Coal Potential of Turkey: Coal and Energy

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ABSTRACT

Coal is one of the largest energy resources of Turkey. Turkey has hard coal reserve of 1.12 billion tons and lignite reserve of 8.05 billion tons. While it is the 9th country in the world in terms of lignite reserve, it is the 8th country in terms of production (Hard coal + lignite) and the 12th country in terms of total coal consumption. While its hard coal production meets only 13% of its consumption, it meets its total lignite consumption. 65% of hard coal production and 78% of lignite production are used for electricity production. Turkey's Total installed capacity is 65587 MW by 2003 and 6774 (19%) of this installed capacity is met by the coal plants. In 2003, the total amount of produced electricity was 140 billion kWh and 19% of this amount was obtained from the coal plants. Turkey has recently concentrated on natural gas for production of electricity. While the share of coal in production of electricity reached 50% in 1986, today natural gas has taken the place of coal. In other words, while Turkey was dependent on foreign countries for fulfilling 21% of its electricity production in 1986, it has become dependent on foreign countries for fulfilling 56% of its electricity production in 2003. Turkey can produce electricity using renewable energy resources, especially coal.

I. INTRODUCTION

Energy is one of the indispensable factors regarding the assurance of social prosperity and economic development of a country. The developing countries struggle to obtain energy sources reliable in the long term to complete their economic development, and the developed countries struggle to get them to keep their present prosperity levels. Coal seems to continue its indispensable position among the other energy sources for many years because of its production in more than 50 countries, because of the least effect it has from the price fluctuation and its usage lifespan of more than 200 years. The countries that are aware of it, have investments in mining fields in the countries rich in coal reserves, and they continue investing considerable amount of Money (Yılmaz, Uslu, 2006).

On the eve of 21st century, Turkey was unable to meet its energy requirement with its limited sources as a result of the increasing population and industrialization and thus the deficit between the energy production and energy consumption

increased rapidly. Under such conditions, utilizing own resources more effectively had become more important increasingly day by day. Turkey became more dependent on imports year to year. It still supplies about 70% of its primary energy consumption from imported energy sources. This percentage is 56% for electricity production. It is now vital for Turkey to attach importance to coal and renewable energy sources, which are the largest domestic energy sources of Turkey, in order to meet this increasing energy deficit. Especially, it is possible to produce electricity using the said domestic sources.

II. ENERGY OUTLOOK OF TURKEY

Since Turkey is an energy importing country more than about 70% of the country's energy consumption is met by imports, and the share of imports is growing each year [Demirbaş, 2006]. While the primary energy consumption in 1970 was 18.84 millions TOE, it reached 78.41 millions TOE with an increase rate of 316% in 2003. While 76.9% of the consumed energy in 1970 was met by the domestic energy sources, this percentage decreased to 28% in 2004 (Fig. 1) [Yılmaz, Uslu, Savaş, 2005; Yılmaz, 2003; Yılmaz, Uslu, 2006].

Turkey is dependent on foreign countries especially in terms of oil, natural gas and coal. 92.3% of consumed oil, 97.4% of consumed natural gas and 88.6% of consumed coal is satisfied by imports in 2003. While the primary energy production growth rate was 1.60% on average for the term 1970–2004, the consumption growth rate was 4.71%. In other words, Turkey consumes 2.9 times of its production [Yılmaz, 2006; Yılmaz, Arıoğlu, 2003].

The installed capacity of Turkey's electricity production was 36824 MW in 2004. While 53% of this capacity was supplied by the Thermal plants (hard coal + lignite + oil + natural gas) the remaining part was supplied by renewable energy resources. Net electricity production has increased to 145 TWh in 2004 from 8 TWh in 1970. Net electricity consumption has increased 17 times, reaching 121 TWh from 7 TWh (Fig. 2). The annual average increase rate was 8.9% for production and 8.7% for consumption. The distribution of electricity consumption by usage areas was as follows in 1970: Industry %64,2; Residential %14.5; Commercial %4.8; Government Office %4.1; Public lighting %2.6 and others %9.8. The consumption rates were realized as follows in 2004: Industry %49.2; Residential %22.8; Commercial %12.9; Government Office %3.7; Public lighting %3.7 and others %7.7 (Fig. 2).

III. COAL POTENTIAL OF TURKEY

Turkey has an important potential from the point of view of coal reserves. Apart from the hard coal and lignite reserves, asphaltite, bituminous shale and peat reserves are also present in the country (Fig. 3). Turkey's coal reserves (hard coal+lignite) are 0.8% of the world reserves (Table 1).

Lignite reserves constitute the large portion of total coal reserves. Lignite deposits dispersed all over the country (Yılmaz, 2006). Total reserve (proven + possible + probable) is about 8.05 billion tons (Table 2). Afşin-Elbistan, Muğla, Soma, Tunçbilek, Seyitömer, Beypazarı and Sivas basins constitutes the most important known lignite

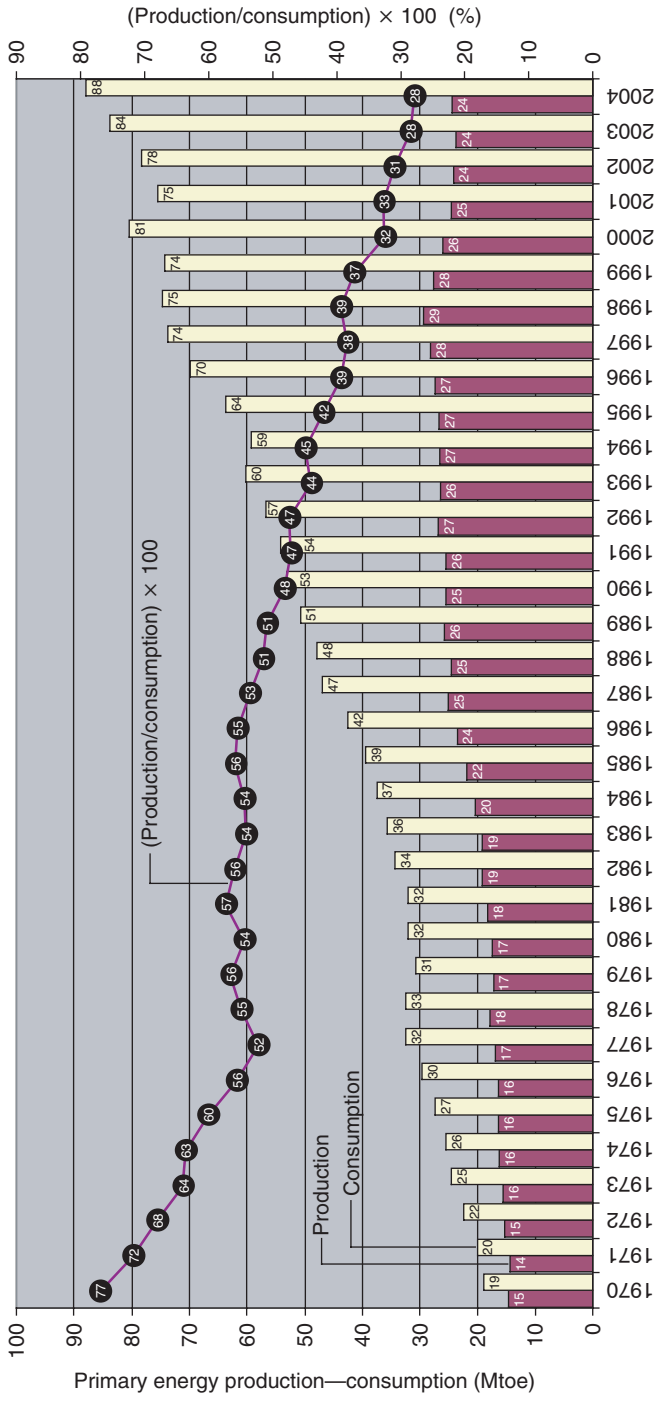


Figure 1. Primary energy production—consumption of Turkey during 1970–2004 and production consumption coverage (data from, MENR, 2006; SIS, 2003-2004;TEIAS, 2004; TPAO, 2006)

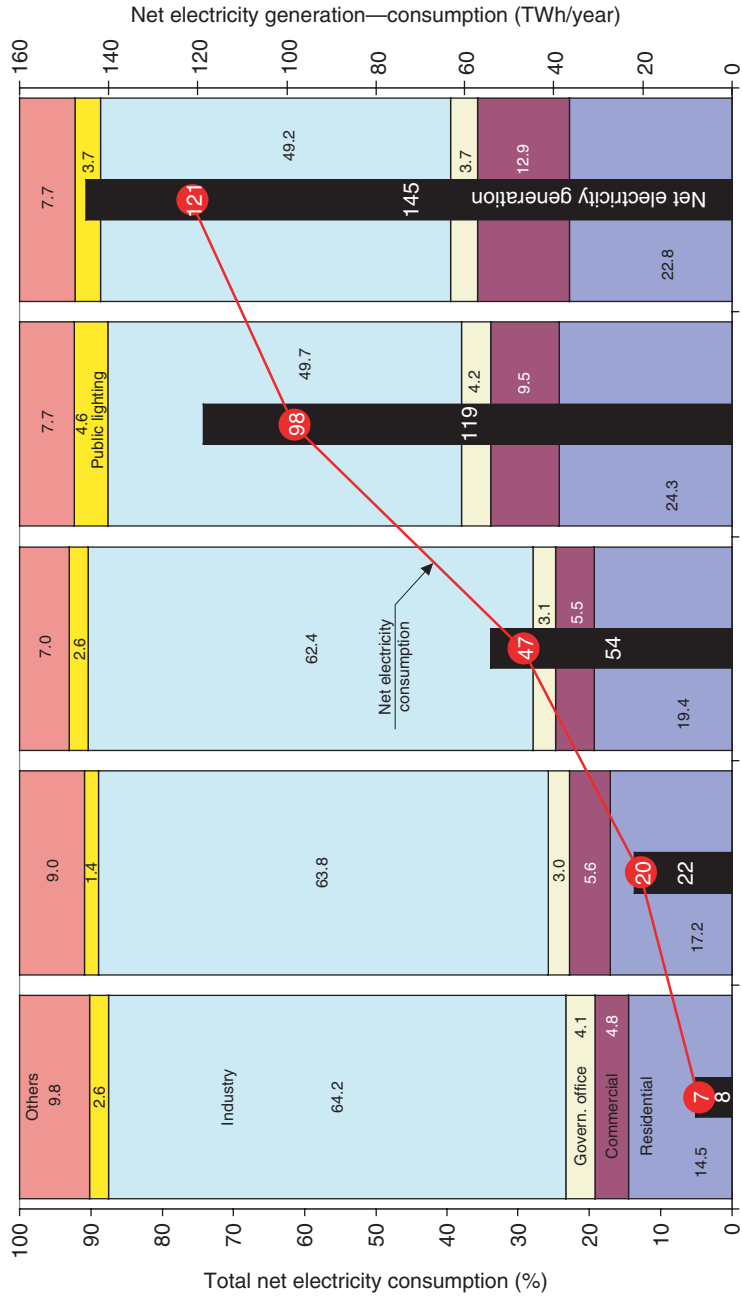


Figure 2. Distribution of electricity production—consumption by usage areas by decades (data from, SIS, 2003–2004;TEIAS, 2004)

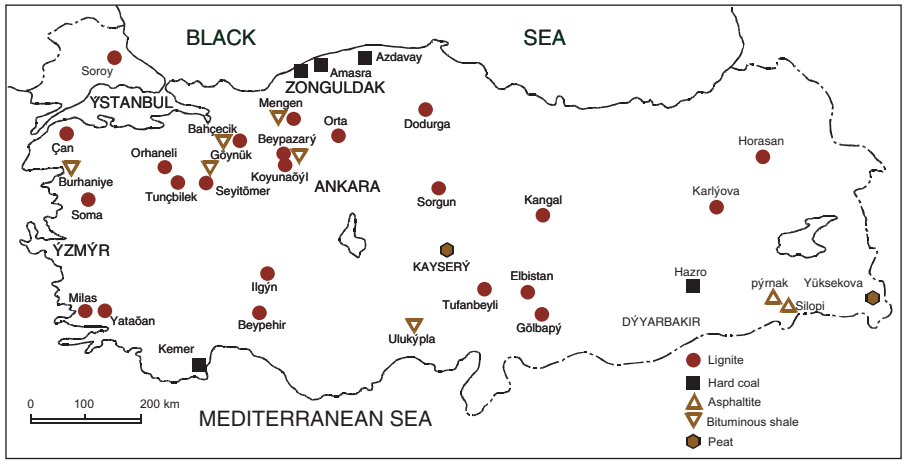


Figure 3. Distribution of Hardcoal, lignite, Asphaltite, Bituminous shale and peat deposits (data from, MTA, 1997)

Table 1. World Proven Coal Reserves, 2003

Range as a total reserve	Countries	Coal reserve [million tonne] Hard coal [1]	Lignite [2]	Total [3]	[1/4] × 100	[2/4] × 100	[3/4] × 100
1	USA	115,891	134,103	249,994	22.3	28.6	25.3
2	Rus. Federation	49,088	107,922	157,010	9.5	23.0	15.9
3	China	62,200	52,300	114,500	12.0	11.2	11.6
4	India	82,396	2,000	84,396	15.9	0.4	8.5
5	Australia	42,550	39,540	82,090	8.2	8.4	8.3
6	Germany	23,000	43,000	66,000	4.4	9.2	6.7
7	S. Africa	49,520	–	49,520	9.5	0.0	5.0
8	Ukraine	16,274	17,879	34,153	3.1	3.8	3.5
9	Kazakhstan	31,000	3,000	34,000	6.0	0.6	3.4
10	Other Europe	1,584	20,761	22,345	0.3	4.4	2.3
11	Poland	20,300	1,860	22,160	3.9	0.4	2.2
12	Brazil	–	11,929	11,929	0.0	2.5	1.2
13	Turkey	535	6,973	7,508	0.1	1.5	0.8
TOTAL WORLD [4]		**519,319**	**468,953**	**988,272**	**100.0**	**100.0**	**100.0**

Source: BP Statistical Review of World Energy June 2004, http://www.bp.com/ statisticalreview2004

reserves (Balat, 2004). Turkey's lignite reserves: TKI; 2492 million tons (30.9%), EUAS; 3381 million tons (41.9%), Private sector; 2184 million tons (27.1%). Turkey has a share of 1.5% of total world lignite reserves. In other words, Turkey ranks 9th in the world in lignite reserves (Yılmaz, 2006). The regional distribution of lignite reserve is: Eastern Anatolia 43%, Aegean 24%, Central Anatolia 16%, Marmara 10%,

Table 2. Distribution of coal reserves of Turkey (data from TK, 2003; TTK, 2004, MTA, 1997)

	Ready [1]	Proven [2]	Probable [3]	Possible [4]	TOTAL [5]	[1/5].100	[2/5].100	[3/5].100	[4/5].100
Coal field			×1000 ton				(%)		
Hard coal	15,418	535,438	424,955	368,447	**1,344,258**	1.15	39.83	31.61	27.41
Lignite	27,210	6,973,129	723,113	335,157	**8,058,609**	0.34	86.53	8.97	4.16
Asphaltite		44,922	28,844	7,579	**81,645**	–	55.02	35.32	9.28
Bituminous shale		554,660	558,037	1,122,697	**2,235,394**	–	24.81	24.96	50.22
Peat	–	105,000	–		**105,000**		100.00		

Table 3. Some properties of lignite of Turkey

	Moisture (%)		Ash (%)		Sulphur (%)		Lower calorific value (Kcal/kg)	
Regions	n	m	n	k	n	s	n	AID
The Marmara	22	29.61	23	26.10	20	2.30	23	2542
Black Sea	18	24.15	17	28.33	12	3.39	19	2831
Central Anatolia	25	30.00	25	24.66	17	2.94	25	2544
Southeast Anatolia	2	49.86	2	20.67	2	1.31	2	1218
Aegean	39	23.57	39	28.82	27	2.68	41	2700
East Anatolia	20	20.92	19	8.99	11	1.78	18	2933
Mediterranean	5	25.09	5	22.74	4	4.07	4	3336
Total	130	26.07	130	27.43	93	2.70	132	2718

n = Number of data, m, k, s, AID, Mean technological properties of coal mentioned above.

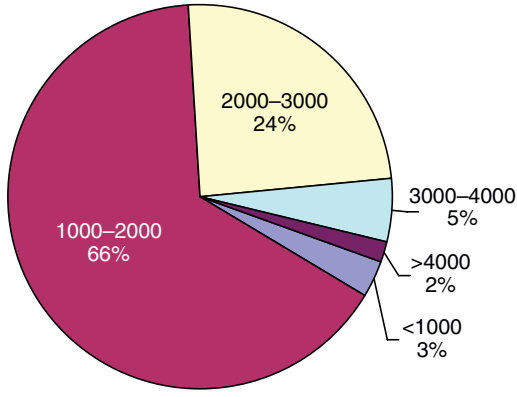


Figure 4. Distribution of Turkey's lignite reserves according to calorific value (data from, Hepbaslı, 2004)

Mediterranean 4%, and Black Sea 3%. Calorific values and some properties of these lignite reserves are given in Table 3. As can be seen in Table 3 the lignite deposits are generally low in calorific values. 66% of the total reserves have calorific values of 1000–2000 Kcal/kg. Only 2% of lignite reserves have a calorific value over 4000 Kcal/kg (Fig. 4). Lignite having low calorific value is used in thermal power plants (Hepbaslı, 2004). Other properties are Moisture, ash and sulphur content. These properties vary 20.92%-49.86, 8.99%-28.33, 1.31-4.09% respectively. Rhe number of data is also illustrated in the Table 3 (Yılmaz, Uslu, Savaş 2005, Balat Ayar, 2004.

In Turkey, hard coal ranks 2nd in reserves after lignite. Although hard coal reserves are only in Zonguldak, situated in the Northwest of the country, small-scale formations have been met in Hazro (Diyarbakır) and Kemer (Antalya) (Fig. 3). Zonguldak and Western Black Sea Region, was nationalized in 1937 and because of its high calorific

Table 4. Some properties of hard coal of Turkey (Arıoğlu, 1996)

Regions	Type of coal	Ash (%)	Sulphur (Max) (%)	Lower calorific value (Kcal/kg)
Kozlu	High volatile-bituminous coal, (Coking coal)	9–13	0.8	6300–6950
Karadon	High volatile-bituminous coal, (Coking coal)	10–14	0.8	6200–6950
Armutçuk	High volatile-bituminous coal, (Coking coal)	11–17	0.9	6800–7050
Amasra	High volatile-bituminous coal, (Steam coal)	12–16	1.5	5820–6050

value, it was used in homes for heating for many years (Table 4). Zonguldak hard coal basin is divided into 5-production district. These are, Armutçuk, Kozlu, Üzülmez, Karadon and Amasra. Total hard coal reserve is about 1.3 billion tons (Table 2). Karadon has highest reserve among others. Amasra, Üzülmez, Kozlu and Armutçuk follow the Karadon, respectively (Yılmaz, 2003; Yılmaz, Arıoğlu, 2003). Some properties of hard coals of the various districts are illustrated in Table 3. 20 million tons of the hard coal reserves are present in the small deposits in Diyarbakır and Antalya (Hepbaslı, 2004). Turkey has a share of 0.1% of world hard coal reserves.

Most of the bituminous shale deposits are located in the western region of the country. Beypazarı, Seyitömer, Hadıldağ and Himmetoğlu deposits are the most important ones among bituminous shale deposits (MTA, 1997) (Fig. 3). Total reserve (proven + possible + probable) is 1.64 billion tons. Ash contents of bituminous shales are high (66–89%), while calorific values of them are low (600–1500) Kcal/kg. Some portion of reserves (Seyitömer and Himmetoğlu) is suitable for open pit mining. Underground mining is necessary in other deposits due to their depths (MTA, 1997). There is no commercial bituminous shale production and consumption in Turkey.

Asphaltite deposits of Turkey are located in Şırnak and Silopi areas in Southwest Anatolia region (Fig. 3). The ash content of asphaltites range between 33% and 52% while their calorific values range between 3100 Kcal/kg and 5500 Kcal/kg. 82 million tons of asphaltite is present in both areas (MTA, 1997).

Peat deposits in Turkey are located in Kayseri and Yüksekova (Hakkari) (Fig. 3). The total proven reserves of both areas is about 190 million tons. Their calorific values are between 1450–3000 Kcal/kg (MTA, 1997).

IV. COAL PRODUCTION-CONSUMPTION

The hard coal, lignite and asphaltite production of Turkey is illustrated in Fig. 5. The hard coal production reaches to 1800s. Production had increased steadily until 1974 and reached to 5 million tons on saleable basis. This production level could not be maintained during the following term and had decreased constantly year-by-year and decreased to 1.9 million tons in 2004. This production level was unable to cover consumption level and could only cover 10% of total consumption in 2004, which

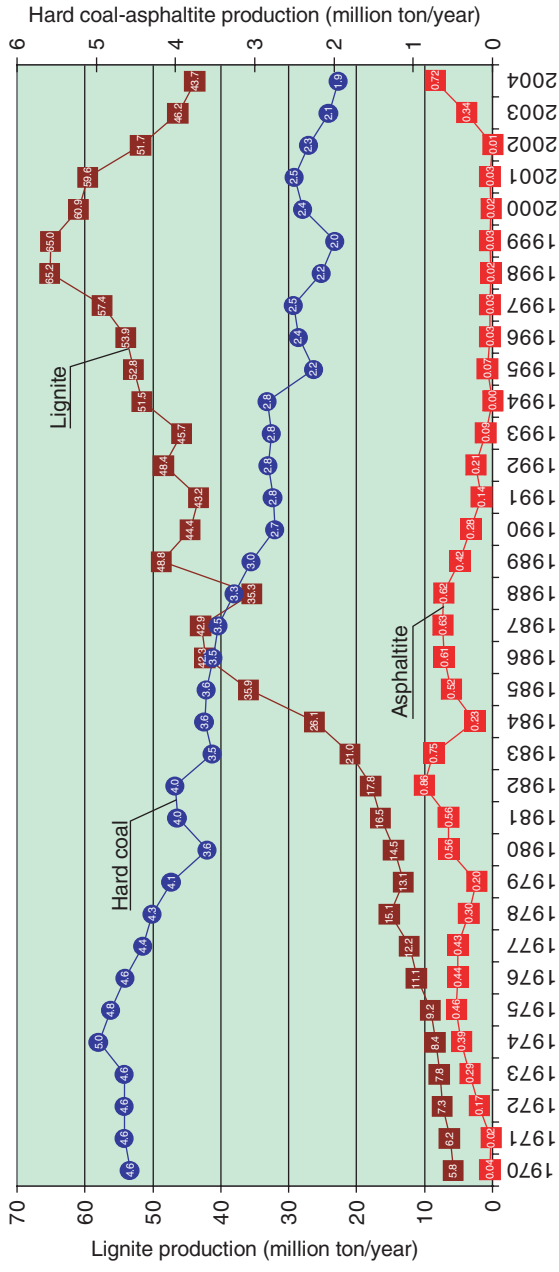


Figure 5. Development of coal production in Turkey during 1970–2004 (data from, MENR, 2006)

were 19 million tons (Fig. 6). The consumption level had been 5 million tons until the beginning of 1980 and the production level of those times was able to meet almost the entire consumption (Fig. 6). While about 65% of the produced hard coal is used for electricity production in recent years, the remaining coal is consumed in iron and steel industry, cement industry, household fuel and other industrial areas.

HARD COAL PRODUCTION BASED ON SALEABLE

Asphaltite production in Turkey is carried out by Turkish Coal Enterprise (TKİ). It is observed that the asphaltite production of Turkey varies largely by years. While the production level was 40,000 tons in 1970, this rate reached to 860,000 tons, the maximum level, in 1982. Production has occasionally decreased to 10,000 tons/year in the recent years and increased again in 2003 and 2004 (Fig. 5). Although asphaltite is produced by open pit mining, underground mining will be inevitable in the future, due to decrease of reserves that are suitable for open pit mining. Almost the entire asphaltite production is consumed as household fuel.

The lignite production of Turkey was 5.8 million tons in 1970. The production level began increasing rapidly after the oil crisis in 1973. Production reached 14.5 million tons in 1980 and 48.8 million tons in 1990. The increase rate was maintained increasingly until the beginning of 2000 and reached 65.2 million tons, which was the maximum production level, in 1999 (Fig. 5). And this rate has decreased continuously after 2000 with the prevalence of natural gas use in electricity production and decreased to 43.7 million tons in 2004. Turkey was the 7th largest lignite producer in 1995 and had become the 8th largest lignite producer in 2003 with some decrease in production (Fig. 7). The largest lignite producer in the world is Germany (20.5%), followed by Russia (9%) and USA (8.4%) and Greece (7.8%).

The overall lignite consumption can be met by the domestic production. Approximately 80% of the produced lignite is consumed in electricity production and the remaining part is consumed in industry and as household fuel.

V. COAL AND ENERGY

Turkey has two main energy resources with large capacities. These are coal and renewable energy resources. Both energy resources constitute 90% of the primary energy production. The total primary energy production was 23.9 Mtoe in 1983 and 10.9 Mtoe (37.8%) of this rate was met by coal. The share of the renewable energy resources was 51%. The total primary energy production increased 1.15 times and reached 23.9 Mtoe in 2003 and the share of coal also increased 8% and reached 45.7% (Fig. 8).

On the other hand, the primary energy consumption in Turkey increased 2.25 times from 37.1 Mtoe to 83.8 Mtoe in 1983. While Turkey supplied 50% of its primary energy consumption from two main energy resources with the largest potentials in 1983, this rate decreased to 27% in 2003 (Fig. 9). While the share of coal in energy production was 21%, this rate decreased to 15% in 2003. In regression of the production consumption coverage, substitution of coal with natural gas, about 100% of which is imported, took an important role. In other words, Turkey has become a country, which imports 70% of its energy resources, during this term.

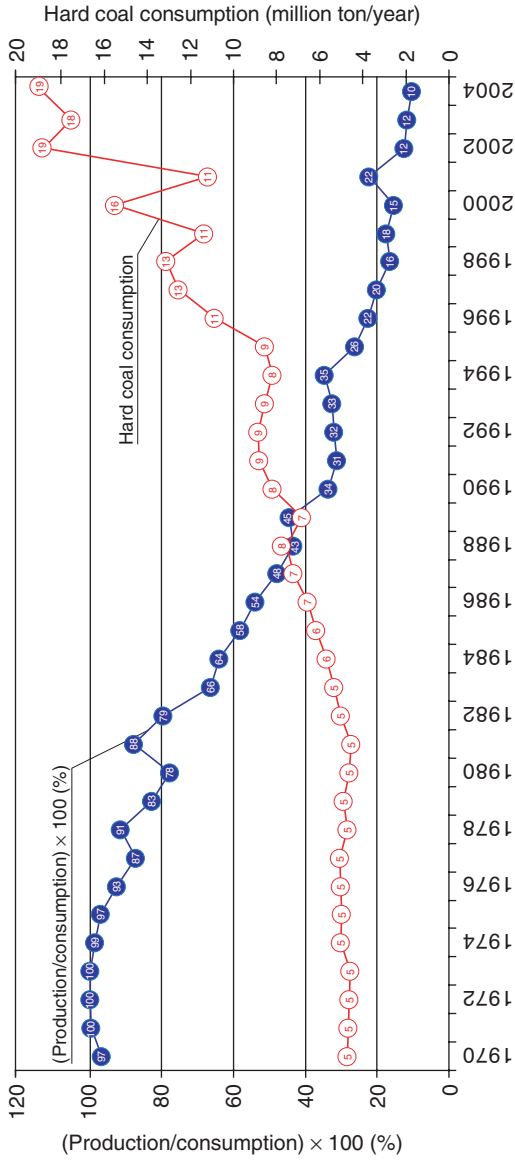


Figure 6. Production—consumption coverage of hard coal

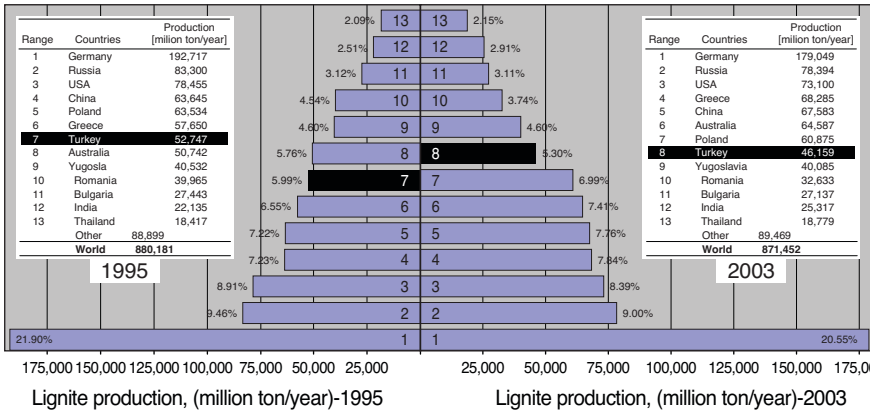


Figure 7. Distribution of total lignite production in the world by countries during 1995–2003, (data from, BP, 2003)

The first of the areas where coal can be used most intensively is electricity production. Electricity production is the most appropriate area where coal can substitute other energy resources (oil, natural gas). Especially since the quality of lignite coal produced in Turkey is low, this increased the use rate of lignite in electricity production. A regression analysis between the lignite coal production per capita and electricity production per capita is given in Fig. 10. When this figure is examined, it is observed that there is a high relation between the coal production and electricity consumption per capita ($r = 0.949$). In other words, lignite production is largely used in electricity production. The decrease in electricity production based on lignite after 2000s is observed in the regression as a deviation (Fig. 10).

In Figure 11, distribution of electricity production by resources is given in a historical order. As seen in the Figure, coal (especially hard coal) has a share of 90% in electricity production in 1940. The rate of electricity production using renewable energy resources has begun increasing in time and the share of coal (lignite + hard coal) decreased to 33% at the beginning of 1970s and the share of renewable energy resources increased to 35% from 3%. By the middle of 1960s, use of oil in electricity production increased, since it is a cheaper than other resources, and this was quickly renounced after the oil crisis in 1973. After the crisis, Turkey gave importance on lignite, one of its own energy resources, and the share of coal in electricity production began increasing and reached 50%. After 2000s, use of natural gas began prevailing in electricity production as in all other areas and its share in electricity production reached 45% in a very short time. The total electricity production was 140 billions kWh/year in 2003 and its distribution by resources was as follows: coal (hard coal %2 + lignite %17) Hydraulic %25, Oil %7, Natural gas %45, other %4 (Fig. 11).

Turkey has 13 operating thermal plants used for electricity production based on coal (Table 5). The total installed capacity of these plants is 8143 MW and their annual total coal consumption is about 81 million tons. If it is considered that the coal consumption in 2003 was 46 million tons, the use rate of thermal plant capacity is about 40–50%.

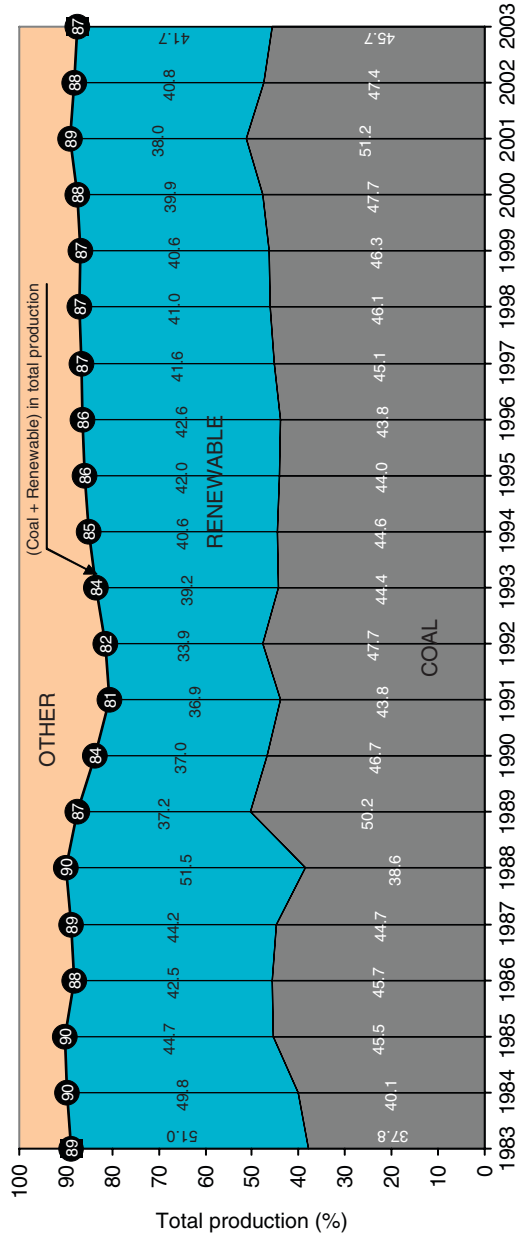


Figure 8. Distribution of primary energy production by energy resources (data from, MENR, 2006; SIS, 2003–2004;TEIAS, 2004)

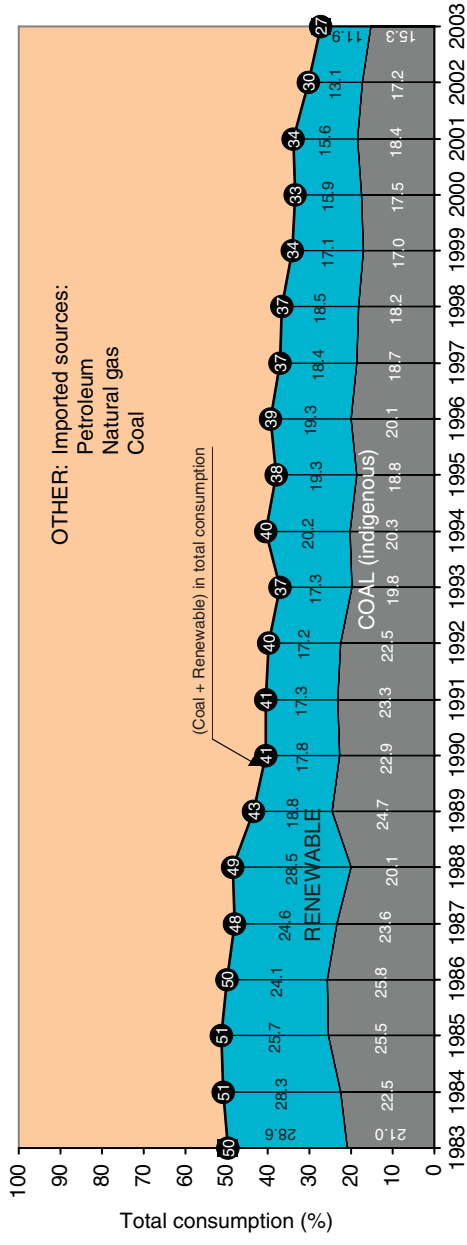


Figure 9. Coverage rate of primary energy consumption with domestic energy resources (coal + renewable) (data from, MENR, 2006; SIS, 2003–2004; TEIAS, 2004)

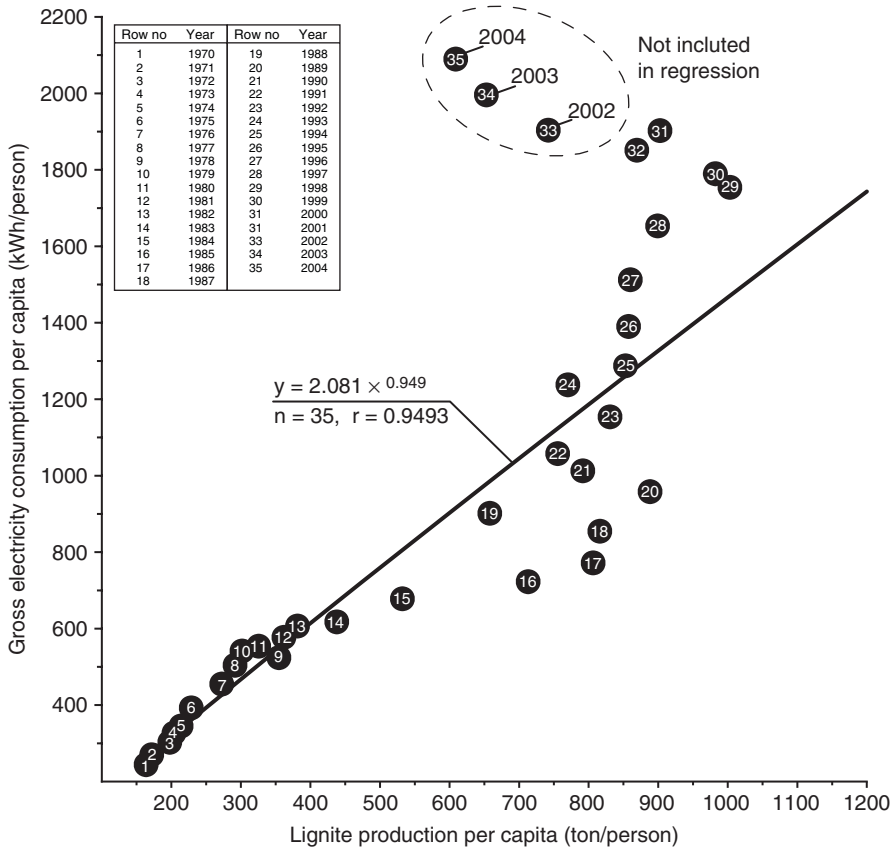


Figure 10. Relation between lignite production per capita and electricity consumption per capita (data from, MENR, 2006; SIS, 2003–2004;TEIAS, 2004)

VI. COAL AND ENVIRONMENT

Turkey has made much progress over the last two decades in setting up infrastructure for addressing its environmental problems an Environment Law was enacted in 1983 and the Ministry of Environment was created in 1991. There are also nongovernmental environmental organizations that have emerged. Turkey is a party to many international environmental agreements, including Air Pollution, Antarctic Treaty, Biodiversity, Desertification, Hazardous Wastes, Nuclear Test Ban, Ozone Layer Protection, Wetlands, and Ship Pollution. Turkey has signed but not yet ratified the Arctic-Environmental Protocol and the Environmental Modification treaty. Additionally, Turkey has neither signed nor ratified the United Nations Framework Convention on Climate Change (Balat, 2006).

The advantage of coal utilization as energy source in Turkey is its being the most widespread energy resource in Turkey and existence in almost all regions of the country (Ersoy and Anaç, 2002). However, coal utilization causes air pollution due to gases such

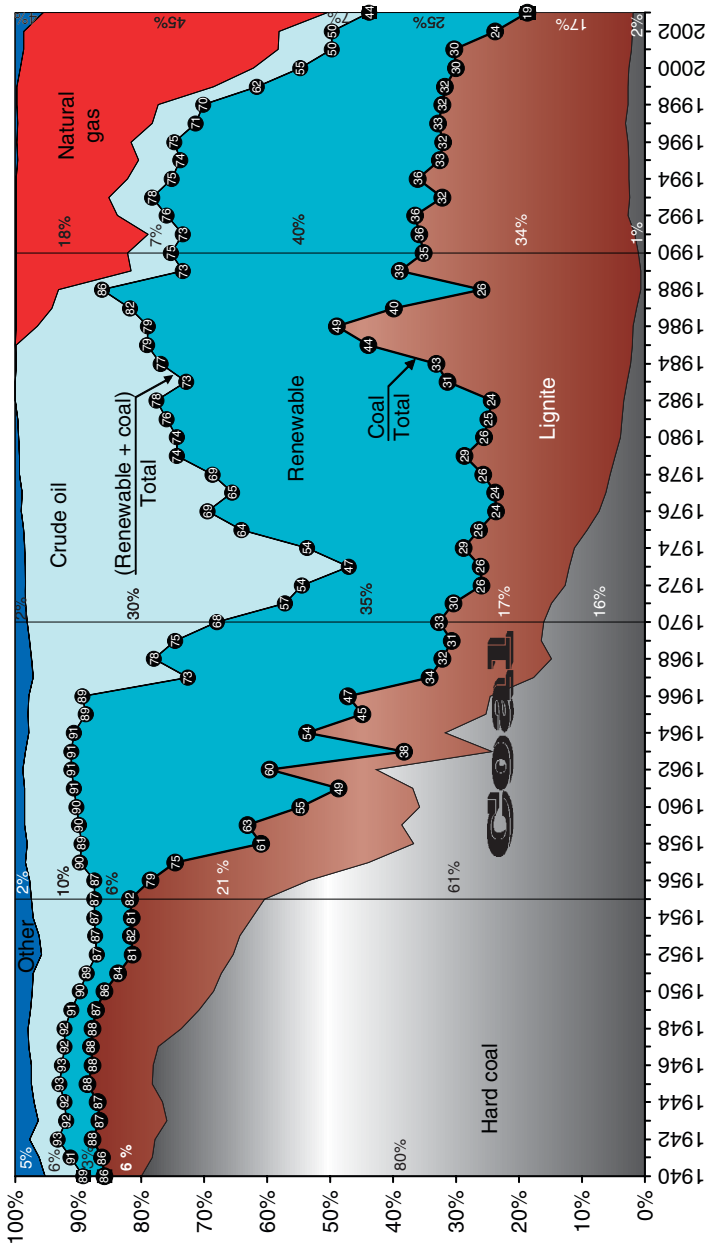


Figure 11. Electricity Production of Turkey By Source During 1940–2002 (data from, TEIAS, 2004; SIS, 2004; Artoğlu, Yılmaz, 2002)

Table 5. Current coal fired power station in Turkey (data from Anaç, 2003; MENR, 2006)

Coal fired power plants	Coal consumption capacity [×1000 ton/year]	Installed capacity [MW]
Muğla-Yatağan	5350	630
Muğla-Milas-Sekköy	3750	420
Muğla-Hüsamlar-Kemerköy	5000	630
Çanakkale-Çan	1800	320
Kütahya-Seyitömer	7100	600
Kütahya-Tunçbilek	2450	429
Manisa-Soma	8000	1034
Bursa-Orhaneli	1500	210
Afşin-Elbistan-A	18000	1360
Afşin-Elbistan-B	19000	1440
Sivas-Kangal	5400	450
Ankara-Çaytrhan	4300	620
Zonguldak-Çatalağzı (Hard coal)	1700	300
TOPLAM	**81650**	**8143**

as carbondioxide (CO_2), sulphurdioxide (SO_2) and nitrogen oxides (NO_X) released to atmosphere during burning. Coal produces more CO_2, primary greenhouse gas, than other energy sources. Coal was the first largest source of CO^2 emissions, accounting for 40.6% (86.7 Mt) of Turkey's total in 1998, followed by oil at 36.9% (78.7 Mt) and natural gas at 21.1% (44.9 Mt) (MENR, 2005). Although air pollution is becoming a great environmental concern (Kaygusuz, 2002), from the geenhouse gas emissions point of view, Turkey is not that critical, CO_2 emissions per capita are 2.9 tons/capita in Turkey, which is much less than those of the world and OECD averages, i.e. 3.87 tons/capita and 11 tons/capita, respectively (OECD/IEA, 2003). CO_2 emissions in different countries is illustrated in Fig. 12. NO_2 emissions are much lower in Turkey than in the European Community countries, i.e., less than one-third of these countries' average (Kaygusuz, 2002).

The Turkish goverment and municipalities have taken several measures to reduce pollution from energy sources. In order to meet European Union (EU) environmental standars, Turkey is requiring flue gas desulfurization (FGD) units on all newly commissioned coal power plants and is retrofitting FGD onto older units (Hepbasli, 2004).

VII. CONCLUSION

Coal will continue being an important resource in energy production with its long use life of more than 200 years. In 2003, the share of coal in primary energy production in the world was realized as 24% and its share in electricity production was realized as 40%. It is envisaged that the share of coal in energy production will be 38% in 2030 in

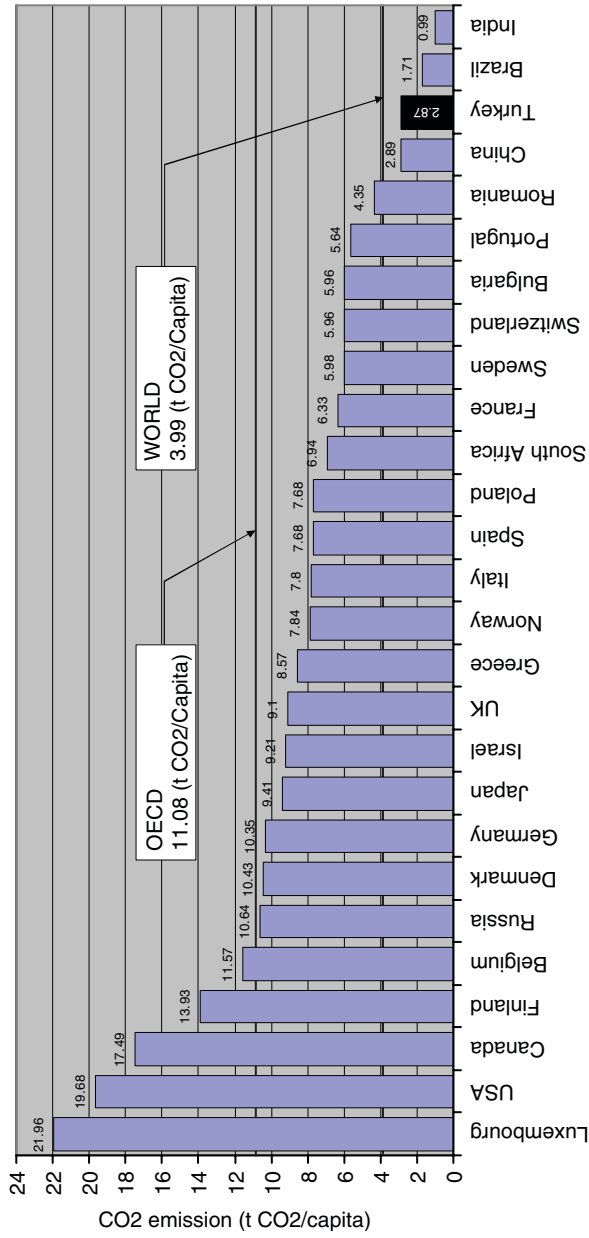


Figure 12. CO_2 emissions in different countries (Yılmaz, Uslu, 2006)

the future projections. In other words, coal will maintain its position of being the energy fuel of future for many years.

Coal is one of the largest energy resources of Turkey. It is not possible to conclude that Turkey benefits from coal sufficiently. The total lignite reserve is 8.05 billion tons and hard coal reserve is 1.2 billion tons. Turkey is the 9th country in terms of largeness of its lignite reserves, holding 1.5% of the total lignite reserves in the world, and the 8th country in terms of lignite production and 12th country in terms of total coal consumption with consumption of 64 million tons (1.3% of the total coal consumption in the world).

Turkey consumes about 80% of its lignite production and about 65% of its hard coal production for production of electricity. Increasing difficulties met in hard coal production caused that the production rate decreased continuously and the production consumption coverage regressed to 10%. On the other hand, the share of hard coal in electricity production, which was about 80%, decreased to 1.9% and Turkey was obliged to meet its hard coal needs by importing hard coal.

A decrease is observed in production of lignite in Turkey in recent years. While production had increased constantly until 2000, it decreased down to 45 million tons in the following term. Leaning towards natural gas in production of electricity after 2000s influenced lignite production negatively and the use rate of lignite in electricity production decreased 17% from 45%. Especially the recent increases in prices of oil and natural gas and the difficulties occurred in supply increased the attempts in Turkey for leaning back to its own resources.

The installed capacity of the thermal plants in Turkey, which are still operated through the use of coal, is 8143 MW. This capacity increases to 17798 MW with the commissioning of additional fields. This installed capacity means safe electricity production of 100 billion kWh. In other words, Turkey will be able to meet 70% of its electricity production, which is currently 150 billions kWh/year. Turkey should emphasize on its own resources in this regard and the coal usage rate should be increased especially in electricity production.

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