from fossil resources by years (million ton CO_2 eq.)

2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
330.95	336.14	339.28	345.04	352.00	355.04	363.03	369.87	373.01	375.61

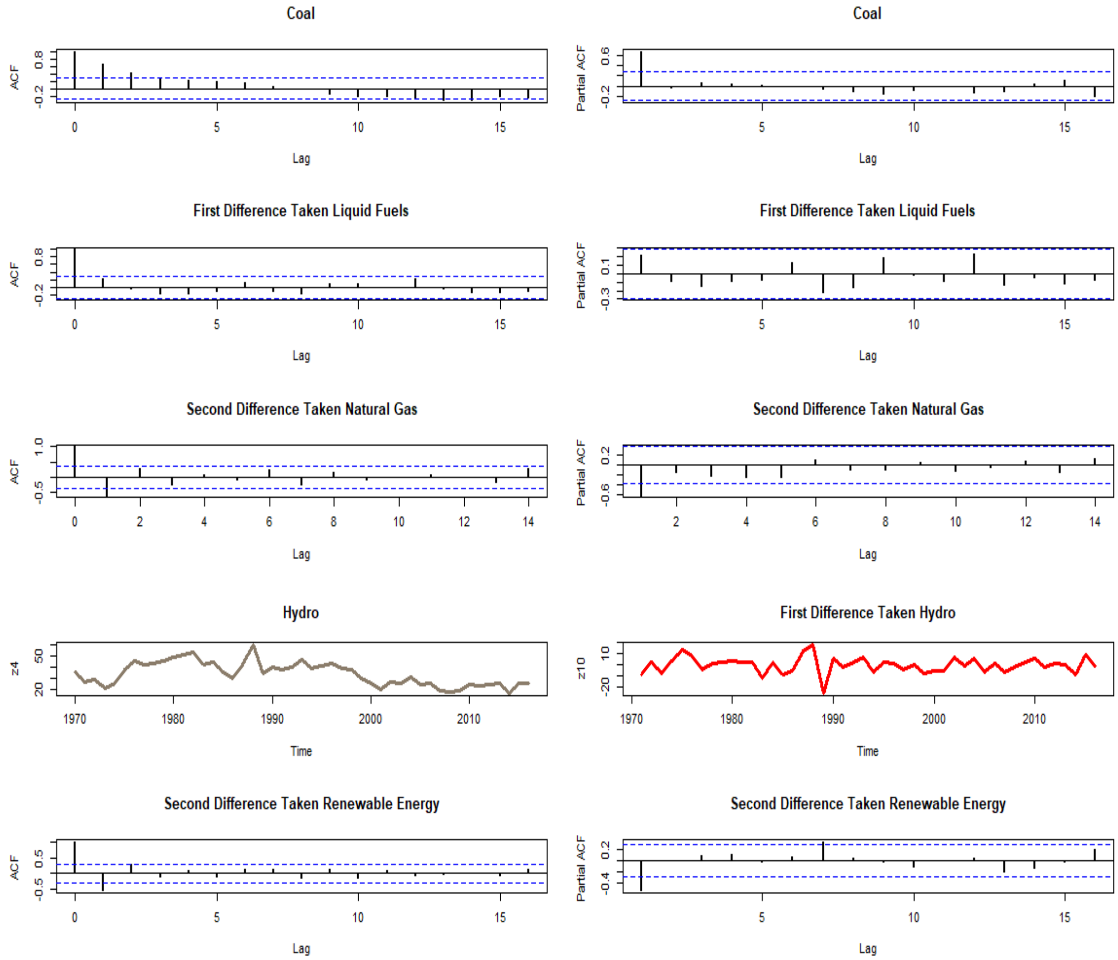

Fig. 6. ACF and PACF plots of the original and differentiated electricity generation by energy resources data

Augmented Dickey-Fuller (ADF) test has been performed to determine the stability. Test statistics are obtained for the coal data =-2.919 (p=0.05), for first difference taken liquid data t=-6.234 (p=0.0), for second difference NG data t=-10,702 (p=0.00) and for the renewable energy and wastes data series t=-12.010 (p=0.00). These results show that the original coal data, first differences taken liquid data, second difference taken NG data and second difference taken renewable energy and wastes data are stationary time series. However, the hydro data is unable to be stationary. Therefore, forecasts for this time series are obtained by considering the random walk model. The obtained time series models were shown in Table 4.

Forecasts for the next decade electricity production of Turkey were calculated and shown in Table 5. It has been predicted that there will be a slight decrease in electricity production from coal-based sources while the shares of the other generation resources will not be changed, significantly (Fig. 7a). The production from petroleum fuels will be quite low (Fig. 7b). The renewables (not including hydraulic) will accelerate in contrast to NG-based one in Turkey for the next decade (Fig. 7e and Fig. 7c), respectively.

There will be limited decrease for Hydro energy (Fig. 7d). The most used three resources for electricity generation will be reached for coal: 33.46%, for renewables: 28.09% and hydraulic: 27.60% in 2026.

Table 4. The obtained time series models for the operative forecasting of electricity production

Fossil fuel	Fixed model	Analysis module
Coal	$X_t = 30{,}4445 + 0{,}6621X_{t-1} + e_t$	$ARIMA(1{,}0{,}0)$
Liquid fuels	$X_t = X_{t-1} - 0{,}3189e_{t-1}$	$ARIMA(0{,}1{,}1)$
Hydro	$X_t = X_{t-1} + e_t$	$ARIMA(0{,}1{,}0)$
NG	$X_t = 2X_{t-1} - X_{t-2} + e_t + 0{,}7989e_{t-1}$	$ARIMA(0{,}2{,}1)$
Renewables	$X_t = 2{,}509X_{t-1} - 0{,}018X_{t-2} - 0.509X_{t-3} + e_t$	$ARIMA(1{,}2{,}0)$

Table 5. Electricity productions forecasts for 2017-2026 years (%)

Years	Coal	Liquid fuels	Natural gas	Hydro	Renewables
2017	32.29	1.03	29.42	26.5	10.16
2018	32.32	1.03	27.46	26.7	12.10
2019	32.65	1.02	26.38	26.9	13.03
2020	32.76	1.02	24.06	27.1	15.02
2021	32.77	1.02	21.02	27.2	17.96
2022	32.83	1.01	18.92	27.6	18.95
2023	32.97	1.01	17.40	26.7	21.90
2024	33.13	1.00	15.04	27.5	23.28
2025	33.28	1.00	12.64	27.0	26.02
2026	33.46	1.00	10.20	27.2	28.09

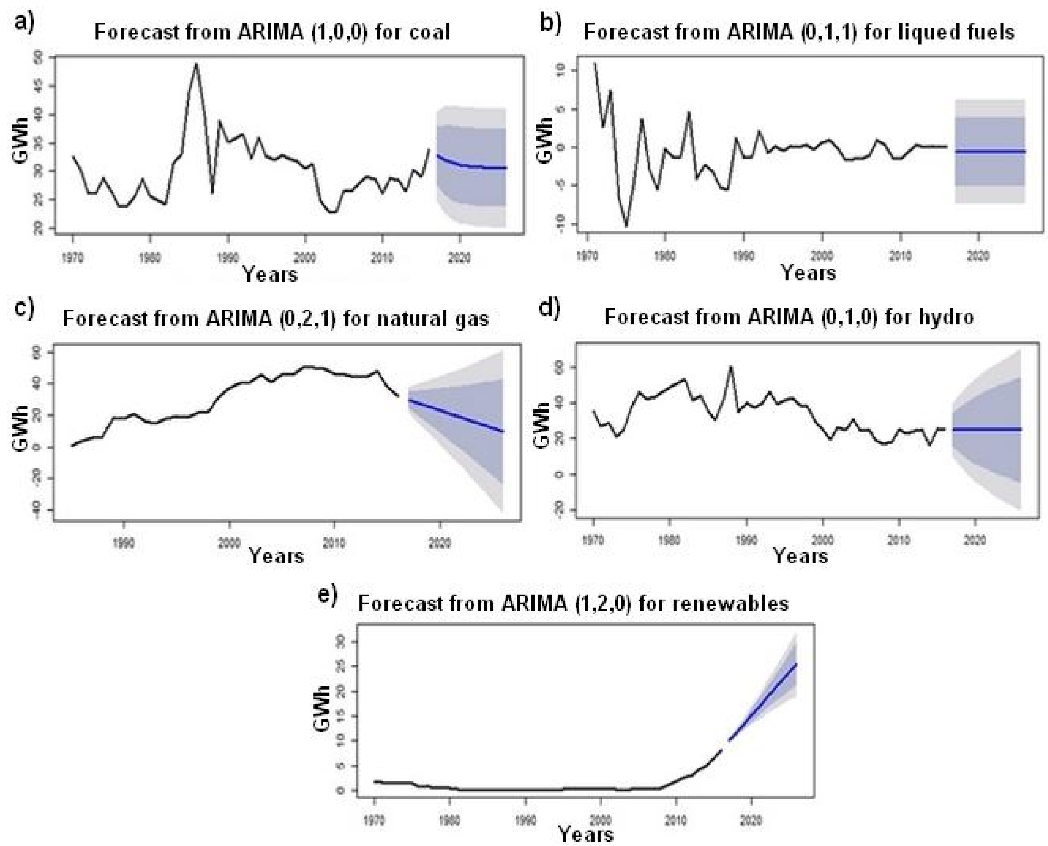

Fig. 7. Probability ranges for electricity productions (GWh) by years

7. CONCLUSIONS AND DISCUSSIONS

The forecasts demonstrate that Turkey will continue to import NG, HC and petroleum. When NG burns, it does not leave ash, soot and sulphur compounds in the air. It does not cause acid rain (SOx ratio is less than 1/2000). NG emissions are very low because it has minimum carbon content between fossil fuels. The most environmentally friendly resource is seen as NG in the fossil fuels. Unfortunately, Turkey does not have NG resources although it continues to search at a rapid pace (Fig. 1d). Fig. 1a and Fig. 1b prove that the same situation is valid for oil reserves. Turkey, which opposes the referendum elections in Iraq, is expected to experience a significant decline in oil imports. However, the other pipeline agreements with Iran envisaged to fill this gap. Fig. 1c shows that NG imports have increased since the 2000s. Turkey's NG imports fell 2.2 billion cubic meters in 2016 compared to 2015. Decreasing gas volume from Russia played an important role in this situation. Nevertheless, the new pipeline projects TANAP and TÜRKAKIM are signs of NG imports and electricity production from the fossil fuels for the future. This can be regarded as a positive development in the name of the environment, though not as much as renewable resources. If the NG pipeline constructions are timely activated, it will be one of the biggest steps to reduce carbon emissions. However, exploiting the domestic lignite reserves have great importance because Turkey has no other fossil resources reserves. In the process of transitioning to renewable and clean energy sources (wind, solar, nuclear etc.), Turkey needs to use domestic lignite resources and increase its exploration efforts in order to reduce its future importing costs. The lignite reserves have low calorific values. However, MENR built the domestic lignite based solution in order to reduce energy related imports. The domestic lignite production was the highest production rate in 2008 and then the big accidents in the lignite mines forced to close some mines in the wake of the increasing societal reactions. After 2008, the import of HC increased in order to supply the increasing coal demand (Fig. 1e). The decrease in the production of domestic HC, which is already small quantities in Turkey, is the most important gain in the name of this environmental impact (Fig. 1f).

The forecast reveals that the NG imports will increase by about half times (Fig. 4a). However, the domestic NG production will have no particular increase in the next a couple years despite being the country that made the most search drillings (Fig. 4b). The Turkish government sees lignite as the sole local resource for reducing dependence on imports. Turkey already has 24 domestic lignite-burning thermal power plants. Nevertheless, the forecast seen in Fig. 4c show that Turkey will not increase the lignite production in the near future. The new 17 domestic lignite-burning thermal power plants are waiting to produce energy. Some of them have preliminary licences while others are in the project status. The coal distributed by the government for social assistance in Turkey is seen as the main actor of air pollution and greenhouse gas emissions in winter. It is not possible to prevent the household-based greenhouse emissions because the government does not even control the flue gas emission values of thermal power plants sufficiently. There is no cleaner province than Rize province in Turkey according to the World Health Organization. Also, the majority of the country has polluted air according to Turkish standards. It is not possible to change this situation in the near future for about 10 years. Turkey's HC imports are estimated to exceed 40 million tons in Fig. 4d. The estimates also show that the production of local HC will finish up to several years (Fig. 4e). One of the most important reasons of this situation is deep mining that the HC is exploited under the Black Sea. Also, domestic oil production has not been improved despite the last ten years of research. This situation is unlikely to change in the near future (Fig. 4f). Not only the domestic oil production but also the imported oil production will have no significant fluctuations (Fig. 4g). When all the estimates are interpreted together, it is likely that Turkey will experience an increase in almost all fossil resources over the next decade. The largest increase is in the NG caused the least amount of CO_2 emissions among fossil fuels.

As a result of the reforms since 2000, the use of renewable energy sources accounts for almost 10% of its total electricity energy needs in Turkey. The incentives given to the energy production resulted from privatised wind turbines and photovoltaic panels are increasing. However, the main energy source is clearly visible as fossil fuels in the estimates (Fig. 7). The second chance for reducing the emissions is seen as nuclear power plants after the renewable sources. Three nuclear power plant are under construction for the next years in Turkey. Akkuyu nuclear power plant, which will have 4 reactors with 1200 MW, aims to meet 10 percent of Turkey's energy needs. Sinop nuclear power plant will have 4 reactor units and a total installed power of 4480 MW. Russian company is building Akkuyu nuclear power plant while Japanese company is founding Sinop nuclear power plant. These steps taken by Turkey, which does not have any experience and knowledge on nuclear topics, stand as a big puzzle to policymakers. The third nuclear power plant project is the discussed topic in the country. Despite planning the operation of 2 nuclear facilities up to 2023, the negative opinions of environmental groups and the people of the region hamper the progress of the project. After the coup attempt on July 15, 2016, instability in politics with America, Russia, and Iraq seems to be the delay of these mega projects.

Considering the carbon emissions in 2016, Turkey ranks 15th in the world. It took second place in Europe after Germany. Carbon dioxide emissions were 10151 million tons in China, 5312 million tons in USA and 2431 million tons in India for 2016. Turkey's contribution to the world CO_2 emissions was 404 million tons for 2016. Of course, in the comparison of such great values here, it is necessary not to ignore the influence of the population. Therefore, CO_2 per capita values are important for the comparison. Britain, Germany and America have completed the industrial revolution and China has huge production values. These outputs may be sufficient for an accurate comparison. All of these states, including Turkey, have grown economies and industrial enterprises. Despite growing industry and economic activity, countries such as Germany, Britain and the USA are able to reduce their carbon emissions per capita. However, the carbon emission values of Turkey and China have shown a very high increase in recent years. Very high population in China and very rapid population growth in Turkey should not be shown as the reason for this. Because, respect to the environment is a responsibility for every country. When the Kyoto Protocol was adopted in 1997, Turkey was not yet a party to the Convention, so no quantified emission limitation or reduction specific to Turkey under the Kyoto Protocol has been identified. The Protocol calls for countries to reduce the amount of carbon they catch atmospheres to levels in 1990. The draft law on the suitability of Turkey to participate in the Kyoto Protocol was adopted and passed in the General Assembly of the Grand National Assembly of Turkey in 2009. It would be correct to say that Turkey does not act in accordance with the protocol. Despite the fact that it is not rich in NG, oil and coal, the increase of these energy sources from day to day and the policy that continues to support this increase is proof of this.

It is predicted that fossil resources based GHG emissions, which were 340.17 million tons CO_2 equivalent in 2015, will rise to 375.61 million tons CO_2 equivalent for 2026 in Turkey (Table 3). These values take attention due to the conformity of the estimations of Yuksel [45] for 2020s. From this point of view, the following results and suggestions can be made:

- Increased air pollution reasons such as the usage of illegal coal, the failure to comply with the rules for burning of boilers, crooked urbanisation and the refurbishment of chimney filters have been negatively affecting life quality of some local residential areas. The usage of NG reduces the flue gas problem at a small scale. However, this effort is not enough. Turkey’s energy policy, which based predominantly on fossil fuels, should shift to clean and renewable energy sources.
- The average growth rate between 2002 and 2014 was 4.7% in Turkey. Turkey's economy grew by 7.4% in 2017 and was able to grow twice as fast as the European average. The employment based on fossil fuels increased. The domestic fossil energy sources should be utilised with the understanding of sustainable mining for the posterity by decreasing the GHG emissions and supplying the better working conditions for miners. Flue gases should be purify from the harmful nitrogen oxides and similar gases. GHG emissions should be captured and converted to valuable CO_2-based products such as plastic, fuel, dry ice etc.
- In partnership with neighbouring countries, Turkey should be applied necessarily comprehensive reforestation projects. Thus, increased oxygen release will be able to brake global warming. Unfortunately, forest fires and fires of oil wells in the Middle East or all over the world are major threats on global warning.
- The ongoing nuclear power plant projects will contribute to minimising GHG. However, nuclear accidents are making the environmental organisations worried about Turkey that does not have a nuclear plant experience.

- Half the G20 countries have implemented mandatory GHG reduction standards for new passenger cars and light commercial vehicles. Turkey is one of the few G20 countries not having implemented mandatory GHG standards for new cars or light commercial vehicles at this point. Turkey has also signed global environmental protection treaties such as UNFCCC and Kyoto Protocol. Intercity and inner-city public transport and new metro lines should be encouraged to reduce fuel consumption. The first Turkish electric vehicle production project has been prepared in 2018. Such projects should continue to be developed and the controls on GHG should be tightened.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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