

**INVESTIGATING THE CO₂ EMISSION OF TURKISH ELECTRICITY
SECTOR AND ITS MITIGATION POTENTIAL**

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SECTOR AND ITS MITIGATION POTENTIAL**

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ABSTRACT

INVESTIGATING THE CO₂ EMISSION OF TURKISH ELECTRICITY SECTOR AND ITS MITIGATION POTENTIAL

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The rapid industrialization, population growth, urbanization and economic and social development cause many environmental problems, such as climate change which is the result of the increase in the emission of greenhouse gases (GHGs) especially CO₂. Combustion of fossil fuels, particularly from electricity generation, has the major responsibility for CO₂ emissions.

Decreasing the amount of CO₂ emission requires a significant shift from our present energy use pattern toward one of lesser reliance on fossil fuels. Using renewable energy sources is one of the ways to supply some of the electricity demand reducing the associated GHG emissions and thus decreasing the adverse effects of climate change.

In this study, generated electricity associated CO₂ emissions and the specific CO₂ emission factors are calculated based on IPCC methodology for each fuel type and each thermal power plant for Turkey between 2001 and 2008. The electricity demand of Turkey is estimated to increase about 7% annually till to 2019. Based on the planned power plant data obtained from EMRA, it was found that the total electricity supply (planned + existing) will not be sufficient to provide the estimated demand between 2011 and 2019. To overcome supply deficiency problem, four different scenarios are developed and the mitigation potential of CO₂ emission from electricity generation based on these scenarios are examined. The results from these scenarios

show that there is a significant decrease in the amount of CO₂ emission from electricity generation. Renewable Energy Scenario which is the best scenario in terms of mitigation of CO₂ emissions, provides to mitigation of 192 millions of CO₂ emissions between 2009 and 2019. with respect to *BAU* scenario

Keyword: CO₂, Climate Change, Electricity Generation, Mitigation of CO₂ Emission, Fuel Specific Emission Factors

ÖZ

TÜRK ELEKTRİK SEKTÖRÜNÜN CO₂ EMİSYONUNUN VE AZALTM POTANSİYELİNİN ARAŞTIRILMASI

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Hızlı sanayileşme, nüfus artışı, kentleşme ile ekonomik ve sosyal kalkınma pek çok çevresel sorunlara neden olmaktadır. Bunlardan biri olan iklim değişikliği, artan sera gazı emisyonlarından özellikle fosil yakıtların yanması sonucu oluşan CO₂ emisyonlarının bir sonucudur. En çok bilinen fosil yakıt kullanıcısı olan termik santraller de yüksek oranlarda CO₂ emisyonları salmaktadır.

CO₂ emisyonlarının azaltılması için mevcut enerji yapısının daha az fosile dayanan şekilde dönüştürülmesi gerekmektedir. Yenilenebilir enerji kaynaklarının elektrik talebini karşılamaya yönelik olarak kullanılması ile sera gazı emisyonları ve iklim değişikliğinin etkileri azaltılabilmektedir.

Bu çalışmada, Türkiye'nin 2001 ile 2008 yılları arası için IPCC yöntemi kullanılarak elektrik üretimine bağlı olan CO₂ emisyonları ve spesifik emisyon faktörleri her bir yakıt türü ve her bir termik santral için hesaplanmıştır. Türkiye'nin elektrik talebi 2019 yılına kadar yıllık yüzde 7 oranı artacağı tahmin edilmektedir. EPDK'nin ilerleme raporlarından lisans almış planlanan santrallere ilişkin bilgiler de dikkate alındığında, toplam (planlanan ve mevcut) santrallerin 2011 ile 2019 yılları arasında elektrik talebini karşılamadığı görülmektedir. Arzdaki bu sıkıntıyı aşmak için dört farklı senaryo geliştirilmiştir. Bu senaryolara göre elektrik üretiminden kaynaklanan CO₂ emisyonlarının azaltım potansiyeli projekte edilmiştir. Bu senaryolar elektrik üretiminden kaynaklanan CO₂ emisyonlarının azaltılabileceğini göstermektedir. CO₂

emisyollarının azaltımı aısından en iyi senaryo olan Yenilenebilir Enerji Senaryosu ile 2009 – 2019 yılları arasında Referans Senaryoya gre 192 milyon ton CO₂ emisyonu azaltımı saėlamaktadır.

Anahtar Kelimeler: CO₂, İklim Deėişikliği, Elektrik Üretimi, CO₂ Emisyonu Azaltımı, Yakıt Spesifik Emisyon Faktörleri

to my wife and my daughter

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ABBREVIATIONS

BAU	Business As Usual
CRF	Common Reporting Format
EGIC	Electricity Generation Incorporated Company [EUAS in Turkish]
EMRA	Energy Market Regulatory Authority [EPDK in Turkish]
EPSA	Electrical Power Survey and Administration [EIE in Turkish]
FO	Fuel Oil
GDP	Gross Domestic Products
Geo	Geothermal
GHG	Greenhouse Gas
GNAT	The Grand National Assembly of Turkey [TBMM in Turkish]
GWh	Giga Watt Hour
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KP	Kyoto Protocol
ktoe	Kilo tons oil equivalent
kWh	Kilo Watt Hour
LHV	Low Heating Value
LPG	Liquid Petroleum Gas
MENR	Ministry of Energy and Natural Resources [ETKB in Turkish]
MoEF	Ministry of Environment and Forestry [ÇOB in Turkish]
MW	Mega Watt
MWG	Municipal Waste Gas
MWh	Mega Watt Hour
NG	Natural Gas
NLDC	National Load Distribution Center
NIR	National Inventory Report

OECD	Organization for Economic Cooperation and Development
PP	Power Plants
PPM	Parts Per Million
TETC	Turkish Electricity Transmission Corporation [TEIAS in Turkish]
TPP	Thermal Power Plant
TURKSTAT	Turkish Statistical Institute [TUIK in Turkish]
SEF	Specific Emission Factor
SHW	State Hydraulic Works [DSİ in Turkish]
SMPT	Small and Medium Private Thermal Power Plants
SPO	State Planning Organization [DPT in Turkish]
UNFCCC	United Nations Framework Conventions on Climate Change
WMO	World Meteorological Organization

CHAPTER 1

INTRODUCTION

1.1. Background Information

The industrialization, high population growth and urbanization cause the depletion of natural resources and many environmental problems. Fossil fuel combustion, as a depletion of natural resources, results in environmental problem such as increasing of greenhouse gases (GHGs) emissions in the atmosphere. The concentration of atmospheric CO₂, which is the major GHG, has increased from a pre-industrial value of about 280 ppm to 379 ppm as of 2005 [1]. Although GHGs trap heat and raise air temperatures near the ground, acting like a greenhouse on the surface of the planet, the increasing concentration of GHGs in the atmosphere causes the climate change. Global warming, changes in sea level, snow cover, ice sheets and rainfall, are results of the climate change. All these disasters affect the ecosystems in many parts of the world [2].

Since the climate change problem threatens all living beings, the solution of this problem needs to be dealt globally. The ultimate objective of United Nations Framework Convention on Climate Change (UNFCCC) is to stabilize the GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In order to accomplish this task, significant amounts of GHGs emissions reduction is required [3].

The emission from the energy sector accounts for up to 80% of the anthropogenic GHGs emissions in the world. Dependent on fossil fuels, the growing world energy demand clearly plays a key role in the CO₂ emissions increase. Since the industrial

revolution, CO₂ emissions from fossil fuel combustion reached to 29 Giga tons, of which 41% of it is associated with electricity generation in 2007. This is due to the fact that the worldwide generation of electricity mainly depends on coal, which is the most intensive fossil fuel [3].

Turkey's total GHGs emission (CO₂, CH₄, N₂O, HFC, PFC, SF₆) has increased 119% from 170 million tons CO₂ eqv. to 372 million tons CO₂ eqv. between 1990 and 2007. The increase in the CO₂ emission for the same period is from 140 to 304 million tons. In the same period, the CO₂ emission from the electricity generation increased 233% from 30 million tons to 100 million tons. The emission from the electricity generation consists of 33% of total CO₂ emissions in Turkey as given Figure 1.1. Consequently, the electricity generation between 1990 and 2007 in Turkey increased 244% from 57,543 GWh to 197,839 GWh [4].

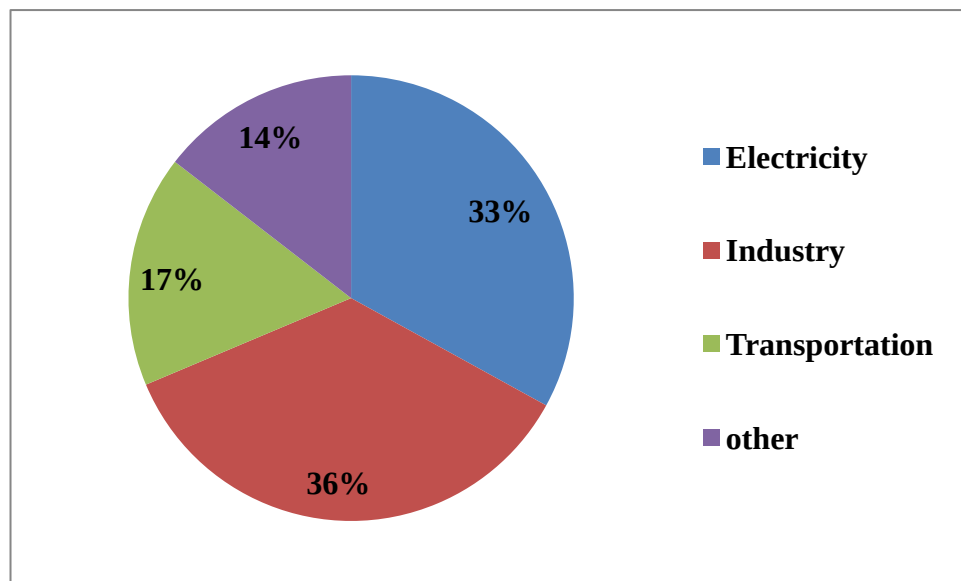


Figure 1.1. Total CO₂ Emissions of Turkey in 2007 [4]

To reduce the CO₂ emissions associated with electricity generation, alternative energy sources are needed as fuel in power plants. Renewable energy sources such as, wind, geothermal, hydro and biomass can be used in electricity generation.

1.2. Problem Definition

As stated earlier, due to industrialization and urbanization more energy and especially electricity is required. Generation of electricity, which is the one of the main CO₂ sources in Turkey, is increasing sharply and causing adverse effects on the climate change.

In Turkey, there are a few studies on the relationship between electricity generation and associated CO₂ emissions. Generally, these are country reports such as National Inventory Reports (NIR) and First National Communication (FNC), which were submitted to UNFCCC secretary due to the responsibility of Turkey. Although the methodology for calculation of GHGs emission depends on Intergovernmental Panel on Climate Change (IPCC) approach, there are some crucial problems in the determination of CO₂ emissions associated with electricity generation. The calculations are based on top down approach and they did not differentiate IPCC default emission factors according to low heating value of each type of fuel consumed.

The studies conducted by Ministry of Environment and Forestry (MoEF) [5], Greenpeace [6] and Türker [7] present the future electricity demand and associated CO₂ emissions. They used different alternatives to supply the needed electricity demand and associated CO₂ emissions. However, in none of these studies, the licensed and planned power plants data was used to calculate the supply side of the electricity demand and its associated CO₂ emissions.

Secondly, all studies have used IPCC's default emission factors but, there is a need for the fuel specific emission factors for Turkey to estimate the CO₂ emissions associated with the total electricity demand between 2009 and 2019. This electricity demand can be provided by using different alternatives, such as using the economically feasible renewable energy sources which have a crucial role in combating the climate change problem.

1.3. Objective of the Study

The major objective of this study is to investigate the mitigation potential of CO₂ emission from electricity generation by using renewable energy sources in the next decade. To date, efforts to investigate future electricity generation and associated CO₂ emissions in Turkey are very limited.

A secondary objective of this thesis is to calculate the historical CO₂ emission from each thermal power plant and country specific emission factors, since there is no study that was based on calculating of CO₂ emission plant by plant and also no study that determines the specific emission factors for Turkey.

Thus, the objectives of the thesis are as follows:

- To calculate CO₂ emission of each thermal power plant in Turkey between 2001 and 2008,
- To determine country specific emission factors for each (kg CO₂/MWh) fuel type in Turkey,
- To estimate the electricity supply based on planned power plants data,
- To develop alternative electricity supply scenarios based on the electricity demand between 2009 and 2019.
- To estimate associated CO₂ emissions based on the scenarios and calculate the total CO₂ mitigation potential between 2009 and 2019.

1.4. Scope of the Study

This thesis deals with CO₂ emission of each thermal power plant between 2001 and 2008. Data on daily generated electricity and amount of fuel consumed from each power plant daily are gathered from National Load Distribution Center (NLDC) [8]. Default emission factors and the calculation of CO₂ emission methodology are based on IPCC Guidelines [9]. Low heating value of each fuel and thermal efficiency data of thermal power plants in Turkey are obtained from the literature. Using these data,

generated electricity associated CO₂ emissions is calculated; specific emission factors for each thermal power plant are determined; country specific emission factors are also determined. Thus, the accuracy of these results is bounded by the accuracy of the information available from these sources.

In this thesis, future electricity demand and associated CO₂ emissions are also estimated. The estimated electricity demand is obtained from Turkish Electricity Transmission Company (TETC) between 2009 and 2018 [10]. The licensed power plants data with completion information are obtained from Energy Market Regulatory Authority (EMRA) [11]. To overcome electricity supply and demand balance problem; new, additional and sustainable primary energy sources are need to be used to generate electricity. In addition to this, mitigation of CO₂ emission from electricity generation is the priority issue to combat the climate change and also the main objective of this study. For these reasons, mitigation potential of CO₂ emission in the electricity supply is projected in four different scenarios which are developed hypothetically by the author.

This study deals with only technical aspect of CO₂ mitigation potential of electricity generation sector by alternating the fuel type of power plants. This study does not include any economic analysis of the scenarios conducted.

1.5. Structure of the Study

Chapter 2 of the study consists of an overview of the available literature. In that chapter, studies on the inventory of CO₂ emission originated from electricity generation, fuel specific emissions factors, and projection CO₂ emission from electricity generation of Turkey are reviewed.

Chapter 3 of the study is the outlook of electricity sector of Turkey. This part is focused on energy policies, structure of electricity supply of Turkey and thermal power plants statistics.

Chapter 4 is the overview of the data related to electricity generation in Turkey. The thermal power plant data between 2001 and 2008 in the daily, monthly and annually forms are presented. Data on licensed and planned power plants, and their properties, such as installed and generation capacity, fuel type, realization ratio, *etc.* are given in this chapter. Economically renewable energy potential and the electricity demand of Turkey between 2009 and 2019 are also presented.

Chapter 5 is on the methodology used to calculate the CO₂ emissions. It consists of the detail steps on the calculations of CO₂ emissions and specific emissions factors according to “IPCC Tier – 1 Approach”. In addition to this, elemental analysis method used to double check the CO₂ emissions is also presented.

Chapter 6 presented the results of the study. The chapter consists of the results of the amount of electricity generated and associated CO₂ emissions in Turkey between 2001 and 2008 based on fuel and ownership type; specific CO₂ emission factors based on fuel type; the amount of electricity that will be supplied by the planned power plants and associated CO₂ emission from the planned plants between 2009 and 2019. The total amount of electricity that will be generated to supply the total estimated demand and associated CO₂ emission between 2009 and 2019 based on four scenarios are also presented.

Chapter 7 presents conclusion and recommendation for future works.

CHAPTER 2

LITERATURE REVIEW

2.1. Overview

This chapter consists of three parts. The first part presents the inventory of CO₂ emissions associated with generated electricity in Turkey and also presents the results of different studies on calculation of CO₂ emissions in Turkey.

The second section is on the specific emission factors in terms of fuel type developed by International Energy Agency (IEA) for Turkey.

In the last section of this chapter, the studies that are related to the electricity generation associated CO₂ emission forecast for Turkey are presented.

2.2. Inventory of Generated Electricity Associated CO₂ Emissions

In this section, the studies on the calculation of CO₂ emissions from electricity generation for Turkey and other countries are summarized.

One study that analyzes the role of factors affecting the evolution of CO₂ emissions from electricity generation in seven countries (Australia, Canada, China, India, Japan, Korea, and USA) between 1990 and 2005 was conducted by Malla [12]. The total CO₂ emission from electricity generation was calculated using the IPCC [9] method in the study. The factors affecting the emission were analyzed using the Logarithmic Mean Division Index method. The results of the study show that there is a potential of efficiency improvement of fossil-fuel-fired power plants and its associated co-benefits among these countries. Another output of this study was that

over the 2005–2030 periods, the effect of energy production remains the key factor responsible for the increase in emissions and energy intensity is responsible for decrease in emissions.

One of the earlier studies on CO₂ emission inventory for Turkey was “*Eight Five Development Plan’s Special Experts Report on Climate Change*” [13]. The report dealt with the CO₂ emission inventory and projections for Turkey. The report used IPCC Tier – 1 approach to develop the emission inventory. Table 2.1 illustrates the inventory data presented in the report between 1970 and 1995.

Table 2.1. CO₂ Emissions from Generated Electricity between 1970 to 1995 [13]

	1970	1975	1980	1985	1990	1995
CO₂ Emission, thousand tons	11,560	16,496	20,437	33,279	51,094	61,271

Another study developed by Can [14] was on the ground level CO₂ concentrations from industry, households, thermal power plants and road vehicles by using US EPA’s ISCLT3 model. The study covered all the provinces and districts of Turkey for CO₂ emissions. IPCC Tier – 1 approach was used to calculate the emission from power plants. The power plant emission calculations were based on the assumption that emissions from power plants using the same type of fuel were the same. In addition, only public thermal power plants were included, private thermal power plants were not included in the study. For projection of CO₂ emissions from thermal power plants, planned and licensed thermal power plants projects were not considered.

One of the well known studies on CO₂ emission is “*National Inventory Report (NIR) of Turkey GHG 1990 to 2007*” [15]. This report was prepared in the scope of responsibilities of Republic of Turkey for UNFCCC. The IPCC Tier – 1 approach was used in this report to calculate the CO₂ emission from electricity sector by taking only the fuel type and fuel amount as an aggregate. Fuel types were classified and

plants using the same fuel were summed as one plant, and also. The results of this report on the CO₂ emission from power plants in Turkey are given in Table 2.2.

Türker [7] estimated Turkey's regional long-term electricity demand and associated CO₂ emission. The IPCC Tier – 1 approach was also used to calculate CO₂ emissions in this study. The results of this study are also given in Table 2.2.

Table 2.2. CO₂ Emission from Electricity Generation in Turkey, 2001 – 2007 (thousand tons)

	2001	2002	2003	2004	2005	2006	2007
NIR [15]	74,515	68,815	68,973	70,499	83,680	85,312	100,662
Türker [7]	63,406	55,968	60,101	64,110	76,186	79,522	

NIR uses the IPCC default emission factors without any differentiation for Turkey to calculate electricity generation associated CO₂ emissions. Since the quality of the Turkish fossil fuels is not same with those used in other countries, CO₂ emissions calculated using these factors directly cannot represent the Turkey's thermal power plants emissions precisely. The method of emission estimation of other study's [7] is also based on IPCC method with country specific emission factors. However, the range of default IPCC factors with respect to low heating value of the each fossil fuel is not considered as well (see Section 5.3 for detailed analysis conducted on this issue for this study). For this reason, it also does not represent the Turkey's generated electricity associated CO₂ emissions accurately.

In this study, generated electricity associated CO₂ emissions are also calculated following IPCC Tier – 1 Approach. However, the IPCC default emission factors are selected according to fuel type and low heating values. The amount of energy consumed in each plant is double checked by comparing the thermal efficiencies of plants with those given in literature. The CO₂ emission calculations are double checked by comparing results with those found using elemental analysis (see Section 5.3). These analyses are conducted for all public and private thermal power plants

generated electricity between 2001 and 2008. Generation, amount of consumed fuel and low heating value of each thermal power plants are taken into consideration.

2.3. Fuel Specific Emission Factors for Turkey

To the author's knowledge there is only one study available on fuel specific emission factors for Turkey, which is conducted by IEA. This study covers country specific emission factors for coal, oil and natural gas between 1990 and 2007 for Turkey and some other countries as given in Table 2.3 and Figure 2.1 [3]. There are different studies related to emission factors in literature, however they are not country specific and not in time series.

Table 2.3. Fuel Specific Emission Factors, kg CO₂ / MWh for Turkey and Some Countries [3]

		1995	1999	2000	2001	2002	2003	2004	2005	2006	2007
Turkey	Coal	1,132	1,131	1,080	1,082	1,102	1,068	1,045	916	1,015	1,037
	Oil	951	889	852	735	672	668	688	654	740	675
	NG	419	408	346	359	357	347	355	357	341	347
World	Coal	883	902	879	899	882	891	912	909	910	903
	Oil	591	658	667	656	659	665	655	675	663	662
	NG	366	395	388	389	390	386	387	390	384	388
EU	Coal	818	813	813	825	829	815	821	814	828	835
	Oil	560	559	571	576	561	583	507	559	499	518
	NG	356	356	343	331	336	324	315	312	315	314
OECD	Coal	909	900	897	939	905	897	904	894	893	903
	Oil	620	669	660	645	635	650	613	641	603	599
	NG	454	449	411	403	400	387	388	386	376	377
USA	Coal	938	913	916	988	921	918	923	914	903	920
	Oil	491	784	811	707	750	747	777	744	731	693
	NG	509	541	462	455	437	427	438	437	393	398
China	Coal	984	951	911	901	902	917	967	937	930	893
	Oil	620	651	637	636	645	667	667	683	648	616
	NG	524	426	388	375	360	367	365	378	392	437
Brazil	Coal	1,543	1,333	1,464	1,487	1,511	1,566	1,455	1,585	1,616	1,605
	Oil	819	785	804	794	702	766	714	764	730	699
	NG	742	494	496	455	478	445	472	473	451	450
India	Coal	1,213	1,220	1,203	1,199	1,153	1,161	1,224	1,244	1,247	1,252
	Oil	1,105	1,003	1,036	1,035	870	915	930	924	843	798
	NG	539	448	503	493	538	469	480	480	480	462

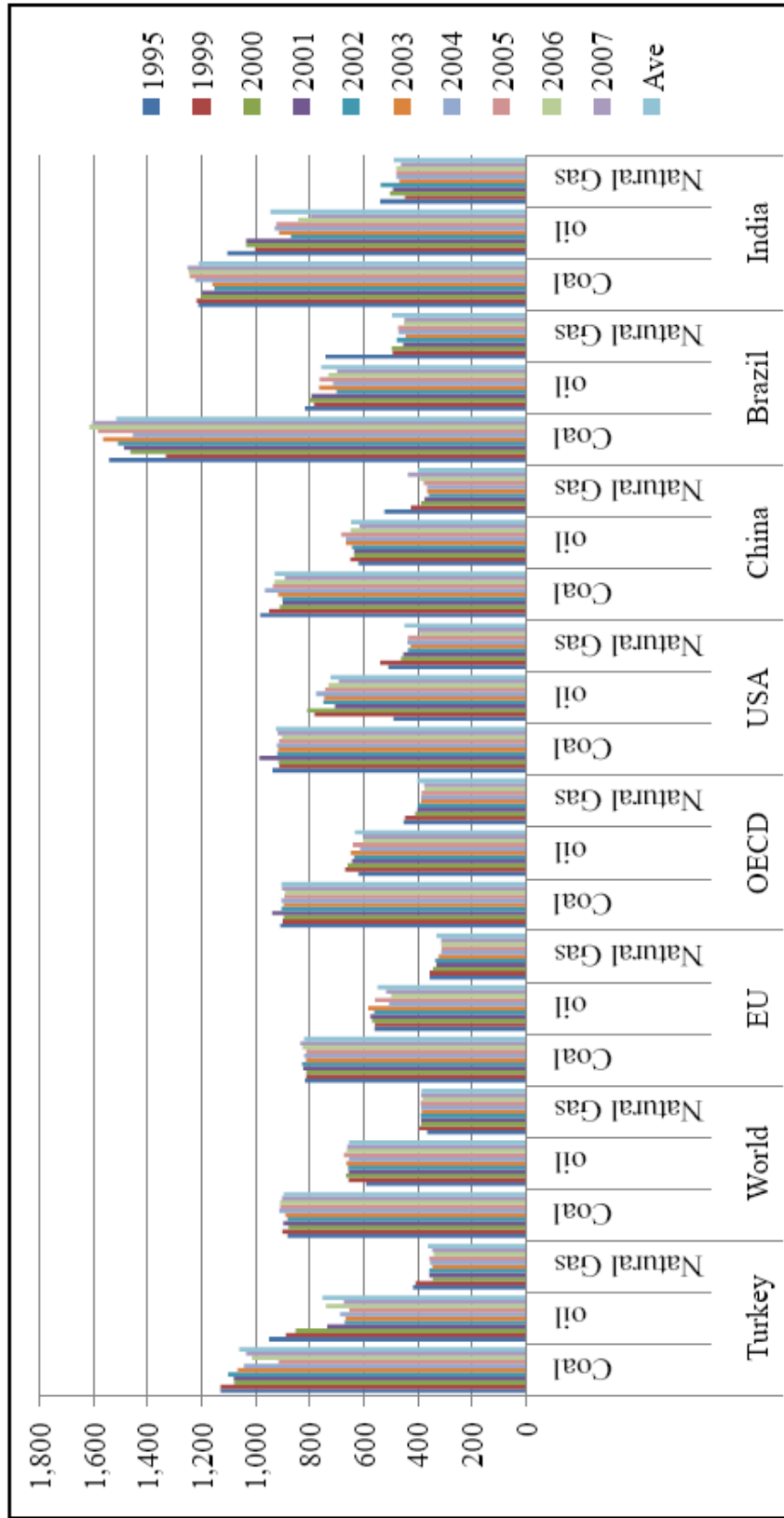


Figure 2.1. Fuel Specific Emission Factors, kg CO₂ / MWh for Turkey and Some Countries [3]

The IEA method to find specific emission factors for each year is to divide CO₂ emissions from coal, oil and natural gas consumed for electricity by outputs of electricity generated from coal, oil and natural gas respectively. However, the study has specific emission factors only for three fuels. Coal and lignite, diesel and fuel, LPG and natural gas based thermal power plants are not differentiated among them. This approach is too general to determine each fuel specific emission factors for each year.

In this study, specific emission factors for eight fuel types are calculated using the data available for more than 300 power plants that generated electricity between 2001 and 2008.

2.4. Projection of CO₂ Emission from Electricity Generation

The studies on the projection of CO₂ emissions from electricity generation in Turkey are very limited and there is no study on the mitigation potential of associated CO₂ emission for Turkey.

There are a few study related to projection of electricity generation and associated CO₂ emission in the world. Al-Ghandoor et al. [16] developed an empirical model for demand side management electricity consumption of the Jordanian industrial sector based on multivariate linear regression. Electricity consumption and associated GHG emissions for the industrial sector are predicted to rise by 63% in the year 2019. If the necessary energy efficiency measures are implemented, electricity consumption and associated CO₂ emissions are forecasted to ascend at a lower rate with low/no cost actions. Although the CO₂ emissions will be constrained at the demand side, there is no consideration in the electricity generation part.

Based on the results of the study conducted by Malla [12], to project the electricity generation associated CO₂ emissions, decomposition factors are deterministic in power sector. Over the 2005–2030 period, the changing of decomposition factors for seven countries (Australia, Canada, China, India, Japan, Korea and USA) are

estimated based on the effects of electricity generation, electricity generation mix, energy intensity and emission factors. The results of this study presented that although the decomposition analysis gives the basic foresight, it could not give the emission mitigation of alternative energy sources solely.

One of the first studies on the CO₂ projection was the report prepared by Ministry of Energy and Natural Resources (MENR) which results were used in the First National Communication of Turkey on Climate Change (FNC) [5, 17]. The report included the results of associated GHG emission projections to 2020 based on four scenarios; reference case, low growth, demand side management, and cogeneration. This scenario stated projected energy supply, energy demand, and GHG emissions. The CO₂ emissions calculations were performed using BALANCE model of the Energy and Power Evaluation Program (ENPEP). The estimation approach of the CO₂ emission for electricity generation is similar to that of NIR [15]; in which there was no differentiation between the thermal power plants using the same fuel type in Turkey. The scenarios included GHG emission reduction were low growth demand side management and cogeneration scenarios. The path way of these scenarios was policy oriented, not plan and program oriented. Also the planned and licensed power plants were not considered in these scenarios.

Another study is a report published in 2009 by Greenpeace Turkey [6]. This study included results of two different scenarios on projection of Turkey's electricity generation associated CO₂ emissions. One of the scenarios of this study, *Energy R – Evolution scenario*, is based on using renewable energy potential for electricity generation. However, only the technical potential of renewable sources is considered in this scenario.

Türker [7] estimated Turkey's regional long-term electricity demand and associated CO₂ emission for 2020 based on low, medium and high scenarios as given in Table 2.4. Although, associated CO₂ emission estimates were based on only for the electricity demand of Turkey, the use of renewable energy as a substitute for the

fossil fuels and planned energy facilities to forecast energy mix and CO₂ emissions were not considered.

Table 2.4. Forecast of CO₂ Emission from Different Studies, million tons

		2010	2015	2020
MENR [16] and MoEF [5]	Reference	117	152	222
	Demand Side Management	110	140	185
	Low Growth	107	137	163
	Cogeneration	122	167	248
Greenpeace [6]	Reference	87		161
	Enerji D – Evrimi	82		100
Türker [7]	Low	102	114	138
	Medium	107	132	177
	High	109	144	207

The study conducted by Say et.al [18] was about the relationship between the total energy consumption and total CO₂ emission in Turkey. Regression analysis was performed and strong relationship between total energy consumption and total CO₂ emission were found. Say et.al [18] used this relationship to forecast Turkey's energy related CO₂ emissions. The authors also compared their forecast results with those calculated using IPCC method, and found that the forecast based on IPCC method resulted in higher estimates. This study includes only the total CO₂ emission from the energy sector, but not specifically from the electricity generation.

As given above, to the author's knowledge, there is no study for Turkey that takes into consideration the planned power plants data for estimating the associated CO₂ emission from electricity generation.

In this study, the electricity generation associated CO₂ emission up to 2019 is estimated taking into account the current power plants, planned power plants and economically feasible energy alternatives, including the renewable energy sources in Turkey.

2.5. Closing Remarks

In this chapter, studies on calculating the CO₂ emission associated with electricity generation, country specific emission factors, and projection of CO₂ emission originated to electricity generation are presented. There are only a few studies on electricity generation associated CO₂ emission calculation and projection in Turkey. In addition to this, these studies did not take into consideration the licensed and planned power plants data for projection analysis.

In this study, bottom up approach, from daily to annually data electricity data, is used to increase the accuracy and reliability of the calculation of CO₂ emissions, and planned power plants' realization ratio are taken into consideration for better emission projection.

CHAPTER 3

ELECTRICITY ISSUES OF TURKEY

3.1. Overview

This chapter summarizes the dramatic changes took place in the electricity sector of Turkey in terms of policies, demand and generation capabilities, and liberalization of power plants in the last decade. This chapter consists of three parts. The first section presents the changes in the energy policies of Turkey since 2000. The second section presents statistics on the generated electricity amount of Turkey from 1970 to 2008 and presents the fossil dependency of the country by stating specific values. The last section presents the classification of thermal power plants according to ownership.

3.2. Energy Policies of Turkey

Turkey has made impressive progress in the energy sector for the last decade. The government is making considerable efforts to address the “3 E’s”, namely energy security, economic efficiency and environmental protection, in a sustainable manner [19].

A new legislation on the energy sector entered into force after 2001 and reduced the role of the government in energy markets strengthening market forces in the sector. In the same year, an independent regulator (EMRA) has been established. About three years later, an ambitious privatization programme has been announced and the UNFCCC has been ratified. In the mean time, the country has prepared legislation to address energy efficiency [19]. Turkey’s energy policy is in progress to be better energy management in terms of generation and consumption.

In transportation side of energy, some important oil and gas transit pipeline projects are under way or nearing completion, which will improve the security of supply in Turkey making it an “energy corridor” between East and West [19]. This also provides the energy supply security for high electricity demand of Turkey.

Especially in last five years, high population and economic growth have lead to increase in electricity demand of Turkey. Over the last five years primary energy and electricity consumption has increased 35% and 43%, respectively. 106 million tons of oil equivalent (mtoe) of primary energy consumption and 1,451 kilograms of oil equivalent (koe) of per capita energy consumption were observed in 2007 [20].

According to Ninth Development Plan (2007 – 2013) of Turkey, the energy sector’s main objective is to supply the energy required for economic and social development in a continuous and secure manner at minimum cost while meeting the energy demand. This will provide by keeping the environmental damages at the minimum level and using energy in the most efficient and economical manner at all stages from generation to final consumption. In order to increase the supply security, a balanced source diversification on the basis of primary energy sources and country of origin differentiation will be ensured. It is targeted that the share of domestic and renewable energy sources in the production system will be raised to the maximum extent [21].

Although, the economic crisis in 2008 has caused a drop in the electricity demand of Turkey for 2009, the projected electricity demand trends show that Turkey should still install new and additional power plants.

According to 2009 Annual Programme [20] energy supply security, usage of indigenous sources, diversification of energy sources and improvement of energy efficiency will be given priority. For this priority, studies towards determining the renewable energy source potential and developing and expanding the applications thereof would be continued. For this objective, to supply the peak energy demand and for more efficient utilization of wind energy potential, potential determination and project studies regarding pumped-storage hydroelectric power plants would be

done. Technical evaluations of the wind plant applications to EMRA would be realized. Solar energy map would be improved and biomass map would be prepared [20]. This also provides the mitigation of climate change in the energy sector. The emission intensity of electricity generation sector will decrease by substitution of renewable energy sources.

Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy [22] has started to take positive results and wind plants' installed capacity jumped threefold and geothermal power plants' installed capacity jumped twofold in 2008 compared to previous year. Total electricity generation increased 2.5 times to reach 1.8 billion kWh. This production met the 11 percent of electricity production increase in 2008. Thereby, share of wind and geothermal electricity in total electricity production has reached almost 1 percent by increasing twofold with respect to previous year [20].

Due to high electricity demand of Turkey, new electricity supply facilities are needed. State and private initiatives know this issue and they act to solve this deficiency. For this objective, these initiatives prepared the power plants projects concept and applications to EMRA for obtaining licensed. This license information about the progress on realization of the projects is available in EMRA web address [11].

3.3. Electricity Supply of Turkey

Electricity generation has been increasing sharply since 1970s. It reached to 197,389 GWh as of 2008. The amount of generated electricity based on the fuel type is presented in Figure 3.1.

Lignite, hard coal, hydro and natural gas are the primary energy sources to generate electricity. The amounts of non-hydro renewable, oil derivatives (naphtha, LPG and diesel) are negligible. The amount of fuel oil contribution is almost same since 1970's.

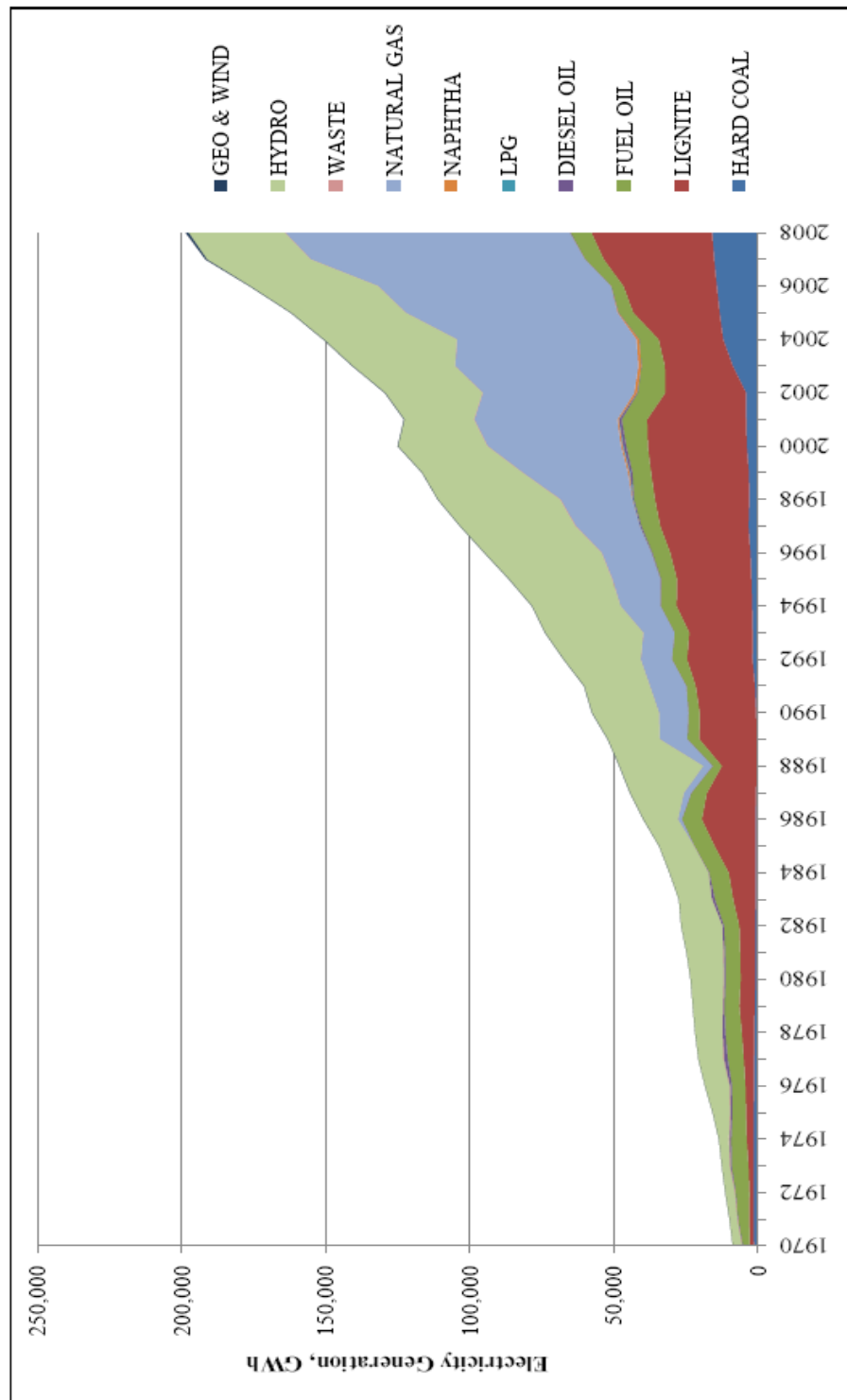


Figure 3.1. Amount of Electricity Generated (GWh) Based on Fuel Type, 1970 – 2008 [23]

The percentage distributions of electricity generated based on fuel type between 1970 and 2008 are presented in Figure 3.2. As seen here, the share of natural gas has been increasing since mid 1980s and it has the highest share of almost 50% in 2008 among other fuels.

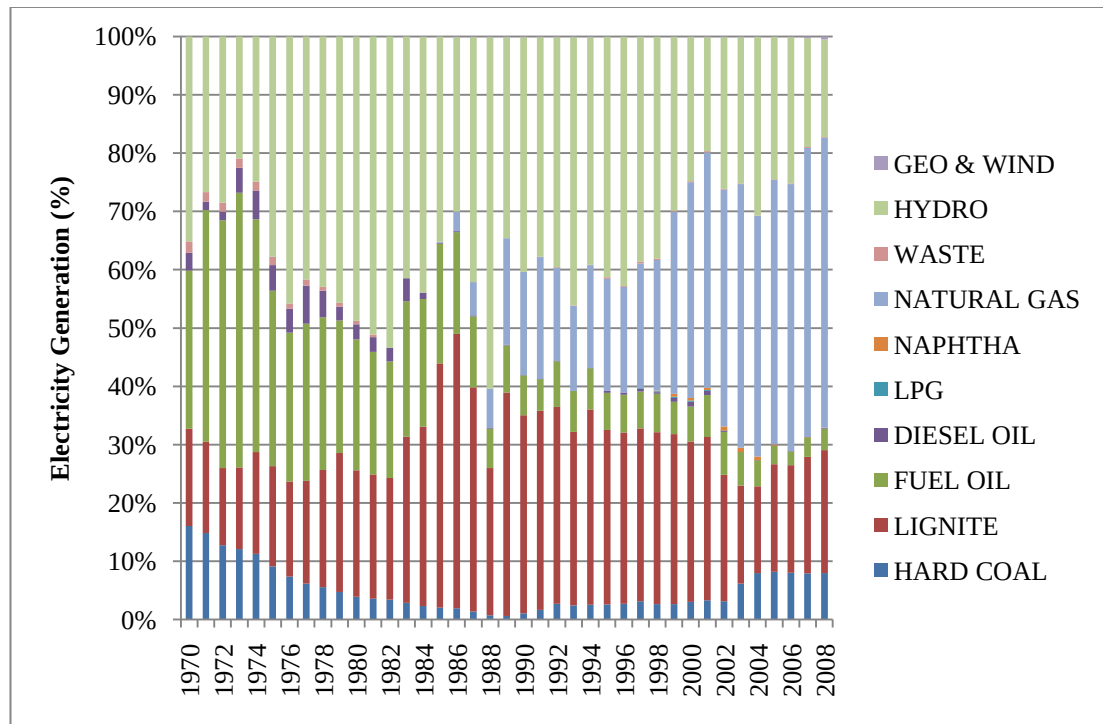


Figure 3.2. Percentage Distributions of Total Electricity Generated by Fuel Type, 1970-2008 [23]

In Turkey, majority of the electricity is generated from the thermal and hydro power plants. Figure 3.3 presents the percentage of electricity generated from thermal and renewable power plants. As seen from this figure, the share of renewable in 1987 and 1988 had increased dramatically. This was mainly due to the fact that the precipitation amounts in these years were higher than expected and thus resulted in higher generation of electricity from hydro power plants [24, 25]. As of 2008 more than 80 % of the generated electricity originated from thermal power plants.

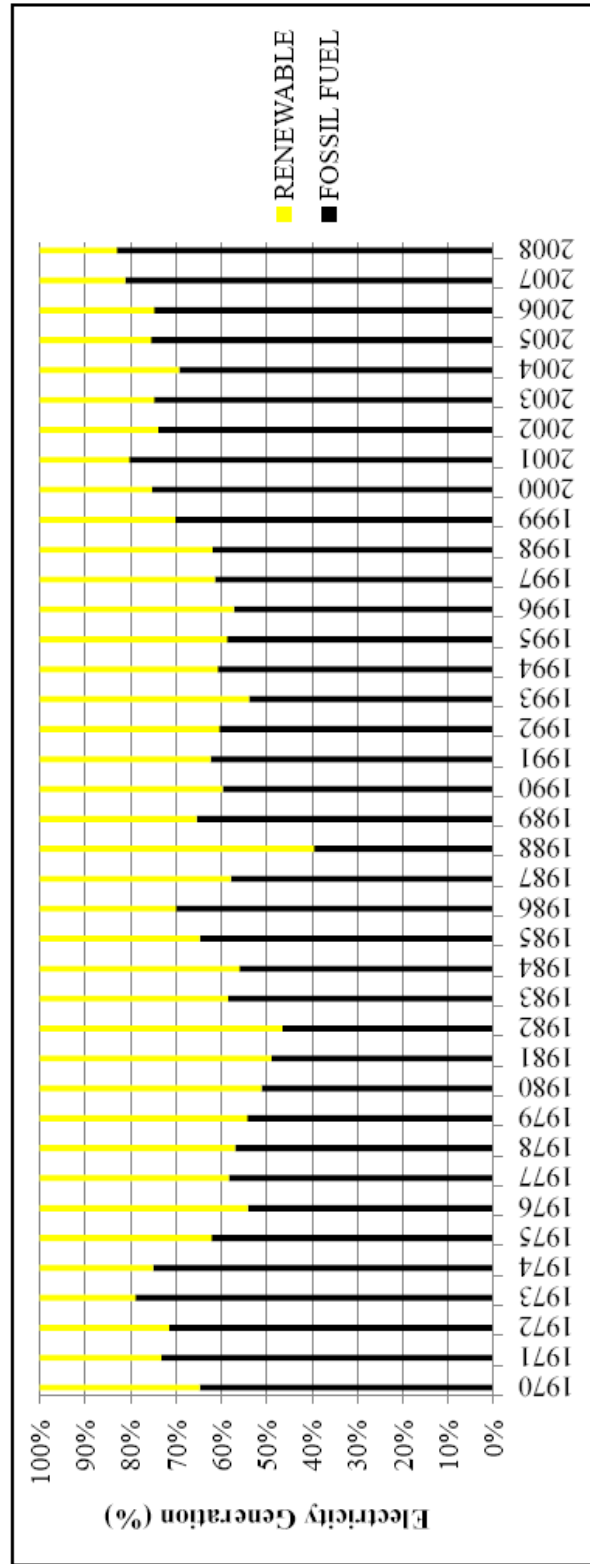


Figure 3.3. Percentage Distributions of Total Electricity Generated by Renewable and Fossil Fuel, 1970-2008 [23]

According to installed electricity capacity of Turkey data thermal power plants capacity has been increasing between 2001 and 2008 as seen in Table 3.1 [23]. The total installed capacity also has increased to supply the electricity demand. The thermal power plants installed capacity ratio increased from 59 % to 66 % between 2001 and 2008. The hydro power installed capacity decreased from 41 % to 33 % for the same period. The geothermal and wind capacity are very small compared to the thermal and hydro capacity.

Table 3.1. Electricity Generation Installed Capacity of Turkey (MW) [23]

Year	Thermal		Hydro		Geothermal + Wind		Total
	MW	%	MW	%	MW	%	MW
2001	16,623	59%	11,673	41%	36	0.13%	28,332
2002	19,569	62%	12,240	38%	36	0.11%	31,846
2003	22,974	65%	12,579	35%	34	0.10%	35,587
2004	24,145	66%	12,645	34%	34	0.09%	36,824
2005	25,902	67%	12,906	33%	35	0.09%	38,844
2006	27,420	68%	13,063	32%	82	0.20%	40,565
2007	27,272	67%	13,395	33%	169	0.41%	40,836
2008	27,595	66%	13,829	33%	394	0.94%	41,817

The amount of electricity generated by fuel type between 2001 and 2008 are calculated using the data obtained from NLDC [8] and presented in Table 3.2. As seen here, the generation electricity increased 62 % between 2001 and 2008. The primary energy supply with the highest share is natural gas and as of 2008 its share is 49%. Wind, geothermal, diesel, waste and LPG have very small portions for electricity generations.

Table 3.2. Fuel Types of Generated Electricity, 2001-2008, GWh [8]

	2001	2002	2003	2004	2005	2006	2007	2008
Fuel oil	8,577	8,680	7,363	6,697	6,651	5,656	8,581	8,595
NG	50,645	54,301	65,471	63,767	73,491	80,219	93,570	96,869
Diesel	1,103	356	0	3	0	21	12	493
Coal	7,968	7,872	10,999	13,878	14,671	17,176	18,184	19,556
Lignite	29,034	22,824	19,668	18,977	26,538	27,154	33,037	36,399
LPG	166	171	167	21	226	170	252	530
Naphtha	327	575	521	593	658	636	582	670
MWG	30	29	33	33	11	126	112	466
Fossil Fuel	97,850	94,807	104,221	103,970	122,247	131,157	154,329	163,578
Wind	64	48	61	54	57	188	359	843
Geo	90	105	88	93	94	94	96	162
Hydro	24,307	33,659	35,546	46,284	39,835	44,856	35,662	33,256
Renewable	24,461	33,811	35,695	46,431	39,986	45,138	36,117	34,261
Total	122,311	128,619	139,916	150,588	162,333	176,295	190,446	197,839

3.4. Thermal Power Plants of Turkey

Turkey's thermal power plants can be classified into two main groups. The first group is "*state-owned power plants*" that are named as public power plants owned by Electricity Generation Incorporated Company (EGIC). The second group is "*private power plants*" that produce electricity, connect to the network directly and sell generated electricity to the national electricity network and grid.

Turkish electricity industry had been dominated by large, publicly owned and vertically integrated companies in previous years, but the situation is changing. In the past, the major player was the Turkish Electricity Authority (TEA), which was established in 1970 and had a statutory monopoly until 1984. Starting in 1984, the private sector was able to participate in generation, transmission and distribution through three different modes, namely Build-Operate-Transfer (BOT), Build-Own-Operate (BOO) and Transfer of Operating Rights (TOOR) [19].

Following recent market liberalization, these modes were abolished but legal obligations arising from them had to be taken into account in market reform [19].

3.4.1. Public Thermal Power Plants

The state-owned company, EGIC, has taken up the responsibility of power plants which are not transferred to private companies. Additionally, it carries on as being sole owner of power plants whose operating rights have been transferred to private companies. In terms of supply security and other reasons, provided that approved by authorized entities, this company is going to build new power plants and operate them. This company has also taken up the responsibility of the operation of the hydraulic power plants constructed by Directorate-General of State Hydraulic Works (SHW) [26].

As of 2009, public companies has 12,788 MW thermal power plants capacity, 11,456 MW renewable (hydro, geothermal and wind) power plants capacity and 24,244 MW total capacity as given in Table 3.3.

3.4.2. Private Thermal Power Plants

Private power plants are the plants that produce electricity, connect to the network directly and sell generated electricity to distribution companies or TETAŞ. Majority of these plants use natural gas as fuel for generating electricity

An autoproducer of electricity is an enterprise that, in support of its primary activity, generates electricity for its own use or for sale, but selling electricity is not its main business. Main activity producers were previously referred to as “Public” electricity and heat suppliers, although, as with autoproducer, they might be publicly or privately owned.

As of 2008, private companies has 14,807 MW thermal power plants capacity and 2,766 MW renewable (hydro, geothermal and wind) power plants capacity and 17,574 MW total capacity as given in Table 3.3.

Table 3.3. Total Power Plants Install Capacity as of 2008 [23]

OWNER	TYPE	INSTALL CAPACITY, MW
PUBLIC	THERMAL	12,788
	HYDRO+GEOTHERM.+WIND	11,456
	TOTAL	24,244
PRIVATE	THERMAL	14,807
	HYDRO+GEOTHERM.+WIND	2,766
	TOTAL	17,574
TOTAL	THERMAL	27,595
	HYDRO+GEOTHERM.+WIND	14,222
	TOTAL	41,817

3.5. Closing Remarks

This chapter presents the changes in the energy policies of Turkey since 2000 and gives statements from official reports how and when this changes took place and how these changes affected the energy policies. The chapter also presents the electricity generation structure of Turkey in terms of primary energy usage, install and generation capacities and owners. According to the official data, Turkey's electricity demand has been increasing rapidly and also electricity generation capacity. The installed capacity of thermal and renewable power plants depend on different primary energy sources such as lignite, coal, fuel oil, diesel, LPG as fossil fuel and hydro, wind and geothermal as renewable. The shares of renewable power plants were the lowest value in last two years. Thus, the Turkish electricity has a highly fossil dependent generation structure nearly 80%.

The total installed capacity as of 2008 is almost 42,000 MW and publicly owned power plants have more than 24,000 MW of installed capacity (about 60% of the total). The shares of installed capacity of thermal and renewable power plants of publicly owned ones are nearly the same. The share of installed capacity of thermal power plants of private companies is 85% and the renewable is 15% as of 2008.

CHAPTER 4

DATA

4.1. Overview

This chapter consists of two sections. The first section is about the power plant data used to calculate the amount of electricity generated and associated CO₂ emission. This section has four sub-sections. The first sub-section presents information on the thermal power plant data between 2001 and 2008 in the daily, monthly and annually forms. The second sub-section presents data on the licensed and planned power plants, and their properties, such as installed and generation capacity, fuel type, realization ratio, *etc.* The third sub-section presents the economically renewable potential of Turkey for generation of electricity. And the electricity demand of Turkey between 2009 and 2019 is presented in the last sub-section.

4.2. Thermal power plants data

Daily and monthly thermal power plants data between 2001 and 2008 was obtained from National Load Distribution Center (NLDC) of TETC in the form of MS Excel spreadsheets [8]. The original data included eight files for the years between 2001 and 2008. In these files there were 12 MS Excel spreadsheets representing the months of each year. There were ten - twelve sheets in these spreadsheets. These sheets contain daily data on:

- Public thermal power plants with consumed fuels and generated electricity,
- Public hydro power plants with generated electricity

- Private and Build – Operate – Transfer thermal power plants with generated electricity and consumed fuels (some of them)
- Private and Build – Operate – Transfer hydro power plants with generated electricity,
- Small and medium private hydropower plants with only generated electricity,
- Small and medium private thermal power plants with only generated electricity,
- Turkey's total generated electricity.

To calculate electricity generation associated CO₂ emissions for each thermal power plant, generated electricity and consumed fuels data are needed. MS excel sheets in the daily forms are cumulated to obtain monthly and annually data. For example 16 public, 5 liberalized, and 308 private thermal power plants generated electricity and consumed fuels (for some of them) data in 2008 are used in this thesis. For each thermal power plant, 12 MS excel sheets for each year are analyzed. For only 2008, 3948 excel sheets are classified in terms of fuel type, generated electricity and consumed fuels. Between 2001 and 2008, approximately 35,000 excel sheets are used to calculate total generated electricity and associated CO₂ emissions and in sheets with thermal power plant data, generated electricity and consumed fuels amounts for public power plants were listed. There are 16 public thermal power plants as of 2008.

Table 4.1 presents daily electricity generation and consumed fuel amounts of *CATES – B* public thermal power plants in December 2008, as an example. Generated electricity (MWh) and consumed fuel (tons) data are used to calculate CO₂ emissions and fuel specific emission factors, respectively. As seen from this table, *CATES – B* used three different fuels to generate electricity. Lignite is the main fuel, fuel oil and diesel are the secondary fuels.

Table 4.1. Daily Electricity Generation and Consumed Fuel Amounts of a Public Power Plant (*CATES –B*) in December 2008 [8]

	Generation, MWh	Consumed Fuel (tons)		
DAYS		Lignite	Fuel Oil	Diesel
1	5,445	4,829	143	0
2	5,322	4,729	137	0
3	5,337	4,746	125	0
4	5,649	5,020	118	0
5	4,971	4,457	116	0
6	2,517	2,352	81	0
7	2,424	2,332	77	0
8	2,637	2,525	88	0
9	2,157	2,091	95	0
10	2,535	2,431	89	0
11	2,787	2,659	72	0
12	2,808	2,678	67	0
13	2,667	2,551	65	0
14	2,829	2,697	78	0
15	4,155	3,877	189	0
16	3,360	3,078	51	0
17	4,194	3,929	111	0
18	5,637	5,176	110	0
19	6,120	5,611	95	0
20	6,294	5,765	77	0
21	6,081	5,576	68	0
22	5,157	5,533	126	0
23	4,971	4,981	146	0
24	5,274	4,630	129	0
25	5,133	4,951	137	0
26	4,974	5,071	185	0
27	5,475	5,101	163	0
28	5,673	5,430	141	0
29	5,604	5,450	125	0
30	5,316	5,070	142	0
31	5,511	4,980	133	0
TOTAL	139,014	130,306	3,479	0

Between 2001 and 2008, daily data of generated electricity and consumed fuel (where available) amount for each of thermal power plants are cumulated to monthly. Table 4.2 gives the monthly data of *CATES-B* thermal power plants in 2008.

Table 4.2. Monthly Electricity Generation and Consumed Fuel Amounts of a Public Power Plant (*CATES –B*) in 2008 [8]

MONTHS	Generation, MWh	Consumed Fuel (tons)		
		Lignite	Fuel Oil	Diesel
January	175,884	148,521	3,957	3
February	176,709	151,853	3,243	0
March	177,774	152,647	3,083	0
April	93,432	83,142	2,009	0
May	86,178	74,346	1,993	20
June	181,050	155,794	2,710	0
July	188,049	162,054	3,105	0
August	180,706	156,080	2,803	1
September	166,134	143,279	3,151	0
October	149,721	129,753	3,472	0
November	167,829	150,699	3,015	0
December	139,014	130,306	3,479	0
TOTAL	1,882,480	1,638,474	36,020	24

Generated electricity and consumed fuel data are also available for some big private companies such as *Kemerköy* as given in Table 4.3. Like *Kemerköy*, there are six other private thermal power plants as of 2008. Their consumed fuels and generated electricity data between 2001 and 2008 are analyzed in this study.

Table 4.3. Daily Electricity Generation and Consumed Fuel Amounts of Private Affiliated Partnerships of EGIC (*Kemerköy*) in December 2008 [8]

	Generation, MWh	Consumed Fuels (tons)	
DAYS		Lignite	Fuel Oil
1	7,960	11,739	103
2	9,810	12,508	44
3	12,160	16,905	7
4	12,230	18,138	2
5	12,040	15,364	2
6	8,100	12,400	0
7	8,180	12,671	0
8	8,180	9,867	0
9	8,090	9,068	0
10	7,910	10,639	15
11	8,080	10,904	1
12	8,360	13,289	0
13	8,470	10,387	0
14	8,400	9,842	0
15	8,220	10,869	0
16	8,220	11,712	0
17	8,230	11,670	6
18	8,100	11,699	1
19	7,830	10,213	8
20	3,810	4,796	0
21	6,780	9,152	38
22	8,030	11,637	3
23	8,040	11,254	4
24	7,790	10,516	63
25	8,110	11,106	3
26	8,120	11,270	11
27	8,090	11,941	1
28	8,080	11,297	12
29	8,000	12,569	15
30	10,180	17,483	73
31	12,200	18,490	0
TOTAL	265,800	371,395	412

There is only electricity generation data for the majority of private thermal power plants. In total, there are more than 300 private power plants as of 2008. There is no data about the amount of fuel consumed by these private plants. To find their fuel consumptions, fuel type, typical technology and thermal efficiency of each thermal power plant are investigated firstly. After that, according to thermal efficiency and generated electricity data are used to find the fuel consumption of each thermal power plant. Table 4.4 presents five private thermal power plants' generated electricity data for December 2008 as an example.

Table 4.4. Daily Electricity Generation (MWh) of Some Private Thermal Power Plants in December 2008 [8]

DAYS	Private-A	Private -B	Private -C	Private -D	Private -E
1	74	160	76	70	10
2	73	158	71	80	9
3	72	137	71	79	8
4	71	124	71	80	7
5	72	153	71	80	7
6	71	155	71	79	7
7	26	157	0	0	0
8	0	160	0	0	0
9	0	165	0	0	0
10	13	167	0	0	0
11	0	165	0	0	0
12	74	162	57	0	0
13	76	160	57	0	0
14	76	162	0	0	0
15	59	161	71	70	9
16	78	101	71	82	0
17	77	162	66	81	0
18	76	161	71	26	0
19	75	160	71	26	0
20	77	162	71	26	0
21	76	158	0	0	0
22	79	165	70	27	0
23	79	167	71	27	9
24	79	167	71	28	10
25	79	169	71	28	8
26	81	168	71	29	7
27	81	170	71	28	0
28	0	168	0	0	0
29	78	170	71	28	0
30	82	136	71	28	0
31	48	169	33	0	0
TOTAL	1902	4899	1566	1002	91

For each year, 12 excel sheets are summed to obtain annually generated electricity data for 300 private thermal power plants. Five private thermal power plants data are for 2008 given in Table 4.5 as an example

Table 4.5. Monthly Electricity Generation (MWh) of Some Private Thermal Power Plants in 2008 [8]

MONTHS	Private-A	Private -B	Private -C	Private -D	Private -E
January	3,175	4,417	3,321	2,119	910
February	2,981	4,185	2,592	1,944	496
March	2,822	4,827	2,383	1,773	859
April	2,776	4,345	2,495	1,525	785
May	2,891	4,282	2,839	1,976	859
June	2,696	4,057	2,457	1,807	568
July	2,863	4,083	2,841	1,964	1,176
August	2,692	4,456	2,107	1,524	601
September	2,519	4,533	2,088	1,584	687
October	2,611	4,818	1,710	1,728	642
November	2,235	4,630	1,909	1,944	489
December	1,902	4,899	1,566	1,002	91
TOTAL	32,163	53,532	28,308	20,890	8,163

After all thermal power plants data are analyzed and summed with hydro and wind power plants data, total electricity generation of Turkey are obtained. Table 4.6 presents daily generated electricity data in terms of primary energy sources for 2008.

Table 4.6. Daily Electricity Generation (MWh) in Turkey in December 2008 [8]

DAYS	THERMAL	HYDRO	WIND	TOTAL
1	454,800	69,455	2,517	526,772
2	467,497	69,946	3,392	540,835
3	458,696	75,835	3,007	537,538
4	459,386	75,316	4,543	539,245
5	464,246	61,385	6,580	532,211
6	442,429	45,465	2,948	490,842
7	377,373	31,845	2,194	411,412
8	339,287	16,394	1,707	357,388
9	334,405	29,002	1,752	365,159
10	343,625	29,313	468	373,406
11	349,465	39,080	1,391	389,936
12	380,811	72,596	2,081	455,488
13	399,808	65,328	1,673	466,809
14	402,311	50,497	910	453,718
15	447,764	76,086	2,346	526,196
16	460,563	85,381	1,612	547,556
17	463,860	86,295	736	550,891
18	465,847	84,155	3,760	553,762
19	475,857	64,419	3,533	543,809
20	462,828	66,867	1,992	531,687
21	450,019	33,189	3,255	486,463
22	464,198	75,580	7,956	547,734
23	473,794	81,255	4,366	559,415
24	477,992	85,279	5,144	568,415
25	484,939	76,324	1,058	562,321
26	488,174	80,817	2,189	571,180
27	481,466	67,062	4,881	553,409
28	464,508	35,354	6,106	505,968
29	482,927	77,544	6,083	566,554
30	497,413	72,269	6,143	575,825
31	498,249	56,840	3,131	558,220
TOTAL	13,714,537	1,936,173	99,454	15,750,164

Finally, 12 excel sheets are brought into together to obtain monthly and annually generated electricity data. Data from January to December 2008 are presented in Table 4.7. The total value gives the Turkey's total electricity generation in 2008. All these calculations and analyzes are repeated for the remaining years between 2001 and 2007.

Table 4.7. Monthly Electricity Generation (MWh) in Turkey in 2008 [8]

MONTHS	Thermal	Hydro	Wind	Total
January	14,008,221	3,825,349	33,451	17,867,021
February	13,662,120	2,755,758	39,614	16,457,492
March	13,200,682	3,091,683	54,425	16,346,790
April	12,151,030	3,472,361	43,349	15,666,740
May	13,046,476	3,131,999	35,276	16,213,751
June	13,576,415	2,902,854	57,143	16,536,412
July	14,681,073	3,514,258	83,174	18,278,505
August	15,010,412	3,298,288	114,580	18,423,280
September	14,005,984	1,967,320	74,858	16,048,162
October	13,283,819	1,450,790	99,973	14,834,582
November	13,383,133	1,869,752	81,378	15,334,263
December	13,714,537	1,936,173	99,454	15,750,164
TOTAL	163,723,902	33,216,585	816,675	197,757,162

4.3. Licensed and planned power plants

License information for power plants projects were taken from EMRA's web site [11]. The web site included detail information about the licensed power plants in terms of company name, plants name, location of plants, types of fuel in the plants, license number, data of license, licensed capacity (MWm), average licensed generation (kWh / year), built capacity (MWm) and realization ratio (%). As of January 2009, there are 565 licensed power plants information on EMRA's web site and some of them listed in Table 4.8.

Table 4.8. Some Licensed Power Plants in Turkey [11]

Company Name	Plant Name	Location	Fuel Type	License No	Install Capacity	Generation (kWh/yr)	Built Capacity (MW)	Realization Ratio (%)
Yeşilbaş Elektrik Üretim Ltd.Şti.	Yeşil Regülatörü ve HES	Sivas	Hidrolik	EÜ/944-1/730	14.7	56,160,000	14.7	86.0
Alize Enerji Elektrik Üretim A.Ş.	Çamseli	Çanakkale	Rüzgâr	EÜ/1167-1/834	20.8	81,800,000	20.8	86.3
YPM Elektrik Üretim A.Ş.	Suşehri HES	Sivas	Hidrolik	EÜ/416-1/507	19.1	109,950,000	7.4	86.5
Rotor Elektrik Üretim A.Ş.	Osmaniye	Osmaniye	Rüzgâr	EÜ/255-6/391	135.0	510,000,000	135.0	89.2
Yurt Enerji Üretim Sanayi	Tocak I HES	Antalya	Hidrolik	EÜ/1280-2/919	4.1	13,160,000	4.1	90.1
Çamlıkaya Enerji Üretim	Çamlıkaya HES	Trabzon	Hidrolik	EÜ/551-3/572	8.1	27,200,000	8.1	90.6
Bayobası Enerji Üretimi A.Ş.	Sırma HES	Aydın	Hidrolik	EÜ/1245-5/896	6.7	23,230,000	6.7	90.7
Gürmat Elektrik Üretim A.Ş.	Germencik	Aydın	Jeotermal	EÜ/308-2/423	47.4	312,497,280	47.4	92.0
Yıldızlar Enerji Elektrik Üretim A.Ş.	Kulp-I HES	Diyarbakır	Hidrolik	EÜ/376-2/485	23.6	78,239,000	23.6	93.3
Yıldızlar Enerji Elektrik Üretim A.Ş.	Kulp-IV HES	Diyarbakır	Hidrolik	EÜ/376-3/486	12.7	39,318,000	12.7	93.3
Güvenen Enerji Elektrik Üretim A.Ş.	Çataloluk HES	Kahramanmaraş	Hidrolik	EÜ/490-2/548	9.2	30,777,000	9.2	96.4
Karadeniz Elektrik Üretim Sanayi A.Ş.	Uzundere I HES	Rize	Hidrolik	EÜ/902-4/710	43.7	164,571,000	43.7	96.5
Bereket Enerji Üretim A.Ş.	Koyulhisar HES	Sivas	Hidrolik	EÜ/434-1/512	43.5	329,400,000	43.5	96.9
Ak Gıda Sanayi ve Ticaret A.Ş.	Ak Gıda Kogen Santrali	Sakarya	Doğal Gaz	EO/1280-1/918	7.5	61,000,000	7.5	98.4
Çelikler Taahhüt İnşaat ve Sanayi A.Ş.	Ankara Oteli Cogeneration Santrali	Ankara	Doğal Gaz	EO/1406-1/1027	2.1	16,000,000	2.1	98.7
Ken Kıpaz Elektrik Üretim A.Ş.	Ken Kıpaz Santrali	Kahramanmaraş	Fuel Oil	EÜ/1613-9/1173	43.0	180,000,000	43.0	98.7

Fuel types (primary energy supply), generation amount and realization ratio data are the crucial information for the study since they are used for estimating of electricity supply and associated CO₂ emissions. Table 4.9 presents the licensed power plants according to their primary energy supply.

Table 4.9 presents the number of the licensed power plants, their capacities and their average electricity generation amounts. According to this table, hard coal, hydro, natural gas and wind power plants have large projected installed capacity. In terms of number of plants, the leading plant is the hydro power plants with 408 plants out of 565 power plants.

Table 4.9. Features of Licensed Power Plants as of January 2009

	Number of Planned Power Plants	Installed capacity, MW	Avg. Generation, GWh
Asphaltite	1	413	2,916
Biogas	6	13	100
Biomass	2	7	49
Landfill gas	2	22	170
Other coal	12	6,947	47,694
Other thermal	2	18	112
Natural gas	33	5,207	39,334
Fuel oil	2	87	565
Hydro	408	11,706	42,196
Geo	3	64	445
Lignite	9	1,460	7,595
Wind	83	3,104	10,978
Hard coal	2	1,168	8,050
Total	565	30,216	160,204

Although progress report related to licensed projects are very comprehensive, this report does not provide information on the completion times of the projects. For this reason, the completion times of the projects are estimated according to their realization ratio as explained in detail in Section 5.4.1.

4.4. Renewable Energy Potential of Turkey

The use of renewable energy sources is a vital step in the mitigation of CO₂ emissions. Realistic estimates should be obtained on the renewable energy source potential that then be used as an alternative to conventional fossil fuel based energy production in Turkey. Assessment of potentials of different forms of renewable energy is beyond the scope of this study, and such assessments were performed by expert government organizations in the country. Due to this reason, best available potential estimates were obtained from relevant government organizations and were used in this study. A brief discussion on national potentials of wind, biomass, geothermal and hydro energies are presented in this sub-section.

Wind Energy

Up to now, a number of studies were carried out by universities on the subject of the wind energy potential of Turkey. In a study in 1993, performed within the scope of OECD countries, the University of Utrecht defined the technical wind potential of Turkey as 80,000 MW [27].

Furthermore, by utilization of satellite data in projects IRESMED (Integration of Renewable Energies into Electricity Network) and MED 2010, performed by the General Directorate of the EPSA in cooperation with the European Union (EU), wind potential in western region of Turkey was also determined through KAMM model by RISOE (Risoe National Laboratory in Denmark) and results were compared with the point measurements performed by the “EPSA” [27].

EPSA in cooperation with the State Meteorological Affairs (SMA) assessing the data on wind provided by the meteorological stations through the program “WASP” prepared the “*Wind Atlas of Turkey*” in 2002 which can be seen in Figure 4.1. The atlas provides distribution of wind energy in Turkey. It can be observed from this atlas that the regions of the Aegean, Marmara and Eastern Mediterranean possess high potentials when the wind potential is studies at heights of 50 m from the ground.

Based on these data it can be stated that under present technical conditions, the wind energy technical potentials of Turkey is about 88,000 MW, while the economic potential is about 10,000 MW [28].

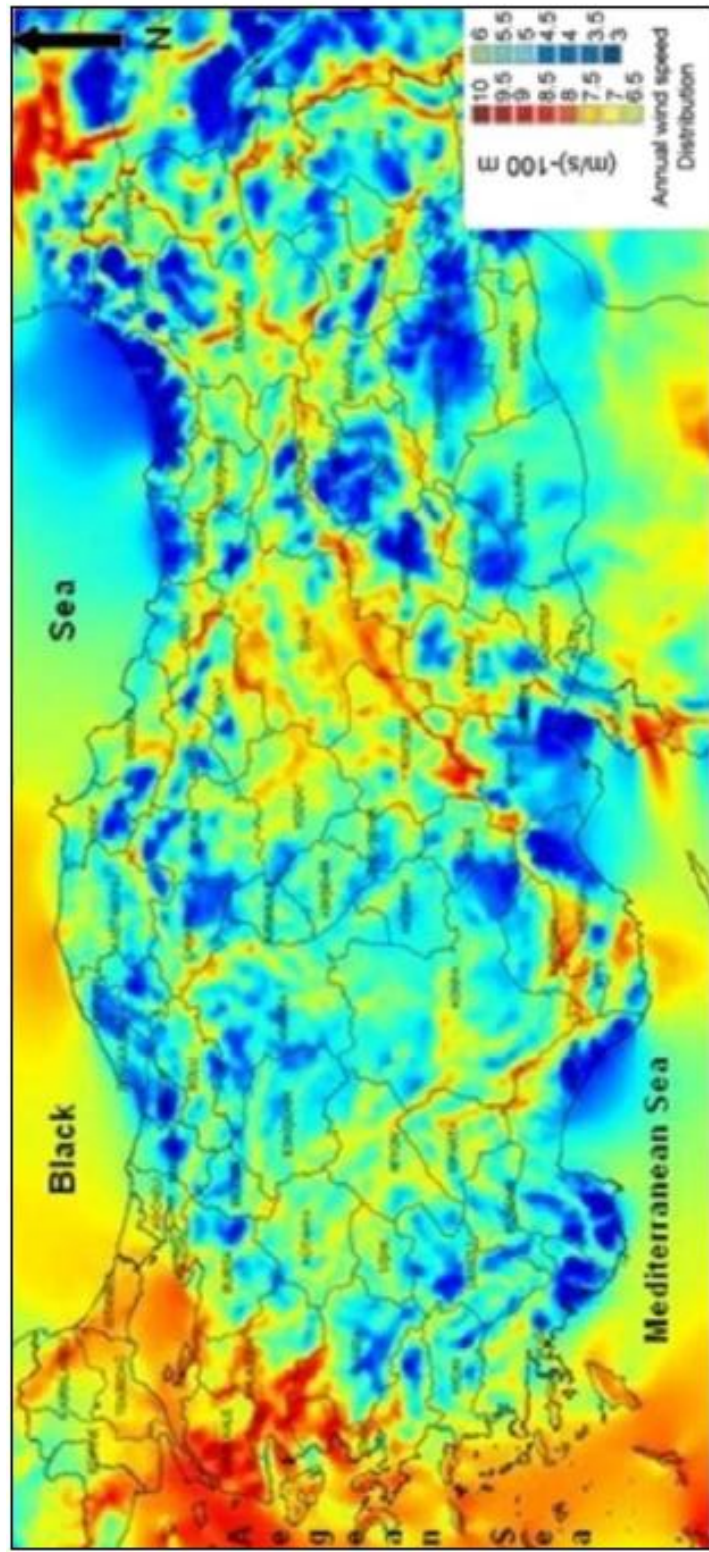


Figure 4.1. Wind Atlas of Turkey [29]

According to the pre-studies about potential of wind energy, MENR predicted 230,000 GWh/year of technical potential and 26,000 GWh/year economical potential [30].

Biomass Energy

In Turkey, there is a use of conventional biomass in form of wood and dried dung; however, modern biomass use is limited related to energy crops [29]. In Turkey, biomass has great potential to provide improved rural energy services based on forest and agricultural residues. Various agricultural residues such as grain dust, wheat straw, and hazelnut shell are economical energy sources that are available in Turkey [31].

Table 4.10 presents the agricultural biomass potential for energy of Turkey in terms of ktoe. As seen here, 13,270 ktoe is the total energy potential. It equals to 154,330 GWh primary energy input for any power facilities. For 30 % thermal efficiency of any thermal power plants, this gross potential equals to gross theoretical electrical potential as 46,300 GWh. The economically viable potential for biomass is assumed as 25 % of the gross theoretical electrical potential. This potential is found as 11,575 GWh (see Table 4.14).

Table 4.10. Agricultural Biomass Potential of Turkey, ktoe [31]

Dry agricultural residue	4,560
Firewood	4,160
Forestry and wood processing residues	4,300
Moist agricultural residue	250
Total	13,270

Geothermal Energy

Presently, there are 172 geothermal locations in Turkey as seen in Figure 4.2. Geothermal electricity production is based on the usage of drilled liquid at 100-200 °C. The total heat potential of Turkey is 31,500 MWt. This potential is equal to heating of 5 million equal housing [28]

The electricity generation potential of geothermal energy is estimated by the MENR to be 2,000 MWe (16,000 GWh/year) [30]. The existing installed capacity of geothermal power plants is presented in Table 4.11.

Table 4.11: Status of Geothermal Power Plants in Turkey [32]

Geothermal Field	Installed Capacity, Mwe	Status
Denizli-Kızıldere	15	In Operation
Aydın-Sultanhisar, (Dora-1)	7.95	In Operation
Aydın-Sultanhisar, (Dora-2)	9.5	Under Construction
Aydın-Germencik	47.4	In Operation
Çanakkale-Tuzla	7.5	Under Construction
Denizli-Kızıldere	6.85	In Operation

While the geothermal electricity production target of Turkey for 2013 is envisaged as 550 MWe (4,000 GWh/year), the total geothermal electricity potential of Turkey is 2,000 MWe on incentive supported condition (16,000 GWh/year) [28].

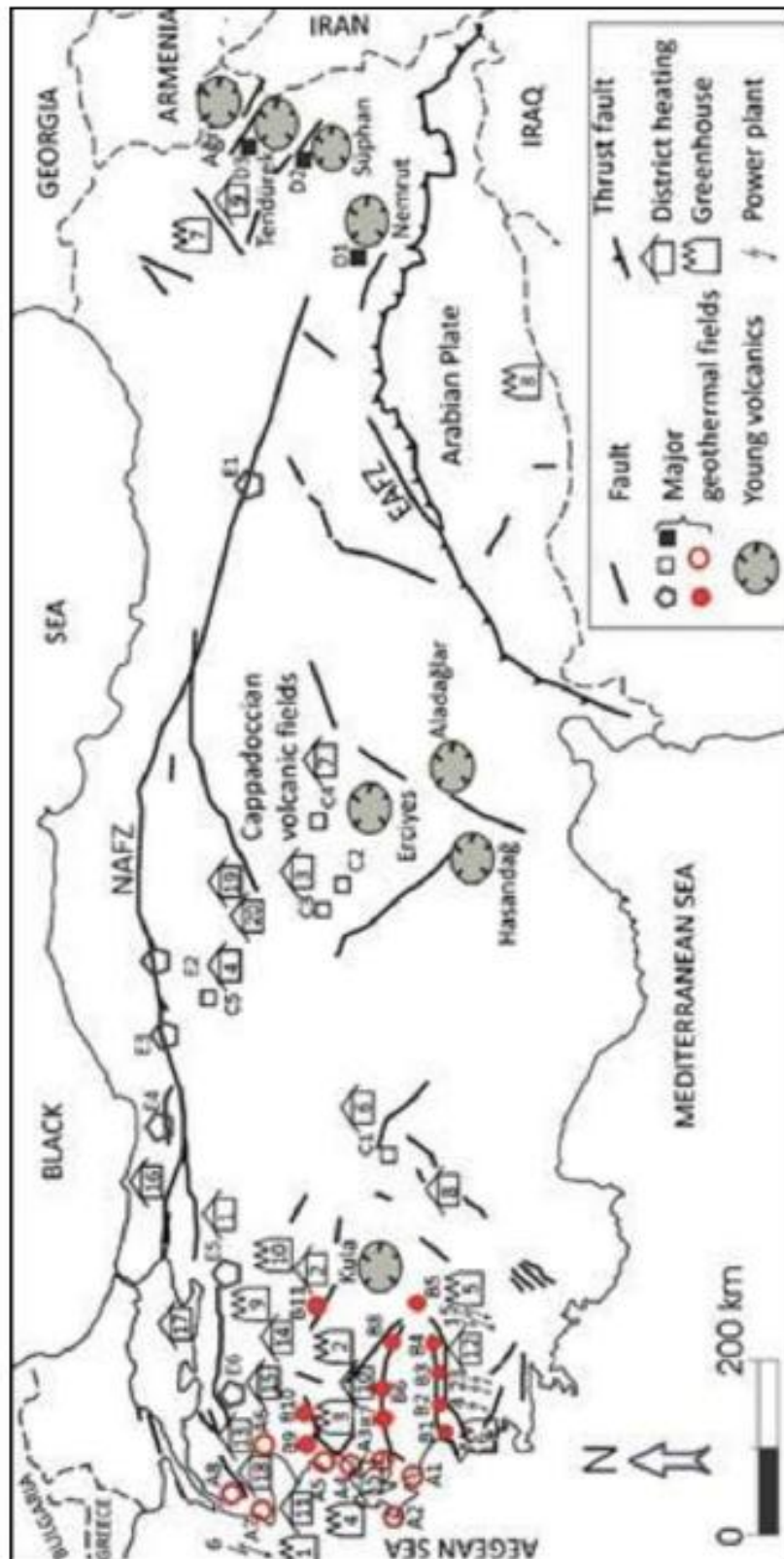


Figure 4.2. Location of Major Geothermal Fields in Turkey [33]

Hydroelectric Energy

The hydroelectric potential of a country is calculated under the presumption that all natural flows, between the country's borders or the sea, will be used with 100% efficiency. This calculation produces the gross theoretical hydroelectric potential of a country. However, even the latest technologies available today cannot make utmost use of this potential. Therefore, the maximum potential that can be used in the existing technologies is referred to as the technically viable hydroelectric potential. Nevertheless, not every technically viable utility is economically viable. Thus, the portion of the technically viable potential that can be realized under the existing and expected local economic conditions is referred to as the economically viable hydroelectric potential. Turkey's theoretical hydroelectric potential is 1% of that of the World and 16% of that of Europe. The gross theoretical viable hydroelectric potential in Turkey is 433 billion kWh and the technically viable potential is 216 billion kWh. The economically viable potential, however, is 127 billion kWh [34].

Table 4.12. Hydroelectric Potential (GWh) of Turkey [34]

Gross Theoretical Potential	Technically Viable Potential	Economically Viable Potential
433,000	216,000	127,381

At present Turkey have 135 hydroelectric power plants in operation with total installed capacity of 12,631 MW generating an average of 45,325 GWh/year, which is 36% of the economically viable hydroelectric potential. Forty-one hydroelectric power plants are currently under construction with 3,187 MW of installed capacity to generate an average annual 10,645 GWh representing 8% of the economically viable potential. In the future, 502 more hydroelectric power plants will be constructed to be able to make maximum use of the remaining 71,411 GWh/year of economically viable potential. As a result of these works, a total of 678 hydroelectric power plants with 36,260 MW will tame rivers to harness the economically viable hydropower of Turkey.

Table 4.13. Status of Economically Viable Potential [34]

	Number of Hydro-electric Plants	Total Installed Capacity(MW)	Average Annual Generation (GWh/year)	%
In Operation	135	12,631	45,325	36
Under Construction	41	3,187	10,645	8
In Program	502	20,442	71,411	56
Total Potential	678	36,260	127,381	100

The overall economically utilizable renewable energy potential of Turkey is given in terms of GWh in Table 4.14. As seen here, hydro owns the biggest share, and then comes the wind power.

Table 4.14. Overall Economically Utilizable Renewable Energy Potential of Turkey, GWh

Renewable Energy Form	Potential (GWh)	References
Hydro	127,381	[34]
Geothermal	16,000	[30]
Wind	26,000	[30]
Biomass	11,575	Author

4.5. Electricity Demand Data for Turkey

Electricity demand data of Turkey was estimated by TETC up to 2018. The report which is called as “*Turkish Electrical Energy 10-Year Generation Capacity Projection (2009 – 2018)*” presents Turkish electricity demand annually [10]. However, the mentioned report projections are only up to 2018. Since one more year was needed for the study; trend analysis was calculated up to 2019 in this thesis study as seen in Table 4.15. The main assumption in this trend analysis is that as the trend in 2019 is the same as the previous years’.

Table 4.15. Electricity Demand of Turkey [10]

Year	ELECTRICITY DEMAND	
	GWh	Rate (%)
2009	194,000	
2010	202,730	4.5
2011	215,907	6.5
2012	232,101	7.5
2013	249,508	7.5
2014	268,221	7.5
2015	288,338	7.5
2016	309,675	7.4
2017	332,591	7.4
2018	357,202	7.4
2019	383,635	7.4

4.6. Closing Remarks

This chapter presents information on the power plant data gathered from NLDC [8]. The data contains information on the amount of the generated electricity from for the public and private power plants in daily, monthly and annually format between 2001 and 2008. The data also present the amount of electricity generated by private companies in daily, monthly and annually format between 2001 and 2008, but not the amount of fuel consumed.

The information on the power plants that will be built in Turkey in the next decade is obtained from EMRA's web site. The progress report on the licensed power plants gives only a basic idea for the completion time of the planned power plants.

The economical potential of renewable energy sources in Turkey is also investigated in this chapter. Turkey has enough renewable energy potential to supply the needed electricity demand.

CHAPTER 5

METHODS FOR CO₂ EMISSION CALCULATION

5.1. Overview

This chapter consists of three sections. The section is on the calculations for the CO₂ emission associated to thermal power plants in Turkey based on IPCC methods. The second section, which is developed to double check the calculated CO₂ emission values, calculates the CO₂ emissions based on elemental analysis method for only coal and lignite power plants. The last section is about the determination of fuel specific emission factors according to IPCC method. All the steps that are followed for CO₂ emission calculations are given in Figure 5.1.

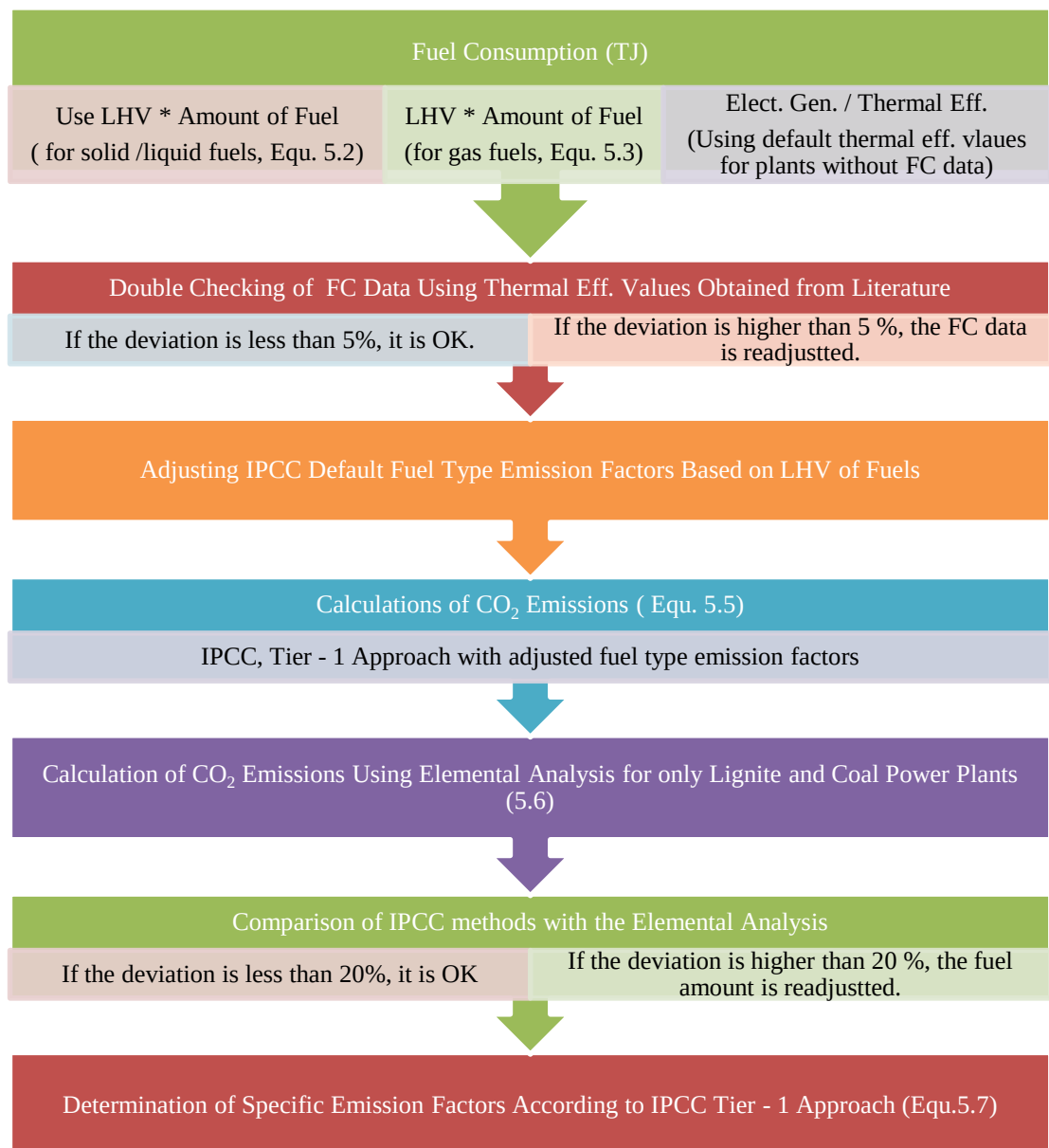


Figure 5.1. Overview of the Methodology Used for CO₂ Calculations

5.2. IPCC Method

IPCC guide for how to calculate emission inventory includes direct GHGs as CO₂ emissions. The emission is different for each activity such as energy industry, manufacture industry, land use and land use change. For this study, the scope is

restricted for thermal power plants emission; thus the energy industry's method is used.

In general, emissions of each greenhouse gas from stationary sources are calculated by multiplying fuel consumptions by the corresponding emission factors. In the sectoral approach, "*Fuel Consumption*" is estimated from energy use statistics and measured in tera joules. Fuel consumption data in mass or volume units must first be converted into the energy content of these fuels [9].

To calculate associated CO₂ emissions of thermal power plants, there are three different approaches in IPCC methods. These approaches required data as listed below.

Tier – 1: fuel combustion from national energy statistics and default emission factors;

Tier – 2: fuel combustion from national energy statistics, together with country-specific emission factors, where possible, derived from national fuel characteristics

Tier – 3: fuel statistics and data on combustion technologies applied together with technology-specific emission factors; this includes the use of models and facility level emission data where available.

In this study, Tier 1 Approach is used since only fuel consumption data was available.

5.2.1. Tier 1 Approach

Applying a Tier 1 emission estimate requires the following for each source category and fuel:

- Data on the amount of fuel combusted in the source category
- A default emission factor

The differentiation point of between countries during the CO₂ emission calculation is fuel consumption. Thus, the accuracy and transparency of the emissions are determined by fuel consumption, in other words country specific fuel low heating values (LHVs) and LHVs associated default emission factors.

Default emission factors were taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [9]. These factors are standard for Tier – 1 approach. UNFCCC invites the party to use this IPCC Guidelines during the preparation of inventories. The default emission factors are listed in Table 5.1 .

Table 5.1. IPCC Default Emission Factors [9]

Fuel	CO ₂ default Emission factors kg CO ₂ /TJ		
	Lower	Average	Upper
MWG	46,200	54,600	66,000
Natural Gas	54,300	56,100	58,300
LPG	61,600	63,100	65,600
Naphta	69,300	73,300	76,300
Diesel	72,600	74,100	74,800
Fuel Oil	75,500	77,400	78,800
Hard coal	89,500	94,600	99,700
Lignite	90,900	101,000	115,000

The equation used for emission calculations is given below:

$$\text{Emissions}_{\text{GHG, fuel}} = \text{Fuel Consumption (FC)}_{\text{fuel}} \times \text{Emission Factor (EF)}_{\text{GHG, fuel}} \quad (5.1)$$

Where:

Emissions_{GHG, fuel}: Emissions of a given GHG by type of fuel (kg GHG)

Fuel Consumption (FC)_{fuel}: Amount of fuel combusted (TJ)

Emission Factor (EF)_{GHG, fuel}: Default emission factor of a given GHG by type of fuel (kg gas/TJ).

To calculate fuel consumption (FC) in Equation 5.1, low heating value (LHV), fuel amount (FA) and fuel type data are used. IPCC default emission factors are taken from IPCC report as given in Table 5.1 and Table 5.3. CO₂ emission factors reflect the full carbon content of the fuel less any nonoxidised fraction of carbon retained in the ash, particulates or soot [9]. For CO₂, carbon oxidation factor is assumed to be 1.

5.3. CO₂ Emission Calculations

To find the total CO₂ emission from the electricity generation and specific emission factor for each thermal power plant, three main steps were implemented.

Step-1: Calculation of Fuel Consumption (FC, TJ)

Primary data on fuel consumption are normally collected in mass or in volume units. Because the carbon content of fuels is generally correlated with the energy content, the energy content of fuels is measured according to LHV of that fuel [9]. Fuel consumption gives the total energy of the fuel that is combusted. Equation 5.2 and 5.3 gives this relationship between fuel consumption, LHV and fuel amount.

(for solid and liquid fuels)

$$FC (TJ) = LHV (kcal/kg) \times FA (tons) \times 4.1868 (J/cal) \times 10^{-6} \quad (5.2)$$

Where:

LHV: Low Heating Value

FA: Fuel Amount

(for gas fuels)

$$FC (TJ) = LHV (kJ/m^3) \times FA (m^3) \times 10^{-6} \quad (5.3)$$

The fuel consumption data is very crucial for accurately calculating CO₂ emissions for fuel used in each thermal power plant. Since the data on private power plants

included only generated electricity, fuel amounts of these plants was estimated based on the data obtained from public power plants with the same fuel. This estimation was based on the thermal efficiency which is the electricity generation / fuel amount ratio as given in Equation 5.4.

$$\text{Thermal Efficiency(\%)} = \text{Electricity Gen. (MWh)} / \text{FC (TJ)} \times 0,0036(\text{TJ/MWh}) \quad (5.4)$$

Unfortunately, thermal efficiency data of a few private power plants were obtained. Since these power plants are similar technically, it was assumed that they have similar thermal efficiencies.

Step-1.1: Double Checking of FC Data Using Thermal Efficiencies

Thermal efficiency of each thermal power plant in Turkey was calculated for 2001 – 2008. The calculation of thermal efficiency is given in Equation 5.4. These numbers are compared with the thermal efficiency data of public and private thermal power plants obtained from the literature as given in Table 5.2.

Table 5.2. Thermal Efficiency of Some Power Plants in Turkey

Thermal Power Plants	Thermal Efficiency (%)	Reference
Park	34.5	[35]
Elbistan	30.1	[35]
Kangal	30.4	[35]
Orhaneli	36.2	[35]
Seyitömer	33	[35]
Tunçbilek	31.5	[35]
Yatağan	32.7	[35]
Kemerköy	33.2	[35]
Soma-A	30.3	[35]
Soma-B	32.4	[35]
Yeniköy	34.8	[35]
Ambarlı FO	37.2	[36]
Hopa	26.3	[36]
Aliağa	33.8	[36]
Ambarlı NG	48.5	[36]
Bursa NG	54.4	[36]
Hamitabat NG	45.8	[36]
Private NG	55-60	[37]
Catalağzı	33.6	[35]
Çan	37	[35]

The comparative assessment was done in the following way. When the calculated thermal efficiency and design efficiency values obtained from literature are close to each other (up to 5 % difference acceptable), the given fuel consumption is accepted to be correct. However, when the difference between design and operation value of the thermal efficiency is greater than 5 %, fuel amount of the related thermal power plant was readjusted in a way that the new calculated efficiency falls near the design one.

Step-2: Adjusting the IPCC Default Emission Factors

In Turkey, the lignite used in *Afşin Elbistan* power plant has the lowest LHV as 950 kcal /kg and the one used in *Park Termik* power plant has the highest LHV as 2,800 kcal /kg. To estimate the default emission factor, LHV pathway was used. This means that the lowest LHV corresponds to the biggest default emission factor and the highest LHV corresponds to the lowest default emission factor. For instance the default emission factor used for the lignite burned in *Afşin Elbistan* power plant is 115,000 kg CO₂ /TJ and the one used for that of *Park Termik* power plant is 90,900 kg CO₂ /TJ. Table 5.3 presents default emission factors according to LHV of each thermal power plant.

Table 5.3. Default Emission Factor of Lignite Thermal Power Plants

Thermal Power Plants	LHV, kcal / kg	Default Emission Factor, kg CO₂ / TJ
AFŞİN ELBİSTAN-A - B	950	115,000
KANGAL	1,300	110,441
SEYİTÖMER	1,500	107,835
KEMERKÖY	1,533	107,405
YENİKÖY	1,750	104,578
YATAĞAN	2,100	100,019
ÇAN	2,340	96,892
ORHANELİ	2,350	96,762
SMPT Lignite	2,400	96,111
SOMA	2,400	96,111
TUTES- A	2,600	93,505
TUTES- B	2,600	93,505
PARK TERMİK	2,800	90,900

Since oil, diesel, natural gas and fuel oil used in thermal power plants have similar LHVs in Turkey with world's average, IPCC average default emission factors given in are used. For the only hard coal thermal power plant, named as CATES, average default emission factor was used during the calculations.

Step-3: Calculation of the CO₂ Emission

Calculation of generated electricity associated CO₂ emission mainly depends on the fuel type. IPCC guidelines give how to calculate the CO₂ emission with known consumed fuel in terms of energy unit and IPCC default emission factors. Due to this factors give the range for all fossil fuels, they could change from country to country. To adjusting these factors Step-2 is applied. In addition to this, the basic approach is used to compare the IPCC method with another. This method is elemental analysis. However, this method is used only for lignite and coal based public power plants due to lack of data.

Step – 3.1: Calculation of CO₂ Emissions According to IPCC Methods

To calculate the total CO₂ emission from each thermal power plant, fuel mix of any thermal power plant such as, lignite, diesel, coal and/or fuel oil, etc. are multiplied with the corresponding IPCC default emissions factors for each fuels types. Thus, the CO₂ emission from each fuel is calculated and summed up to find the total CO₂ emissions from each plant as given in Equation 5.5.

$$\text{CO}_2 \text{ Emissions (tons)} = \sum_{i=1}^n \text{FC (TJ)} \times \sum_{i=1}^n \text{IPCC Default Emission Factor (kg/TJ)} \times 10^{-3} \quad (5.5)$$

where:

i : each fuel type; *n* : number of different fuel type

Step-3.2: Calculation of CO₂ Emissions According to Elemental Analysis Method

The other method for electricity generation associated CO₂ emission is elemental analysis. To apply this method, elemental analyses of lignite/hard coal used in public owned thermal power plants are obtained from EGIC between 2005 and 2007.

In this method the crucial factor is carbon content of the fuel used in power plants.

Table 5.4 presents the elemental analysis of fuel used in some public power plants in terms of percentages for carbon, sulphur, hydrogen, nitrogen, oxygen, ash and humidity. The carbon content of the fuel is the most important component for chemical composition to calculate CO₂ emissions.

Table 5.4. Elemental Analysis of Some Public Thermal Power Plants [38]

TPP		Humidity (%)	Ash (%)	C (%)	H (%)	S (%)	N+O (%)
AFŞİN - ELBİSTAN A	2005	51.55	17.87	17.47	1.15	0.38	11.07
	2006	51.76	18.53	17.97	1.22	0.47	10.57
	2007	51.09	19.23	19.53	1.51	0.56	10.92
AFŞİN - ELBİSTAN B	2005	53.25	16.44	18.52	1.37	0.38	10.03
	2006	51.77	18.07	18.74	1.01	0.30	9.94
	2007	51.21	18.98	16.87	1.39	0.86	10.19
ÇAN	2005	13.07	31.70	37.35	2.57	3.13	12.17
	2006	22.58	27.33	33.52	2.43	1.54	11.00
	2007	19.79	19.79	33.52	2.43	1.54	11.00
KANGAL	2005	50.96	18.78	16.95	1.23	0.36	10.03
	2006	48.12	21.97	17.02	1.14	0.63	8.92
	2007	48.75	20.91	18.23	1.25	0.83	9.75
KEMERKÖY	2005	32.62	42.85	21.72	1.63	0.64	12.54
	2006	31.84	42.61	22.97	1.39	1.01	11.73
	2007	30.62	29.14	24.49	2.21	2.45	11.20
ORHANELİ	2005	30.81	31.28	25.18	1.88	0.79	9.43
	2006	26.04	36.05	25.46	1.65	0.84	8.66
	2007	31.09	31.33	23.00	2.01	0.77	9.19
SEYİTÖMER	2005	33.63	34.76	20.81	1.71	0.60	8.29
	2006	32.95	33.68	26.09	1.90	0.32	9.20
	2007	33.30	22.66	23.52	2.14	0.39	8.77
SOMA A	2005	18.96	25.49	40.08	2.92	0.38	13.04
	2006	20.14	23.18	40.08	2.92	0.38	13.04
	2007	20.26	25.27	40.08	2.92	0.38	13.04
SOMA B	2005	17.34	43.78	32.13	1.49	0.12	14.16
	2006	17.60	41.07	24.73	1.49	0.12	14.16
	2007	18.66	38.47	24.73	1.49	0.12	14.16
TUNÇBİLEK A	2005	21.14	16.57	48.31	3.35	1.92	10.53
	2006	21.50	17.67	48.31	3.35	1.92	10.53
	2007	21.30	12.80	48.31	3.35	1.92	10.53
TUNÇBİLEK B	2005	16.38	42.57	28.89	2.17	0.84	8.50
	2006	15.04	42.09	32.15	2.21	0.94	7.50
	2007	13.92	41.65	30.10	2.75	1.29	8.03
YATAĞAN	2005	37.43	23.83	23.66	1.96	1.11	9.88
	2006	37.42	24.77	23.66	1.96	1.01	9.88
	2007	32.15	26.86	20.89	2.05	1.34	10.12
YENİKÖY	2005	29.34	32.87	21.31	1.51	0.67	13.94
	2006	27.59	44.67	21.31	1.81	1.10	13.93
	2007	27.93	40.13	29.00	2.44	1.37	14.86

Equation 5.6 presents the calculation of CO₂ emission of a thermal power plant by using elemental analysis method.

$$\text{Elemental CO}_2 \text{ (tons)} = \text{FA (tons)} \times \% \text{ wt Carbon} \times \frac{\text{MW CO}_2 \text{ (g)}}{\text{MW C (g)}} \times \text{Combustion Efficiency} \quad (5.6)$$

Where:

FA: Fuel Amount (tons)

% wt Carbon: weight percentage of carbon in fuel

MWCO₂ : Molecular Weight of CO₂ 44 grams

MWC: Molecular Weight of C 12 grams

Combustion efficiency: 80 % - 90 % efficiency

Step-3.3: Comparison of IPCC and Elemental Analysis Method

The CO₂ emission of each thermal power plant based on the elemental analysis was compared with that calculated using the IPCC Tier – 1 approach. The difference between the elemental analysis and IPCC approaches is accepted when the difference is up to 20 %. This assumption is based on the statement of an expert on Turkish thermal power plants and combustion of fossil fuels for electricity [39]. The results of the two approaches and the difference between them are given in Table 5.5. As seen here, majority of the difference is less than ±20%. This shows that the results obtained from IPCC and Elemental analysis method are close to each other.

Table 5.5. Comparison of Elemental Analysis and IPCC Tier – 1 Approach

Thermal Power Plants	Year	Elemental Analysis	IPCC Tier – 1	Difference
AFŞİN - ELBİSTAN A	2005	3,628,244	3,221,109	11%
	2006	1,687,462	1,471,591	13%
	2007	6,897,430	5,662,912	18%
AFŞİN - ELBİSTAN B	2005	7,063,000	5,946,303	16%
	2006	8,534,650	7,090,567	17%
	2007	9,449,752	8,690,750	8%
ÇAN	2005	455,057	394,230	13%
	2006	1,140,351	1,083,345	5%
	2007	2,173,502	1,848,194	15%
KANGAL	2005	2,685,304	2,837,465	-6%
	2006	3,339,236	3,496,043	-5%
	2007	3,470,841	3,458,388	0%
KEMERKÖY	2005	1,404,563	1,513,029	-8%
	2006	3,312,269	3,360,502	-1%
	2007	3,584,900	3,444,469	4%
ORHANELİ	2005	83,798	95,414	-14%
	2006	1,076,477	1,203,629	-12%
	2007	854,804	1,044,133	-22%
SEYİTÖMER	2005	3,978,278	3,915,265	2%
	2006	3,521,421	3,245,038	8%
	2007	3,585,056	3,194,768	11%
SOMA A	2005	79,595	76,809	3%
	2006	208,363	198,829	5%
	2007	315,646	307,912	2%
SOMA B	2005	3,867,293	3,840,439	1%
	2006	2,595,078	3,045,365	-17%
	2007	3,979,702	4,597,480	-16%
TUNÇBİLEK A	2005	115,637	84,570	27%
	2006	107,630	79,844	26%
	2007	8,062	5,687	29%
TUNÇBİLEK B	2005	1,056,331	1,120,667	-6%
	2006	1,185,840	1,136,816	4%
	2007	1,575,461	1,577,723	0%
YATAĞAN	2005	3,455,368	3,808,546	-10%
	2006	3,109,099	3,456,026	-11%
	2007	3,035,450	3,617,270	-19%
YENİKÖY	2005	1,607,218	1,744,866	-9%
	2006	1,644,252	1,978,078	-20%
	2007	2,559,491	2,371,693	7%

5.4. Determination of Specific Emission Factors

Specific emission factors (amount of CO₂ emission per MWh of electricity generated for each fuel type) are necessary for estimating the associated CO₂ emission from the planned or licensed electricity generation facilities. In Turkey, there are various thermal power plants with different fuel types with different low heating values, thus the thermal efficiencies and associated CO₂ emissions per MWh of electricity from each plant are different. For these reasons, knowledge of emission factors for each plant is a crucial issue. By using these fuel type specific emission factors for Turkey, the associated CO₂ emission can then be estimated. Equation 5.7 presents the electricity generation and CO₂ emission relationship in terms of specific emission factor (SEF). The SEF values presents information about the energy and emission intensity of any thermal power in Turkey.

$$\text{SEF (kg/MWh)} = \text{CO}_2 \text{ Emissions (tons)} / (\text{Electricity Generation (MWh)} \times 10^3) \quad (5.7)$$

5.5. Closing Remarks

This chapter presents the methodology for estimating the CO₂ emissions and specific emission factors. The calculations for the CO₂ emission associated to thermal power plants in Turkey based on IPCC methods are double checked by elemental analysis used for coal and lignite based thermal power plants. The comparison of this method with IPCC Tier – 1 approach shows that the application of IPCC method can be acceptable for Turkey.

Thermal efficiency value of each thermal power plant obtained from literature is compared with that calculated using the consumed fuel and generated electricity data to double check the amount of consumed fossil fuels in each thermal power plant. Based on this comparison, the consumed fuel data of some power plants are readjusted. In addition to this, thermal efficiency is used for power plants without any information on fuel consumptions. By using the thermal efficiency and generated

electricity values, the consumed fuel is calculated and so the associated CO₂ emissions are found.

The last section is about the determination of fuel specific emission factors according to IPCC method. All the steps that are followed for CO₂ emission calculations are given in Figure 5.1.

CHAPTER 6

RESULTS

6.1. Overview

This chapter consists of five parts. The first part presents the amount of electricity generated and associated CO₂ emissions in Turkey between 2001 and 2008 based on fuel and ownership type. The second part presents specific CO₂ emission factors based on fuel type which were calculated using the data between 2001 and 2008 as explained in detail in Section 5.2. and 5.4.

The electricity that will be supplied by the planned power plants and associated CO₂ emission from the planned plants between 2009 and 2019 are presented in third and fourth parts of this chapter.

In the last part of this chapter, the amount of electricity that will be generated to supply the total estimated demand and associated CO₂ emission between 2009 and 2019 based on four scenarios are presented.

6.2. Generated Electricity and Associated CO₂ Emissions between 2001 – 2008

As explained in detail in Section 4.2, the amount of generated electricity in Turkey between 2001 and 2008 is calculated using the data from NLDC [8]. The amount of associated CO₂ emission is calculated using the methodology explained in Section 5.2. The results on the electricity generated and associated CO₂ emission is given in Table 6.1. As seen here, the average annual change of total electricity generation and CO₂ emissions are same as 7 %. The amount of total electricity generated, thermal

electricity generation and associated CO₂ emissions increased 62%, 67% and 56% between 2001 and 2008, respectively.

Table 6.1. Generated Electricity and Associated CO₂ Emissions, 2001 – 2008

Year	Total Electricity Generation (GWh)	Annual Change (%)	Thermal Electricity Generation (GWh)	Annual Change (%)	CO ₂ Emissions (million tons)	Annual Change (%)
2001	122,311		97,850		68.19	
2002	128,619	5%	94,807	-3%	62.79	-8%
2003	139,916	9%	104,221	10%	64.03	2%
2004	150,588	8%	104,157	0%	64.66	1%
2005	162,333	8%	122,347	17%	78.03	21%
2006	176,295	9%	131,157	7%	83.91	8%
2007	190,446	8%	154,329	18%	98.91	18%
2008	197,839	4%	163,578	6%	106.6	8%
Avg		7%		8%		7%

Figure 6.1 presents the relationship between thermal generated electricity and associated CO₂ emissions between 2001 and 2008. As seen in this figure, there is a strong correlation of 0.99 between these two variables.

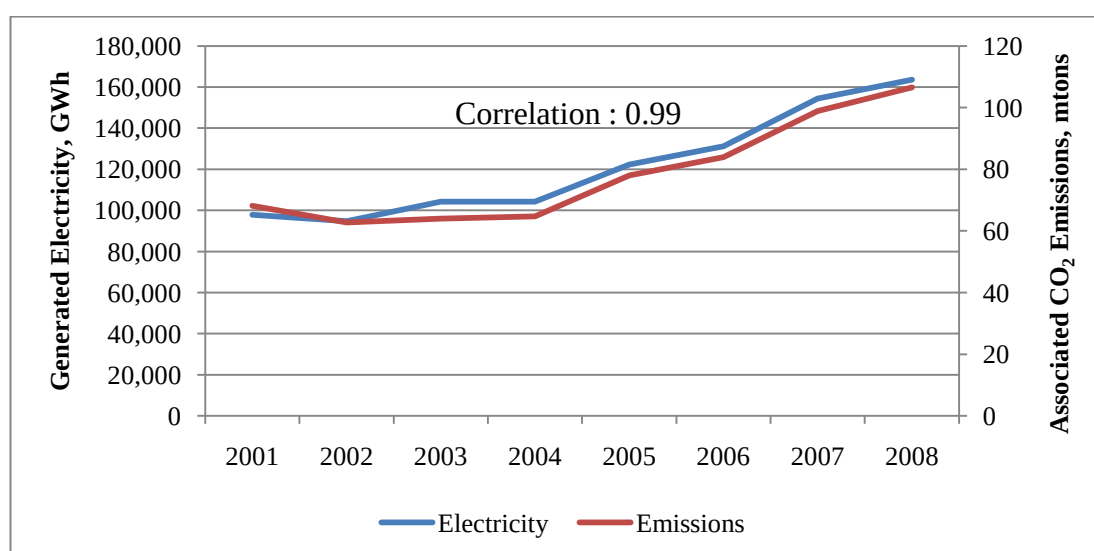


Figure 6.1. Thermal Generated Electricity and Associated CO₂ Emissions, 2001 – 2008

There are only a few studies on the amount of CO₂ emission from electricity generation in Turkey. National Inventory Report (NIR) [15], which is submitted to UNFCCC annually, is the basic reference point for the emission results comparison. Another study on electricity generation associated CO₂ emission is conducted by Türker [7]. The results of these three studies are given in Table 6.2 for comparison. As seen here, the results of this study are in line with those of the NIR [15] numbers and Türker [7]. The emission numbers of the three studies are also given in Figure 6.2. As seen here, these numbers are almost parallel to each other, and calculated emission amounts from this study are between those of other two studies. Although, the average annual emission increase of three studies is close to each other, *i.e.* NIR (6%), Türker (5%) and this study (7%), in terms of amount of CO₂ emissions, this study represents Turkey's emissions better than other studies since the calculations are based on CO₂ emissions calculated from each thermal power plant generated electricity between 2001 and 2008.

Table 6.2. Generated Electricity Associated CO₂ Emission Results

	This Study		NIR [15]		Türker [7]	
	Emission, mtons	Annual Increase	Emission, mtons	Annual Increase	Emission, mtons	Annual Increase
2001	68.19	-	74.52	-	63.41	-
2002	62.79	-8%	68.81	-8%	55.97	-12%
2003	64.03	2%	68.97	0%	60.10	7%
2004	64.66	1%	70.50	2%	64.11	7%
2005	78.03	21%	83.68	19%	76.19	19%
2006	83.91	8%	85.31	2%	79.52	4%
2007	98.91	18%	100.66	18%		
2008	106.6	8%				
Ave		7%		6%		5%

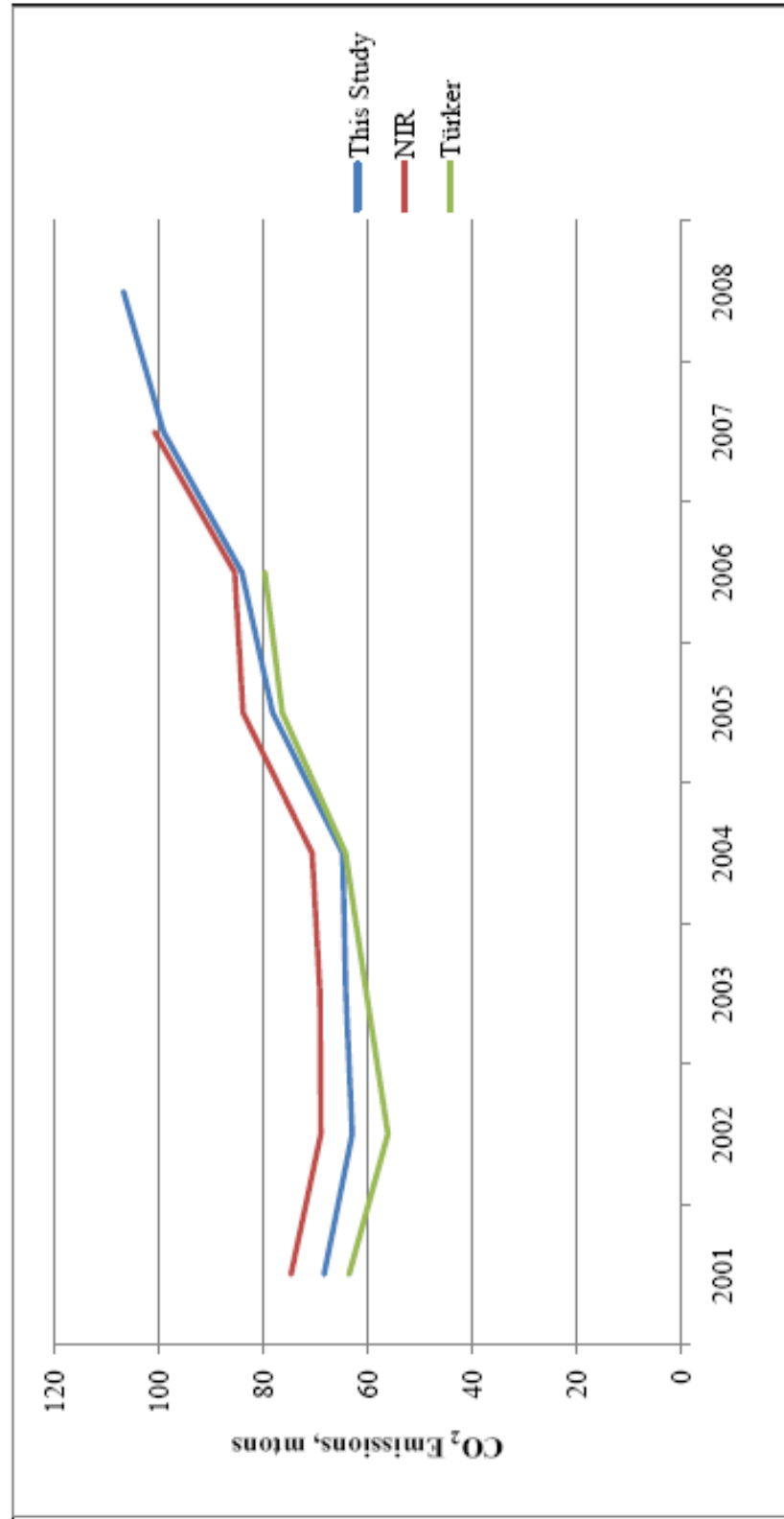


Figure 6.2. CO₂ Emissions Results of Three Studies

6.2.1. Generated Electricity and Associated CO₂ Emissions Based on Fuel Type between 2001 and 2008

The generated electricity and associated CO₂ emission between 2001 and 2008 based on fuel type is given in Table 6.3. As seen here, the main energy sources for electricity generation are natural gas, lignite, hydro, hard coal, and fuel oil.

Table 6.3. Amount of Electricity Generated (GWh) Based on Fuel Type, 2001 – 2008

	2001	2002	2003	2004	2005	2006	2007	2008
NG	50,645	52,270	65,471	63,767	73,491	80,219	93,570	96,869
Lignite	34,175	27,768	23,333	22,203	29,724	32,110	38,156	41,738
Hard Coal	2,826	2,928	7,333	10,652	11,484	12,220	13,065	14,216
Fuel Oil	8,577	10,710	7,363	6,697	6,651	5,656	8,581	8,595
Diesel	1,103	356	0	3	0	21	12	493
LPG	166	171	167	208	226	170	252	530
Naphta	327	575	521	593	658	636	582	670
MWG	30	29	33	33	111	126	112	466
Fossil Fuel	97,850	94,807	104,221	104,157	122,347	131,157	154,329	163,578
Hydro	24,307	33,659	35,546	46,284	39,835	44,856	35,662	33,256
Geo	90	105	88	93	94	94	96	162
Wind	64	48	61	54	57	188	359	843
Renewable	24,461	33,811	35,695	46,431	39,986	45,138	36,117	34,261
Total	122,311	128,619	139,916	150,588	162,333	176,295	190,446	197,839

The percentage distributions of electricity generated based on fuel type between 2001 and 2008 are given in Table 6.4. As seen here, almost half of the electricity generated between 2001 and 2008 from natural gas power plants.

Table 6.4. Percentage Distribution of Electricity Generated Based on Fuel Type, 2001 – 2008

	2001	2002	2003	2004	2005	2006	2007	2008
NG	41.4%	40.6%	46.8%	42.3%	45.3%	45.5%	49.1%	49.0%
Lignite	27.9%	21.6%	16.7%	14.7%	18.3%	18.2%	20.0%	21.1%
Hard Coal	2.3%	2.3%	5.2%	7.1%	7.1%	6.9%	6.9%	7.2%
Fuel Oil	7.0%	8.3%	5.3%	4.4%	4.1%	3.2%	4.5%	4.3%
Diesel	0.9%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
LPG	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.3%
Naphta	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%
MWG	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%
Fossil Fuel	80.0%	73.7%	74.5%	69.2%	75.4%	74.4%	81.0%	82.7%
Hydro	19.9%	26.2%	25.4%	30.7%	24.5%	25.4%	18.7%	16.8%
Geo	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Wind	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%
Renewable	20.0%	26.3%	25.5%	30.8%	24.6%	25.6%	19.0%	17.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The amount of associated CO₂ emission based on fuel type between 2001 and 2008 is given in Table 6.5. As seen here, lignite power plants are the main emitter of CO₂ emissions for this period. This is due the fact that lignite has the highest emission factor among other fossil fuel.

Table 6.5. Associated CO₂ Emissions (thousand tons) Based on Fuel Type, 2001 – 2008

	2001	2002	2003	2004	2005	2006	2007	2008
NG	19,590	19,846	24,595	23,619	27,568	30,281	33,716	37,098
Lignite	36,317	30,600	23,908	24,194	32,639	34,811	44,278	46,958
Hard Coal	2,986	2,946	7,488	10,839	11,395	12,042	13,436	13,539
Fuel Oil	8,095	8,697	5,892	5,588	5,944	6,322	7,010	7,094
Diesel	961	345	1,817	40	73	68	65	1,201
LPG	69	71	69	86	93	70	107	219
Naphta	157	276	250	285	272	263	273	321
MWG	11	10	12	12	46	52	25	167
Fossil Fuel	68,186	62,790	64,029	64,661	78,029	83,910	98,910	106,598
Renewable	0	0	0	0	0	0	0	0
Total	68,186	62,790	64,029	64,661	78,029	83,910	98,910	106,598

The percentage distributions of associated CO₂ emission based on fuel type between 2001 and 2008 are given in Table 6.6. As seen here, more than 60% of the CO₂ emissions are from lignite power plants. The detailed data on the generated electricity associated CO₂ emissions, consumed fuels, specific emission factors for each thermal power plant are given in Appendix – A.

Table 6.6. Percentage Distribution of Associated CO₂ Emissions Based on Fuel Type, 2001 – 2008,

	2001	2002	2003	2004	2005	2006	2007	2008
NG	28.7%	31.6%	38.4%	36.5%	35.3%	36.1%	34.1%	34.8%
Lignite	53.3%	48.7%	37.3%	37.4%	41.8%	41.5%	44.8%	44.1%
Hard Coal	4.4%	4.7%	11.7%	16.8%	14.6%	14.4%	13.6%	12.7%
Fuel Oil	11.9%	13.9%	9.2%	8.6%	7.6%	7.5%	7.1%	6.7%
Diesel	1.4%	0.5%	2.8%	0.1%	0.1%	0.1%	0.1%	1.1%
LPG	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%
Naphta	0.2%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%
MWG	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.2%
Fossil Fuel	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Renewable	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The average percentage distributions of generated electricity and associated CO₂ emission based on fuel type between 2001 and 2008 are given of Figure 6.3. As seen in this figure, natural gas is the dominant fuel used in electricity generation among other fuels with a share of 45%. The shares of lignite, hydro and hard coal follow the share of natural gas with 20%, 23% and 6%, respectively. As also can be seen in this figure, lignite power plants contribute the highest share of the associated CO₂ emissions among other fossil fuels. Although natural gas thermal power plants generated about 45% of total electricity generated between 2001 and 2008, their CO₂ emission contribution is about 33% which is lower than that of lignite. This is due to the fact that emission factor of natural has is lower than other major fossil fuels. Since, renewable energies do not generate any CO₂ emissions during operation, their emissions are zero.

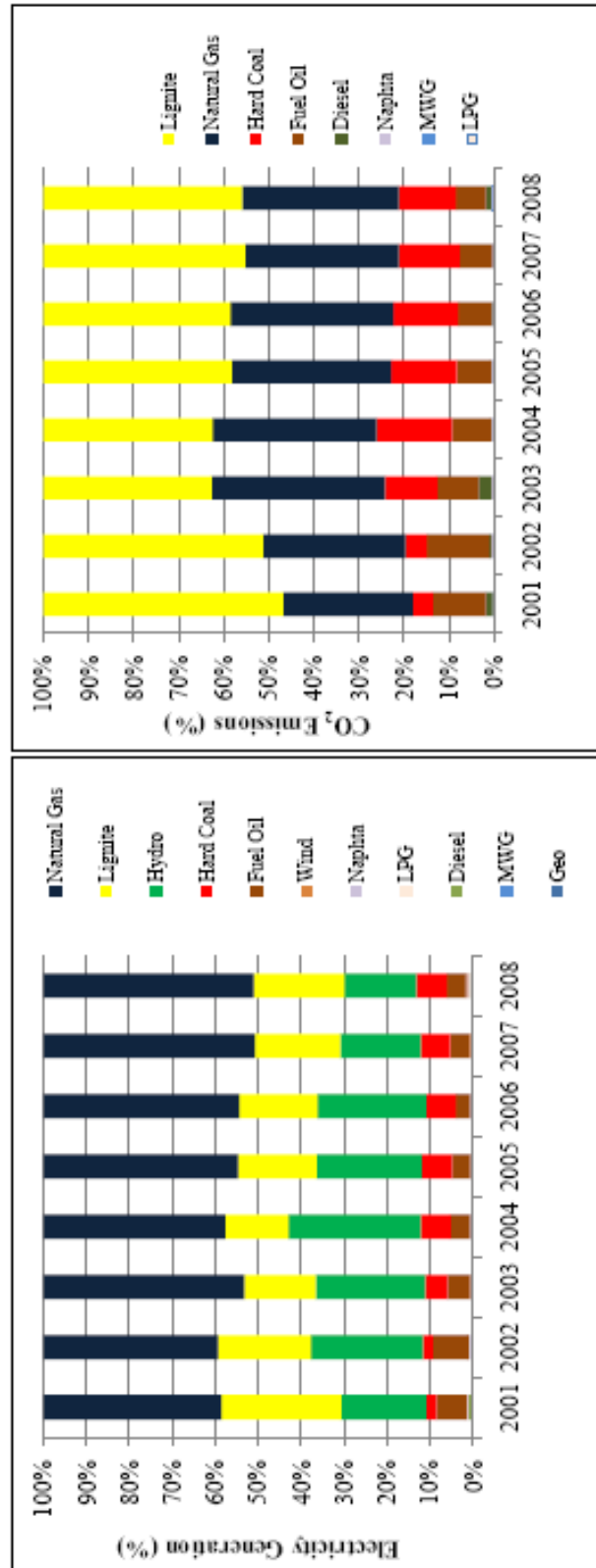


Figure 6.3. Average Percentage Distributions of Electricity Generated and Associated CO₂ Emission Based on Fuel Type, 2001 – 2008

6.2.2. Generated Electricity and Associated CO₂ Emissions Based on Ownership between 2001 and 2008

As explained in Section 3.4, the power plants in Turkey can be classified based on ownership as private and public. Table 6.7 presents the amount and percentage of electricity generated by private and public power plants between 2001 and 2008. Although public power plants were the main electricity generators of Turkey in 2001, after that year the share of public power plants started to decrease and private power plants generated more than half of the electricity in Turkey as seen in Table 6.7.

Table 6.7. Generated Electricity (GWh) by Public and Private Power Plants, 2001 - 2008

	PRIVATE		PUBLIC		TOTAL
	Electricity (GWh)	Share	Electricity (GWh)	Share	Electricity (GWh)
2001	51,987	43%	70,325	57%	122,311
2002	64,448	50%	64,171	50%	128,619
2003	80,177	57%	59,739	43%	139,916
2004	86,379	57%	64,209	43%	150,588
2005	95,508	59%	66,825	41%	162,333
2006	99,290	56%	77,005	44%	176,295
2007	111,361	58%	79,085	42%	190,446
2008	117,912	60%	79,927	40%	197,839

The amount and percentage of CO₂ emission from public and private power plants between 2001 and 2008 are given in Table 6.8. In 2001, 2002, 2007 and 2008, the shares of electricity generated and associated CO₂ emissions from public power plants are close to each other. However, this relationship is not valid between 2003 and 2006, and the share of CO₂ emission from public power plants is lower than the share for electricity generation. This is due to the fact that the share of generated electricity from renewable sources especially from hydro by public power plants was higher than private power plants between 2003 and 2006, and thus associated CO₂ emissions in these years were less than the ones from private power plants.

Table 6.8. Associated CO₂ Emissions (million tons) by Public and Private Power Plants, 2001 – 2008

	PRIVATE		PUBLIC		TOTAL
	Emission (million ton)	Share	Emission (million ton)	Share	Emission (million ton)
2001	28.75	42%	39.44	58%	68.19
2002	33.22	53%	29.56	47%	62.79
2003	39.66	62%	24.36	38%	64.03
2004	45.51	70%	19.15	30%	64.66
2005	49.71	64%	28.31	36%	78.03
2006	51.23	61%	32.68	39%	83.91
2007	58.14	59%	40.77	41%	98.91
2008	64.14	60%	42.46	40%	106.6

6.3. Fuel Specific CO₂ Emission Factors

Fuel specific emission factors for all types of fuel consumed for the electricity generation was calculated based on the methodology given in Section 5.2 and 5.4. The data included emission factors (kg CO₂/MWh) from more than 300 power plants that generated electricity between 2001 and 2008 using natural gas, fuel oil, lignite, hard coal, naphtha, diesel, LPG, and municipal waste gas (MWG). This data is analyzed using *SPSS* software [40]. The detail results of specific emission factors for each fuel are given in Appendix – B. The *Normal Distribution* for each primary fuel type between 2001 and 2008 is given in Table 6.9. According to these results, lignite and hard coal have higher CO₂ emission factors than natural gas and municipal waste gas.

Table 6.9. Fuel Specific CO₂ Emission Factors, kg CO₂ / MWh

		MWG	NG	Fuel Oil	Lignite	LPG	Diesel	Naphtha	Hard Coal
N	Valid	7	131	28	107	7	6	7	26
Mean		373	374	755	1,080	413	805	461	1,018
Median		357	367	753	1,057	413	789	480	1,014
Std. Deviation		27	20	9	129	0	31	33	28
Minimum		357	356	741	712	413	780	413	919
Maximum		413	456	789	1,384	413	860	480	1,078
Percentiles	10	357	367	752	935	413	780	413	1,006
	20	357	367	753	970	413	784	413	1,014
	30	357	367	753	1,019	413	789	440	1,014
	40	357	367	753	1,048	413	789	480	1,014
	50	357	367	753	1,057	413	789	480	1,014
	60	357	367	753	1,078	413	796	480	1,014
	70	391	367	753	1,136	413	821	480	1,014
	80	413	367	753	1,191	413	846	480	1,030
	90	413	396	766	1,267	413	860	480	1,055

Fuel specific emission factors developed for Turkey are compared with those of IEA [3] for the same period as given in Section 2.3. This comparison shows that the specific emission factors developed in this study is close to those of IEA as given Table 6.10. The last three rows of the table present IEA numbers. As seen here, in this study specific emission factors for all fossil fuel types are developed between 2001 and 2008. However, the IEA [3] included specific emission factors for only coal, oil and natural gas.

Table 6.10. Comparison of Specific Emission Factors, kg CO₂ / MWh

	2001	2002	2003	2004	2005	2006	2007	2008
MWG	357	357	357	357	413	413	-	357
Fuel Oil	827	821	833	762	754	759	759	604
Hard Coal	1035	1009	1022	1021	925	936	1044	844
Lignite	1054	1064	1055	1091	966	988	1043	1018
LPG	413	413	413	413	413	413	-	413
Naphta	480	480	480	480	413	413	-	480
Natural Gas	375	372	375	326	354	330	374	375
Oil [3]	735	672	668	688	654	740	675	-
Coal [3]	1082	1102	1068	1045	916	1015	1037	-
Natural Gas [3]	359	357	347	355	357	341	347	-

6.4. Planned Electricity Supply and Associated CO₂ Emissions of Turkey

As presented in Section 4.5., the electricity demand of Turkey will increase about 7% annually till to 2019. To supply this demand, new and additional power plants will be built in Turkey. The planned electricity generation capacity of Turkey is obtained from EMRA [11] as explained in detailed in Section 4.3. This section presents the amount of electricity that will be generated and associated CO₂ by fuel type between 2009 and 2019 from planned power plants.

6.4.1. Estimation of Completion Time of Planned Power Plants

In the planned power plant data given in Section 4.3., the power plant completion year information was not given. The data only contained information on the “realization ratio” which was given as percentage as seen in Table 6.11. This ratio gives information on the completion timing of the power plant projects. As we needed to know when each planned power plant will be completed, this realization ratio data is converted to year data. In order to do this, the realization ratio data is divided into ten equal increments from 0 to 100% percentage. Each increment of this classification refers to estimated completion time of the planned power plants. The classification is given in Table 6.11. The table also contains data on the total number of planned power plants and total generation (GWh) between 2009 and 2019.

Table 6.11. Estimated Completion Year of the Licensed

Realization Ratio	Corresponding Completion Year	Number of PP	Total Generation, GWh
100 - 90 %	2009	24	2,243
89.9 - 80 %	2010	13	2,997
79.9 - 70 %	2011	6	1,079
69.9 - 60 %	2012	12	2,206
59.9 - 50 %	2013	14	6,164
49.9 - 40 %	2014	18	7,785
39.9 - 30 %	2015	25	10,501
29.9 - 20 %	2016	28	16,724
19.9 - 10 %	2017	38	16,177
9.9 – 0.1 %	2018	232	60,778
0%	2019	155	33,549

The amount of electricity generation by planned power plants based on fuel type and the plant completion time is given in Table 6.12. As seen in this table, planned power plants that use hard coal has the highest share of 35%, and followed by natural gas and hydro power plants with shares of 25% and 26%, respectively. About 40% of the total generation capacity of the planned power plants will be built in 2018, and 25% in 2019. To calculate the amount of total electricity supply of electricity between 2009 and 2019, the planned generation data given in Table 6.12 and the current 2008 generated electricity data given in Table 6.3 are summed and the total electricity supply (existing and planned) is presented in Table 6.13.

Table 6.12. Electricity Generation (GWh) of the Planned Power Plants Based on Fuel Type, 2009 -2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	8	126	0	204	565	926	81	312	20	0	2,243
2010	0	1,064	0	500	0	841	592	0	0	0	2,997
2011	0	0	0	0	0	576	440	63	0	0	1,079
2012	0	0	0	924	0	1,103	178	0	0	0	2,206
2013	0	2,916	0	1,854	0	1,119	165	0	0	110	6,164
2014	0	0	0	6,293	0	1,257	235	0	0	0	7,785
2015	0	0	0	8,920	0	1,067	453	0	0	60	10,501
2016	0	12,336	0	0	0	4,121	267	0	0	0	16,724
2017	0	4,320	0	6,949	0	4,554	355	0	0	0	16,177
2018	7,168	24,557	0	2,094	0	19,928	6,999	0	32	0	60,778
2019	531	10,425	2,916	11,595	0	6,703	1,212	70	97	0	33,549

Table 6.13. Total Annual Electricity Supply Capacity [Existing + Planned, (GW/h)] Based on Fuel Type, 2008 - 2019

	Lignite	Coal	Asphaltite	NG	FO	Hydro	Wind	Geo	Biomass	MWG	Total
2008	41,738	14,216	670	97,399	9,089	33,256	843	162	0	466	197,839
2009	41,747	14,342	670	97,603	9,654	34,181	924	474	20	466	200,082
2010	41,747	15,407	670	98,103	9,654	35,022	1,516	474	20	466	203,080
2011	41,747	15,407	670	98,103	9,654	35,598	1,956	537	20	466	204,158
2012	41,747	15,407	670	99,028	9,654	36,702	2,135	537	20	466	206,365
2013	41,747	18,323	670	100,882	9,654	37,821	2,300	537	20	576	212,529
2014	41,747	18,323	670	107,175	9,654	39,078	2,534	537	20	576	220,314
2015	41,747	18,323	670	116,095	9,654	40,145	2,988	537	20	636	230,815
2016	41,747	30,658	670	116,095	9,654	44,267	3,255	537	20	636	247,539
2017	41,747	34,978	670	123,044	9,654	48,820	3,610	537	20	636	263,716
2018	48,915	59,536	670	125,138	9,654	68,748	10,609	537	52	636	324,494
2019	49,445	69,961	3,586	136,733	9,654	75,452	11,821	607	149	636	358,043

The percentage distribution of the total electricity supply (existing + planned) based on fuel type between 2008 and 2019 is given in Table 6.14. As seen here, natural gas power plants still have the largest generation share, which is followed by similar shares of lignite and hydro power plants, on average.

Table 6.14. Percentage Distribution of Total Electricity Supply (Existing + Planned) Based on Fuel Type between 2008 and 2019

	Lignite	Coal	Asphaltite	NG	FO	Hydro	Wind	Geo	Biomass	MWG
2008	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2009	20.9%	7.2%	0.3%	48.8%	4.8%	17.1%	0.5%	0.2%	0.0%	0.2%
2010	20.6%	7.6%	0.3%	48.3%	4.8%	17.2%	0.7%	0.2%	0.0%	0.2%
2011	20.4%	7.5%	0.3%	48.1%	4.7%	17.4%	1.0%	0.3%	0.0%	0.2%
2012	20.2%	7.5%	0.3%	48.0%	4.7%	17.8%	1.0%	0.3%	0.0%	0.2%
2013	19.6%	8.6%	0.3%	47.5%	4.5%	17.8%	1.1%	0.3%	0.0%	0.3%
2014	18.9%	8.3%	0.3%	48.6%	4.4%	17.7%	1.2%	0.2%	0.0%	0.3%
2015	18.1%	7.9%	0.3%	50.3%	4.2%	17.4%	1.3%	0.2%	0.0%	0.3%
2016	16.9%	12.4%	0.3%	46.9%	3.9%	17.9%	1.3%	0.2%	0.0%	0.3%
2017	15.8%	13.3%	0.3%	46.7%	3.7%	18.5%	1.4%	0.2%	0.0%	0.2%
2018	15.1%	18.3%	0.2%	38.6%	3.0%	21.2%	3.3%	0.2%	0.0%	0.2%
2019	13.8%	19.5%	1.0%	38.2%	2.7%	21.1%	3.3%	0.2%	0.0%	0.2%

To estimate CO₂ emission from the total electricity supply (existing + planned) between 2009 and 2019, fuel specific emission factors (kg CO₂ / MWh) given in Table 6.9 are multiplied by the electricity generation data based on fuel type given in Table 6.13. The results are presented in Table 6.15.

Table 6.15. Associated CO₂ Emission (million tons) from Total Electricity Supply Based on Fuel Type, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	45.09	14.60	0.31	36.50	7.29	0.17	0.00	103.96
2010	45.09	15.68	0.31	36.69	7.29	0.17	0.00	105.23
2011	45.09	15.68	0.31	36.69	7.29	0.17	0.00	105.23
2012	45.09	15.68	0.31	37.04	7.29	0.17	0.00	105.58
2013	45.09	18.65	0.31	37.73	7.29	0.21	0.00	109.28
2014	45.09	18.65	0.31	40.08	7.29	0.21	0.00	111.64
2015	45.09	18.65	0.31	43.42	7.29	0.24	0.00	114.99
2016	45.09	31.21	0.31	43.42	7.29	0.24	0.00	127.55
2017	45.09	35.61	0.31	46.02	7.29	0.24	0.00	134.55
2018	52.83	60.61	0.31	46.80	7.29	0.24	0.00	168.07
2019	53.40	71.22	1.65	51.14	7.29	0.24	0.00	184.94

The associated CO₂ emission percentage distribution based on fuel type is presented in Table 6.16. Although the lignite is forth large primary energy supply, it has the biggest emission factor, which makes it the most polluter fuel. Renewable energy sources such as hydro, wind, geothermal and biomass have not any CO₂ emissions since their emission factors are zero.

Table 6.16. Percentage Distribution of Associated CO₂ Emission from Total Electricity Supply (Existing + Planned) Based on Fuel Type, 2009 and 2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable
2009	43.40%	14.00%	0.30%	35.10%	7.00%	0.20%	0.00%
2010	42.80%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2011	42.80%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2012	42.70%	14.90%	0.30%	35.10%	6.90%	0.20%	0.00%
2013	41.30%	17.10%	0.30%	34.50%	6.70%	0.20%	0.00%
2014	40.40%	16.70%	0.30%	35.90%	6.50%	0.20%	0.00%
2015	39.20%	16.20%	0.30%	37.80%	6.30%	0.20%	0.00%
2016	35.30%	24.50%	0.20%	34.00%	5.70%	0.20%	0.00%
2017	33.50%	26.50%	0.20%	34.20%	5.40%	0.20%	0.00%
2018	31.40%	36.10%	0.20%	27.80%	4.30%	0.10%	0.00%
2019	28.90%	38.50%	0.90%	27.70%	3.90%	0.10%	0.00%

6.5. Developing Electricity Demand and Supply Balance

As presented in Table 4.15, the electricity demand in Turkey is expected to increase above 7% annually between 2009 and 2019, and reach to 383,635 GWh in 2019. However, the annual increase in total electricity supply is lower than of the demand for this period. This shows that new and additional power plants need to be built in order to provide this expected demand. The expected demand and total supply of electricity and the difference between these values are given in Table 6.17.

As seen in Table 6.17, in 2009 and 2010 the expected demand is lower than the total supply. It can also be observed from this table that the annual increase of demands in these years is lower than other years due to the effects of the economic crisis. However, between 2011 and 2019, the total supply (existing + planned) will not be sufficient to provide the estimated demand.

Table 6.17. Electricity Supply and Demand (GWh), 2009-2019

Year	DEMAND	SUPPLY	DIFFERENCE
2009	194,000	200,082	-6,082
2010	202,730	203,080	-350
2011	215,907	204,158	11,749
2012	232,101	206,365	25,736
2013	249,508	212,529	36,979
2014	268,221	220,314	47,907
2015	288,338	230,815	57,523
2016	309,675	247,539	62,136
2017	332,591	263,716	68,875
2018	357,202	324,494	32,708
2019	383,635	358,043	25,592

Figure 6.4 presents electricity supply and demand traces. As seen here, expected demand will be higher than the supply between 2011 and 2019. In Figure 6.5, the composition of the expected electricity demand is given. As seen here, the expected demand will be provided by the existing, planned and additional power plants.

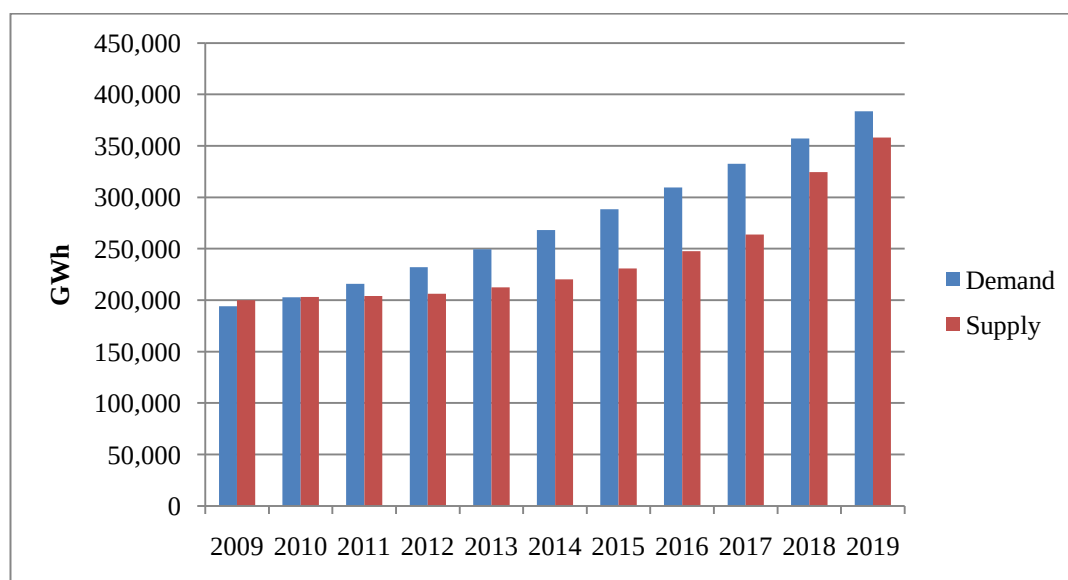


Figure 6.4. Electricity Supply and Demand, 2009-2019.

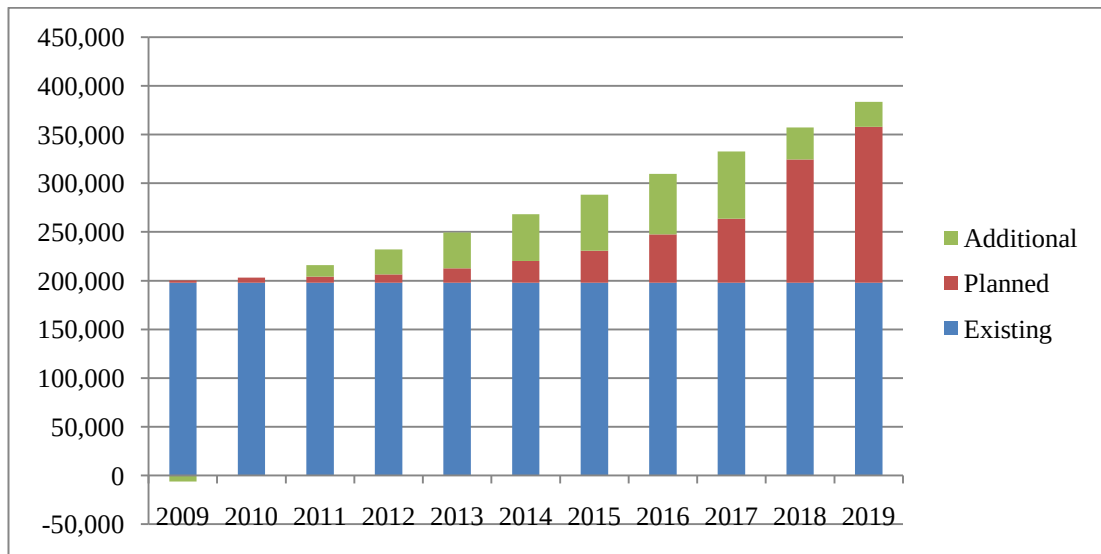


Figure 6.5. Expected Electricity Supply Mixture

To overcome electricity supply and demand balance problem; new, additional and sustainable primary energy sources are need to be used to generate electricity. In addition to this, mitigation of CO₂ emission from electricity generation is the priority issue to combat the climate change and also the main objective of this study. For these reasons, the deficient part of the electricity supply between 2011 and 2019 can be provided by economically useful renewable energy sources as a key solution for CO₂ emission reduction.

The economically feasible renewable energy sources in terms of total economic potential, existing usage as of 2008, planned usage up to 2019, and remaining amounts are presented in Table 6.18. This shows that the deficient part of the electricity supply between 2011 and 2019 can be provided using the remaining renewable sources as given in Table 6.18.

Table 6.18. Overview of the Renewable Energy Sources (GWh)

	Total Economic Potential	Existing Usage as of 2008	Planned Usage up to 2019	Remaining
Hydro	127,381	33,256	42,196	51,929
Geothermal	16,000	162	445	15,393
Wind	26,000	843	10,978	14,179
Biomass	11,575	0	149	11,426
Total	180,956	34,261	53,768	92,927

Figure 6.6 presents the existing, planned and remaining amounts of total renewable energy sources of Turkey. As seen here, only 19% of the total economic renewable potential is being used and 30% of it is planned to be used in the near future. However, remaining 51% of the total economic renewable potential of Turkey is not benefitted, which could be used to generate electricity to provide the deficient part of the electricity supply.

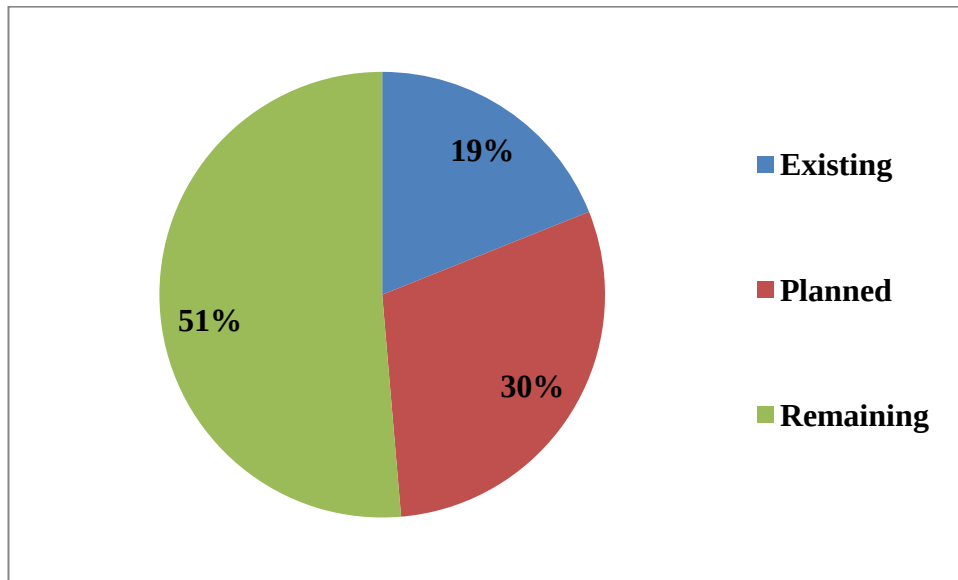


Figure 6.6. Percentage Distribution of Total Economic Renewable Energy Potential of Turkey

6.6. Scenarios on Providing Electricity for the Deficient Part of the Total Supply and Associated CO₂ Emissions of Turkey

The section presents results of the four scenarios used to overcome the supply deficiency problem presented in Table 6.17. The first scenario is *Business as Usual (BAU) Scenario*. As a basic approach, the BAU scenario considers electricity supply security rather than climate change issue. For this scenario, shares of each primary energy sources to generate electricity are estimated to have the same share values of 2008 as given in Table 6.4 and to be constant between 2009 and 2019.

The second scenario, named as *Renewable Scenario*, is developed considering economically feasible renewable energy sources of Turkey as given in Table 6.18. The third scenario, named as *Fossil Fuel Scenario*, is based on using only fossil fuel sources with the shares from 2008 generation. The last and the fourth scenario is, named as *Natural Gas Scenario*, developed based on the assumption that natural gas is the only energy source to generate electricity for the deficit of the total supply.

This section presents the assumptions, results and comparative assessments of the scenarios based on generation by fuel type and associated CO₂ emission.

6.6.1. Business as Usual (BAU) Scenario

The main assumptions of this scenario are:

- Total electricity demand will be supplied only by the national electricity generation.
- All power plants as of 2008 will be running till to 2019.
- All planned power plants will be completed up to 2019 based on the timing given in Table 6.11.
- To overcome the deficiency between demand and supply as presented in Table 6.17, all primary energy sources will be used to generate electricity.

The shares of the primary energy sources will be those of 2008 as given in Table 6.4 and be constant between 2009 and 2019.

- To obtain the associated CO₂ emissions, the amount of electricity generated by each fuel type is multiplied with its fuel specific emission factors in Table 6.9.
- The fuel specific emission factors of all renewable energy sources are accepted as zero.

The amount of the incremental electricity supply based on *BAU Scenario* by fuel type is given in Table 6.19. As seen in Table 6.19, the amounts of electricity to be generated in 2009 and 2010 have negative signs. The reason for this is that the supply in these years is higher than the demand, and thereby there is no need to generate more electricity than needed. Consequently, the amount of electricity that will be deducted from each fuel type is calculated and given in this table. Also as given in Appendix - C, the shares of primary energy sources used to generate the deficiency between demand and supply are constant between 2009 and 2019, as it is one of the main assumptions of this scenario.

Table 6.19. Amount of Incremental Electricity (GWh) Supply by Fuel Type Based on BAU Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	-1,283	-437	-21	-2,994	-279	-1,022	-26	-5	0	-14	0
2010	-74	-25	-1	-172	-16	-58	-1	0	0	-1	0
2011	2,479	844	40	5,784	540	1,975	50	10	0	28	11,749
2012	5,430	1,849	87	12,670	1,182	4,326	109	22	0	61	25,736
2013	7,801	2,657	125	18,205	1,699	6,216	157	31	0	87	36,979
2014	10,107	3,442	162	23,585	2,201	8,053	205	40	0	113	47,907
2015	12,136	4,133	195	28,319	2,643	9,670	245	48	0	135	57,523
2016	13,109	4,465	210	30,591	2,855	10,444	265	51	0	146	62,136
2017	14,531	4,950	233	33,908	3,164	11,578	293	57	0	162	68,875
2018	6,900	2,350	111	16,102	1,503	5,498	139	27	0	77	32,708
2019	5,399	1,839	87	12,599	1,176	4,301	109	21	0	60	25,592

Table 6.13 and incremental electricity supply given in Table 6.19 are combined to determine the total amount of electricity to be generated to provide the estimated demand between 2009 and 2019. The amount and percentage distribution of total electricity generated by fuel type based *BAU* Scenario is given in Table 6.20 and Table 6.21, respectively. As seen in Table 6.21, there is a small fluctuation in the percentage of each primary energy sources. When primary energy allocation is compared with that of 2008; lignite and natural gas shares are decreasing, on the other hand hydro and coal shares are increasing between 2009 and 2019. Also, the renewable energy share is increasing continuously from 18% to 24% in this period.

Table 6.20. Amount of Total Electricity Generated (GWh) by Fuel Type Based on BAU Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	40,464	13,905	649	94,609	9,375	33,159	898	469	20	452	194,000
2010	41,673	15,382	669	97,931	9,638	34,964	1,515	474	20	465	202,730
2011	44,226	16,251	710	103,887	10,194	37,573	2,006	547	20	494	215,907
2012	47,177	17,256	757	111,698	10,836	41,028	2,244	559	20	527	232,101
2013	49,548	20,980	795	119,087	11,353	44,037	2,457	568	20	663	249,508
2014	51,854	21,765	832	130,760	11,855	47,131	2,739	577	20	689	268,221
2015	53,883	22,456	865	144,414	12,297	49,815	3,233	585	20	771	288,338
2016	54,856	35,123	880	146,686	12,509	54,711	3,520	588	20	782	309,675
2017	56,278	39,928	903	156,952	12,818	60,398	3,903	594	20	798	332,591
2018	55,815	61,886	781	141,240	11,157	74,246	10,748	564	52	713	357,202
2019	54,844	71,800	3,673	149,332	10,830	79,753	11,930	628	149	696	383,635

Table 6.21. Percentage Distributions of Total Electricity Generated by Fuel Type Based on BAU Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Fossil	Renewable
2009	20.9%	7.2%	0.3%	48.8%	4.8%	17.1%	0.5%	0.2%	0.0%	0.2%	82.2%	17.8%
2010	20.6%	7.6%	0.3%	48.3%	4.8%	17.2%	0.7%	0.2%	0.0%	0.2%	81.8%	18.2%
2011	20.5%	7.5%	0.3%	48.1%	4.7%	17.4%	0.9%	0.3%	0.0%	0.2%	81.4%	18.6%
2012	20.3%	7.4%	0.3%	48.1%	4.7%	17.7%	1.0%	0.2%	0.0%	0.2%	81.1%	18.9%
2013	19.9%	8.4%	0.3%	47.7%	4.6%	17.6%	1.0%	0.2%	0.0%	0.3%	81.1%	18.9%
2014	19.3%	8.1%	0.3%	48.8%	4.4%	17.6%	1.0%	0.2%	0.0%	0.3%	81.2%	18.8%
2015	18.7%	7.8%	0.3%	50.1%	4.3%	17.3%	1.1%	0.2%	0.0%	0.3%	81.4%	18.6%
2016	17.7%	11.3%	0.3%	47.4%	4.0%	17.7%	1.1%	0.2%	0.0%	0.3%	81.0%	19.0%
2017	16.9%	12.0%	0.3%	47.2%	3.9%	18.2%	1.2%	0.2%	0.0%	0.2%	80.5%	19.5%
2018	15.6%	17.3%	0.2%	39.5%	3.1%	20.8%	3.0%	0.2%	0.0%	0.2%	76.0%	24.0%
2019	14.3%	18.7%	1.0%	38.9%	2.8%	20.8%	3.1%	0.2%	0.0%	0.2%	75.9%	24.1%

To obtain the associated CO₂ emissions, the amount of electricity generated by each fuel type are multiplied with its fuel specific emission factors as given in Table 6.9. The amount of associated CO₂ emission of the incremental electricity supply presented in Table 6.19 is given in Table 6.22. As explained previously, the supply in 2009 and 2010 was higher than demand, thus less electricity and also less CO₂ will be generated than the ones given for the total supply. Therefore, the amount of associated CO₂ emission by fuel type for 2009 and 2010 are given in negative values, which means that these amounts will be deducted from those of the total supply.

As also seen here, lignite and natural gas are the main CO₂ emitters among other fuels. Since the shares of energy sources of the incremental electricity supply are constant, the shares of the associated CO₂ emission of each fuel type are also constant between 2009 and 2019 as given in Appendix - C.

Table 6.22. Amount of Associated CO₂ Emissions of the Incremental Electricity Supply by Fuel Type Based on BAU Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	-1,386	-445	-10	-1,120	-211	-6	0	-3,176
2010	-80	-25	-1	-65	-12	-1	0	-183
2011	2,677	860	18	2,163	407	10	0	6,136
2012	5,864	1,883	40	4,739	892	22	0	13,440
2013	8,425	2,705	58	6,809	1,282	32	0	19,313
2014	10,915	3,504	75	8,821	1,661	42	0	25,020
2015	13,106	4,208	90	10,591	1,995	51	0	30,041
2016	14,157	4,546	97	11,440	2,155	55	0	32,451
2017	15,693	5,038	107	12,682	2,389	61	0	35,970
2018	7,452	2,393	51	6,022	1,134	29	0	17,082
2019	5,831	1,872	40	4,712	887	23	0	13,365

The associated CO₂ emissions of the total electricity generated based on *BAU Scenario* by fuel type are given in Table 6.23. The percentage distribution of the associated CO₂ emission of the total electricity generated by each fuel type based on *BAU Scenario* is presented in Table 6.24.

The associated CO₂ emission from the total electricity generation in 2019 is calculated to be a little more than 198 million tons, which is almost two times of the value in 2008. As pointed in Section 5.4.1, there is a sharp increase in the amount of electricity generated by the coal planned power plants in 2016 and 2018. This increase in coal power plants result in a sharp increase in the amount of associated CO₂ emission in these years as seen in Table 6.23.

Table 6.23. Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based on BAU Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	43,701	14,156	299	35,384	7,078	168	0	100,786
2010	45,007	15,659	308	36,626	7,277	173	0	105,050
2011	47,764	16,544	327	38,854	7,696	184	0	111,369
2012	50,951	17,567	349	41,775	8,181	196	0	119,019
2013	53,512	21,358	367	44,539	8,571	247	0	128,594
2014	56,002	22,157	384	48,904	8,950	257	0	136,655
2015	58,193	22,861	399	54,011	9,284	288	0	145,035
2016	59,244	35,756	406	54,860	9,444	292	0	160,002
2017	60,780	40,646	416	58,700	9,678	298	0	170,518
2018	60,280	63,000	360	52,824	8,423	266	0	185,153
2019	59,232	73,092	1,693	55,850	8,176	260	0	198,303

Table 6.24. Percentage Distribution of Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based on BAU Scenario

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable
2009	43.40%	14.00%	0.30%	35.10%	7.00%	0.20%	0.00%
2010	42.80%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2011	42.90%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2012	42.80%	14.80%	0.30%	35.10%	6.90%	0.20%	0.00%
2013	41.60%	16.60%	0.30%	34.60%	6.70%	0.20%	0.00%
2014	41.00%	16.20%	0.30%	35.80%	6.50%	0.20%	0.00%
2015	40.10%	15.80%	0.30%	37.20%	6.40%	0.20%	0.00%
2016	37.00%	22.30%	0.30%	34.30%	5.90%	0.20%	0.00%
2017	35.60%	23.80%	0.20%	34.40%	5.70%	0.20%	0.00%
2018	32.60%	34.00%	0.20%	28.50%	4.50%	0.10%	0.00%
2019	29.90%	36.90%	0.90%	28.20%	4.10%	0.10%	0.00%

6.6.2. Renewable Scenario

This scenario includes the following assumptions:

- Total energy demand will be supplied only by national electricity generation.
- All power plants as of 2008 will be on operation till to 2019.
- All planned power plants will be completed up to 2019 based on the timing given in Table 6.11.
- To overcome the deficiency between demand and supply as presented in Table 6.17, the remaining economically feasible renewable energy potential of Turkey, as given in Table 6.18, is used as the primary energy sources.
- These renewable sources are put into operation according to their investment costs as given in Table 6.25. The ones with the lower investment cost per MW are expected to be built prior than others.
- To obtain the associated CO₂ emissions, the amount of electricity generated by each fuel type is multiplied with its fuel specific emission factors in Table 6.9.

- The fuel specific emission factors of all renewable energy sources are accepted as zero.

The contribution of renewable energy sources are prioritized according to their investment costs as given in Table 6.25. The ones with the lower investment costs per MW are expected to be built prior than others.

Table 6.25. The unit of investment cost of renewable energy sources [28]

	Investment Cost
Hydro	\$1500/kW - \$5500/kW
Geothermal	\$1700/kW - \$5700/kW
Wind	\$900/kW - \$2500/kW
Biomass	\$1000/kW - \$2500/kW

Since, the supply in 2009 and 2010 is higher than the demand; there is no need to generate more electricity than needed. Thus, the incremental electricity supply by renewable energy sources in these years is taken as zero. The amount of incremental electricity supply between 2011 and 2019 are presented in Table 6.26.

Table 6.26. Amount of Incremental Electricity (GWh) Supply by Renewable Energy Sources Based on Renewable Scenario, 2009-2019

Year	Geothermal	Wind	Biomass	Hydro	Sum
2009	0	0	0	0	0
2010	0	0	0	0	0
2011	1,997	3,877	3,525	2,350	11,749
2012	4,375	8,493	7,721	5,147	25,736
2013	6,286	12,203	11,094	7,396	36,979
2014	8,144	14,179	11,426	14,157	47,907
2015	9,779	14,179	11,426	22,140	57,524
2016	10,563	14,179	11,426	25,968	62,136
2017	11,709	14,179	11,426	31,561	68,875
2018	5,560	10,794	9,812	6,542	32,708
2019	4,351	8,445	7,677	5,118	25,592

The amount of the incremental electricity supply based on *Renewable Scenario* by fuel type is given in Table 6.27. As explained in section 6.6.1, the amounts of electricity to be generated in 2009 and 2010 have negative signs as seen in Table 6.27. Also as seen Appendix -C, there will be no incremental contribution from fossil fuels to generate the deficiency between demand and supply between 2009 and 2019 and the contributions of renewable energy sources will be increasing in this period.

Table 6.27. Amount of Incremental Electricity (GWh) Supply by Fuel Type Based on Renewable Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	-1,283	-437	-21	-2,994	-279	-1,022	-26	-5	0	-14	-6,082
2010	-74	-25	-1	-172	-16	-59	-1	0	0	-1	-350
2011	0	0	0	0	0	2,350	3,877	1,997	3,525	0	11,749
2012	0	0	0	0	0	5,147	8,493	4,375	7,721	0	25,736
2013	0	0	0	0	0	7,396	12,203	6,286	11,094	0	36,979
2014	0	0	0	0	0	14,157	14,179	8,144	11,426	0	47,907
2015	0	0	0	0	0	22,140	14,179	9,779	11,426	0	57,524
2016	0	0	0	0	0	25,968	14,179	10,563	11,426	0	62,136
2017	0	0	0	0	0	31,561	14,179	11,709	11,426	0	68,875
2018	0	0	0	0	0	6,542	10,794	5,560	9,812	0	32,708
2019	0	0	0	0	0	5,118	8,445	4,351	7,677	0	25,592

Table 6.13 and incremental electricity supply given in Table 6.27 are combined to determine the total amount of electricity to be generated to provide the estimated demand between 2009 and 2019. The amount and percentage distribution of total electricity generated by fuel type based Renewable Scenario is given in Table 6.28 and Table 6.29, respectively. As seen in Table 6.29, the shares of renewable energy sources increased sharply from 18% to 30% between 2009 and 2019. As pointed out earlier, there is a high increase in the number of coal planned power plants in 2018 and 2019, which decreases the share of renewable in the electricity generation in these years.

Table 6.28. Amount of Total Electricity Generated (GWh) by Fuel Type Based on Renewable Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	40,464	13,905	649	94,609	9,375	33,159	898	469	20	452	194,000
2010	41,673	15,382	669	97,931	9,638	34,964	1,515	474	20	465	202,730
2011	41,747	15,407	670	98,103	9,654	37,948	5,833	2,535	3,544	466	215,907
2012	41,747	15,407	670	99,028	9,654	41,849	10,628	4,913	7,741	466	232,101
2013	41,747	18,323	670	100,882	9,654	45,217	14,503	6,824	11,113	576	249,508
2014	41,747	18,323	670	107,175	9,654	53,235	16,713	8,682	11,446	576	268,221
2015	41,747	18,323	670	116,095	9,654	62,285	17,167	10,316	11,446	636	288,338
2016	41,747	30,658	670	116,095	9,654	70,235	17,434	11,101	11,446	636	309,675
2017	41,747	34,978	670	123,044	9,654	80,381	17,789	12,246	11,446	636	332,591
2018	48,915	59,536	670	125,138	9,654	75,290	21,402	6,098	9,864	636	357,202
2019	49,445	69,961	3,586	136,733	9,654	80,570	20,266	4,958	7,826	636	383,635

Table 6.29. Percentage Distributions of Total Electricity Generated by Fuel Type Based on Renewable Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geothermal	Biomass	MWG	Fossil	Ren
2009	20.9%	7.2%	0.3%	48.8%	4.8%	17.1%	0.5%	0.2%	0.0%	0.2%	82.2%	17.8%
2010	20.6%	7.6%	0.3%	48.3%	4.8%	17.2%	0.7%	0.2%	0.0%	0.2%	81.8%	18.2%
2011	19.3%	7.1%	0.3%	45.4%	4.5%	17.6%	2.7%	1.2%	1.6%	0.2%	76.9%	23.1%
2012	18.0%	6.6%	0.3%	42.7%	4.2%	18.0%	4.6%	2.1%	3.3%	0.2%	71.9%	28.1%
2013	16.7%	7.3%	0.3%	40.4%	3.9%	18.1%	5.8%	2.7%	4.5%	0.2%	68.9%	31.1%
2014	15.6%	6.8%	0.2%	40.0%	3.6%	19.8%	6.2%	3.2%	4.3%	0.2%	66.4%	33.6%
2015	14.5%	6.4%	0.2%	40.3%	3.3%	21.6%	6.0%	3.6%	4.0%	0.2%	64.9%	35.1%
2016	13.5%	9.9%	0.2%	37.5%	3.1%	22.7%	5.6%	3.6%	3.7%	0.2%	64.4%	35.6%
2017	12.6%	10.5%	0.2%	37.0%	2.9%	24.2%	5.3%	3.7%	3.4%	0.2%	63.4%	36.6%
2018	13.7%	16.7%	0.2%	35.0%	2.7%	21.1%	6.0%	1.7%	2.8%	0.2%	68.5%	31.5%
2019	12.9%	18.2%	0.9%	35.6%	2.5%	21.0%	5.3%	1.3%	2.0%	0.2%	70.4%	29.6%

The associated CO₂ emissions of the total electricity generated based on *Renewable Scenario* by fuel type are given in Table 6.30. The percentage distribution of the associated CO₂ emission of the total electricity generated by each fuel type based on *Renewable Scenario* is presented in Table 6.31.

The associated CO₂ emission from the total electricity generation in 2019 is calculated to be almost 185 million tons, which is lower than that of the *BAU Scenario*. As pointed in Section 6.4.1, there is a sharp increase in the amount of electricity generated by the coal planned power plants in 2016 and 2018. This increase in coal power plants result in a sharp increase in the amount of associated CO₂ emission in these years as seen in Table 6.30.

Table 6.30. Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based on Renewable Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	43,701	14,156	299	35,384	7,078	168	0	100,786
2010	45,007	15,659	308	36,626	7,277	173	0	105,050
2011	45,087	15,684	309	36,691	7,289	174	0	105,233
2012	45,087	15,684	309	37,036	7,289	174	0	105,579
2013	45,087	18,653	309	37,730	7,289	215	0	109,281
2014	45,087	18,653	309	40,083	7,289	215	0	111,635
2015	45,087	18,653	309	43,420	7,289	237	0	114,994
2016	45,087	31,210	309	43,420	7,289	237	0	127,551
2017	45,087	35,608	309	46,018	7,289	237	0	134,548
2018	52,828	60,607	309	46,802	7,289	237	0	168,071
2019	53,401	71,220	1,653	51,138	7,289	237	0	184,938

Table 6.31. Percentage Distribution of Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based of Renewable Scenario

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Biomass
2008	43.60%	14.00%	0.30%	35.30%	6.60%	0.20%	0.00%
2009	43.40%	14.00%	0.30%	35.10%	7.00%	0.20%	0.00%
2010	42.80%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2011	42.80%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2012	42.70%	14.90%	0.30%	35.10%	6.90%	0.20%	0.00%
2013	41.30%	17.10%	0.30%	34.50%	6.70%	0.20%	0.00%
2014	40.40%	16.70%	0.30%	35.90%	6.50%	0.20%	0.00%
2015	39.20%	16.20%	0.30%	37.80%	6.30%	0.20%	0.00%
2016	35.30%	24.50%	0.20%	34.00%	5.70%	0.20%	0.00%
2017	33.50%	26.50%	0.20%	34.20%	5.40%	0.20%	0.00%
2018	31.40%	36.10%	0.20%	27.80%	4.30%	0.10%	0.00%
2019	28.90%	38.50%	0.90%	27.70%	3.90%	0.10%	0.00%

6.6.3. Fossil Fuel Scenario

This scenario includes the following assumptions:

- Total energy demand will be supplied only by national electricity generation.
- All power plants as of 2008 will be running till to 2019.
- All planned power plants will be completed up to 2019 based on the timing given in Table 6.11.
- To overcome the deficiency between demand and supply as presented in Table 6.17, only fossil fuels are used as the primary energy source.
- The shares of each fossil fuel in the total fossil fuel mix of 2008 generation are used as the fossil fuel shares between 2009 and 2019. These shares are estimated to be constant between 2009 and 2019.
- To obtain the associated CO₂ emissions, the amount of electricity generated by each fuel type is multiplied with its fuel specific emission factors in Table 6.9.

- The fuel specific emission factors of all renewable energy sources are accepted as zero.

The amount of the incremental electricity supply based on *Fossil Fuel Scenario* by fuel type is given in Table 6.32. As explained in Section 6.6.1, the amounts of electricity to be generated in 2009 and 2010 have negative signs in. Also as seen in Appendix - C, there will be no incremental contribution from renewable energy sources and share of fossil fuels as primary energy supplies are constant between 2009 and 2019.

Table 6.32. Amount of Incremental Electricity (GWh) Supply by Fuel Type Based on Fossil Fuel Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	-1,552	-528		-25	-3,621	0	0	0	0	-17	-6,082
2010	-89	-31		-2	-208	0	0	0	0	-1	-350
2011	2,998	1,021		48	6,996	653	0	0	0	33	11,749
2012	6,567	2,236		105	15,324	1,430	0	0	0	73	25,736
2013	9,435	3,214		151	22,018	2,055	0	0	0	105	36,979
2014	12,224	4,163		196	28,525	2,662	0	0	0	136	47,907
2015	14,677	4,999		235	34,251	3,196	0	0	0	164	57,523
2016	15,855	5,401		254	36,998	3,452	0	0	0	177	62,136
2017	17,574	5,986		282	41,010	3,827	0	0	0	196	68,875
2018	8,345	2,842		134	19,475	1,817	0	0	0	93	32,708
2019	6,530	2,224		105	15,238	1,422	0	0	0	73	25,592

Table 6.13 and incremental electricity supply given in Table 6.32 are combined to determine the total amount of electricity to be generated to provide the estimated demand between 2009 and 2019. The amount and percentage distribution of total electricity generated by fuel type based Fossil Fuel Scenario are given in Table 6.33 and Table 6.34, respectively. According to Table 6.34, the fossil fuel ratio reaches to nearly 85 % between 2013 and 2017. Since the deficiency is high for these years, more fossil fuel is required to provide the demand. The decrease in fossil fuel ratio for 2018 and 2019 is due to high amount of hydro power plant contribution from the planned part of electricity supply.

Table 6.33. Amount of Total Electricity Generated (GWh) by Fuel Type Based on Fossil Fuel Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	FO	Hydro	Wind	Geo	Biomass	MWG	Total
2009	40,195	13,814	645	93,982	9,316	34,181	924	474	20	449	194,000
2010	41,658	15,376	668	97,895	9,635	35,022	1,516	474	20	465	202,730
2011	44,745	16,428	718	105,099	10,307	35,598	1,956	537	20	499	215,907
2012	48,314	17,643	775	114,352	11,084	36,702	2,135	537	20	539	232,101
2013	51,182	21,537	821	122,900	11,709	37,821	2,300	537	20	681	249,508
2014	53,971	22,486	866	135,700	12,316	39,078	2,534	537	20	712	268,221
2015	56,424	23,322	905	150,346	12,850	40,145	2,988	537	20	800	288,338
2016	57,602	36,059	924	153,093	13,106	44,267	3,255	537	20	813	309,675
2017	59,321	40,964	952	164,054	13,481	48,820	3,610	537	20	832	332,591
2018	57,260	62,378	804	144,613	11,471	68,748	10,609	537	52	729	357,202
2019	55,975	72,185	3,691	151,971	11,076	75,452	11,821	607	149	709	383,635

Table 6.34. Percentage Distributions of Total Electricity Generated by Fuel Type Based on Fossil Fuel Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	FO	Hydro	Wind	Geo	Biomass	MWG	Fossil	Renewable
2009	20.7%	7.1%	0.3%	48.4%	4.8%	17.6%	0.5%	0.2%	0.0%	0.2%	81.6%	18.4%
2010	20.5%	7.6%	0.3%	48.3%	4.8%	17.3%	0.7%	0.2%	0.0%	0.2%	81.7%	18.3%
2011	20.7%	7.6%	0.3%	48.7%	4.8%	16.5%	0.9%	0.2%	0.0%	0.2%	82.3%	17.7%
2012	20.8%	7.6%	0.3%	49.3%	4.8%	15.8%	0.9%	0.2%	0.0%	0.2%	83.0%	17.0%
2013	20.5%	8.6%	0.3%	49.3%	4.7%	15.2%	0.9%	0.2%	0.0%	0.3%	83.7%	16.3%
2014	20.1%	8.4%	0.3%	50.6%	4.6%	14.6%	0.9%	0.2%	0.0%	0.3%	84.3%	15.7%
2015	19.6%	8.1%	0.3%	52.1%	4.5%	13.9%	1.0%	0.2%	0.0%	0.3%	84.8%	15.2%
2016	18.6%	11.6%	0.3%	49.4%	4.2%	14.3%	1.1%	0.2%	0.0%	0.3%	84.5%	15.5%
2017	17.8%	12.3%	0.3%	49.3%	4.1%	14.7%	1.1%	0.2%	0.0%	0.3%	84.1%	15.9%
2018	16.0%	17.5%	0.2%	40.5%	3.2%	19.2%	3.0%	0.2%	0.0%	0.2%	77.6%	22.4%
2019	14.6%	18.8%	1.0%	39.6%	2.9%	19.7%	3.1%	0.2%	0.0%	0.2%	77.1%	22.9%

To obtain the associated CO₂ emissions, the amount of electricity generated by each fuel type are multiplied with its fuel specific emission factors as given in Table 6.9. The amount of associated CO₂ emission of the incremental electricity supply presented in Table 6.32 is given in Table 6.35. As explained previously, the supply in 2009 and 2010 was higher than demand, thus less electricity and also less CO₂ will be generated than the ones given for the total supply. Therefore, the amount of associated CO₂ emission by fuel type for 2009 and 2010 are given in negative values, which means that these amounts will be deducted from the those of the total supply.

As seen here, lignite and natural gas are the main CO₂ emitters. Since the shares of incremental energy sources are constant, shares of incremental CO₂ emission are also constant between 2009 and 2019 as given in Appendix - C.

Table 6.35. Amount of Associated CO₂ Emissions of the Incremental Electricity Supply by Fuel Type Based on Fossil Fuel Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	-1,675.65	-538.60	-11.83	-1,354.64	-254.78	-6.80	0.00	-3,842.30
2010	-96.65	-31.10	-0.83	-77.64	-14.78	-0.80	0.00	-220.80
2011	3,237.35	1,039.90	22.17	2,616.36	493.22	12.20	0.00	7,421.20
2012	7,092.35	2,276.90	48.17	5,731.60	1,079.22	27.20	0.00	16,255.44
2013	10,190.35	3,271.42	70.17	8,235.26	1,551.22	39.17	0.00	23,357.59
2014	13,201.35	4,238.42	90.17	10,668.56	2,009.22	51.17	0.00	30,259.88
2015	15,851.35	5,089.42	108.17	12,809.48	2,413.22	60.79	0.00	36,333.42
2016	17,123.35	5,497.71	117.17	13,837.48	2,606.22	65.79	0.00	39,247.72
2017	18,980.35	6,093.95	130.17	15,337.63	2,889.22	72.79	0.00	43,504.11
2018	9,013.19	2,893.73	62.17	7,283.47	1,372.22	34.79	0.00	20,659.57
2019	7,052.12	2,264.08	47.89	5,698.84	1,073.22	26.79	0.00	16,164.93

The associated CO₂ emissions of the total electricity generated based on *Fossil Fuel Scenario* by fuel type are given in Table 6.36. The percentage distribution of the associated CO₂ emission of the total electricity generated by each fuel type based on fossil scenario is presented in Table 6.37.

The associated CO₂ emission from the total electricity generation in 2019 is calculated to be more than 201 million tons, which is more than two times of the value in 2009 and higher than those of *BAU* and *Renewable Scenarios*. Since the incremental electricity supply is highly based on fossil fuels, this scenario has more CO₂ emission than the previously explained ones. The percentage distribution of associated CO₂ emissions by fuel type is given in Table 6.37. As seen in this table, there is a rapid increase in CO₂ emission in 2016 and 2018, due to high piling of lignite and coal, rather than natural gas, power plants.

Table 6.36. Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based on Fossil Fuel Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2008	45,078	14,472	309	36,427	6,862	174	0	103,322
2009	43,411	14,062	297	35,149	7,034	167	0	100,120
2010	44,990	15,653	308	36,613	7,274	173	0	105,012
2011	48,324	16,724	331	39,307	7,782	186	0	112,654
2012	52,179	17,961	357	42,768	8,368	201	0	121,834
2013	55,277	21,924	379	45,965	8,840	254	0	132,639
2014	58,288	22,891	399	50,752	9,298	266	0	141,895
2015	60,938	23,742	417	56,229	9,702	298	0	151,327
2016	62,210	36,708	426	57,257	9,895	303	0	166,799
2017	64,067	41,702	439	61,356	10,178	310	0	178,052
2018	61,841	63,501	371	54,085	8,661	272	0	188,731
2019	60,453	73,484	1,701	56,837	8,362	264	0	201,103

Table 6.37. Percentage Distribution of Associated CO₂ Emissions of the Total Electricity Generated by Fossil Type Based of Fossil Fuel Scenario

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable
2008	43.60%	14.00%	0.30%	35.30%	6.60%	0.20%	0.00%
2009	43.40%	14.00%	0.30%	35.10%	7.00%	0.20%	0.00%
2010	42.80%	14.90%	0.30%	34.90%	6.90%	0.20%	0.00%
2011	42.90%	14.80%	0.30%	34.90%	6.90%	0.20%	0.00%
2012	42.80%	14.70%	0.30%	35.10%	6.90%	0.20%	0.00%
2013	41.70%	16.50%	0.30%	34.70%	6.70%	0.20%	0.00%
2014	41.10%	16.10%	0.30%	35.80%	6.60%	0.20%	0.00%
2015	40.30%	15.70%	0.30%	37.20%	6.40%	0.20%	0.00%
2016	37.30%	22.00%	0.30%	34.30%	5.90%	0.20%	0.00%
2017	36.00%	23.40%	0.20%	34.50%	5.70%	0.20%	0.00%
2018	32.80%	33.60%	0.20%	28.70%	4.60%	0.10%	0.00%
2019	30.10%	36.50%	0.80%	28.30%	4.20%	0.10%	0.00%

6.6.4. Natural Gas Scenario

This scenario includes the following assumptions:

- Total energy demand will be supplied only by national electricity generation.
- All power plants as of 2008 will be running till to 2019.
- All planned power plants will be completed up to 2019 based on the timing given in Table 6.11.
- To overcome the deficiency between demand and supply as presented in Table 6.17, only natural gas is used the primary energy sources.
- To obtain the associated CO₂ emissions, the amount of electricity generated by each fuel type is multiplied with its fuel specific emission factors in Table 6.9.
- The fuel specific emission factors of all renewable energy sources are accepted as zero.

The amount of the incremental electricity supply based on *Natural Gas Scenario* by fuel type is given in Table 6.38 and Appendix-C, respectively. As seen in Appendix - C, all incremental contribution is from natural gas between 2009 and 2019, and the shares of this incremental electricity generation by natural gas are 100 %.

Table 6.38. Amount of Incremental Electricity (GWh) Supply by Fuel Type Based on Natural Gas Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2009	0	0	0	-6,082	0	0	0	0	0	0	-6,082
2010	0	0	0	-349	0	0	0	0	0	0	-350
2011	0	0	0	11,749	0	0	0	0	0	0	11,749
2012	0	0	0	25,736	0	0	0	0	0	0	25,736
2013	0	0	0	36,979	0	0	0	0	0	0	36,979
2014	0	0	0	47,907	0	0	0	0	0	0	47,907
2015	0	0	0	57,523	0	0	0	0	0	0	57,523
2016	0	0	0	62,136	0	0	0	0	0	0	62,136
2017	0	0	0	68,875	0	0	0	0	0	0	68,875
2018	0	0	0	32,707	0	0	0	0	0	0	32,708
2019	0	0	0	25,592	0	0	0	0	0	0	25,592

Table 6.13 and incremental electricity supply given in Table 6.38 are combined to determine the total amount of electricity to be generated to provide the estimated demand between 2009 and 2019. The amount and percentage distribution of total electricity generated by fuel type based *Natural Gas Scenario* are given in Table 6.39 and Table 6.40, respectively. As seen in Table 6.40, the fossil fuel share is the same as that of *Fossil Fuel Scenario* seen in Table 6.34, since natural gas is a fossil fuel. In the view of the fact that the deficiency is very high between 2013 and 2017, more fossil fuel is required to provide the demand. The decrease in fossil fuel ratio in 2018 and 2019 is due to high amount of hydro contribution from the planned part of electricity supply.

Table 6.39. Amount of Total Electricity Generated (GWh) by Fuel Type Based on Natural Gas Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG	Total
2008	41,738	14,216	670	97,399	9,089	33,256	843	162	0	466	197,839
2009	41,747	14,342	670	91,521	9,654	34,181	924	474	20	466	194,000
2010	41,747	15,407	670	97,754	9,654	35,022	1,516	474	20	466	202,730
2011	41,747	15,407	670	109,852	9,654	35,598	1,956	537	20	466	215,907
2012	41,747	15,407	670	124,764	9,654	36,702	2,135	537	20	466	232,101
2013	41,747	18,323	670	137,861	9,654	37,821	2,300	537	20	576	249,508
2014	41,747	18,323	670	155,082	9,654	39,078	2,534	537	20	576	268,221
2015	41,747	18,323	670	173,618	9,654	40,145	2,988	537	20	636	288,338
2016	41,747	30,658	670	178,231	9,654	44,267	3,255	537	20	636	309,675
2017	41,747	34,978	670	191,919	9,654	48,820	3,610	537	20	636	332,591
2018	48,915	59,536	670	157,845	9,654	68,748	10,609	537	52	636	357,202
2019	49,445	69,961	3,586	162,325	9,654	75,452	11,821	607	149	636	383,635

Table 6.40. Percentage Distributions of Total Electricity Generated by Fuel Type Based on Natural Gas Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	FO	Hydro	Wind	Geo	Biomass	MWG	Fossil	Renewable
2008	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%	82.7%	17.3%
2009	21.5%	7.4%	0.3%	47.2%	5.0%	17.6%	0.5%	0.2%	0.0%	0.2%	81.6%	18.4%
2010	20.6%	7.6%	0.3%	48.2%	4.8%	17.3%	0.7%	0.2%	0.0%	0.2%	81.7%	18.3%
2011	19.3%	7.1%	0.3%	50.9%	4.5%	16.5%	0.9%	0.2%	0.0%	0.2%	82.3%	17.7%
2012	18.0%	6.6%	0.3%	53.8%	4.2%	15.8%	0.9%	0.2%	0.0%	0.2%	83.0%	17.0%
2013	16.7%	7.3%	0.3%	55.3%	3.9%	15.2%	0.9%	0.2%	0.0%	0.2%	83.7%	16.3%
2014	15.6%	6.8%	0.2%	57.8%	3.6%	14.6%	0.9%	0.2%	0.0%	0.2%	84.3%	15.7%
2015	14.5%	6.4%	0.2%	60.2%	3.3%	13.9%	1.0%	0.2%	0.0%	0.2%	84.8%	15.2%
2016	13.5%	9.9%	0.2%	57.6%	3.1%	14.3%	1.1%	0.2%	0.0%	0.2%	84.5%	15.5%
2017	12.6%	10.5%	0.2%	57.7%	2.9%	14.7%	1.1%	0.2%	0.0%	0.2%	84.1%	15.9%
2018	13.7%	16.7%	0.2%	44.2%	2.7%	19.2%	3.0%	0.2%	0.0%	0.2%	77.6%	22.4%
2019	12.9%	18.2%	0.9%	42.3%	2.5%	19.7%	3.1%	0.2%	0.0%	0.2%	77.1%	22.9%

The associated CO₂ emission of the incremental electricity supply presented in Table 6.38 is given Table 6.41. As seen here, natural gas is the only CO₂ emitter.

Table 6.41. Amount of Associated CO₂ Emissions of the Incremental Electricity Supply by Fuel Type Based on Natural Gas Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	0	0	0	-2,275	0	0	0	-2,275
2010	0	0	0	-131	0	0	0	-131
2011	0	0	0	4,394	0	0	0	4,394
2012	0	0	0	9,626	0	0	0	9,625
2013	0	0	0	13,830	0	0	0	13,831
2014	0	0	0	17,918	0	0	0	17,917
2015	0	0	0	21,513	0	0	0	21,513
2016	0	0	0	23,238	0	0	0	23,239
2017	0	0	0	25,760	0	0	0	25,759
2018	0	0	0	12,232	0	0	0	12,233
2019	0	0	0	9,571	0	0	0	9,571

To obtain the associated CO₂ emissions of *Natural Gas Scenario*, each fuel is multiplied with the fuel specific emission factors in Table 6.9. Table 6.42 presents the CO₂ emissions from each primary energy supplies and total annual CO₂ emissions. The percentage of each fuel associated emissions is pointed out in Table 6.43.

The associated CO₂ emission from the total electricity generation in 2019 is calculated to be 194 million tons, which is less than that of *Fossil Fuel Scenario*, though it is higher than that of *Renewable Scenario*.

Table 6.42. Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based on Natural Gas Scenario, thousands tons

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2008	45,078	14,472	309	36,427	6,862	174	0	103,322
2009	45,087	14,601	309	34,229	7,289	174	0	101,687
2010	45,087	15,684	309	36,560	7,289	174	0	105,102
2011	45,087	15,684	309	41,085	7,289	174	0	109,627
2012	45,087	15,684	309	46,662	7,289	174	0	115,204
2013	45,087	18,653	309	51,560	7,289	215	0	123,112
2014	45,087	18,653	309	58,001	7,289	215	0	129,552
2015	45,087	18,653	309	64,933	7,289	237	0	136,507
2016	45,087	31,210	309	66,658	7,289	237	0	150,790
2017	45,087	35,608	309	71,778	7,289	237	0	160,307
2018	52,828	60,607	309	59,034	7,289	237	0	180,304
2019	53,401	71,220	1,653	60,709	7,289	237	0	194,509

Table 6.43. Percentage Distribution of Associated CO₂ Emissions of the Total Electricity Generated by Fuel Type Based of Natural Gas Scenario

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable
2008	43.60%	14.00%	0.30%	35.30%	6.60%	0.20%	0.00%
2009	44.30%	14.40%	0.30%	33.70%	7.20%	0.20%	0.00%
2010	42.90%	14.90%	0.30%	34.80%	6.90%	0.20%	0.00%
2011	41.10%	14.30%	0.30%	37.50%	6.60%	0.20%	0.00%
2012	39.10%	13.60%	0.30%	40.50%	6.30%	0.20%	0.00%
2013	36.60%	15.20%	0.30%	41.90%	5.90%	0.20%	0.00%
2014	34.80%	14.40%	0.20%	44.80%	5.60%	0.20%	0.00%
2015	33.00%	13.70%	0.20%	47.60%	5.30%	0.20%	0.00%
2016	29.90%	20.70%	0.20%	44.20%	4.80%	0.20%	0.00%
2017	28.10%	22.20%	0.20%	44.80%	4.50%	0.10%	0.00%
2018	29.30%	33.60%	0.20%	32.70%	4.00%	0.10%	0.00%
2019	27.50%	36.60%	0.80%	31.20%	3.70%	0.10%	0.00%

6.6.5. Comparative Assessment of the Scenarios

The percentage distributions of the fossil fuels and renewable energies based on the four scenarios are given in Table 6.44. As seen here, the share of the fossil fuels and the renewable energies are the same for the *Fossil Fuel* and *Natural Gas Scenarios*. In *BAU Scenario*, there is a continuous increase in renewable energy ratio. Especially this increasing will be accelerated for the 2018 and 2019, due to high the contribution of hydro energy into electricity generation.

For *Renewable Scenario*, there is a rapid increase in renewable energy usage in 2013. Contribution of renewable energies are increasing continuously between 2009 and 2019, particularly the ratio of the renewable contribution / total electricity demand will be the highest for 2013. In addition to this, as expected, renewable energy usage is much higher than other scenarios.

Table 6.44. Fossil and Renewable energy dependency of all scenarios

	Business As Usual		Renewable		Fossil Fuel		Natural Gas	
	Fossil	Renewable	Fossil	Renewable	Fossil	Renewable	Fossil	Renewable
2008	82.7%	17.3%	82.7%	17.3%	82.7%	17.3%	82.7%	17.3%
2009	82.2%	17.8%	82.2%	17.8%	81.6%	18.4%	81.6%	18.4%
2010	81.8%	18.2%	81.8%	18.2%	81.7%	18.3%	81.7%	18.3%
2011	81.4%	18.6%	76.9%	23.1%	82.3%	17.7%	82.3%	17.7%
2012	81.1%	18.9%	71.9%	28.1%	83.0%	17.0%	83.0%	17.0%
2013	81.1%	18.9%	61.5%	38.5%	83.7%	16.3%	83.7%	16.3%
2014	81.2%	18.8%	66.4%	33.6%	84.3%	15.7%	84.3%	15.7%
2015	81.4%	18.6%	64.9%	35.1%	84.8%	15.2%	84.8%	15.2%
2016	81.0%	19.0%	64.4%	35.6%	84.5%	15.5%	84.5%	15.5%
2017	80.5%	19.5%	63.4%	36.6%	84.1%	15.9%	84.1%	15.9%
2018	76.0%	24.0%	68.5%	31.5%	77.6%	22.4%	77.6%	22.4%
2019	75.9%	24.1%	70.4%	29.6%	77.1%	22.9%	77.1%	22.9%

There are fluctuations in the shares of the fossil fuel and renewable energies among the scenarios due to various reasons. The first reason is based on using different types of primary energy sources for each scenario. The second reason is related to the ratio of renewable energy contribution / total electricity demand. The increasing of the share of renewable energy sources are different than the increasing of total electricity demand. The last reason is the piling problem of planned power plants. Planned power plants are not distributed equally in terms of fuel type and time range. Especially for 2018 and 2019, the characteristics of the related scenario could not be observed easily, due to the piling of supply problem. Despite everything, there is an apparent difference between four scenarios.

Figure 6.7 presents the renewable energy ratio fluctuation between 2009 and 2019 for four scenarios. There is convergence among all scenarios for 2018 and 2019. The reason is that the completion times of planned projects are piling in these two years. Natural gas, coal, lignite and hydro are main primary energy parts of this piling. There is a convergence in renewable scenario due to less amount of additional renewable sources are required for 2018 and 2019, so the renewable energy contribution is also less than other years. For the same reason, there is converging in other scenarios.

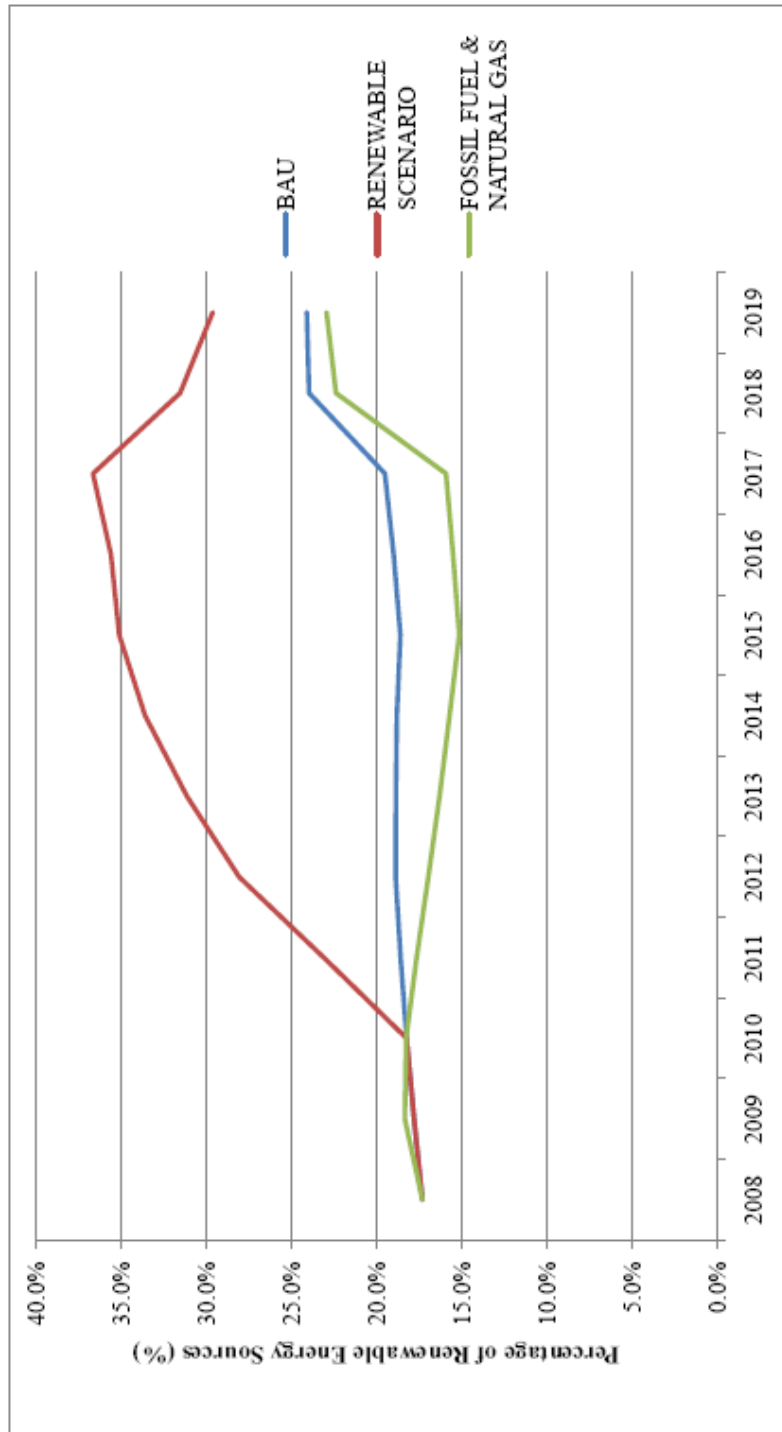


Figure 6.7. Fluctuation of Renewable Energy Ratio for Four Scenarios

Comparison of CO₂ emissions of all scenarios gives the best mitigation option for electricity sector. The associated CO₂ emissions of four scenarios are presented in Table 6.45. Fossil fuel scenario has the maximum emissions. Renewable energy has the minimum emissions. Totally, the associated CO₂ emission of *Fossil Fuel Scenario* will have the highest increase at 89 % between 2008 and 2019. It is followed by the *Business As Usual Scenario* (86%), *Natural Gas Scenario* (82%) and *Renewable Scenario* (73%).

Table 6.45. Comparison of CO₂ Emissions for Four Scenarios, million tons

CO ₂	BAU		RENEWABLE		FOSSIL		NATURAL GAS	
2008	106.60		106.60		106.60		106.60	
2009	100.79	-6%	100.79	-6%	100.12	-6%	101.69	-5%
2010	105.05	4%	105.05	4%	105.01	5%	105.10	3%
2011	111.37	6%	105.23	0%	112.65	7%	109.63	4%
2012	119.02	6%	105.58	0%	121.83	8%	115.20	5%
2013	128.59	7%	109.28	3%	132.64	8%	123.11	6%
2014	136.65	6%	111.64	2%	141.89	7%	129.55	5%
2015	145.04	6%	114.99	3%	151.33	6%	136.51	5%
2016	160.00	9%	127.55	10%	166.80	9%	150.79	9%
2017	170.52	6%	134.55	5%	178.05	6%	160.31	6%
2018	185.15	8%	168.07	20%	188.73	6%	180.30	11%
2019	198.30	7%	184.94	9%	201.10	6%	194.51	7%
% 09-19		86%		73%		89%		82%

Figure 6.8 presents the emission pathway of each scenario. Starting with 2011, emissions of *Renewable Scenario* are differentiated from the other scenarios. However, in 2018 and 2019, there is convergence of emission of renewable scenario to the other scenario. This is also due to ratio of renewable energy usage and total electricity demand and piling problem in planned power plants for these years.

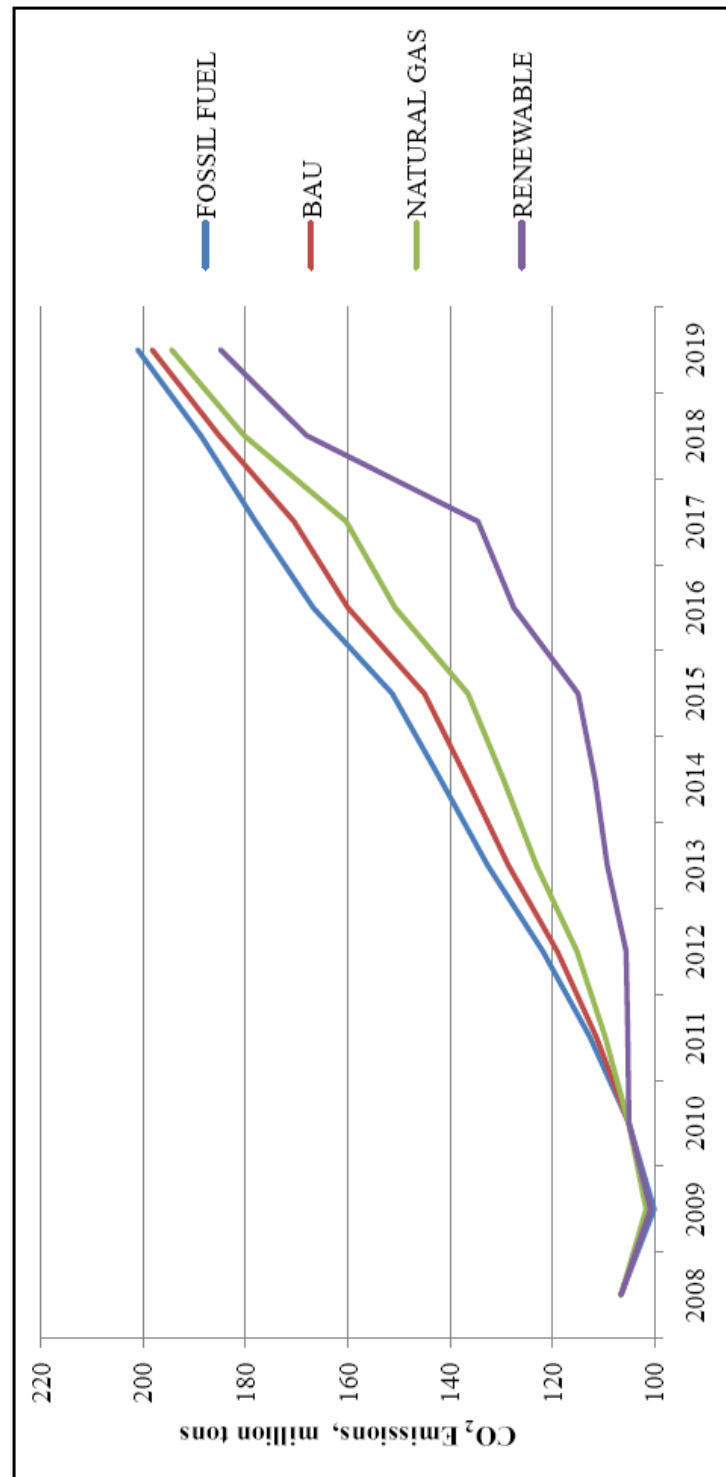


Figure 6.8. Traces of Each Scenario's Emission

6.7. Closing Remarks

This chapter presents the amount of electricity generated and associated CO₂ emissions calculated using the IPCC methodology based on fuel and ownership type. These results show that there is a strong correlation of 0.99 between thermal generated electricity and associated CO₂ emission between 2001 and 2008 in Turkey. In addition to this, the calculated emissions are in line with those of other studies are also presented. The results also showed that the main energy sources for electricity generation are natural gas, lignite, hydro, hard coal and fuel oil, and almost half of the electricity generated between 2001 and 2008 from natural gas power plants. Due to lignite's higher emission factor, more than 60% of the CO₂ emissions are from lignite power plants.

This chapter also presents the specific CO₂ emission factors calculated based on IPCC methodology for each fuel type using the power plants data between 2001 and 2008. These values are found to be close to those of International Energy Agency which were developed for Turkey.

The classification of the power plants in Turkey based on ownership showed that the share of public power plants decreases and private power plants generated more than half of the electricity as of 2008. Due to the fact that the share of generated electricity from renewable sources, especially hydro, by public power plants fluctuated, associated CO₂ emissions of them were also oscillating.

In order to provide the rapidly increasing electricity demand of Turkey, the planned power plants data are gathered from EMRA and classified based on completion year and fuel type between 2009 and 2019. The results show that the planned power plants that use hard coal has the highest share of 35%, and followed by natural gas and hydro power plants with shares of 25% and 26%, respectively. The percentage distribution of the total electricity supply (existing + planned) based on fuel type also

shows that the natural gas power plants still have the largest generation share, which is followed by similar shares of lignite and hydro power plants, on average.

It is also found that the total electricity supply (planned + existing) will not be sufficient to provide the estimated demand between 2011 and 2019, thus new additional power plants should be built to overcome this deficiency. In addition to this, mitigation of CO₂ emission from electricity generation is the priority issue to combat the climate change and also the main objective of this study. For these reasons, different four scenarios are developed to overcome this issue.

The first scenario, *Business as Usual (BAU) Scenario*, considers electricity supply security rather than climate change issue. In this scenario shares of each primary energy sources to generate electricity are estimated to have the same share values of 2008. The electricity generation associated CO₂ emissions of this scenario is estimated as 198.30 million tons for 2019, which will yield an increase of 86 % between 2008 and 2019. The results of scenario are accepted as a reference point for the comparison with the other scenarios.

The second scenario, named as *Renewable Scenario*, is developed considering economically feasible renewable energy sources of Turkey. In this scenario, the contribution of renewable energies is increasing continuously between 2009 and 2019. The electricity generation associated CO₂ emissions of this scenario is estimated as 184.94 million tons for 2019, which will yield an increase of 73 % between 2008 and 2019. In this scenario, the overall mitigation of CO₂ emissions between 2009 and 2019 compare to *BAU* scenario is estimated as 192.82 million tons CO₂ emissions.

The third scenario, named as *Fossil Fuel Scenario*, is based on using only fossil fuel sources with the shares from 2008 generation. The electricity generation associated CO₂ emissions of this scenario is estimated as 201.10 million tons as of 2019, which will yield an increase of 89 % between 2008 and 2019. In this scenario, the overall

increase of CO₂ emissions between 2009 and 2019 compare to *BAU* scenario is estimated as 39.68 million tons CO₂ emissions

The last and the fourth scenario, named as *Natural Gas Scenario*, is developed based on the assumption that natural gas is the only energy source to generate electricity for the deficit of the total supply. The electricity generation associated CO₂ emissions of this scenario is estimated as 194.51 million tons as of 2019, which will yield an increase at 82 % between 2008 and 2019. In this scenario, the overall mitigation of CO₂ emissions between 2009 and 2019 compare to *BAU* scenario is estimated as 53.78 million tons CO₂ emissions

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

In this study, the mitigation potential of CO₂ emission from electricity generation by using renewable energy sources for the deficit part between estimated demand and supply (planned + existing) is investigated. The amount of electricity generated and fuel consumption data of the power plants between 2001 and 2008 obtained from NLDC [8] is used for analyses.

This study is the first comprehensive study that;

- analyzes the associated CO₂ emission from electricity generation using the data available from each of the major power plant in Turkey
- calculates specific emission factors by fuel type using the power plant data
- determines the amount of electricity that will be generated by fuel type annually between 2009 and 2019
- analyzes the amount of associated CO₂ emission reduction by using available economically feasible renewable sources.

In the first part of the study, the generated electricity based on fuel type and ownership, associated CO₂ emissions, and fuel specific emission factors are calculated using this data. Based on these calculations, the amount of total electricity generation increased from 122,311 GWh to 197,839 GWh between 2001 and 2008 in Turkey, which corresponds to a total of 62% increase for this period.. For the same period, the associated CO₂ emissions increased about 55% from 68 million tons to 106 million tons.

The classification of the power plants in terms of ownership showed that the share of private power plants in total electricity generation has increased from 43% to 60% between 2001 and 2008. According to the associated CO₂ emission distribution, the emissions from the private power plants have higher shares than those from the public ones. This is due to the fact that majority of the private power plants are fossil fueled.

In this study, fuel specific emission factors for Turkey are also generated. Lignite and hard coal have the highest fuel specific emission factors as 1,080 kg CO₂/MWh and 1,018 kg CO₂/MWh, respectively. The specific emission factor for natural gas is calculated as 374 kg CO₂/MWh which is lower than those of lignite and hard coal.

In the second part, the power plants that are planned to be built in Turkey between 2009 and 2019 are determined using the data obtained from EMRA [11]. The amount of electricity that will be generated by fuel type annually between 2009 and 2019 shows mainly power plants using natural gas, hydro and coal are expected to be built in this period.

The electricity demand in Turkey is expected to increase above 7% annually between 2009 and 2019, and reach to 383,635 GWh in 2019 [10]. However, the annual increase in total electricity supply (existing and planned) is lower than of the demand for this period. For this reason, new and additional power plants need to be built to generate electricity for the estimated demand when necessary.

In 2009 and 2010, due to economic crisis, the expected demand is lower than the total supply. However, between 2011 and 2019, the total supply (existing and planned) will not be sufficient to supply the estimated demand. To overcome this problem new, additional and sustainable primary energy sources are need to be used to generate electricity taking into account the reduction of associated CO₂ emission.

In this part of this study, four scenarios are developed to supply the deficit part of the total supply, and the amounts of electricity generated by fuel type and associated CO₂ emission is compared.

The first scenario, *BAU Scenario*, considers electricity supply security rather than climate change issue. In this scenario shares of each primary energy sources to generate electricity are estimated to have the same share values of 2008. The electricity generation associated CO₂ emissions of this scenario is estimated as 198.30 million tons for 2019, which will yield an increase of 86 % between 2008 and 2019. The results of scenario are accepted as a reference point for the comparison with those of the other scenarios.

The second scenario, named as *Renewable Scenario*, is developed considering economically feasible renewable energy sources of Turkey. The electricity generation associated CO₂ emissions of this scenario is estimated as 184.94 million tons for 2019, which will yield an increase of 73 % between 2008 and 2019. In this scenario, the overall mitigation of CO₂ emissions between 2009 and 2019 compared to *BAU* scenario is estimated as 192.82 million tons CO₂ emissions.

The third scenario, named as *Fossil Fuel Scenario*, is based on using only fossil fuel sources with the shares from 2008 generation. The electricity generation associated CO₂ emissions of this scenario is estimated as 201.10 million tons as of 2019, which will yield an increase of 89 % between 2008 and 2019. In this scenario, the overall increase of CO₂ emissions between 2009 and 2019 compared to *BAU* scenario is estimated as 39.68 million tons CO₂ emissions

The last and the fourth scenario, named as *Natural Gas Scenario*, is developed based on the assumption that natural gas is the only energy source to generate electricity for the deficit of the total supply. The electricity generation associated CO₂ emissions of this scenario is estimated as 194.51 million tons as of 2019, which will yield an increase of 82 % between 2008 and 2019. In this scenario, the overall mitigation of

CO₂ emissions between 2009 and 2019 compared to *BAU* scenario is estimated as 53.78 million tons CO₂ emissions

The total CO₂ emissions of *Business As Usual*, *Renewable*, *Fossil Fuel*, and *Natural Gas Scenarios* between 2009 and 2019 are given in Figure 7.1. As seen here, *Renewable Scenario* has the least CO₂ emissions as 1,368 million tons, *Natural Gas Scenario* follows the *Renewable Scenario* with 1,507 million tons of CO₂ emissions, and *Fossil Fuel Scenario* has the highest CO₂ emission as 1,600 million tons between 2009 and 2019.

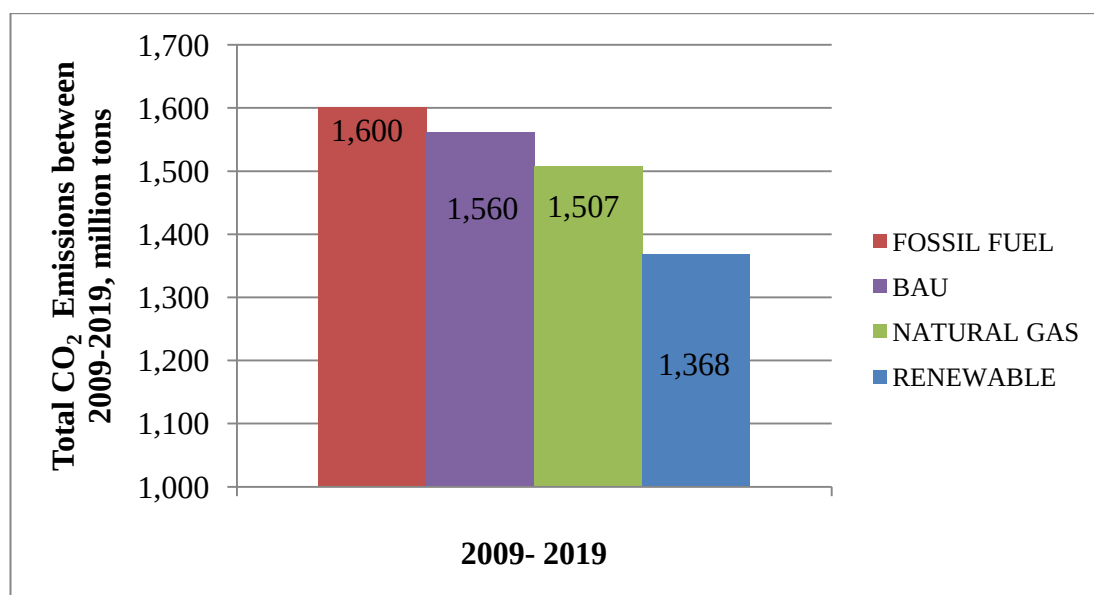


Figure 7.1. Comparison of Total CO₂ Emission of four Scenarios between 2009 and 2019

In conclusion, Turkey's deficient part of electricity demand will be supplied by four scenarios with different shares of renewable energies. In terms of mitigation of CO₂ emissions, the scenario with lowest emission is *Renewable Energy Scenario*. This scenario provides a reduction of 192 millions of CO₂ emissions with respect to *BAU Scenario* between 2009 and 2019. In climate change negotiations under UNFCCC, this amount could be declared as the deviation of CO₂ emissions from the business as usual conditions. In addition to this, Turkey could use this mitigation potential to get benefit from flexible mechanisms in the climate change issue, such as the

emission trading. Renewable energy scenario also provides an increase of share of national energy sources in the electricity generation by using the hydro, geothermal, wind, and biomass potentials of Turkey. This would also reduce the energy dependency on foreign sources.

7.1. Recommendations

The recommendations for future work are as follows:

- IPCC Tier 3 approach, which includes the use of the combustion technology, operating conditions, age of equipment, *etc.*, can be used to calculate the CO₂ emission if the required data will be available in the future.
- The regional historical and future associated CO₂ emission in each of the nine load distribution regions of Turkey can be calculated.
- The CO₂ emission from autoproducer power plants can be calculated using the exact fuel consumption data if it will be available in the future.
- The economic cost and Cost / Benefit Analysis of these scenarios can also be performed, if required data will be available in the future.
- CO₂ mitigation potential by carbon capture and storage technologies in electricity sector can be calculated especially for hard coal and lignite thermal power plants in Turkey.
- Electricity generation associated CO₂ emissions with different electricity demand scenario can be calculated.
- CO₂ mitigation potential by carbon sequestration technologies can be calculated in Turkey.

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APPENDIX – A

CO₂ EMISSIONS OF EACH THERMAL POWER PLANT IN TURKEY

In this section generated electricity, fuel consumption, LHV, Specific Emission Factors, and CO₂ emissions of each thermal power plant in Turkey between 2001 and 2008 are given in Table A.1 - Table A.8.

Table A1. Thermal Power Plants in 2001

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	4,319,752	Fuel Oil	1,030,629	9,580	77,400	41,338	3,199,566
AMBARLI-B	8,928,203	NG	1,915,411	34,901	56,100	66,850	3,750,271
BURSA DG	10,520,641	NG	1,909,610	34,960	56,100	66,760	3,745,234
		Hard Coal	1,597,112	3,200	94,600	21,398	2,024,225
		Fuel Oil	19,352	9,560	77,400	775	59,952
CATES-B	1,877,602	Diesel	319	10,300	74,100	14	1,019
		Lignite	1,435,015	2,350	96,762	14,119	1,366,191
		Fuel Oil	5,516	9,560	77,400	221	17,089
ORHANELİ	1,461,640	Diesel	7	10,300	74,100	0	22
ALİAĞA	813,806	Diesel	209,739	10,300	74,100	9,045	670,219
		Lignite	5,916,205	1,500	107,835	37,155	4,006,604
		Fuel Oil	2,831	9,560	77,400	113	8,770
SEYİTÖMER	3,829,468	Diesel	6,928	10,300	74,100	299	22,138
TUTES - A	229,614	Lignite	241,704	2,600	93,505	2,631	246,023
		Lignite	1,696,876	2,600	93,505	18,472	1,727,192
		Fuel Oil	9,559	9,560	77,400	383	29,614
TUTES - B	1,606,561	Diesel	912	10,300	74,100	39	2,914
		Lignite	4,498,785	2,100	100,019	39,555	3,956,209
		Fuel Oil	9,890	9,560	77,400	396	30,639
YATAĞAN	3,567,875	Lignite	12,321,496	950	115,000	49,008	5,635,950
		Fuel Oil	368,691	9,560	77,400	14,757	1,142,204
		Diesel	8,940	10,300	74,100	386	28,568
ELBİSTAN-A	5,249,720	Diesel					

Table A1. Thermal Power Plants in 2001 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg/kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
ENGIL	7,958	Diesel	3,076	10,300	74,100	133	9,831
		Lignite	5,797,556	1,300	110,441	31,555	3,484,984
		Fuel Oil	10,313	9,560	77,400	413	31,950
KANGAL	2,719,416	Diesel	1,261	10,300	74,100	54	4,030
HOPA	179,981	Fuel Oil	65,711	9,600	77,400	2,641	204,424
		Lignite	1,778,311	2,800	90,900	20,847	1,895,011
		Fuel Oil	2,996	9,560	77,400	120	9,282
PARK 3-4	1,949,922	Diesel	118	10,300	74,100	5	377
		Lignite	1,964,793	2,800	90,900	23,033	2,093,731
		Fuel Oil	11,444	9,560	77,400	458	35,453
PARK 1-2	2,257,727	Diesel	0	10,300	74,100	0	0
HAMITABAT	7,601,735	NG	1,804,177	33,896	56,100	61,154	3,430,761
		Lignite	4,539,992	1,533	107,405	29,139	3,129,709
KEMRKÖY	2,914,470	Fuel Oil	8,625	9,560	77,400	345	26,720
SOMA - A	357,431	Lignite	274,258	3,325	90,900	3,818	347,054
		Lignite	5,965,893	2,400	96,111	59,947	5,761,586
		Fuel Oil	61,668	9,560	77,400	2,468	191,047
SOMA - B	5,761,820	Diesel	10	10,300	74,100	0	32
		Lignite	3,421,524	1,750	104,578	25,069	2,621,683
YENİKÖY	2,226,665	Fuel Oil	12,256	9,560	77,400	491	37,969
P-1	3,783,079	NG	709,512	34,900	56,100	24,762	1,389,147
P-2	3,759,630	NG	705,114	34,900	56,100	24,608	1,380,536

Table A1. Thermal Power Plants in 2001 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-3	2,329,643	NG	436,922	34,900	56,100	15,249	855,445
P-4	2,142,232	NG	401,773	34,900	56,100	14,022	786,628
P-5	1,453,786	NG	272,656	34,900	56,100	9,516	533,830
P-6	1,289,328	NG	241,812	34,900	56,100	8,439	473,441
P-7	924,487	Fuel Oil	224,730	9,560	77,400	8,995	696,214
P-8	897,522	Fuel Oil	218,175	9,560	77,400	8,733	675,907
P-9	887,564	NG	166,462	34,900	56,100	5,810	325,914
P-10	885,526	NG	166,079	34,900	56,100	5,796	325,165
P-11	830,243	NG	155,711	34,900	56,100	5,434	304,865
P-12	708,683	NG	132,913	34,900	56,100	4,639	260,228
P-13	702,076	NG	131,674	34,900	56,100	4,595	257,802
P-14	668,896	Hard Coal	534,921	3,200	94,600	7,167	677,974
P-15	577,995	NG	108,402	34,900	56,100	3,783	212,240
P-16	449,498	NG	84,303	34,900	56,100	2,942	165,056
SMPT	3,587,098	NG	672,756	34,900	56,100	23,479	1,317,182
SMPT	2,255,583	Fuel Oil	548,302	9,560	77,400	21,946	1,698,637
SMPT	43,113	Lignite	46,806	2,400	96,111	470	45,203
SMPT	166,479	LPG	99,971	10,900	63,100	1,090	68,759
SMPT	327,071	Naphtha	205,849	10,400	73,300	2,141	156,923
SMPT	279,947	Hard Coal	223,876	3,200	94,600	2,999	283,746
SMPT	29,697	MWG	28,951	6,714	54,600	194	10,613
SMPT	280,759	Diesel	69,343	10,300	74,100	2,990	221,584

Table A2. Thermal Power Plants in 2002

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	1,812,395	Fuel Oil	433,432	9,580	77,400	17,385	1,345,580
AMBARLI-B	8,053,976	NG	1,588,238	34,901	56,100	55,431	3,109,684
BURSA DG	8,595,254	NG	1,695,874	34,960	56,100	59,288	3,326,043
CATES-B		Hard Coal	1,405,560	3,200	94,600	18,831	1,781,446
		Fuel Oil	22,797	9,560	77,400	912	70,625
		Diesel	274	10,300	74,100	12	876
ORHANELİ		Lignite	964,025	2,350	96,762	9,485	917,790
		Fuel Oil	4,100	9,560	77,400	164	12,702
		Diesel	36	10,300	74,100	2	115
ALİAĞA	1,013,891	Diesel	49,506	10,300	74,100	2,135	158,196
		Lignite	5,699,226	1,500	107,835	35,792	3,859,660
		Fuel Oil	4,327	9,560	77,400	173	13,405
SEYİTÖMER	3,243,485	Diesel	3,593	10,300	74,100	155	11,481
TUTES - A	277,759	Lignite	288,522	2,600	93,505	3,141	293,676
		Lignite	769,908	2,600	93,505	8,381	783,663
		Fuel Oil	81,748	9,560	77,400	3,272	253,255
TUTES - B	1,013,965	Diesel	1,805	10,300	74,100	78	5,768
		Lignite	3,684,408	2,100	100,019	32,394	3,240,050
		Fuel Oil	12,122	9,560	77,400	485	37,554
YATAĞAN	2,671,620	Lignite	7,497,915	950	115,000	29,823	3,429,606
ELBİSTAN-A	2,880,176	Fuel Oil	7,925	9,560	77,400	317	24,552
		Diesel	5,643	10,300	74,100	243	18,032

Table A2. Thermal Power Plants in 2002 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
ENGIL	4,225	Diesel	1,705	10,300	74,100	74	5,449
		Lignite	4,515,005	1,300	110,441	24,574	2,714,027
		Fuel Oil	9,812	9,560	77,400	393	30,398
KANGAL	2,080,494	Diesel	2,998	10,300	74,100	129	9,580
HOPA	66,049	Fuel Oil	23,444	9,600	77,400	942	72,933
		Lignite	1,904,708	2,800	90,900	22,329	2,029,703
		Fuel Oil	9,143	9,560	77,400	366	28,325
PARK 3-4	2,184,125	Diesel	884	10,300	74,100	38	2,825
		Lignite	1,853,976	2,800	90,900	21,734	1,975,642
		Fuel Oil	0	9,560	77,400	0	0
PARK 1-2	1,938,714	Diesel	0	10,300	74,100	0	0
HAMITABAT	6,827,464	NG	1,492,152	33,896	56,100	50,578	2,837,425
		Lignite	5,047,770	1,533	107,405	32,398	3,479,753
KE M E R K Ö Y	3,262,230	Fuel Oil	8,795	9,560	77,400	352	27,247
SOMA - A	265,953	Lignite	196,745	3,325	90,900	2,739	248,967
		Lignite	5,772,282	2,400	96,111	58,002	5,574,605
		Fuel Oil	35,933	9,560	77,400	1,438	111,320
SOMA - B	5,209,028	Diesel	10	10,300	74,100	0	32
		Lignite	2,617,545	1,750	104,578	19,178	2,005,648
YENİKÖY	1,681,395	Fuel Oil	5,660	9,560	77,400	227	17,535
P-17	4,276,739	NG	802,097	34,900	56,100	27,993	1,570,419
P-2	3,730,957	NG	699,737	34,900	56,100	24,421	1,370,007
P-1	3,021,818	NG	566,738	34,900	56,100	19,779	1,109,612

Table A2. Thermal Power Plants in 2002 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-3	2,450,023	NG	459,499	34,900	56,100	16,037	899,648
P-18	2,024,789	NG	379,747	34,900	56,100	13,253	743,503
P-4	1,972,094	NG	369,864	34,900	56,100	12,908	724,153
P-5	1,527,049	NG	286,396	34,900	56,100	9,995	560,732
P-6	1,354,024	NG	253,946	34,900	56,100	8,863	497,198
P-8	1,083,733	Fuel Oil	263,441	9,560	77,400	10,544	816,139
P-19	971,261	NG	182,159	34,900	56,100	6,357	356,647
P-7	946,726	Fuel Oil	230,136	9,560	77,400	9,211	712,961
P-9	870,687	NG	163,296	34,900	56,100	5,699	319,716
P-11	845,117	NG	158,501	34,900	56,100	5,532	310,327
P-10	817,025	NG	153,232	34,900	56,100	5,348	300,012
P-14	742,674	Hard Coal	593,922	3,200	94,600	7,957	752,753
P-16	736,748	NG	138,176	34,900	56,100	4,822	270,534
P-12	728,916	NG	136,707	34,900	56,100	4,771	267,658
SMPT	2,656,319	NG	498,190	34,900	56,100	17,387	975,400
SMPT	6,801,552	Fuel Oil	1,653,365	9,560	77,400	66,177	5,122,120
SMPT	44,887	Lignite	48,732	2,400	96,111	490	47,063
SMPT	171,071	LPG	102,728	10,900	63,100	1,120	70,655
SMPT	575,472	Naphtha	362,185	10,400	73,300	3,767	276,101
SMPT	405,967	Hard Coal	324,655	3,200	94,600	4,350	411,477
SMPT	28,564	MWG	27,847	6,714	54,600	187	10,208
SMPT	167,602	Diesel	41,395	10,300	74,100	1,785	132,277

Table A3. Thermal Power Plants in 2003

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	850,162	Fuel Oil	206,753	9,580	77,400	8,293	641,860
AMBARLI-B	6,109,981	NG	1,323,132	34,901	56,100	46,179	2,590,621
BURSA DG	3,097,441	NG	595,535	34,960	56,100	20,820	1,167,996
		Hard Coal	1,425,189	3,200	94,600	19,094	1,806,325
		Fuel Oil	20,628	9,560	77,400	826	63,905
CATES-B	1,727,487	Diesel	159	10,300	74,100	7	508
		Lignite	737,392	2,350	96,762	7,255	702,026
		Fuel Oil	5,247	9,560	77,400	210	16,255
ORHANELİ	695,834	Diesel	1,866	10,300	74,100	80	5,963
ALİAĞA	0	Diesel	0	10,300	74,100	0	0
		Lignite	4,772,562	1,500	107,835	29,973	3,232,100
		Fuel Oil	3,441	9,560	77,400	138	10,660
SEYİTÖMER	2,801,563	Diesel	2,850	10,300	74,100	123	9,107
TUTE S - A	149,780	Lignite	160,437	2,600	93,505	1,746	163,303
		Lignite	616,053	2,600	93,505	6,706	627,059
		Fuel Oil	4,834	9,560	77,400	193	14,976
TUTE S - B	615,588	Diesel	601	10,300	74,100	26	1,920
		Lignite	2,881,511	2,100	100,019	25,355	2,533,987
YATAĞAN	2,096,939	Fuel Oil	7,224	9,560	77,400	289	22,380
		Lignite	9,100,321	950	115,000	36,196	4,162,559
		Fuel Oil	13,087	9,560	77,400	524	40,543
ELBİSTAN-A	3,081,250	Diesel	6,245	10,300	74,100	269	19,956

Table A3. Thermal Power Plants in 2003 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
ENGİL		Diesel		10,300	74,100	0	0
KANGAL	1,694,838	Lignite	3,825,524	1,300	110,441	20,822	2,299,571
		Fuel Oil	17,566	9,560	77,400	703	54,419
HOPA	853	Diesel	17,870	10,300	74,100	771	57,103
		Fuel Oil	315	9,600	77,400	13	980
PARKI-2-3-4	4,238,097	Lignite	3,835,801	2,800	90,900	44,967	4,087,523
		Fuel Oil	6,135	9,560	77,400	246	19,006
		Diesel	657	10,300	74,100	28	2,099
		Lignite	7,846	2,340	96,892	77	7,448
ÇAN	7,930	Fuel Oil	0				
		Diesel	0				
HAMİTABAT	2,207,153	NG	519,076	33,896	56,100	17,595	987,057
		Lignite	3,103,541	1,533	107,405	19,920	2,139,471
KEMERKÖY	2,071,710	Fuel Oil	5,524	9,560	77,400	221	17,113
		Lignite	156,859	3,325	90,900	2,184	198,494
S O M A - A	195,330	Lignite	1,920,044	2,400	96,111	19,293	1,854,291
		Fuel Oil	21,531	9,560	77,400	862	66,703
S O M A - B	3,978,504	Diesel	538,215	10,300	74,100	23,210	1,719,861
		Lignite	2,326,555	1,750	104,578	17,046	1,782,682
YENİKÖY	1,594,110	Fuel Oil	6,059	9,560	77,400	243	18,771
		NG	2,005,296	34,900	56,100	69,985	3,926,148
P-20	10,692,125	NG	1,808,374	34,900	56,100	63,112	3,540,597
P-21	9,642,148	NG					
P-18	5,417,400	NG	1,016,027	34,900	56,100	35,459	1,989,269

Table A3. Thermal Power Plants in 2003 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-2	3,813,482	NG	715,214	34,900	56,100	24,961	1,400,310
P-3	2,513,474	NG	471,399	34,900	56,100	16,452	922,948
P-4	2,045,907	NG	383,707	34,900	56,100	13,391	751,257
P-6	1,686,276	NG	316,259	34,900	56,100	11,037	619,201
P-5	1,497,141	NG	280,787	34,900	56,100	9,799	549,750
P-7	1,069,563	Fuel Oil	259,996	9,560	77,400	10,407	805,468
P-8	1,063,668	Fuel Oil	258,563	9,560	77,400	10,349	801,028
P-10	902,112	NG	169,190	34,900	56,100	5,905	331,255
P-11	882,639	NG	165,538	34,900	56,100	5,777	324,105
P-23	866,894	NG	162,585	34,900	56,100	5,674	318,323
P-9	846,074	NG	158,680	34,900	56,100	5,538	310,678
P-14	782,097	Hard Coal	625,449	3,200	94,600	8,380	792,711
P-16	737,251	NG	138,271	34,900	56,100	4,826	270,719
P-10	707,492	NG	132,689	34,900	56,100	4,631	259,791
SMPT	7,527,016	NG	1,411,683	34,900	56,100	49,268	2,763,920
SMPT	4,378,642	Fuel Oil	1,064,388	9,560	77,400	42,603	3,297,472
SMPT	111,874	Lignite	121,457	2,400	96,111	1,220	117,298
SMPT	167,388	LPG	100,517	10,900	63,100	1,096	69,134
SMPT	520,833	Naphtha	327,797	10,400	73,300	3,409	249,886
SMPT	324,552	Hard Coal	259,547	3,200	94,600	3,477	328,957
SMPT	32,709	MWG	31,888	6,714	54,600	214	11,690
SMPT	0	Diesel	0	10,300	74,100	0	0

Table A4. Thermal Power Plants in 2004

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	702,914	Fuel Oil	178,641	9,580	77,400	7,165	554,587
AMBARLI-B	5,552,166	NG	1,128,487	34,901	56,100	39,385	2,209,517
BURSA DG	764,917	NG	143,000	34,960	56,100	4,999	280,460
CATES-B	1,475,931	Hard Coal	1,213,302	3,200	94,600	16,256	1,537,773
		Fuel Oil	16,743	9,560	77,400	670	51,870
		Diesel	75	10,300	74,100	3	240
ORHANELİ	1,055,285	Lignite	789,655	2,350	96,762	7,769	751,782
		Fuel Oil	75,075	9,560	77,400	3,005	232,582
		Diesel	269	10,300	74,100	12	860
ALIAĞA	2,873	Diesel		10,300	74,100	0	0
		Lignite	4,456,124	1,500	107,835	27,985	3,017,800
SEYİTÖMER	2,600,685	Fuel Oil	1,371	9,560	77,400	55	4,247
		Diesel	1,609	10,300	74,100	69	5,142
TUTES-A	63,501	Lignite	65,472	2,600	93,505	713	66,642
		Lignite	1,283,748	2,600	93,505	13,974	1,306,683
TUTES-B	1,188,106	Fuel Oil	7,476	9,560	77,400	299	23,161
		Diesel	2,672	10,300	74,100	115	8,538
		Lignite	4,754,638	950	115,000	18,911	2,174,809
ELBİSTAN-A	1,825,440	Fuel Oil	6,051	9,560	77,400	242	18,746
		Diesel	5,589	10,300	74,100	241	17,860
ENGİL		Diesel		10,300	74,100	0	0

Table A4. Thermal Power Plants in 2004 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emiss. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
KANGAL	1,491,321	Lignite	3,327,670	1,300	110,441	18,112	2,000,305
		Fuel Oil	6,802	9,560	77,400	272	21,073
		Diesel	1,783	10,300	74,100	77	5,698
PARK 1-2-3-4	3,876,819	Lignite	3,416,274	2,800	90,900	40,049	3,640,465
		Fuel Oil	5,240	9,560	77,400	210	16,234
		Diesel	523	10,300	74,100	23	1,671
ÇAN	456,561	Lignite	450,000	2,340	96,892	4,409	427,168
		Fuel Oil					
		Diesel					
ELBİSTAN-B	573,240	Lignite	1,700,000	950	115,000	6,762	777,593
		Fuel Oil					
		Diesel					
HAMİTABAT	520,049	NG	117,750	33,896	56,100	3,991	223,910
		Lignite	2,649,972	1,533	107,405	17,008	1,826,796
KEMERKÖY	1,727,520	Fuel Oil	11,691	9,560	77,400	468	36,219
S O M A – A	60,486	Lignite	56,753	3,325	90,900	790	71,817
		Lignite	3,853,894	2,400	96,111	38,725	3,721,913
		Fuel Oil	23,499	9,560	77,400	941	72,800
S O M A – B	3,547,110	Diesel	31	10,300	74,100	1	99
		Lignite	2,146,743	1,750	104,578	15,729	1,644,904
YENİKÖY	1,498,305	Fuel Oil	4,866	9,560	77,400	195	15,075
YATAĞAN	2,123,525	Lignite	3,006,923	2,100	100,019	26,438	2,644,273
		Fuel Oil	8,562	9,560	77,400	343	26,525

Table A4. Thermal Power Plants in 2004 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-20	9,743,218	NG	1,827,329	34,900	56,100	63,774	3,577,710
P-21	9,202,131	NG	1,725,849	34,900	56,100	60,232	3,379,023
P-22	8,183,708	Hard Coal	6,544,570	3,200	94,600	87,683	8,294,772
P-18	5,082,238	NG	953,168	34,900	56,100	33,266	1,866,198
P-23	4,340,976	NG	814,145	34,900	56,100	28,414	1,594,006
P-18	3,738,920	NG	701,230	34,900	56,100	24,473	1,372,931
P-2	3,561,073	NG	667,875	34,900	56,100	23,309	1,307,626
P-3	2,427,109	NG	455,201	34,900	56,100	15,887	891,234
P-4	2,024,465	NG	379,686	34,900	56,100	13,251	743,384
P-6	1,836,596	NG	344,452	34,900	56,100	12,021	674,398
P-5	1,436,299	NG	269,376	34,900	56,100	9,401	527,409
P-7	1,133,096	Fuel Oil	275,440	9,560	77,400	11,025	853,313
P-11	1,060,826	NG	198,957	34,900	56,100	6,944	389,535
P-8	968,144	Fuel Oil	235,343	9,560	77,400	9,420	729,091
P-10	937,955	NG	175,912	34,900	56,100	6,139	344,417
P-9	872,425	NG	163,622	34,900	56,100	5,710	320,354
SMPT	10,112,937	NG	1,896,670	34,900	56,100	66,194	3,713,470
SMPT	3,893,336	Fuel Oil	946,417	9,560	77,400	37,881	2,931,997
SMPT	115,203	Lignite	125,072	2,400	96,111	1,257	120,788
SMPT	207,920	LPG	124,856	10,900	63,100	1,361	85,875
SMPT	593,468	Naphtha	373,511	10,400	73,300	3,885	284,735
SMPT	231,995	Hard Coal	185,528	3,200	94,600	2,486	235,144
SMPT	32,646	MW/G	31,826	6,714	54,600	214	11,667

Table A5. Thermal Power Plants in 2005

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emiss. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	854,788	Fuel Oil	208,949	9,580	77,400	8,381	648,678
AMBARLI-B	6,275,498	NG	1,417,663	34,901	56,100	49,478	2,775,708
BURSA DG	2,384,146	NG	442,990	34,960	56,100	15,487	868,817
		H. Coal	1,346,482	3,200	94,600	18,040	1,706,570
		Fuel Oil	45,383	9,560	77,400	1,816	140,596
CATES-B	1,856,671	Diesel	14	10,300	74,100	1	45
		Lignite	100,221	2,350	96,762	986	95,414
		Fuel Oil	143,742	9,560	77,400	5,753	445,312
ORHANELİ	633,964	Diesel	1,715	10,300	74,100	74	5,480
		Lignite	5,781,333	1,500	107,835	36,308	3,915,265
		Fuel Oil	2,419	9,560	77,400	97	7,494
SEYİTÖMER	3,455,120	Diesel	2,698	10,300	74,100	116	8,621
TUTES-A	78,402	Lignite	83,086	2,600	93,505	904	84,570
		Lignite	1,100,997	2,600	93,505	11,985	1,120,667
		Fuel Oil	8,041	9,560	77,400	322	24,911
TUTES - B	1,132,063	Diesel	648	10,300	74,100	28	2,071
		Lignite	7,042,094	950	115,000	28,010	3,221,109
		Fuel Oil	8,506	9,560	77,400	340	26,352
ELBİSTAN-A	2,511,250	Diesel	7,863	10,300	74,100	339	25,126
		Lignite	4,720,355	1,300	110,441	25,692	2,837,465
		Fuel Oil	18,816	9,560	77,400	753	58,292
KANGAL	2,049,803	Diesel	8,601	10,300	74,100	371	27,484

Table A5. Thermal Power Plants in 2005 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
K A N G A L	2,049,803	Lignite	4,720,355	1,300	110,441	25,692	2,837,465
		Fuel Oil	18,816	9,560	77,400	753	58,292
		Diesel	8,601	10,300	74,100	371	27,484
P A R K 1-2-3-4	4,058,327	Lignite	3,666,388	2,800	90,900	42,981	3,906,992
		Fuel Oil	5,397	9,560	77,400	216	16,720
		Diesel	1,134	10,300	74,100	49	3,624
Ç A N	825,210	Lignite	415,302	2,340	96,892	4,069	394,230
		Fuel Oil	92,458	9,560	77,400	3,701	
		Diesel	3,274	10,300	74,100	141	
E L B İ S T A N - B	4,432,056	Lignite	13,000,000	950	115,000	51,707	5,946,303
		Fuel Oil	0				
		Diesel	0				
H A M İ T A B A I	1,416,677	NG	320,000	33,896	56,100	10,847	608,501
		Lignite	2,194,818	1,533	107,405	14,087	1,513,029
		Fuel Oil	5,435	9,560	77,400	218	16,838
K E M E R K Ö Y	73,998	Lignite	60,698	3,325	90,900	845	76,809
		Lignite	3,976,622	2,400	96,111	39,958	3,840,439
		Fuel Oil	47,279	9,560	77,400	1,892	146,470
S O M A - B	3,810,654	Diesel	41	10,300	74,100	2	131
		Lignite	2,277,202	1,750	104,578	16,685	1,744,866
		Fuel Oil	8,112	9,560	77,400	325	25,131
Y E N İ K Ö Y	1,698,305	Lignite	4,330,870	2,100	100,019	38,078	3,808,546
		Lignite					
		Fuel Oil					
Y A T A Ğ A N	3,334,000	Fuel Oil	7,029	9,560	77,400	281	21,776

Table A5. Thermal Power Plants in 2005 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-21	10,990,843	NG	2,061,320	34,900	56,100	71,940	4,035,838
P-20	10,907,591	NG	2,045,706	34,900	56,100	71,395	4,005,267
P-22	8,597,796	Hard Coal	6,875,720	3,200	94,600	92,119	8,714,481
P-18	5,530,108	NG	1,037,165	34,900	56,100	36,197	2,030,655
P-23	5,498,317	NG	1,031,203	34,900	56,100	35,989	2,018,982
P-2	3,724,684	NG	698,560	34,900	56,100	24,380	1,367,704
P-18	3,641,913	NG	683,037	34,900	56,100	23,838	1,337,311
P-3	2,593,816	NG	486,467	34,900	56,100	16,978	952,449
P-6	1,899,317	NG	356,215	34,900	56,100	12,432	697,429
P-4	1,851,386	NG	347,225	34,900	56,100	12,118	679,829
P-5	1,347,958	NG	252,808	34,900	56,100	8,823	494,970
P-7	1,167,135	Fuel Oil	283,715	9,560	77,400	11,356	878,947
P-11	1,078,569	NG	202,284	34,900	56,100	7,060	396,050
P-24	919,947	Fuel Oil	223,627	9,560	77,400	8,951	692,795
P-10	902,159	NG	169,199	34,900	56,100	5,905	331,273
P-9	785,412	NG	147,303	34,900	56,100	5,141	288,403
SMPT	12,036,666	NG	2,257,463	34,900	56,100	78,785	4,419,864
SMPT	2,977,482	Fuel Oil	723,785	9,560	77,400	28,970	2,242,285
SMPT	142,677	Lignite	34,683	9,560	96,111	1,388	133,422
SMPT	226,364	LPG	135,932	10,900	63,100	1,482	93,493
SMPT	657,719	Naphtha	394,961	10,900	63,100	4,305	271,650
SMPT	267,931	Hard Coal	65,130	9,560	77,400	2,607	201,774
SMPT	111,110	MWG	66,722	10,900	63,100	727	45,890

Table A6. Thermal Power Plants in 2006

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	1,035,917	Fuel Oil	257,292	9,580	77,400	10,320	798,758
AMBARLI-B	7,654,051	NG	1,782,045	34,901	56,100	62,195	3,489,148
BURSA DG	5,009,001	NG	926,575	34,960	56,100	32,393	1,817,251
		Hard Coal	1,566,921	3,200	94,600	20,993	1,985,960
CATES-B	1,909,362	Fuel Oil	44,126	9,560	77,400	1,766	136,702
		Diesel	45	10,300	74,100	2	144
		Lignite	1,264,264	2,350	96,762	12,439	1,203,629
ORHANELİ	1,139,424	Fuel Oil	14,580	9,560	77,400	584	45,169
ALIAGA		Diesel	30	10,300	74,100	1	96
K.ÇEVİRİM	20,517	Diesel	4,675	10,300	74,100	202	14,939
JEOTERMAL	94,072	Steam					
		Lignite	4,791,666	1,500	107,835	30,093	3,245,038
		Fuel Oil	2,598	9,560	77,400	104	8,049
SEYİTÖMER	2,986,695	Diesel	2,871	10,300	74,100	124	9,174
T U T E S - A	78,254	Lignite	78,443	2,600	93,505	854	79,844
		Lignite	1,116,863	2,600	93,505	12,158	1,136,816
		Fuel Oil	8,257	9,560	77,400	330	25,580
T U T E S - B	1,070,008	Diesel	2,947	10,300	74,100	127	9,417
		Lignite	3,217,241	950	115,000	12,796	1,471,591
ELBİSTAN-A	2,760,443	Fuel Oil	510,403	9,560	77,400	20,429	1,581,227
		Diesel	7,738	10,300	74,100	334	24,727
		Lignite	5,815,952	1,300	110,441	31,655	3,496,043
KANGAL	2,545,428	Fuel Oil	18,744	9,560	77,400	750	58,069
		Diesel	2,008	10,300	74,100	87	6,417

Table A6. Thermal Power Plants in 2006 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
PARK 1-2-3-4	4,065,979	Lignite	3,602,008	2,800	90,900	42,226	3,838,387
		Fuel Oil	5,122	9,560	77,400	205	15,868
		Diesel	1,005	10,300	74,100	43	3,211
ÇAN	1,260,805	Lignite	1,141,250	2,340	96,892	11,181	1,083,345
		Fuel Oil	517	9,560	77,400	21	
		Diesel	2,503	10,300	74,100	108	
ELBİSTAN-B HAMİTABAT	4,888,346 2,268,459	Lignite	15,501,627	950	115,000	61,657	7,090,567
		Fuel Oil	0				
		Diesel	0				
KEMERKÖY S O M A - A	2,945,160 186,023	NG	510,000	33,896	56,100	17,287	969,798
		Lignite	4,874,783	1,533	107,405	31,288	3,360,502
		Fuel Oil	6,460	9,560	77,400	259	20,013
S O M A - B	3,141,574	Lignite	157,124	3,325	90,900	2,187	198,829
		Lignite	3,153,354	2,400	96,111	31,686	3,045,365
		Fuel Oil	33,793	9,560	77,400	1,353	104,691
YENİKÖY	2,011,385	Diesel	113	10,300	74,100	5	361
		Lignite	2,581,563	1,750	104,578	18,915	1,978,078
		Fuel Oil	6,552	9,560	77,400	262	20,298
YATAĞAN P-20	2,894,958 11,710,707	Lignite	3,930,004	2,100	100,019	34,554	3,456,026
		Fuel Oil	9,129	9,560	77,400	365	28,282
		NG	2,196,330	34,900	56,100	76,652	4,300,172
P-21	11,047,257	NG	2,071,900	34,900	56,100	72,309	4,056,553
P-22	8,797,573	Hard Coal	7,035,483	3,200	94,600	94,260	8,916,969
P-18	5,760,921	NG	1,080,454	34,900	56,100	37,708	2,115,410

Table A6. Thermal Power Plants in 2006 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emiss. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-23	5,417,030	NG	1,015,958	34,900	56,100	35,457	1,989,134
P-2	3,740,371	NG	701,502	34,900	56,100	24,482	1,373,464
P-18	3,687,550	NG	691,596	34,900	56,100	24,137	1,354,068
P-3	2,384,805	NG	447,267	34,900	56,100	15,610	875,700
P-4	2,045,357	NG	383,604	34,900	56,100	13,388	751,055
P-6	1,804,948	NG	338,516	34,900	56,100	11,814	662,777
P-5	1,455,860	NG	273,045	34,900	56,100	9,529	534,592
P-11	1,057,966	NG	198,420	34,900	56,100	6,925	388,485
P-16	1,026,036	NG	192,432	34,900	56,100	6,716	376,760
P-7	943,447	Fuel Oil	229,339	9,560	77,400	9,179	710,492
P-9	783,553	NG	146,934	34,900	56,100	5,129	287,721
P-10	710,546	NG	133,262	34,900	56,100	4,651	260,912
SMPT	11,962,015	NG	2,243,462	34,900	56,100	78,297	4,392,452
SMPT	3,676,611	Fuel Oil	893,734	9,560	77,400	35,772	2,768,786
SMPT	135,836	Lignite	33,020	9,560	96,111	1,322	127,025
SMPT	170,039	LPG	102,108	10,900	63,100	1,113	70,229
SMPT	635,936	Naphtha	381,880	10,900	63,100	4,162	262,653
SMPT	1,512,764	Hard Coal	367,732	9,560	77,400	14,719	1,139,234
SMPT	126,243	MWG	75,809	10,900	63,100	826	52,141

Table A7. Thermal Power Plants in 2007

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	2,224,365	Fuel Oil	547,900	9,580	77,400	21,976	1,700,944
AMBARLI-B	9,519,538	NG	2,000,000	34,901	56,100	69,802	3,915,892
BURSA DG	8,110,908	NG	1,550,000	34,960	56,100	54,188	3,039,947
		Hard Coal	1,758,209	3,200	94,600	23,556	2,228,403
		Fuel Oil	33,162	9,560	77,400	1,327	102,736
CATES-B	2,072,541	Diesel	11	10,300	74,100	0	35
		Lignite	1,096,733	2,350	96,762	10,791	1,044,133
		Fuel Oil	11,276	9,560	77,400	451	34,933
ORHANELİ	1,159,910	Diesel	44	10,300	74,100	2	141
ALİAĞA	10,288	Diesel	2,500	10,300	74,100	108	7,989
		Lignite	4,717,437	1,500	107,835	29,626	3,194,768
		Fuel Oil	9,475	9,560	77,400	379	29,354
SEYİTÖMER	3,121,865	Diesel	3,247	10,300	74,100	140	10,376
TUTES - A	5,219	Lignite	5,587	2,600	93,505	61	5,687
		Lignite	1,550,031	2,600	93,505	16,873	1,577,723
		Fuel Oil	5,312	9,560	77,400	213	16,457
TUTES - B	1,472,841	Diesel	570	10,300	74,100	25	1,821
		Lignite	12,380,442	950	115,000	49,243	5,662,912
		Fuel Oil	12,372	9,560	77,400	495	38,328
ELBİSTAN-A	4,160,682	Diesel	9,134	10,300	74,100	394	29,188
		Lignite	5,753,311	1,300	110,441	31,314	3,458,388
		Fuel Oil	21,815	9,560	77,400	873	67,583
KANGAL	2,745,000	Diesel	4,471	10,300	74,100	193	14,287

Table A7. Thermal Power Plants in 2007 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
PARK 1-2-3-4	4,266,191	Lignite	3,782,560	2,800	90,900	44,343	4,030,788
		Fuel Oil	5,205	9,560	77,400	208	16,125
		Diesel	353	10,300	74,100	15	1,128
ÇAN	2,050,869	Lignite	1,946,980	2,340	96,892	19,075	1,848,194
		Fuel Oil	377	9,560	77,400	15	
		Diesel	958	10,300	74,100	41	
ELBİSTAN-B	6,148,858	Lignite	19,000,000	950	115,000	75,572	8,690,750
		Fuel Oil	0				
		Diesel	0				
HAMİTABAT	5,620,849	NG	1,300,000	33,896	56,100	44,065	2,472,035
KEMERKÖY	2,906,544	Lignite	4,996,586	1,533	107,405	32,070	3,444,469
		Fuel Oil	5,644	9,560	77,400	226	17,485
S O M A - A	292,082	Lignite	243,326	3,325	90,900	3,387	307,912
		Lignite	4,760,508	2,400	96,111	47,835	4,597,480
		Fuel Oil	34,980	9,560	77,400	1,400	108,368
S O M A - B	4,396,405	Diesel	27	10,300	74,100	1	86
		Lignite	3,095,265	1,750	104,578	22,679	2,371,693
YENİKÖY	2,212,483	Fuel Oil	5,706	9,560	77,400	228	17,677
		Lignite	4,113,362	2,100	100,019	36,166	3,617,270
YATAĞAN	3,069,165	Fuel Oil	6,322	9,560	77,400	253	19,586
		NG	2,211,964	34,900	56,100	77,198	4,330,781
P-20	11,794,067	NG					
P21	11,651,160	NG	2,185,162	34,900	56,100	76,262	4,278,306

Table A7. Thermal Power Plants in 2007 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-22	9,926,153	Hard Coal	7,938,017	3,200	94,600	106,352	10,060,865
P-18	5,849,938	NG	1,097,149	34,900	56,100	38,291	2,148,097
P-23	5,626,235	NG	1,055,194	34,900	56,100	36,826	2,065,953
P-18	3,817,610	NG	715,988	34,900	56,100	24,988	1,401,826
P-2	3,735,888	NG	700,661	34,900	56,100	24,453	1,371,818
P-6	2,267,500	NG	425,267	34,900	56,100	14,842	832,626
P-4	2,024,619	NG	379,715	34,900	56,100	13,252	743,440
P-3	1,893,462	NG	355,117	34,900	56,100	12,394	695,279
P-24	1,608,409	NG	301,655	34,900	56,100	10,528	590,608
P-5	1,477,016	NG	277,013	34,900	56,100	9,668	542,360
P-8	1,021,660	Fuel Oil	248,352	9,560	77,400	9,940	769,392
P-11	1,012,099	NG	189,818	34,900	56,100	6,625	371,643
P-16	1,003,226	NG	188,154	34,900	56,100	6,567	368,385
P-25	983,131	NG	184,385	34,900	56,100	6,435	361,006
P-26	934,834	NG	175,327	34,900	56,100	6,119	343,271
P-27	933,701	NG	175,115	34,900	56,100	6,111	342,855
SMPT	11,116,883	NG	2,335,593	6,453	56,100	44,173	2,478,132
SMPT	5,335,354	Fuel Oil	1,314,191	9,560	77,400	52,602	4,071,360
SMPT	148,277	Lignite	441,210	2,400	96,111	4,433	426,100
SMPT	251,637	LPG	52,867	10,900	63,100	1,689	106,567
SMPT	581,818	Naphtha	122,236	10,400	73,300	3,726	273,098
SMPT	1,066,149	Hard Coal	904,451	3,200	94,600	12,118	1,146,327
SMPT	111,674	MW/G	23,462	6,714	54,600	462	25,207

Table A8. Thermal Power Plants in 2008

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
AMBARLI-A	3,365,052	Fuel Oil	826,463	9,580	77,400	33,149	2,565,737
AMBARLI-B	9,336,449	NG	2,000,000	34,901	56,100	69,802	3,915,892
BURSA DG	8,956,395	NG	1,764,000	34,960	56,100	61,669	3,459,656
		Hard Coal	819,237	3,200	94,600	10,976	1,038,324
		Fuel Oil	36,020	9,560	77,400	1,442	111,590
CATES-B	1,882,480	Diesel	232,156	10,300	74,100	10,012	741,852
ORHANELİ		Lignite	1,474,825	2,350	96,762	14,511	1,404,091
		Fuel Oil	12,572	9,560	77,400	503	38,948
	1,332,442	Diesel	29	10,300	74,100	1	93
ALİAĞA	491,426	Diesel	120,000	10,300	74,100	5,175	383,459
		Lignite	6,515,731	1,500	107,835	40,920	4,412,618
		Fuel Oil	3,584	9,560	77,400	143	11,103
SEYİTÖMER	4,051,390	Diesel	1,490	10,300	74,100	64	4,761
		Lignite	1,462,438	2,600	93,505	15,920	1,488,565
		Fuel Oil	5,473	9,560	77,400	219	16,955
TUTTES-B	1,608,337	Diesel	424	10,300	74,100	18	1,355
		Lignite	11,090,041	950	115,000	44,110	5,072,672
		Fuel Oil	14,370	9,560	77,400	575	44,518
ELBİSTAN-A	4,197,646	Diesel	14,692	10,300	74,100	634	46,948
		Lignite	3,648,475	1,300	110,441	19,858	2,193,145
		Fuel Oil	15,597	9,560	77,400	624	48,319
KANGAL	1,811,214	Diesel	2,518	10,300	74,100	109	8,046

Table A8. Thermal Power Plants in 2008 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m3	LHV, kcal/kg / kJ/m3	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
PARK 1-2-3-4	4,315,206	Lignite	3,945,793	2,800	90,900	46,257	4,204,733
		Fuel Oil	6,437	9,560	77,400	258	19,942
		Diesel	1,943	10,300	74,100	84	6,209
CAN		Lignite	2,167,459	2,340	96,892	21,235	2,057,486
		Fuel Oil	1,674	9,560	77,400	67	5,186
		Diesel	2,205	10,300	74,100	95	7,046
ELBISTAN-B		Lignite	20,000,000	950	115,000	79,549	9,148,158
		Fuel Oil					
		Diesel					
HAMITABAI	7,241,275	NG	2,000,000	33,896	56,100	67,792	3,803,131
		Lignite	5,059,368	1,333	107,405	32,473	3,487,748
KEMERKÖY	3,410,490	Fuel Oil	22,246	9,560	77,400	890	68,918
S O M A - A	273,704	Lignite	239,582	3,325	90,900	3,335	303,174
		Lignite	6,657,439	2,400	96,111	66,896	6,429,449
		Fuel Oil	27,074	9,560	77,400	1,084	83,875
S O M A - B	5,208,409	Diesel	30	10,300	74,100	1	96
		Lignite	2,648,420	1,750	104,578	19,405	2,029,305
Y E N İ K Ö Y	1,928,835	Fuel Oil	22,626	9,560	77,400	906	70,095
		Lignite	5,151,907	2,100	100,019	45,297	4,530,562
Y A T A Ğ A N	3,980,975	Fuel Oil	22,710	9,560	77,400	909	70,356
		NG	2,231,732	34,900	56,100	77,887	4,369,486
P-21	11,899,471	NG					
P20	10,400,236	NG	1,950,552	34,900	56,100	68,074	3,818,967

Table A8. Thermal Power Plants in 2008 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
P-23	5,681,935	NG	1,065,640	34,900	56,100	37,191	2,086,407
P-18	5,317,197	NG	997,234	34,900	56,100	34,803	1,952,475
P-2	3,517,349	NG	659,675	34,900	56,100	23,023	1,291,571
P-18	3,407,282	NG	639,032	34,900	56,100	22,302	1,251,154
P-6	2,842,349	NG	533,079	34,900	56,100	18,604	1,043,711
P-3	2,452,383	NG	459,942	34,900	56,100	16,052	900,515
P-4	1,854,833	NG	347,872	34,900	56,100	12,141	681,095
P-24	1,836,259	NG	344,388	34,900	56,100	12,019	674,274
P-5	1,470,226	NG	275,739	34,900	56,100	9,623	539,867
P-16	1,088,880	NG	204,218	34,900	56,100	7,127	399,837
P-8	1,082,043	Fuel Oil	263,030	9,560	77,400	10,528	814,866
P-27	1,060,713	Hard Coal	848,260	3,200	94,600	11,365	1,075,108
P-11	1,055,063	NG	197,876	34,900	56,100	6,906	387,419
P-14	980,609	Hard Coal	784,200	3,200	94,600	10,507	993,917
P-26	919,792	NG	172,506	34,900	56,100	6,020	337,748
P-25	893,649	NG	167,603	34,900	56,100	5,849	328,148
P-9	882,283	NG	165,471	34,900	56,100	5,775	323,974
P-10	875,024	NG	164,110	34,900	56,100	5,727	321,309
P-7	850,814	Fuel Oil	206,821	9,560	77,400	8,278	640,732
P-27	823,787	NG	154,500	34,900	56,100	5,392	302,495
SMPT	13,272,465	NG		34,900	56,100	86,874	4,873,649

Table A8. Thermal Power Plants in 2008 (Continued)

	Electricity, MWh	Fuel Type	Fuel Amount, ton / m ³	LHV, kcal/kg / kJ/m ³	Emis. Factors, kg GHG/TJ	Fuel Cons (TJ)	CO ₂ Emissions (ton)
SMPT	187,064	Lignite		2,400	96,111	2,041	196,134
SMPT	529,652	LPG		10,900	63,100	3,467	218,756
SMPT	669,914	Naphtha		10,400	73,300	4,385	321,413
SMPT	190,107	Hard Coal		3,200	94,600	2,037	192,687
SMPT	465,947	MWG		6,714	54,600	3,050	166,521
SMPT	1,659	Diesel		10,300	74,100	18	1,309
SMPT	36,378	Hard Coal		3,200	94,600	387	36,654
SMPT	3,297,584	Fuel Oil		9,560	77,400	32,085	2,483,348

APPENDIX – B

SPECIFIC EMISSIONS FACTORS

In this section, normal distribution and mean of Specific Emissions Factors obtained from thermal power plant data of Turkey is presented in Figure B.1 to Figure B.7 for each fossil fuel type.

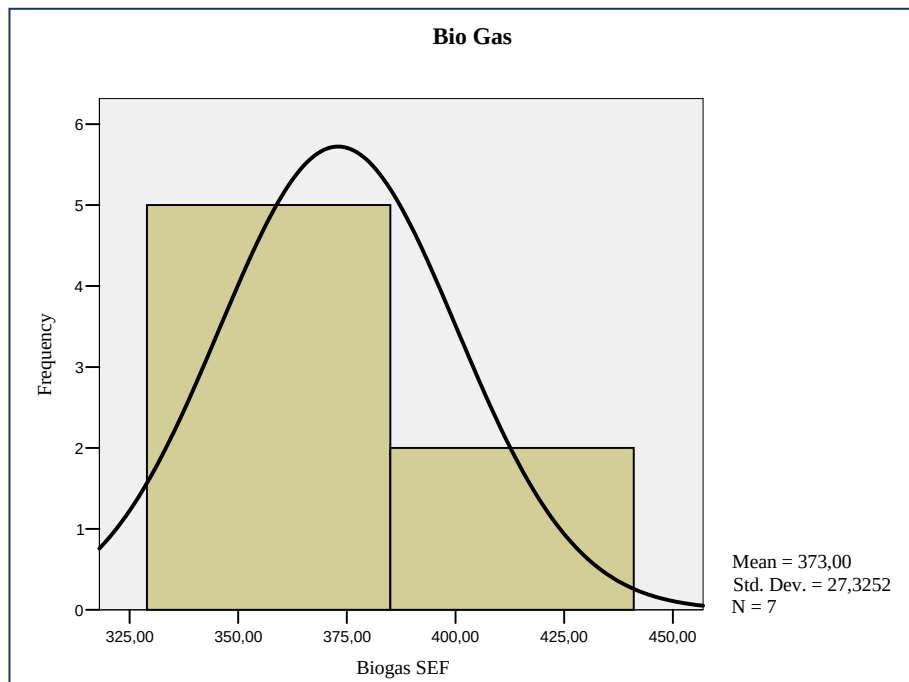


Figure B1. Normal Distribution and Mean of the MWG Thermal Power Plants

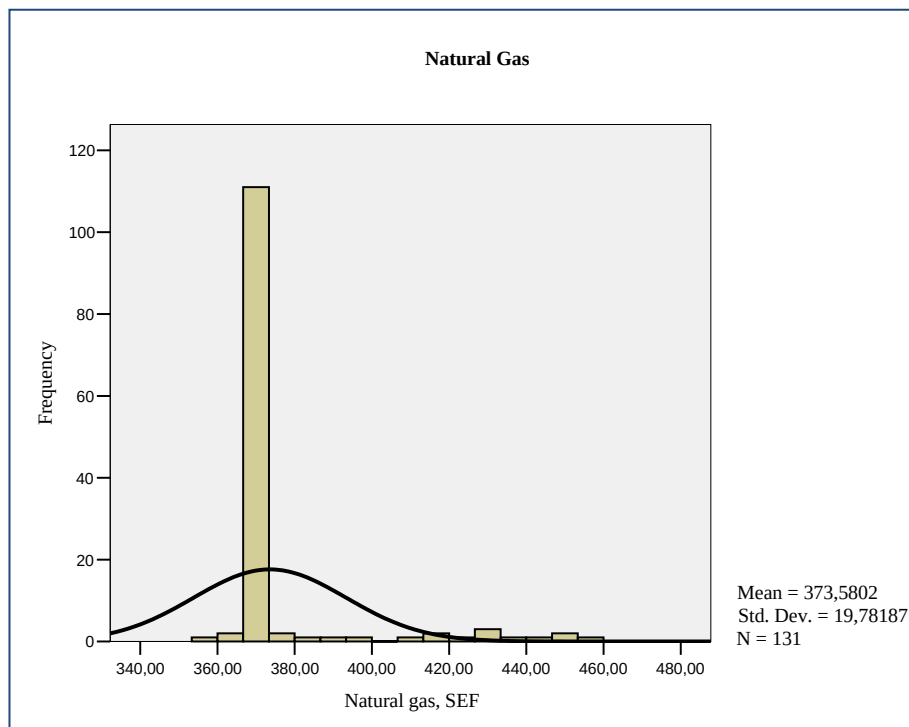


Figure B2. Normal Distribution and Mean of the Natural Gas Thermal Power Plants

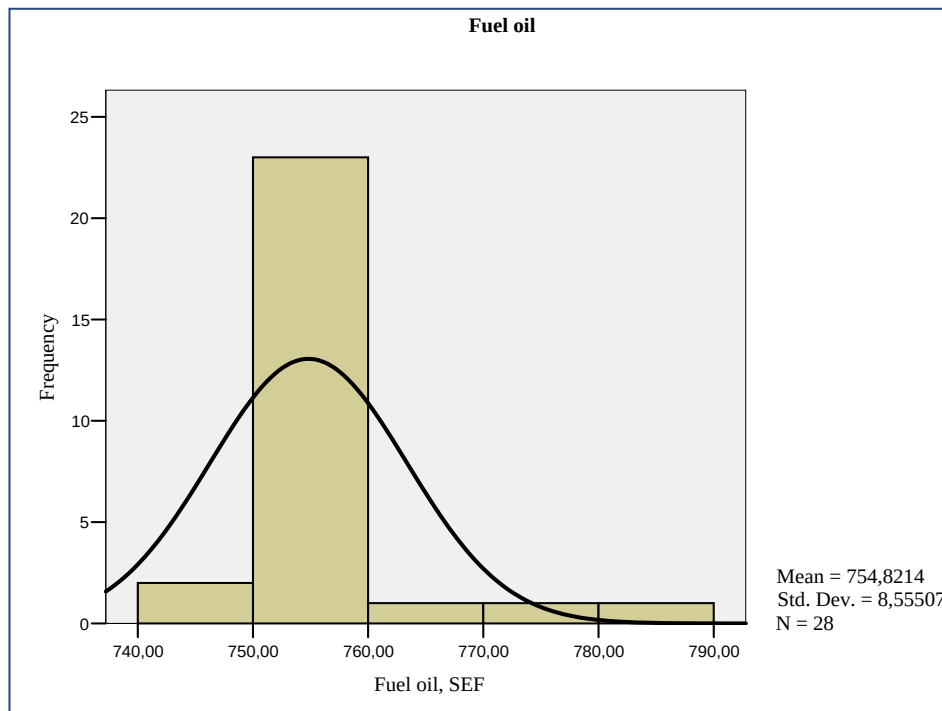


Figure B3. Normal Distribution and Mean of the Fuel Oil Thermal Power Plants

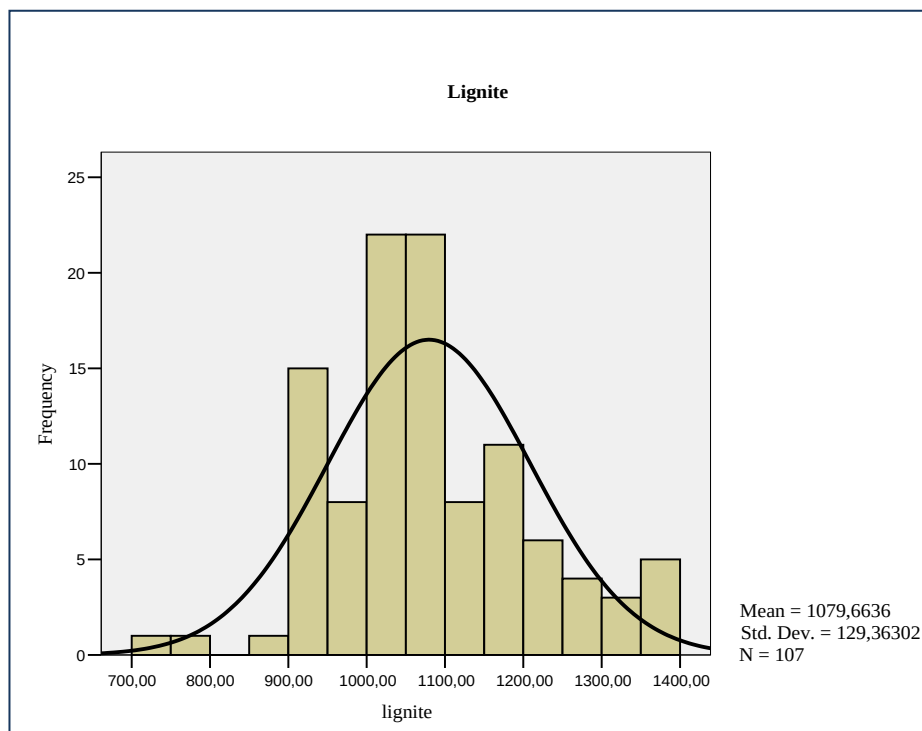


Figure B4. Normal Distribution and Mean of the Lignite Thermal Power Plants

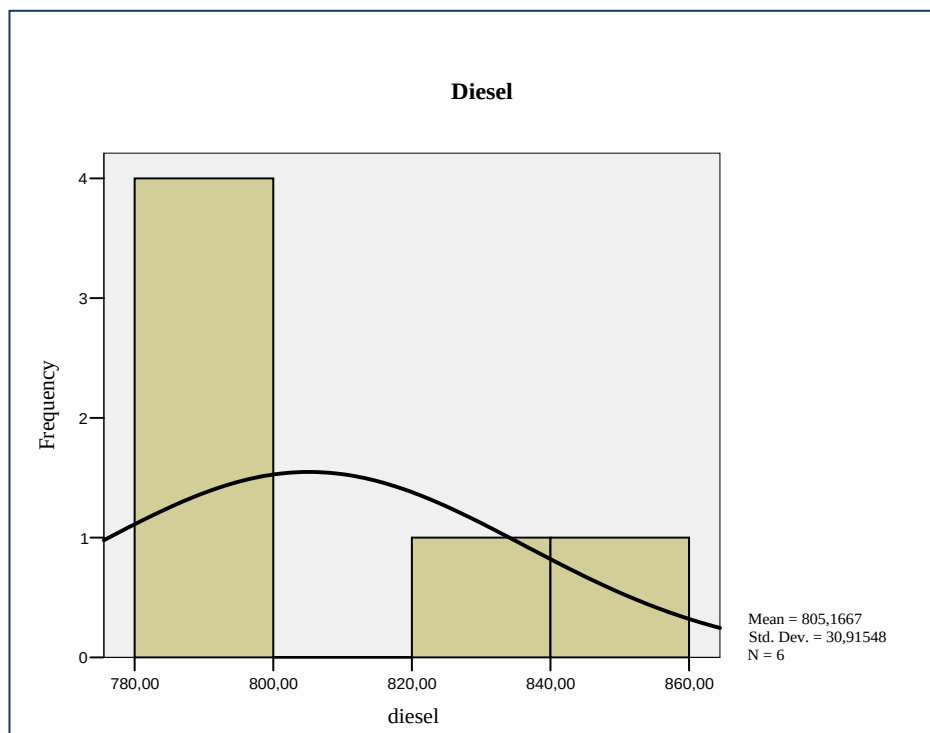


Figure B5. Normal Distribution and Mean of the Diesel Thermal Power Plants

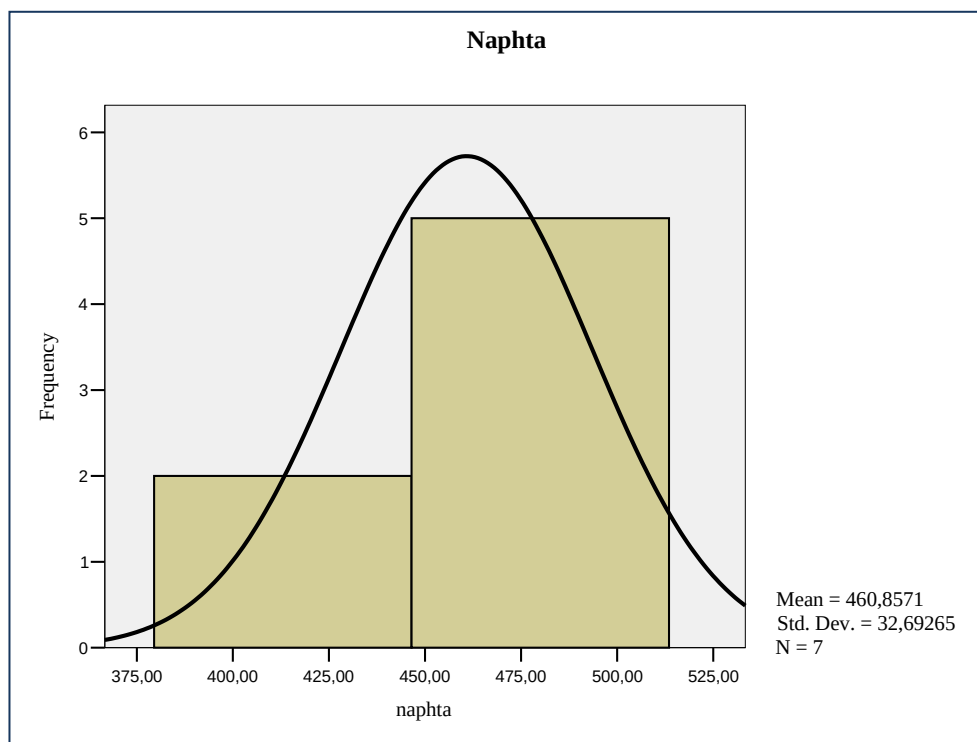


Figure B6. Normal Distribution and Mean of the Naphta Thermal Power Plants

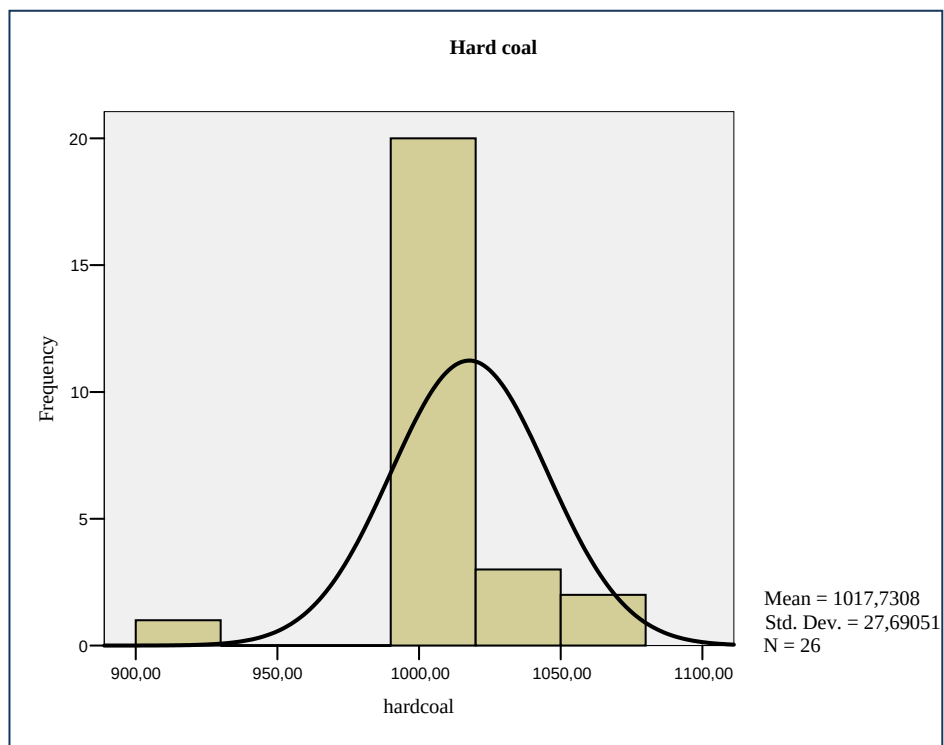


Figure B7. Normal Distribution and Mean of the Hard Coal Thermal Power Plants

APPENDIX – C

PERCENTAGE DISTRIBUTION OF INCREMENTAL ELECTRICITY SUPPLY AND ASSOCIATED CO₂ EMISSIONS OF EACH SCENARIOS

Table C1. Percentage Distributions of Incremental Electricity Supply by Fuel Type Based on BAU Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG
2009	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2010	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2011	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2012	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2013	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2014	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2015	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2016	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2017	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2018	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2019	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%

Table C2. Percentage Distribution of Associated CO₂ Emissions of the Incremental Electricity Supply by Fuel Type Based of BAU Scenario

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable	Total
2009	43.6%	14.0%	0.3%	35.2%	6.6%	0.2%	0.0%	0.0%
2010	43.6%	14.0%	0.3%	35.2%	6.6%	0.2%	0.0%	0.0%
2011	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2012	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2013	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2014	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2015	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2016	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2017	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2018	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%
2019	43.6%	14.0%	0.3%	35.3%	6.6%	0.2%	0.0%	0.0%

Table C3. Percentage Distributions of Incremental Electricity Supply by Fuel Type Based on Renewable Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG
2009	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2010	21.1%	7.2%	0.3%	49.2%	4.6%	16.8%	0.4%	0.1%	0.0%	0.2%
2011	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	33.0%	17.0%	30.0%	0.0%
2012	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	33.0%	17.0%	30.0%	0.0%
2013	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	33.0%	17.0%	30.0%	0.0%
2014	0.0%	0.0%	0.0%	0.0%	0.0%	29.6%	29.6%	17.0%	23.9%	0.0%
2015	0.0%	0.0%	0.0%	0.0%	0.0%	38.5%	24.6%	17.0%	19.9%	0.0%
2016	0.0%	0.0%	0.0%	0.0%	0.0%	41.8%	22.8%	17.0%	18.4%	0.0%
2017	0.0%	0.0%	0.0%	0.0%	0.0%	45.8%	20.6%	17.0%	16.6%	0.0%
2018	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	33.0%	17.0%	30.0%	0.0%
2019	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	33.0%	17.0%	30.0%	0.0%

Table C4. Percentage Distributions of Incremental Electricity Supply by Fuel Type Based on Fossil Fuel Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	FO	Hydro	Wind	Geo	Biomass	MWG
2009	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2010	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2011	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2012	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2013	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2014	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2015	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2016	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2017	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2018	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%
2019	25.5%	8.7%	0.4%	59.5%	5.6%	0.0%	0.0%	0.0%	0.0%	0.3%

Table C5. Percentage Distribution of Associated CO₂ Emissions of the Incremental Electricity Supply by Fossil Type Based of Fossil Fuel Scenario

	Lignite	Coal	Asphaltite	NG	Fuel oil	MWG	Renewable
2009	44%	14%	0%	35%	7%	0%	0%
2010	44%	14%	0%	35%	7%	0%	0%
2011	44%	14%	0%	35%	7%	0%	0%
2012	44%	14%	0%	35%	7%	0%	0%
2013	44%	14%	0%	35%	7%	0%	0%
2014	44%	14%	0%	35%	7%	0%	0%
2015	44%	14%	0%	35%	7%	0%	0%
2016	44%	14%	0%	35%	7%	0%	0%
2017	44%	14%	0%	35%	7%	0%	0%
2018	44%	14%	0%	35%	7%	0%	0%
2019	44%	14%	0%	35%	7%	0%	0%

Table C6. Percentage Distributions of Incremental Electricity Supply by Fuel Type Based on Natural Gas Scenario, 2009-2019

	Lignite	Coal	Asphaltite	NG	Fuel oil	Hydro	Wind	Geo	Biomass	MWG
2009	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2010	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2011	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2012	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2013	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2014	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2015	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2016	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2017	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2018	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2019	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%